114th Congress, 2d Session – – – – – – – – – – – – – House Document 114–139

SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION, MASON COUNTY, WASHINGTON

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

THE SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION PROJECT IN MASON COUNTY, WASHINGTON FOR APRIL 2015, PURSUANT TO PUBLIC LAW 87–874, SEC. 209; (76 STAT. 1197)

PART 1 OF 2

MAY 23, 2016.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

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HOUSE DOCUMENT NUMBER 114-139

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

18 APR 2016

Honorable Paul Ryan
Speaker of the House of Representatives
U.S. Capitol Building, Room H-232
Washington, DC 20510-0012

Dear Mr. Speaker:

In response to section 209 of the River and Harbor Act of 1962, Public Law 87-874, the Secretary of the Army supports the authorization and construction of the Skokomish River Basin Ecosystem Restoration project in Mason County, Washington for the purpose of aquatic ecosystem restoration. The proposal is described in the Report of the Chief of Engineers, dated December 14, 2015, which includes other pertinent documents. The Secretary of the Army plans to implement the project at the appropriate time, considering National priorities and the availability of funds.

The project study was conducted to analyze and formulate restoration of aquatic ecosystem habitat in the Skokomish River, Washington. The recommended plan is the National Ecosystem Restoration (NER) plan. The recommended plan includes the following elements:

a) Removal of a levee at the confluence of the North and South Forks of the Skokomish River near river mile 9;
b) Installation of large woody debris and engineered logjams on the South Fork Skokomish River, between river miles 9 and 11;
c) Reconnection of an historical side channel of the Skokomish River, between river miles 4.5 and 5.5; and,
d) Restoration of wetland habitat on the south bank of the Skokomish River between river miles 8.3 and 9.2 (the River Mile 9 site) and river miles 7.5 and 8.0 (the Grange site).

Based on October 2015 (Fiscal Year (FY) 2016) price levels, the estimated project first cost is $19,664,000. The total project first costs includes $2,605,000 for Pre-construction, Engineering and Design costs; $12,992,000 for aquatic ecosystem restoration construction costs; $1,846,000 for construction management costs; $383,000 for monitoring costs; $129,000 for adaptive management costs; and $1,711,000 for the value of any lands, easements, rights of way, relocations and disposal areas (LERRDs).

Mason County and the Skokomish Indian Tribe are the non-Federal cost-sharing sponsors for all features. The estimated Federal and non-Federal shares of the project

first cost for the recommended plan are $12,782,000 and $6,882,000, respectively (which equates to 65 percent Federal and 35 percent non-Federal), as apportioned in accordance with the cost sharing provisions of section 103 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 2213). Operation, maintenance, repair, replacement, and rehabilitation expenses are estimated to be approximately $10,000 per year and are the responsibility of the non-Federal sponsors.

Based on FY 2016 price levels, a 3.125 percent discount rate, and a 50-year period of analysis, the total equivalent average annual costs of the project are estimated to be $824,000. The recommended plan is estimated to restore 186.6 average annual habitat units of non-monetary benefits. The recommended plan will restore 277 acres of aquatic habitat that provides substantial benefits to nationally significant habitat including habitat within and adjacent to Puget Sound, a designated estuary of national significance, designated critical habitat for four salmon species listed under the Endangered Species Act, designated tribal usual and accustomed fishing areas, and designated Essential Fish Habitat under the Magnuson-Stevens Act. The recommended plan improves habitat for the largest source of freshwater in Hood Canal -- the Skokomish River, improves important floodplain, riparian and wetland habitat supporting unique flora and fauna and addresses U.S. Fish and Wildlife Service identified critical limiting factors for fish and wildlife in the Skokomish Basin. Removal of the levee near the confluence provides significant upstream fish passage to an approximate additional 40 miles of habitat that is periodically inaccessible due to lack of water in the river channel.

An Environmental Impact Statement and Record of Decision were prepared in accordance with the National Environmental Policy Act. The recommended plan has been identified as the environmentally preferred plan. Adverse environmental impacts have been avoided and minimized where practicable. No compensatory mitigation is required.

In accordance with the Endangered Species Act of 1973, as amended, the U.S. Fish and Wildlife Service and National Marine Fisheries Service concurred that the project is compliant with the Programmatic Biological Opinions for fish passage and restoration projects issued in 2008. The project will not jeopardize the existence of Federally listed species or modify designated critical habitat. All terms and conditions resulting from these consultations shall be implemented in order to minimize take of endangered species.

The Independent External Peer Review was completed by Battelle Memorial Institute. The review comments resulted in expanded narratives throughout the report to support the decision-making process and justify the recommended plan. All comments from the above referenced reviews have been addressed and incorporated into the final documents.

The Office of Management and Budget (OMB) advises that there is no objection to the submission of the report to Congress and concludes that the report recommendation

is consistent with the policy and programs of the President. A copy of OMB's letter, dated April 8, 2016, is enclosed. I am providing a copy of this transmittal and the OMB letter to the Subcommittee on Water Resources and Environment of the House of Representatives Committee on Transportation and Infrastructure, and the Subcommittee on Energy and Water Development of the House of Representatives Committee on Appropriations. I am also providing an identical letter to the President of the Senate.

Very truly yours,

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

Enclosures

Enclosures

1. Report of the Chief of Engineers, December 14, 2015
2. OMB Clearance Letter, April 8, 2016
3. Record of Decision, April 13, 2016
4. Summary of State and Agency Review
5. Final Integrated Feasibility Report and Environmental Impact Statement, April 2015 (CD)

DEPARTMENT OF THE ARMY
CHIEF OF ENGINEERS
2600 ARMY PENTAGON
WASHINGTON, DC 20310-2600

DEC 14 2015

DAEN

SUBJECT: Skokomish River Basin Ecosystem Restoration, Washington

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on ecosystem restoration along the Skokomish River in Mason County, Washington. It is accompanied by the reports of the district and division engineers. These reports were completed under the authority of Section 209 of the River and Harbor Act of 1962, Public Law 87-874, which directed the Secretary to "cause surveys for flood control and allied purposes" in a number of named localities, including "Puget Sound, Washington, and adjacent waters, including tributaries, in the interest of flood control, navigation, and other water uses and related land resources." Preconstruction engineering and design activities, if funded, for the Skokomish River Basin Ecosystem Restoration Project will continue under the authority provided by the resolution cited above.

2. The reporting officers recommend authorization of a plan to restore aquatic ecosystem structure and function to the lower eleven miles of the Skokomish River. The recommended plan for ecosystem restoration includes;

- removal of a levee at the confluence of the North and South Forks of the Skokomish River near river mile 9;
- installation of large woody debris and engineered logjams on the South Fork Skokomish River, between river miles 9 and 11;
- reconnection of an historical side channel between river miles 4.5 and 5.5 of the Skokomish River;
- wetland restoration on the south bank of the Skokomish River between river miles 8.3 and 9.2 (the River Mile 9 site); and
- wetland restoration on the south bank of the Skokomish River between river miles 7.5 and 8 (the Grange site).

The recommended plan provides restoration on a total of 277 acres in the study area and provides substantial benefits to nationally significant resources. In addition, the removal of the levee at the confluence of the North and South Forks of the Skokomish River provides significant benefits for upstream fish passage to an approximate additional 40 miles of habitat in the South Fork Skokomish River that is periodically inaccessible due to the lack of water in the river channel adjacent to the confluence. The recommended plan is the National Ecosystem Restoration (NER) Plan. The recommended plan also includes a monitoring and adaptive management plan to ensure success, as described in Appendix E of the final report.

DAEN
SUBJECT: Skokomish River Basin, Mason County, Washington

3. Based on an October 2015 price level, the estimated project first cost of the recommended plan is $19,664,000, which includes monitoring costs of $383,000 and adaptive management costs of $129,000. In accordance with the cost sharing provisions of Section 103(c) of the Water Resources Development Act (WRDA) of 1986, as amended (33 U.S.C. 2213(c)), ecosystem restoration features are cost-shared at a rate of 65 percent federal and 35 percent non-federal. Thus, the federal share of the total project first cost is estimated to be $12,782,000 and the non-federal share is estimated at $6,882,000, which includes the costs of lands, easements, rights-of-way, relocations, and dredged or excavated material disposal areas estimated at $1,711,000. The Skokomish Indian Tribe and Mason County, Washington are the non-federal cost-sharing sponsors for the recommended plan. Operation, maintenance, repair, replacement, and rehabilitation expenses are estimated to be approximately $10,000 per year and are the responsibility of the non-federal sponsors.

4. The restoration actions would improve aquatic habitats for the fish and wildlife species found in the lower eleven miles of the Skokomish River, including four fish species listed under the Endangered Species Act (chinook salmon, chum salmon, steelhead trout and bull trout), and would also provide benefits to over 100 additional species known to utilize the habitats associated with the Skokomish River for some part of their life cycles. Cost effectiveness and incremental cost analysis techniques were used to evaluate the alternative plans to ensure that a cost effective ecosystem restoration plan was recommended. The cost of the recommended restoration features is justified by restoring 187 average annual habitat units on 277 acres of floodplain and aquatic habitat and by allowing access to the 40 miles of the South Fork upstream of the confluence. The average annual cost of the plan is $824,000. The average annual cost per average annual habitat unit is $4,400, and the average annual cost per acre is $3,000.

5. The recommended plan was developed in coordination and consultation with federal, state, and local agencies and the Skokomish Tribe. Risk and uncertainty were addressed during the study by completing a cost and schedule risk analysis and a sensitivity analysis that evaluated the potential impacts of a change in economic assumptions.

6. In accordance with Corps' guidance on the review of decision documents, all technical, engineering and scientific work underwent an open, dynamic and rigorous review process to ensure technical quality. This includes a District Quality Control review, an Agency Technical Review (ATR), an Independent External Peer Review (IEPR) (Type 1), and a Corps Headquarters policy and legal review. All comments from the above referenced reviews have been addressed and incorporated into the final documents.

7. Washington level review indicates the plan recommended by the reporting officers is environmentally justified, technically sound, cost effective, and socially acceptable. The plan complies with all essential elements of the U.S. Water Resources Council's Economic and Environmental Principal and Guidelines for Water and Land Related Resources Implementation Studies. The recommended plan complies with other administration and legislative policies and guidelines. The views of interested parties including federal, state, and local agencies have been considered.

DAEN
SUBJECT: Skokomish River Basin, Mason County, Washington

8. I concur in the findings, conclusions, and recommendations of the reporting officers. Accordingly, I recommend that the plan for ecosystem restoration in the Skokomish River Basin, Washington be authorized in accordance with the reporting officers' recommended plan at an October 2015 estimated project first cost of $19,664,000. My recommendation is subject to cost sharing, financing, and other applicable requirements of federal and state laws and policies, including Public Law 99-662, the WRDA of 1986, as amended, and in accordance with the required items of local cooperation that the non-federal sponsors shall, prior to project implementation, agree to perform:

a. Provide 35 percent of total ecosystem restoration costs as further specified below:

1. Provide the required non-federal share of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;

2. Provide, during the first year of construction, any additional funds necessary to pay the full non-federal share of design costs;

3. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the government to be required or to be necessary for the construction, operation, and maintenance of the project, and provide relocation assistance, all in compliance with applicable provisions of the Uniform Relocation and Assistance and Real Property Acquisition Policies act of 1970, as amended (42 U.S.C. 4601-4655) and the regulations contained in 49 C.F.R. Part 24;

4. Provide, during construction, any funds necessary to make its total contributions equal to 35 percent of total project costs.

b. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities that might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;

c. Shall not use the project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project;

d. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable federal and state laws and regulations and any specific directions prescribed by the federal government;

e. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

f. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction, operation, and maintenance of the project. However, for lands that the federal government determines to be subject to the navigation servitude, only the federal government shall perform such investigations unless the federal government provides the non-federal sponsors with prior specific written direction, in which case the non-federal sponsors shall perform such investigations in accordance with such written direction;

g. Assume, as between the federal government and the non-federal sponsors, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction, operation, and maintenance of the project; and

h. Agree, as between the federal government and the non-federal sponsors, that the non-federal sponsors shall be considered the operators of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA.

9. The recommendations contained herein reflect the information available at this time and current departmental policies governing the formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of the national civil works construction program or the perspective of higher levels within the executive branch. Consequently, the recommendations may be modified before they are transmitted to Congress for authorization and/or implementation funding. However, prior to transmittal to Congress, the State of Washington, interested federal agencies, and other parties will be advised of any significant modifications in the recommendations and will be afforded an opportunity to comment further.

THOMAS P. BOSTICK
Lieutenant General, USA
Chief of Engineers

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

April 8, 2016

The Honorable Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington, DC 20310-0108

Dear Ms. Darcy:

As required by Executive Order 12322, the Office of Management and Budget has reviewed a January 2015 Army Corps of Engineers (Corps) feasibility study of the aquatic ecosystem restoration project at the Skokomish River Basin, Mason County, Washington, with a first cost of $19,664,000 (October 2015 price level).

Based on our review of the Corps' report, an authorization to construct this project would be consistent with the programs and policies of the President. The Office of Management and Budget does not object to your submitting this report to Congress. When you do so, please advise the Congress that should the Congress authorize this project for construction, the project would need to compete with other proposed investments for funding in future budgets.

Sincerely,

John Pasquantino
Deputy Associate Director

RECORD OF DECISION

SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION STUDY
MASON COUNTY, WASHINGTON

The Final Integrated Feasibility Report and Environmental Impact Statement (FR/EIS) dated April 2015, for the Skokomish River Basin Ecosystem Restoration, incorporated herein by reference, addresses ecosystem restoration opportunities and feasibility in the Skokomish River Basin, Mason County, Washington. The final recommendation is contained in the report of the Chief of Engineers, dated December 14, 2015. Based on these reports, the reviews by other Federal, State and local agencies, Tribes, input of the public, and the review by my staff, I find the plan recommended by the Chief of Engineers to be technically feasible, environmentally justified, cost effective, in accordance with environmental statutes, and in the public interest.

The Final FR/EIS, incorporated herein by reference, evaluated various alternatives that would restore ecosystem processes, structures, and functions in the study area. The recommended plan is the National Environmental Restoration (NER) plan and includes:

- Removal of a levee at the confluence of the North and South Forks of the Skokomish River near river mile 9;
- Installation of large woody debris and engineered logjams on the South Fork Skokomish River, between river miles 9 and 11;
- Reconnection of an historical side channel of the Skokomish River, between river miles 4.5 and 5.5; and,
- Restoration of wetland habitat on the south bank of the Skokomish River between river miles 8.3 and 9.2 (the River Mile 9 site) and river miles 7.5 and 8.0 (the Grange site).
- A Monitoring and Adaptive Management Plan that provides a framework for evaluating the effectiveness of proposed restoration actions and outlines adaptive measures if the project restoration metrics are not met. It includes monitoring to track progress and the triggers for when a new action may be taken to meet restoration objectives.

In addition to a "no action" plan, six alternatives were evaluated. The alternatives included different locations of levee removal, wetland restoration, side channel reconnections, barrier removals, road relocations, and river channel deepening. Based on the comparison of effects presented in the FR/EIS, Alternative #27 (Confluence Levee removal and 7 additional increments) is the Environmentally Preferable Alternative as it has the greatest net benefits to the biological and physical environment. Based on coordination with the public and sponsors, and project feasibility level designs, Alternative #27 contained three increments with insurmountable real estate issues. As such, these features were removed to formulate the recommended plan (Alternative #18). While smaller in scope than the

environmentally preferred alternative, the recommended plan restores the critical needs of the study area, providing year-round flow for fish passage, in channel habitat and complexity, and off-channel refugia and habitat. The recommended plan is supported by the non-Federal sponsors, the Skokomish Indian Tribe and Mason County, Federal and state agencies, and the public.

All practical means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. In accordance with section 7 of the Endangered Species Act of 1973, as amended, the U.S. Fish and Wildlife Service and National Marine Fisheries Service confirmed that the recommended plan falls under the parameters of their respective Programmatic Biological Opinions and will not jeopardize the continued existence of federally listed species or adversely modified designated critical habitat. All terms and conditions resulting from these consultations shall be implemented in order to minimize take of endangered species. No compensatory mitigation is required.

The Corps hosted a public meeting to solicit comments on the Draft FR/EIS on March 20, 2014. Public review of the draft FR/EIS was completed on April 7, 2014. All comments submitted during the public comment period were responded to in the Final FR/EIS. A 30-day waiting period of the Final FR/EIS was completed on October 25, 2015. Comments from state and Federal agencies did not result into any changes to the final FR/EIS.

Technical, environmental, economic and cost-effective criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on the review of these evaluations, I find that the recommended plan reasonably maximizes the ecosystem restoration benefits compared to costs and any adverse effects. This Record of Decision completes the National Environmental Policy Act process.

april 18, 2016
Date

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

United States Department of the Interior

Office of the Secretary
Washington, D.C. 20240

OCT 30 2015

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ER14/0102

Ms. Nancy C. Gleason
U.S. Army Corps of Engineers
CENWS-EN-ER
P.O. Box 3755
Seattle, Washington 98124

Re: Final Integrated Feasibility Report and Final Environmental Impact Statement for the Skokomish River Ecosystem Restoration Study, Mason County, WA

Dear Ms. Gleason:

The Department of the Interior (Department) has reviewed the above referenced document. According to project materials, the recommended plan would restore about 280 acres of habitat in the Skokomish River Basin. The Department has no further comments to submit at this time.

For questions or further information regarding this response, please contact Cheryl Kelly on my Natural Resources Management Team, at (202) 208-7565 or at cheryl_kelly@ios.doi.gov.

Thank you for the opportunity to review and comment on this plan.

Sincerely,

Willie R. Taylor
Director, Office of Environmental
Policy and Compliance

cc: USACE (Trish Bee: Patricia.L.Bee@usace.army.mil

TRANSMITTED ELECTRONICALLY – NO HARDCOPY TO FOLLOW

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF
ECOSYSTEMS, TRIBAL AND
PUBLIC AFFAIRS

October 26, 2015

Mr. Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works
U.S. Army Corps of Engineers
441 G Street NW
Washington, D.C. 20314-1000

Dear Mr. Brown:

The U.S. Environmental Protection Agency has reviewed the Final Integrated Feasibility Report and Environmental Impact Statement for the Skokomish River Basin Ecosystem Restoration (EPA Region 10 Project Number 10-056-COE), as well as the proposed report of the Chief of Engineers and the report of the district engineer on the Skokomish River Basin Ecosystem Restoration Project, Mason County, Washington. We are submitting comment on the Final EIS in accordance with our responsibilities under the National Environmental Policy Act and Section 309 of the Clean Air Act. We would also like to convey our concurrence with the Chief of Engineers proposed report, which was prepared in accordance with established coordination procedures on water resources reports.[1]

EPA issued a Lack of Objections rating for the Draft EIS and supported Alternative 27, the preferred alternative. However, the Final EIS identifies Alternative 18 as the preferred alternative. Alternative 18 is more acceptable to landowners and includes the same components as Alternative 27 except for restoration of Hunter Creek and Weaver Creek tributaries. While this is a reduction in anticipated project benefits, we agree that the Corps' recommended plan will achieve critical restoration needs in the project study area and appreciate that the Corps' cost effectiveness analysis has identified the most promising projects for consideration in future restoration efforts.

We also appreciate the Corps' response to our detailed comments and recommendations on the Draft EIS. Specifically, the Corps:

- has learned more about past and current restoration in the watershed and used this information in a risk analysis on sediment input rate and the effects to restoration designs;
- will improve water quality by expanding wetland areas through levee breaching and removal, will revegetate with high density native plantings to accelerate ground coverage and canopy development, and will monitor and adaptively manage the sites;
- will verify sources of large woody debris (logs, root wads) used for engineered log jams and ensure that restoration actions do not cause unnecessary ecological impacts elsewhere; and
- has sampled the car body levee for hazardous and toxic wastes and found no results warranting further evaluation.

[1] Per the Corps' request, letter of September 18, 2015.

The Corps states that during construction, the car bodies will be considered solid waste and will be disposed of at an appropriate disposal site. Our remaining recommendation is that any car bodies or other debris excavated during construction that is suitable for recycling be recycled rather than disposed of as solid waste.

We thank the Corps for the opportunity to review the Final EIS and the proposed report of the Chief of Engineers and district engineer for this beneficial project. We look forward to implementation of the restoration plan and encourage you to contact us if we can be of assistance. You may contact me at (206) 553-1601 or via electronic mail at littleton.christine@epa.gov, or contact Elaine Somers at (206) 553-2966 or via electronic mail at somers.elaine@epa.gov.

Sincerely,

Christine B. Littleton

Christine B. Littleton, Manager
Environmental Review and Sediment Management Unit

Cc: Nancy C. Gleason, U.S. Army Corps of Engineers

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United States Department of the Interior

FISH AND WILDLIFE SERVICE

Washington Fish and Wildlife Office
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503

OCT 16 2015

In Reply Refer to:
01EWFW00-2016-CPA-0003
xRef: **01EWFW00-2014-CPA-0015**

Theodore A. Brown, P.E.
U.S. Army Corps of Engineers
Headquarters
CECW-P (SA)
7701 Telegraph Road
Alexandria, Virginia 22315-3860

Dear Mr. Brown:

Subject: Report of the Chief of Engineers and Final Environmental Impact Statement, Skokomish River Basin Ecosystem Restoration Project

This letter is in response to your September 18, 2015 request for U.S. Fish and Wildlife Service (Service) comments and recommendations on the Report of the Chief of Engineers and the Final Environmental Impact Statement (FEIS) for the Skokomish River Basin Ecosystem Restoration Project in Mason County, Washington. The Service provided comments and recommendations on this project to the U.S. Army Corps of Engineers (Corps) in our final Fish and Wildlife Coordination Act Section 2(b) report dated February 27, 2015 (01EWFW00-2015-CPA-0018). The current project description outlined in the FEIS embodies many of the recommendations offered in our report. We are pleased with the Corps' effort to incorporate our recommendations for both minimizing the potential for unintended negative impacts and maximizing ecosystem restoration benefits.

Based on our review, we believe the Report of the Chief of Engineers and the FEIS accurately describe the restoration benefits of implementing the project as described. The proposed restoration activities will reverse some of the primary causes and consequences of ecosystem degradation and will benefit many target and non-target species, the aquatic ecosystem as a whole, and the broader watershed. For these reasons, the Service strongly supports implementation of this project as described in the Report of the Chief of Engineers and the FEIS.

We have appreciated and enjoyed cooperating with the Corps as this project has proceeded. Please contact Mark Celedonia at (360) 534-9327, or Martha Jensen at (360) 753-9000 for questions about our comments and/or for future coordination and collaboration on the Skokomish River Basin Ecosystem Restoration Project.

Sincerely,

Martha L. Jensen

for Eric V. Rickerson, State Supervisor
Washington Fish and Wildlife Office

cc:
USACE, Seattle, WA (E. Lewis)

State of Washington
DEPARTMENT OF FISH AND WILDLIFE
Mailing Address: 600 Capitol Way N, Olympia, WA 98501-1091 • (360) 902-2200 • TDD (360) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia, WA

October 26, 2015

Mark Matusiak
U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

RE: Skokomish River Basin Integrated Feasibility Report and Environmental Impact Statement

Dear Mr. Matusiak:

The Washington Department of Fish and Wildlife (WDFW) appreciates the long-term efforts of the Corps of Engineers, Mason County and the Skokomish Indian Tribe to develop alternatives for ecosystem restoration of natural processes in the lower Skokomish River watershed. It was a daunting task, but the restoration alternatives were thoroughly investigated and vetted through stakeholders and community to produce an effective science-based recommended restoration plan/preferred alternative. As identified in the report, restoration of habitat and natural habitat processes in the Skokomish watershed is vital for recovery of listed salmon species and critical to the overall health of Hood Canal.

WDFW has reviewed the integrated feasibility report and Environmental Impact Statement and offers the following comments.

- WDFW supports the primary objectives selected for the focus of ecosystem restoration work of providing year-round fish passage near the confluence and improvement of habitat quality and quantity. The selection of objectives is crucial to the success of development of an appropriate ecosystem restoration plan.

- WDFW supports the approach used to select the recommended restoration plan/preferred alternative. The approach used to compare a suite of measures, sites and alternatives was systematic and science-based. The technical work completed to inform this analysis was well done and appropriate. The independent review panel identified areas for further evaluation (e.g. cost estimates and sustainability) and should be considered as the project analysis and development moves forward.

- WDFW supports the selection of Confluence Levee Removal Alternative 18 as the recommended restoration plan/preferred alternative. The project components of levee removal, side channel reconnection, wetland restoration and large woody material placement will improve habitat and restore flows near the confluence.

Ecosystem restoration in the Skokomish watershed will require a basin-wide collaborative effort to implement several watershed plans and complementary actions to be successful. To be sustainable, the actions identified in the recommended restoration plan will require additional work upstream of the project area. Work of this type is currently underway and additional projects are in planning stages, as led by the Skokomish Watershed Action Team. Habitat protection and restoration work is needed to complement these actions for ecosystem restoration, as identified in the Skokomish Chinook Salmon Recovery Plan. The local sponsors are working hard to develop, design and implement these projects simultaneously with the recommended restoration plan work. The habitat restoration and changes associated with the Cushman settlement will further advance ecosystem restoration goals. Restoration projects are underway in the estuary and throughout the watershed, funded by numerous watershed restoration and species recovery sources working in partnership to restore the Skokomish watershed. Mason County, U.S. Forest Service and National Park Service are leading efforts protecting critical areas in the watershed and working toward flood protection in the river valleys.

The current focus on ecosystem restoration in the Skokomish River basin through the many synergistic efforts underway is paramount to success. WDFW is committed to participate in and provide technical support for project development and design as needed. If you have questions about this response, please contact Jennifer Quan at (360) 902-2224.

Sincerely,

James Unsworth, Ph.D.
Director

cc: Jennifer Quan

REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

DEC 08 2015

Mr. Rick Mraz
Wetland Specialist, Washington State Department of Ecology
Southwest Regional Office
Post Office Box 47775
Olympia, Washington 98504

Dear Mr. Mraz:

This letter is in response to Ecology's October 16, 2015, comment letter on the U.S. Army Corps of Engineers final Feasibility Report (FR) and Environmental Impact Statement (EIS) for the Skokomish River Basin Ecosystem Restoration Project. Your letter identified a number of observations in response to the information provided in Appendices C, F, and L of the Final FR/EIS.

As noted in the final FR/EIS, the recommended plan includes ecosystem restoration activities at five sites in the Skokomish River Basin. The Hunter Creek projects and Dips Road relocation are not included in the recommended plan, so the Corps will not be pursuing construction activities at these sites. The Corps will conduct a wetland delineation in the next phase of design at the sites where wetland embankments (setback levees) are proposed for construction; the 57 acres of wetland restoration due to levee breaches will more than offset the minor fill, as described in the Clean Water Act Section 404(b)(1) evaluation included in Appendix L of the Final FR/EIS. Post-construction monitoring and adaptive management will track progress toward restoration goals and provide for adaptive management measures. Prior to submitting the documentation to your agency for formal review and concurrence, the Corps will update the project's Coastal Zone Management Act consistency determination to reflect final design. This updated consistency determination will accompany the Clean Water Act Section 401 documents submitted to your office. The Seattle District Office will also continue to invite your agency to participate in project design. Finally, the non-federal sponsors, the Skokomish Indian Tribe and Mason County, will be responsible for maintenance of the setback levees. Financial assurances for maintenance were included in letters of intent from the non-federal sponsors and will also be included in a cost-sharing agreement to be executed with the non-federal sponsors prior to construction

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Thank you for your comments on the Corps Skokomish River Basin Ecosystem Restoration Project and I look forward to future coordination with your agency. If you have additional questions or concerns, please contact Mr. Steven Kopecky, Deputy Chief, Northwestern and Pacific Ocean Divisions Regional Integration Team, at (202) 761-4527.

Sincerely,

Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47775 · Olympia, Washington 98504-7775 · (360) 407-6300
711 for Washington Relay Service · Persons with a speech disability can call 877-833-6341

October 16, 2015

Mr. Mark Matusiak
Office of Water Project Review
U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandra, VA 22315-3860

Dear Mr. Matusiak:

Thank you for the opportunity to comment on the NEPA/Final EIS for the Skokomish River Basin Ecosystem Restoration Project located in Mason County. The Department of Ecology (Ecology) reviewed the information provided and has the following comment(s):

SHORELANDS & ENVIRONMENTAL ASSISTANCE: Rick Mraz (360) 407-6221

Appendix L, which is the *Integrated Feasibility Report and Environmental Impact Statement*, includes the following statement: "A full description and evaluation of project impacts is not possible since the PA/TSP is only at the conceptual stage of development and many project details have yet to be proposed."

As such, Ecology cannot provide specific comments on some of the alternative listed in Sections VI & VII without field investigation and additional information. However, we can offer the following comments regarding wetland impacts.

- Ecology has conducted site visits with regard to the car body levee removal, LWD installation, and side channel reconnection. These activities do not appear to produce significant deleterious effects to wetlands.

Ecology has not reviewed several other actions that are tentatively identified as proposed alternatives. We offer the following observations in response to the limited information provided in Appendices C, F & L.

- The Hunter Creek projects appear to be proposed in areas that are currently wetland. Construction of open water channels in wetlands is a conversion of habitat types and

may require mitigation for loss of wetland functions. As noted in Appendix L, "there are no data to confirm the necessity of this intervention".

- The wetland berms are essentially setback levees and are proposed to be constructed, at least in part, in wetlands. Ecology will require a detailed analysis of these impacts (wetland area lost, wetland category impacted) and a clear, objective analysis of wetland area created by these actions. The Wetlands Inventory (Appendix C) is inadequate in this regard. Please also provide information regarding monitoring activities associated with documenting the targeted wetland creation for the levee setback elements.

- The Dips Road relocation does not include an analysis of potential wetland impacts from this action. This information should be provided.

- The CZMA consistency determination does not include an analysis of the landfill section of the Mason County Shoreline Master Program. Construction of levees constitutes landfill. This element should be include in the CZMA analysis.

Who will be responsible for maintenance of the setback levees? What financial assurances will accompany this maintenance responsibility?

Ecology's comments are based upon information provided by the lead agency. As such, they may not constitute an exhaustive list of the various authorizations that must be obtained or legal requirements that must be fulfilled in order to carry out the proposed action.

If you have any questions or would like to respond to these comments, please contact the appropriate reviewing staff listed above.

Department of Ecology
Southwest Regional Office

(SM:15-4970)

cc: Rick Mraz, SEA

SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

Integrated Feasibility Report and Environmental Impact Statement

April 2015

US Army Corps of Engineers
Seattle District

RECORD OF DECISION

SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION STUDY
MASON COUNTY, WASHINGTON

The Final Integrated Feasibility Report and Environmental Impact Statement (FR/EIS) dated April 2015, for the Skokomish River Basin Ecosystem Restoration, incorporated herein by reference, addresses ecosystem restoration opportunities and feasibility in the Skokomish River Basin, Mason County, Washington. The final recommendation is contained in the report of the Chief of Engineers, dated December 14, 2015. Based on these reports, the reviews by other Federal, State and local agencies, Tribes, input of the public, and the review by my staff, I find the plan recommended by the Chief of Engineers to be technically feasible, environmentally justified, cost effective, in accordance with environmental statutes, and in the public interest.

The Final FR/EIS, incorporated herein by reference, evaluated various alternatives that would restore ecosystem processes, structures, and functions in the study area. The recommended plan is the National Environmental Restoration (NER) plan and includes:

- Removal of a levee at the confluence of the North and South Forks of the Skokomish River near river mile 9;
- Installation of large woody debris and engineered logjams on the South Fork Skokomish River, between river miles 9 and 11;
- Reconnection of an historical side channel of the Skokomish River, between river miles 4.5 and 5.5; and,
- Restoration of wetland habitat on the south bank of the Skokomish River between river miles 8.3 and 9.2 (the River Mile 9 site) and river miles 7.5 and 8.0 (the Grange site).
- A Monitoring and Adaptive Management Plan that provides a framework for evaluating the effectiveness of proposed restoration actions and outlines adaptive measures if the project restoration metrics are not met. It includes monitoring to track progress and the triggers for when a new action may be taken to meet restoration objectives.

In addition to a "no action" plan, six alternatives were evaluated. The alternatives included different locations of levee removal, wetland restoration, side channel reconnections, barrier removals, road relocations, and river channel deepening. Based on the comparison of effects presented in the FR/EIS, Alternative #27 (Confluence Levee removal and 7 additional increments) is the Environmentally Preferable Alternative as it has the greatest net benefits to the biological and physical environment. Based on coordination with the public and sponsors, and project feasibility level designs, Alternative #27 contained three increments with insurmountable real estate issues. As such, these features were removed to formulate the recommended plan (Alternative #18). While smaller in scope than the

environmentally preferred alternative, the recommended plan restores the critical needs of the study area, providing year-round flow for fish passage, in channel habitat and complexity, and off-channel refugia and habitat. The recommended plan is supported by the non-Federal sponsors, the Skokomish Indian Tribe and Mason County, Federal and state agencies, and the public.

All practical means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. In accordance with section 7 of the Endangered Species Act of 1973, as amended, the U.S. Fish and Wildlife Service and National Marine Fisheries Service confirmed that the recommended plan falls under the parameters of their respective Programmatic Biological Opinions and will not jeopardize the continued existence of federally listed species or adversely modified designated critical habitat. All terms and conditions resulting from these consultations shall be implemented in order to minimize take of endangered species. No compensatory mitigation is required.

The Corps hosted a public meeting to solicit comments on the Draft FR/EIS on March 20, 2014. Public review of the draft FR/EIS was completed on April 7, 2014. All comments submitted during the public comment period were responded to in the Final FR/EIS. A 30-day waiting period of the Final FR/EIS was completed on October 25, 2015. Comments from state and Federal agencies did not result into any changes to the final FR/EIS.

Technical, environmental, economic and cost-effective criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on the review of these evaluations, I find that the recommended plan reasonably maximizes the ecosystem restoration benefits compared to costs and any adverse effects. This Record of Decision completes the National Environmental Policy Act process.

april 18, 2016
Date

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

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LIST OF ABBREVIATIONS AND ACRONYMS

AAHU Average Annual Habitat Unit
ACE Annual Chance of Exceedance
ATR Agency Technical Review
BA Biological Assessment
BMP Best Management Practice
CAA Clean Air Act
CE/ICA Cost Effective/Incremental Cost Analysis
CEQ Council for Environmental Quality
CEQA California Environmental Quality Act
CERCLA Comprehensive Environmental Response, Compensation, and Liability Act
CFS Cubic feet per second
Corps U.S. Army Corps of Engineers
CSYU Shelton Cooperative Sustained-Yield Unit
CY Cubic yards
CZMA Coastal Zone Management Act
DAHP Department of Archaeology and Historic Preservation
DO Dissolved Oxygen
DPS Distinct Population Segment
DQC District Quality Control
EA Environmental Assessment
EC Engineering Circular
ECO-PCX Ecosystem Planning Center of Expertise
EFH Essential Fish Habitat
EO Ecosystem Outputs
ER Engineer Regulation
ERDC Engineer Research and Development Center
ESA Endangered Species Act
EPA U.S. Environmental Protection Agency
FERC Federal Energy Regulatory Commission
FMP Fishery Management Plan
FPPA Farmland Protection Policy Act
FR/EIS Feasibility Report/Environmental Impact Statement
FONSI Finding of No Significant Impact
FSM Feasibility Scoping Meeting
FWCA Fish and Wildlife Coordination Act
GHG Greenhouse Gas
GI General Investigation
HAPC Habitat Area of Particular Concern
HCCC Hood Canal Coordinating Council
IDC Interest during construction
IEPR Independent External Peer Review
IWR Institute for Water Resources
LWD Large Woody Debris
LOS Level of service
MBTA Migratory Bird Treaty Act
MCACES Micro-Computer Aided Cost Estimating System
MMPA Marine Mammal Protection Act
MSFCMA Magnuson-Stevens Fishery Conservation and Management Act
NAGPRA Native American Graves Protection and Repatriation Act
NEPA National Environmental Policy Act
NER National Ecosystem Restoration
NHPA National Historic Preservation Act
NMFS National Marine Fisheries Service
NOAA National Oceanic and Atmospheric Administration
NOI Notice of Intent
NPDES National Pollutant Discharge Elimination System
NRHP National Register of Historic Places
NWI National Wetlands Inventory
O&M Operations and Maintenance
ONF Olympic National Forest
PDT Project Delivery Team
PED Preconstruction engineering and design
PPA Project Partnership Agreement
RCO Recreation and Conservation Office
RM River Mile
SHPO State Historic Preservation Officer
SMA Shoreline Management Act
SWAT Skokomish Watershed Action Team
TCP Traditional Cultural Properties
Tribe Skokomish Indian Tribe
TSP Tentatively Selected Plan
U&A Usual and Accustomed
USACE U.S. Army Corps of Engineers
USC United States Code
USFS U.S. Forest Service
USFWS U.S. Fish and Wildlife Service
WDFW Washington State Department of Fish and Wildlife
WDNR Washington State Department of Natural Resources
WDOE Washington Department of Ecology
WRDA Water Resources Development Act
WRIA Water Resource Inventory Area
WQC Water Quality Certification

Executive Summary

This integrated feasibility report and environmental impact statement presents the results of a U.S. Army Corps of Engineers (Corps) Ecosystem Restoration feasibility study undertaken to identify and evaluate alternatives for restoring degraded ecosystem structures, functions, and processes in the Skokomish River Basin, Washington. The Corps is undertaking this action in partnership with Mason County and the Skokomish Indian Tribe. This report provides documentation of the plan formulation process to select a recommended restoration plan, along with environmental, engineering, and cost details of the recommended plan, which will allow additional design and construction to proceed following approval of this report.

The Skokomish River Basin is located on the Great Bend of Hood Canal, a natural fjord-like arm of the Puget Sound and water of national significance identified by the U.S. Environmental Protection Agency (EPA). The Skokomish River is the largest source of freshwater to Hood Canal and of critical importance to the overall health of Hood Canal. The primary concern to be addressed in this study is ecosystem degradation in the Skokomish River Basin, which includes the Skokomish Indian Reservation. High sediment load, reduced flows, and encroachment on the floodplain by human-made structures are causing continued degradation of natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat throughout the basin. The decline in populations has resulted in the listing of four anadromous fish species under the Endangered Species Act (ESA) (e.g., Chinook salmon, chum salmon, steelhead, and bull trout) that use the river as their primary habitat. The impaired ecosystem has adversely affected riverine, wetland, and estuarine habitats that are critical to these and other important fish and wildlife species such as bears, bald eagles, and river otters to name a few.

As part of the planning process for the study, the Project Delivery Team (PDT) identified the ecosystem restoration goals for the study. Providing year-round fish passage near the confluence of the North Fork and South Fork of the Skokomish River as well as improving the quantity, quality, and complexity of pools were identified as priority objectives for the study. The PDT, in coordination with interested stakeholders and the public, developed a series of measures and alternatives for consideration as potential elements of the project solution. The array of alternatives was formulated based on preliminary data collection and analysis as well as best professional judgment. The study team identified 60 potential restoration sites and completed multiple rounds of screening to identify which sites meet the priority objectives of the study. Each alternative was formulated to include a "base" measure that addresses these critical needs of the study area. Incremental measures (e.g., side channel reconnections, wetland restoration, and placement of large woody debris) were added to these bases to capture supplementary benefits associated with restoration of additional habitat features.

The PDT developed preliminary cost estimates for each site and calculated habitat benefits that could accrue from restoration measures. Habitat benefits were calculated using the Skokomish River Ecosystem Benefits Model, a habitat suitability index model accounting for the quality and quantity of available habitat for salmonids (an indicator species for overall ecosystem health in the Pacific Northwest). The preliminary costs and habitat benefits were used in a Cost Effectiveness and

Incremental Cost Analysis (CE/ICA) to identify alternatives that provide high levels of habitat benefit relative to the costs. The CE/ICA was a primary element used to select the recommended restoration plan.

A recommended restoration plan was selected that includes a levee removal, a side channel reconnection, wetland restoration at two sites, and placement of large woody debris. The total area of the proposed sites included in the recommended plan is approximately 277 acres, the average annual habitat units are estimated at 187, and the total estimated project first cost of the recommended plan is $19,343,000 (October 2014 price level), which includes monitoring costs of $374,000 and adaptive management costs of $127,000. The fully funded cost estimate to the midpoint of construction is $21,712,000. Minimal operations, maintenance, repair, rehabilitation, and replacement (OMRR&R) expenses is estimated to be $10,000 per year. The current Federal portion of the cost is $12,573,000 and the non-Federal sponsors' portion is $6,770,000, or 65 and 35 percent of the total estimated cost respectively (October 2014 price level). The recommended plan reasonably maximizes environmental benefits considering cost effectiveness and incremental cost analyses, significance of outputs, completeness, efficiency, effectiveness, and acceptability. The alternative referred to as the recommended plan in this document is the agency preferred alternative as it is called under the National Environmental Policy Act (NEPA).

No compensatory mitigation is included in the recommended plan as none is required. During construction, there could be temporary adverse effects such as increases in turbidity, temporary clearing of vegetation, and handling of fish for removal from construction areas. These effects would be minimized by providing erosion and pollution control best management practices and conducting all fish salvage and removal activities according to State and Federal requirements. Conservation measures would be implemented during construction to minimize effects to ESA-listed species.

The recommended plan is one element of an integrated restoration effort in the entire Skokomish River watershed and was conceived as part of a comprehensive restoration effort to help address more chronic, systemic problems such as aggradation. The overall cumulative effects of the recommended plan would be synergistic benefits to all aquatic species through process-based restoration in the lower Skokomish River. The benefits of increasing the number and size of in-channel pools, placing enough large woody debris (LWD) to mimic quantities in nearby more natural rivers, reconnecting aquatic habitats in the adjacent floodplain, and greatly increasing the acreage of riparian zones along the river is predicted to provide substantial benefits to fish and wildlife habitat, especially for salmon species.

1. Introduction

This report documents the planning process for ecosystem restoration in the Skokomish River Basin, Washington, to demonstrate consistency with U.S. Army Corps of Engineers (Corps) planning policy and to meet the regulations that implement the National Environmental Policy Act (NEPA). The following sections provide background information regarding the basis for this study. The sections that are required for NEPA compliance are denoted with an asterisk (*).

1.1 Study Purpose and Scope

The purpose of the Skokomish River Basin feasibility study is to evaluate significant ecosystem degradation in the Skokomish River Basin; to formulate, evaluate, and screen potential solutions to these problems; and to recommend a series of actions and projects that have a Federal interest and are supported by a local entity willing to provide the necessary items of local cooperation.

The Skokomish River Basin is located on Hood Canal, a natural fjord-like arm of the Puget Sound and water of national significance. The Skokomish River is the largest source of freshwater to Hood Canal as it flows into Annas Bay and is of critical importance in the overall health of Hood Canal. Environmental degradation can be seen throughout the Skokomish River Basin including a loss of natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat. Four anadromous fish species (Chinook salmon, chum salmon, steelhead, and bull trout) that use the river as their primary habitat are listed under the Endangered Species Act (ESA) and have experienced population declines. The impaired ecosystem has adversely affected riverine, wetland, and estuarine habitats that are critical to these and other listed species. The underlying need for development of a plan for process-based ecosystem restoration in the Basin has arisen from recognition and analysis of these problems. Process-based restoration in aquatic ecosystems seeks to remove human-made stressors from the channel and landscape so that natural ecosystem forces are allowed the freedom to influence the aquatic environment longitudinally in the channel, laterally across the floodplain, and vertically through the riparian zone.

Since the completion of the Reconnaissance Phase (USACE 2000), continued flooding of the Skokomish Valley has led to significant interest in pursuing a multi-purpose feasibility study (addressing ecosystem restoration and flood risk management) by the public. Mason County has been proactive in flood mitigation projects collaborating with the Federal Emergency Management Agency, the State of Washington's Emergency Management Division and the Department of Ecology (WDOE). Past Corps studies (USACE 1988, 1995) indicate a low benefit-to-cost ratio for flood risk management alternatives. More recent economic analyses indicate very low expected annual flood damages due to the rural nature of the study area and implementation of previous flood risk management projects by Mason County including residential acquisitions (buy-outs), strict development/zoning regulations, implementation of a flood warning system and evacuation plan, and raising of structures in the floodplain. Based on these developments, the non-Federal sponsors and study team have agreed to continue to pursue a single-purpose (ecosystem restoration) feasibility study. Although the study is a single-purpose study focusing on ecosystem restoration, the recommended plan has been formulated and designed to ensure flood heights in the study area will not cause significant changes in future with-

project flood conditions compared to future without-project conditions. Additionally, local and State government agencies will continue locally funded flood damage reduction efforts to achieve local flood risk management goals, such as preserving local business, communities, and historic land uses. Section 4.3.1 and Section 4.3.2 discuss the existing and forecasted flood conditions in the study area absent a Corps flood risk management project.

1.2 Study Authority*

The Feasibility Study for the Skokomish River Basin is being conducted under the Authority of Section 209 of the River and Harbor Act of 1962, Public Law 87-874 (Puget Sound and Adjacent Waters):

"The Secretary of the Army is hereby authorized and directed to cause surveys for flood control and allied purposes, including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects, to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the following named localities: Provided, That after the regular or formal reports made on any survey are submitted to Congress, no supplemental or additional report or estimate shall be made unless authorized by law except that the Secretary of the Army may cause a review of any examination or survey to be made and a report thereon submitted to Congress, if such review is required by the national defense or by changed physical or economic conditions: Provided further, That the Government shall not be deemed to have entered upon any project for the improvement of any waterway or harbor mentioned in this title until the project for the proposed work shall have been adopted by law:

Puget Sound, Washington, and adjacent waters, including tributaries, in the interest of flood control, navigation, and other water uses and related land resources."

Seattle District Office of Counsel has confirmed the appropriateness of this authority with USACE Headquarters Office of Counsel. The Act's reference to "other water uses and related land resources" provides sufficient authority to study ecosystem restoration opportunities in the Skokomish River Basin.

1.3 Lead Federal Agency and Non-Federal Sponsors*

The study documented herein has been conducted jointly by the Corps (lead Federal agency) and two non-Federal sponsors, Mason County (County) and the Skokomish Indian Tribe (Tribe). As the non-Federal sponsors, the County and Tribe contribute 50 percent of the total feasibility study costs in the form of cash or in-kind contributions; a feasibility cost sharing agreement was signed in 2006.

1.4 Cooperating Agencies*

Prior to the Feasibility Scoping Meeting on October 7, 2010, the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) expressed willingness to consider a cooperating agency role. Although they declined upon formal invitation, both agencies remain actively involved in the study.

1.5 Location of the Study Area*

The Skokomish River Basin is located on the Olympic Peninsula in northwestern Washington (Figure 1-2). The study area is approximately 11 square miles comprised of the lower Skokomish watershed, the

Skokomish Valley, and Skokomish River estuary (Figure 1-2). The area is characteristic of the enormous beauty and versatile environment of Hood Canal and Puget Sound.

The Skokomish watershed drains approximately 230 square miles from three major tributary basins, the North Fork (118 square miles), the South Fork (76 square miles) and Vance Creek (29 square miles). The river collects flow from these steep, mountainous basins and drains into a flat, alluvial plain approximately ¾ to 1½ miles wide known as the Skokomish Valley. Richert Springs, Hunter, Weaver, and Purdy Creeks are predominantly spring fed tributaries that flow through agricultural lands in the southern portion of the Skokomish Valley floodplain before entering the mainstem Skokomish River. The Skokomish River mainstem flows through the Skokomish Valley to the Skokomish estuary, consisting of the mouth of the Skokomish River and the delta that is tidally influenced. It is the largest and most complex river estuary in Hood Canal. The Skokomish River empties into Annas Bay at the southern end of Hood Canal, an arm of Puget Sound.

The Skokomish Valley has a population of approximately 730 residents (2011 Census) with an economy dominated by rural agriculture. The lower six miles of the river, including a substantial portion of the estuary, are located on the 4,950-acre Skokomish Indian Reservation. There are two privately owned hydroelectric dams near the project area, Cushman Dams 1 and 2, which impound flows on the North Fork Skokomish River, and which have historically influenced flows in the lower reach of the river.

The Skokomish River Basin is a large and complex watershed. Numerous Federal, State, and local agencies are working within their individual authorities to implement restoration projects throughout the watershed. While existing restoration efforts will have localized benefits, a need for action by the Corps still exists. The Corps has a unique opportunity to address problems in the Lower South Fork, Skokomish River mainstem, and tributaries (Weaver Creek, Vance Creek, and Purdy Creek) where many impacts from the upper watershed are manifested and where a number of significant ecosystem restoration opportunities exist. As a result, the study area for the General Investigation (GI) will focus on the lower 11 miles of the river. Figure 1-1 and Figure 1-2 show the location of the Skokomish River Basin and GI study area.

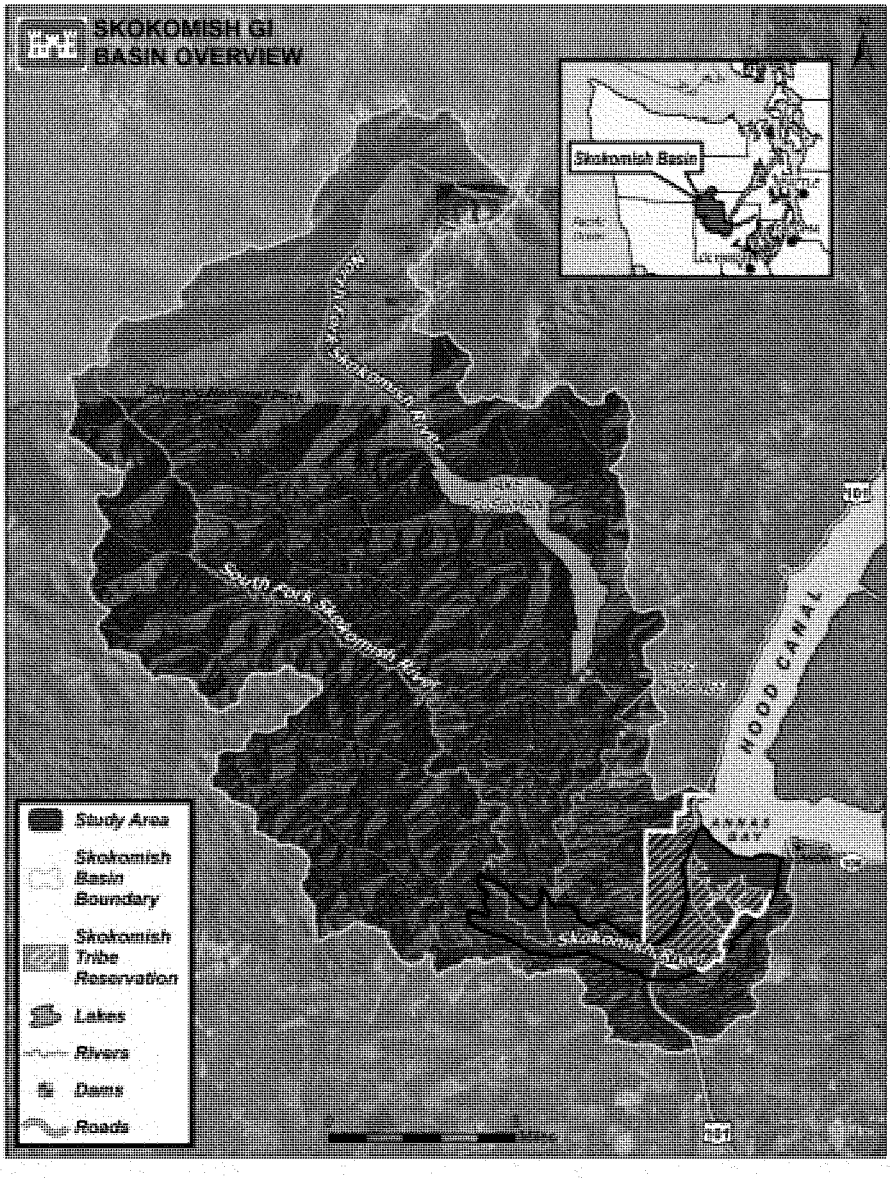


Figure 1-1. Skokomish River Basin Overview

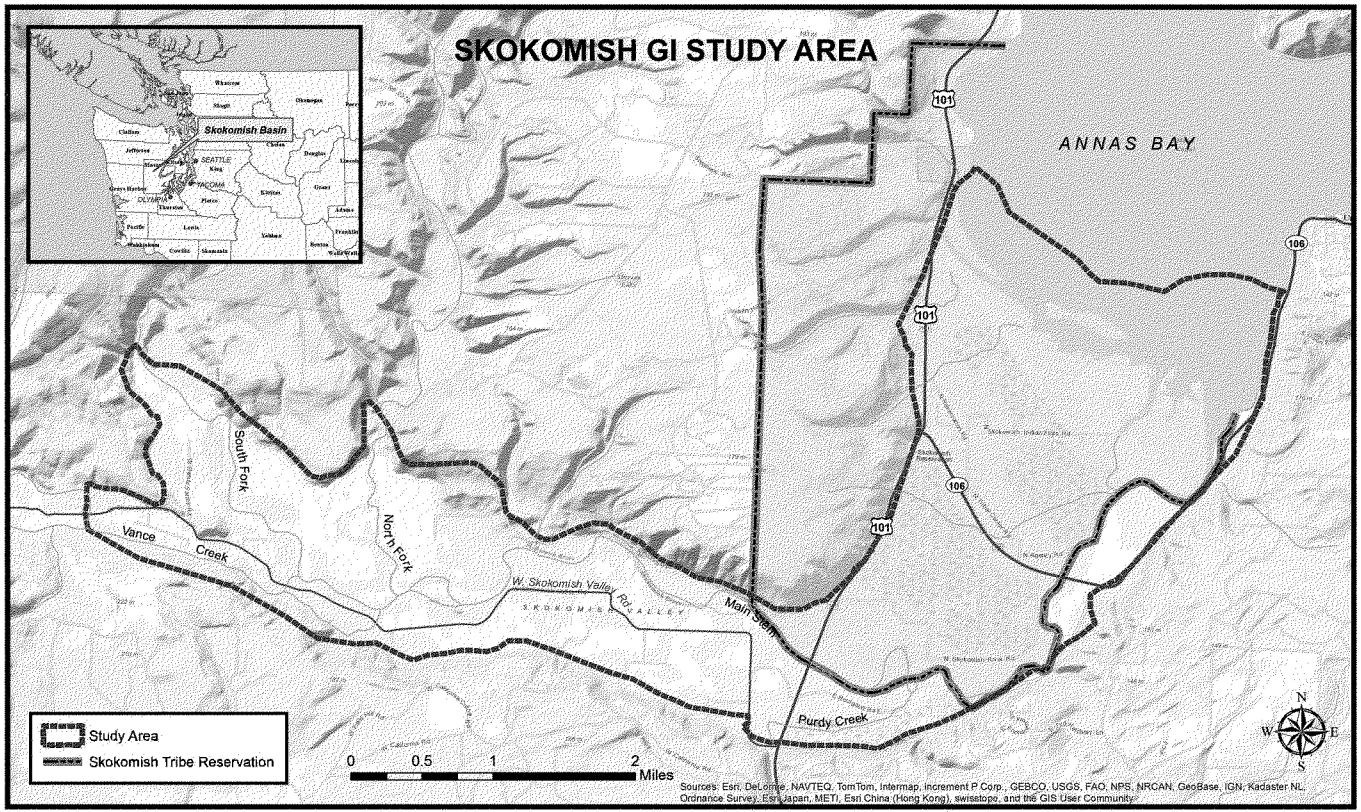


Figure 1-2. Skokomish River Basin GI: Study Area

1.6 Proposal for Federal Action*

The proposal to implement ecosystem restoration in the Skokomish River Basin triggered the NEPA process recorded in this document (40 CFR 1501.2). Based on study results, the Corps is proposing restoration of the Skokomish River in the lower Skokomish Valley. The proposed Federal (Corps) action area is focused on the lower Skokomish Valley because various Federal, State, and local agencies as well as private entities are addressing problems within their individual authorities and in specific areas of the upper watershed as well as the estuary. The Corps has a unique opportunity to address problems in the Lower South Fork, Skokomish River mainstem, and tributaries (Weaver Creek, Vance Creek, and Purdy Creek) where many impacts from the upper watershed are manifested and where a number of significant ecosystem restoration opportunities exist.

1.7 Overview of Integrated FR/EIS

This document is a combined Feasibility Report and Environmental Impact Statement (FR/EIS). The purpose of the feasibility report is to identify the plan that reasonably maximizes ecosystem restoration benefits, is technically feasible, and preserves environmental and cultural values. The purpose of the EIS portion of the report is to identify and present information about any potentially significant environmental effects of the alternatives and to incorporate environmental considerations into the decision-making process. The six steps of the Corps planning process each align with a NEPA requirement. The list of planning steps appears below with the document chapter and NEPA element to which they relate:

Table 1-1. Overview of FR/EIS

Planning Step:	Analogous NEPA Requirement & Document Chapter:
Step One: **Problems and Opportunities**	Purpose and Need for Action; Chapter 2
Step Two: **Inventory and Forecast of Conditions**	Affected Environment; Chapter 4
Step Three: **Formulate Alternative Plans**	Alternatives including Proposed Action; Chapter 3
Step Four: **Evaluate Effects of Alternative Plans**	Environmental Consequences; Chapter 4
Step Five: **Compare Alternative Plans**	Alternatives including Proposed Action; Chapter 3 and 4
Step Six: **Select Recommended Plan**	Agency Preferred Alternative; Chapter 5

2. Need for and Objectives of Action

This chapter presents results of the first step of the planning process, the specification of water and related land resources problems and opportunities in the study area. The chapter also establishes the planning objectives and planning constraints, which are the basis for formulation of alternative plans.

2.1 Problems and Opportunities

The primary concern this study addresses is ecosystem degradation in the Skokomish River Basin, which includes public and private lands and the Skokomish Indian Reservation. Alteration of the river environment and encroachment on the floodplain by human-made structures have degraded and continue to affect natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat throughout the basin. The degraded stream, wetland, and riparian habitat cannot support a healthy population of critical fish and wildlife species.

Historically, the Skokomish River system produced the largest runs of salmon and steelhead in Hood Canal (Correa 2003). Since the settlement of the Skokomish Valley in the 1850s by European and American settlers, human activities have altered the Skokomish River's hydraulic and geomorphic processes and reduced the fisheries resource. Specific anthropogenic impacts to the Skokomish River Basin include the following:

- Removal of large woody debris (LWD) simplified the stream habitat by reducing the occurrence of pools, caused loss of nutrients and substrate to support aquatic insects, and removed the complex rootwad structures that allow juvenile fish to hide from predators. Pools are critical habitat as sheltered areas for spawning adults to rest and for juvenile salmon to rear. Aquatic insects are an important component of a healthy aquatic ecosystem and are the primary food source for juvenile salmonids rearing in the river. LWD is essential for supporting these ecosystem components.

- Removal of the riparian forest has reduced the supply of LWD, overhanging vegetation that provides food sources for terrestrial and aquatic insects, and shade cover (approximately 62% of the mainstem is sparsely vegetated). Leaf and litter fall from overhanging vegetation provides food for aquatic insects, and drops terrestrial insects into the river where they become fish food. The loss of shade cover has contributed to high water temperatures during the summer, which causes stress to adults on their spawning migration and reduces the growth rate of juveniles rearing in the river and off-channel habitats. The substantial loss of riparian forest has reduced these beneficial inputs to the aquatic ecosystem.

- Intensive logging activities that disturbed and destabilized the stream banks reduced streamside vegetation due to erosion. This prevents new vegetation from establishing to provide energy inputs to the river, and the erosion causes sedimentation downstream that can smother salmon eggs or settle at tributary mouths and reduce their accessibility for fish. The accumulation of sediment in the riverbed has resulted in an unfavorable width to depth ratio such that the main channels are too shallow to support good habitat for salmon, and sediment has filled in nearly all the high value pool habitat.

- Protection of agricultural lands from erosion led to construction of bank protection measures. Those measures stopped natural channel migration, which reduces the rate of habitat creation in the river and in the floodplain.
- Logging activities in the South Fork and Vance Creek watersheds may have increased the upper basin sediment supply that is accumulating in the river reaches of the study area. This accumulation of gravel in the riverbed has resulted in cutting off access to aquatic habitats in the floodplain. Such side channel closures eliminated fish access to slack water, an important rearing habitat that supports more juvenile fish than do medium and higher velocities, and important spawning habitat for chum and coho salmon.
- The Cushman Dam Project, channel straightening, and levees have, to varying degrees, reduced ecosystem functions and habitat availability for all riverine fish species and the aquatic-oriented mammals such as beaver, river otter, and mink (construction of Cushman Dam blocked 25% of mainstem habitat and 18% of tributary habitat available to salmon).
- The removal of LWD, disturbance of the stream banks, bank protection, and side-channel closures have all contributed to altering the bedload transport and deposition in the South Fork, Vance Creek, and the mainstem Skokomish River. In addition, flow regulation by the Cushman Project has altered bedload transport and deposition in the mainstem Skokomish River. A significant problem of the sediment accumulation is that the river dries up for a mile for nearly two months each year in the late summer. This poses a total block for upstream and downstream fish migration, and can prevent salmon from reaching their spawning grounds in time to spawn before dying.
- The U.S. Highway 101 and State Route 106 road embankments disrupt overbank flood flows and reduce habitat connectivity. Connections from the mainstem to the aquatic habitats in the adjacent floodplain are highly important for fish to find additional food sources, spawning habitat, and low velocity refuge, as well as pathways back into the mainstem after floodwaters carry them out of the main channel.

The effects outlined above have led to the degradation of ecosystem processes, structures, and functions in the Skokomish Basin. Four ESA-listed salmonid species are represented in six unique populations in the study area; two of these six stocks are already extirpated from the Skokomish River. The major problem affecting salmon survival and migration is extensive aggradation in the South Fork and mainstem riverbeds. One reach of the South Fork Skokomish River near the North Fork confluence started running subsurface in late summer months (Figure 2-1, top row) about 10 years ago. Abundance estimates of coho, chum, Chinook, and steelhead have dropped dramatically since 2004 (Skokomish Tribe 2013). This relatively new blockage problem delays or completely precludes some adult salmon access to upstream habitat and spawning areas preventing successful spawning, and delays juvenile migration downstream to the abundant food sources of the estuary. Additionally, low channel capacity leads to frequent flooding of the river, transporting juvenile and adult salmon out of the river, and stranding them in the floodplain to die during even modest flow events (Figure 2-1, bottom row). Finally, altered bedload deposition causes instability of the gravel bed in the river, the shifting pattern of the

riverbed, and riverbed aggradation, ultimately producing annual changes in spawning gravel locations and negatively affecting spawning success for some of the salmon stocks.

Figure 2-1. Existing Conditions in the Skokomish River. Top Row: Riverbed aggradation blocks fish passage during migration season for some species and limits the availability of high quality pool habitat. Bottom row: Limited channel capacity also leads to frequent flooding of the river, causing fish stranding and mortality.

Based on the above-mentioned anthropogenic impacts, the study team identified the following problems during the early stage of this study:

1. In the Skokomish Basin, salmon populations have been impaired so greatly by anthropogenic actions that two of the ESA-listed populations have been extirpated from the system. Detrimental actions have included channel alterations, large wood removal, overfishing, and the conversion of forestland to agriculture.
2. Aggradation causes areas of the South Fork Skokomish River to run subsurface during the summer low flow period, which blocks passage for endangered fish species during the migration season.
3. Aggradation in the Skokomish River has reduced channel capacity in the mainstem, which causes frequent overbank flows and stranding fish during even modest flow events.

4. Connections of the Skokomish River main channel to side channels, tributaries, and backwater habitats have been reduced due to numerous anthropogenic impacts and land management activities including dam construction, flow diversion, levee construction, and channelization.
5. The Skokomish River mainstem and tributaries lack high quality and complex habitats including pools, side-channels, hiding places, and floodplain habitats because of levee and dike construction, closure of side channels and sloughs, agricultural development, and the removal of large woody debris and riparian vegetation.

Opportunities to address problems for this study include the following:

1. Restore degraded ecosystem structures, functions, and dynamic processes of the Skokomish River for the benefit of four ESA-listed salmonid species.
2. Restore a continuous low flow channel in the Skokomish River to maintain fish passage during summer low flow periods.
3. Restore channel capacity to rebuild critical habitat for ESA-listed salmonid species.
4. Restore the connection of the Skokomish River mainstem to side channels and tributaries.
5. Return habitat quality, complexity, and functionality of the Skokomish River system to a less degraded, more natural state.
6. There is potential for ecosystem projects that secondarily contribute to local flood risk management goals.

2.2 Purpose and Need for Action*

The need for the proposed Federal action arises from the significant degradation of natural processes that sustain the ecological functions of the watershed as described in the previous section. The purpose for the proposed Federal action is to work within the defined study area to enact solutions within the Corps' authority to restore ecosystem process, structure, and function in the aquatic environment by addressing the primary problems identified during the feasibility study. Effort toward improving the aquatic ecosystem should include addressing lack of wetland and side-channel connections, increasing channel complexity, increasing large woody debris, increasing pool depth and frequency, restoring degraded riparian conditions, improving conditions in the reach of the river that dries up each summer, and improving channel capacity to the maximum extent practicable. Restoration of ecosystem structures, functions, and processes will benefit nationally significant resources in the study area.

2.3 Resource Significance – Technical, Institutional, Public

The Skokomish River is the largest and most diverse tributary to Hood Canal, a 70-mile-long natural fjord-like arm of Puget Sound that supports vital natural resources. Significant environmental resources in the Skokomish River Basin have declined to a point that the ecosystem may no longer be self-sustaining without immediate intervention to curtail considerable ecological degradation. These resources are technically, institutionally, and publicly significant as described in the following sections.

2.3.1 Technical Significance

The Pacific Northwest ecoregion is home to many species of the Salmonidae family. These fish serve as an indicator of the overall health of not only the aquatic environment where they dwell, but also the

connected riparian, wetland, and upland habitats. A comprehensive restoration plan for all species in the Salmonidae family, as keystone species, can provide direct and indirect benefits for a broad suite of over 130 other native plant and animal species (Cederholm et al. 2000). Keystone species play a unique and crucial role in the way an ecosystem functions; these fish are extremely sensitive to changes in water quality, trophic webs, and perturbations to the river flow, turbidity, and temperature. Pacific salmon are a food source for a variety of marine, freshwater, and land animals and provide a source of marine-derived nutrients to freshwater environments after spawning (Cederholm et al. 1999). Juvenile salmonids feed on aquatic invertebrates that are indicators of water quality. Additionally, ESA-listed Orca whales, a top predator and iconic species of the Puget Sound region, have been recorded following and feeding on adult Skokomish-bound salmon.

Generally, the more pristine, diverse, and productive the ecosystem is, the healthier the salmon stocks. A decline in the capacity of a watershed to support juvenile salmonids is one indication of declining ecosystem health. Restoration planning centered on habitat for the Salmonidae family reinstitutes dynamic processes that tend to maintain healthy ecosystem characteristics.

Wetlands in the Skokomish watershed provide significant ecological functions including rearing and resting sites for aquatic and land species, natural drainage, storage areas for floodwater, groundwater discharge areas critical to summer low flow, and significant water purification functions through natural filtration. The wetlands associated with the Skokomish River benefit water quality in Hood Canal.

2.3.2 Institutional Significance

Four ESA-listed fish species of the Puget Sound area occur in the Skokomish River. These are represented by six unique populations: Spring and fall Chinook salmon, Hood Canal summer chum salmon, winter and summer steelhead, and bull trout. Two specific runs of salmon, summer chum salmon and spring Chinook, have been extirpated from the Skokomish River. The decline of these particularly sensitive species indicates degradation of environmental health of the Skokomish River and Hood Canal aquatic systems, representing an urgent need to address degradation in the study area. NMFS designated Essential Fish Habitat (EFH) within the South Fork Skokomish watershed under the Magnuson-Stevens Fishery Conservation and Management Act (NMFS 2002). EFH includes all Chinook, coho, and pink salmon habitat.

Puget Sound is an estuary of national significance identified by the U.S. Environmental Protection Agency (EPA) and encompasses a highly interactive system that depends on the continuing cycle of clean water and nutrients to sustain its biological character. As the largest source of freshwater to Hood Canal, improving the health of the Skokomish River watershed is critical to the overall health of Hood Canal, which forms a significant portion of Puget Sound. Restoration of the Skokomish will contribute to the larger mission of the Puget Sound Partnership, a State agency whose primary goal is to restore Puget Sound by 2020. The Puget Sound Partnership's Action Agenda identifies a number of vital sign indicators and recovery targets for Puget Sound as well as identification of near-term actions and performance measures for Hood Canal salmon recovery.

The Skokomish Tribal Reservation is located at the mouth of the Skokomish River. The multiple species of fish and shellfish resources in the Skokomish River play an integral part of tribal culture, religion, and

physical sustenance. The Skokomish Indian Tribe has treaty-protected harvest rights within their Tribe's usual and accustomed (U&A) harvest area, which reflects the historical region in which finfish, shellfish, and other natural resources were collected. As a Federal agency, the Corps has a Federal trust responsibility to act in the Tribes' best interests, including duties to protect Tribal lands and cultural and natural resources. In addition to supporting the feasibility study as a cost-sharing non-Federal sponsor, the Skokomish Indian Tribe has invested funds in restoration of the Skokomish River estuary though the Estuary Restoration Act and continues to support restoration of the Skokomish River Basin.

2.3.3 Public Significance

Members of the public have recognized the significance of the Skokomish River's resources both formally and informally. Ecosystem restoration was a common theme in comments received during the NEPA scoping period (beginning in September 2010) as well as during public meetings held throughout the course of the study. In addition to the numerous comments and letters of concern from members of the public, multiple partnerships have formed to acknowledge and advocate for restoration of the resources of the Skokomish River Basin. Strong, durable partnerships have formed in the Skokomish watershed and beyond that seek to halt worsening conditions and restore the river's ecosystem. The Skokomish Watershed Action Team (SWAT) – a diverse, informal partnership of governments, land managers, the public, and others (including representatives from the Mason County Conservation District, WDOE, NMFS, Green Diamond Resource Company, Olympic Forest Coalition, Hood Canal Coordinating Council, The Wilderness Society, and more) are working collaboratively to restore a healthy Skokomish watershed. This extraordinary collaborative effort and recognition of a need for restoration is indicative of the public significance of the resources of the Skokomish River.

The Skokomish Valley is the largest agricultural area in Mason County with a long history of agricultural production. Agriculture in the Skokomish Valley is of public importance and declining productivity in the study area is a significant concern. Proposed ecosystem restoration projects presented in this report are intended to be compatible with ongoing farming and agricultural practices and were not formulated to deliberately impact agricultural production in the Skokomish Valley. Ecosystem restoration projects implemented in conjunction with local flood risk management projects, agricultural best management practices, and other actions throughout the watershed are intended to more holistically restore the Skokomish River Basin for the benefit of both humans and ecosystem resources.

Table 2-1 summarizes the technically, institutionally, and publicly valued resources in the study area.

Table 2-1. Technical, Institutional, and Public Significance

Technical Significance	Institutional Significance	Public Significance
✓ Salmon – keystone species; indicators of overall ecosystem health ✓ Wetlands – improve water quality and support unique flora and fauna	✓ Four ESA-listed salmon species represented in six unique populations ✓ Puget Sound – estuary of national significance (CEQ) ✓ NMFS Essential Fish Habitat ✓ Tribal Trust Responsibility	✓ NEPA Scoping – Public concern for ecosystem restoration ✓ Skokomish Watershed Action Team

2.4 National Objective

The Federal objective of water and related land resources project planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. The objective of ecosystem restoration is to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition. Ecosystem restoration aims to reverse the adverse impacts of human activity and restore ecological resources, including fish and wildlife habitat, to as close to previous levels of productivity as feasible, but not a higher level than would have existed under natural conditions in the absence of human activity.

2.5 Planning Objectives

Based on the problems identified in the study area, planning objectives include the following and consist of an effect, subject, location, and timing per Engineer Regulation (ER) 1105-2-100:

- Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
- Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary networks including Hunter and Weaver Creeks for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

Table 2-2 shows which problem each objective addresses.

Table 2-2. Restoration Objectives and the Problems they Address

	Problems in the Study Area			
Objectives	**Year-round passage is blocked during summer low-flow period**	**Reduced channel capacity causes frequent floods and fish stranding**	**Disconnected and degraded side channel and tributary networks**	**Lack of high quality and complex in-channel and floodplain habitats**
Provide year-round passage near confluence	X			
Restore side channel and tributary network			X	X
Improve riparian and floodplain habitats			X	X
Improve quantity, quality, and complexity of pools	X	X		

2.6 Planning Constraints

Planning constraints are significant barriers or restrictions that limit the extent of the planning process. Study-specific planning constraints are statements of things unique to a specific planning study that alternative plans should avoid. The following constraints (i.e. limitations on the range of measures and alternatives that can be proposed) have been identified for the study:

1. Cushman Settlement Agreement: The Federal Energy Regulatory Commission (FERC) Settlement Agreement related to Cushman Dam (the "Cushman Settlement Agreement") affects the existing condition, future without-project condition, and future with-project condition for this study. NMFS, Tacoma Public Utilities, the Skokomish Indian Tribe, and State and other Federal agencies (excluding USACE) signed a settlement and relicensing agreement for Tacoma Power's Cushman Hydroelectric Project in 2009. The agreement resolved a $5.8 billion damages claim and long-standing disputes over the terms of a long-term license for Cushman Dam. The licensing settlement agreement concludes two years of negotiations and decades of contention between Tacoma Power, the Skokomish Indian Tribe, and the many State and Federal agencies that will oversee implementation of the terms of the agreement. Due to the history and controversy surrounding this settlement agreement, USACE will not propose structural modifications to Cushman Dam, including dam removal, flow modifications, or operation adjustments.
2. Mason County Flood Ordinance: Comply with Mason County Flood Damage Prevention Ordinance No. 87-08. A special flood risk zone was established for the Zone A and A2 floodplain of the Skokomish River, Vance Creek, and tributaries, as shown on Flood Insurance Rate Maps; these zones are located in the feasibility study area. The special flood risk zone is designated as a floodway and an avulsion risk area, which imposes restrictions on new structures, existing structures, water flow modification structures, bridges, and roadways.
3. The Skokomish Indian Tribe is a federally recognized tribal nation that has treaty-reserved fishing, hunting, and gathering rights on the Skokomish River and has strong cultural and economic interests in the Basin. Proposed projects will avoid negative effects to tribal interests.

2.7 Public Scoping Comments and Resources of Concern*

Several public concerns have been identified during the course of the study. While many public scoping comments were related to the flooding problems in the study area, the non-Federal sponsors and study team have agreed to continue to pursue a single-purpose study focusing on ecosystem restoration only. More discussion of the study's single-purpose scope appears in Chapter 1.

In addition to the flood risk management concerns raised by the public, scoping comments acknowledged that the problems facing the Skokomish River Basin have had negative effects on aquatic habitat and species including endangered fish species. Comments specifically noted that frequent flooding and sediment buildup contribute to poor water quality, which can negatively affect certain fish species. Comments encouraged channel restoration to improve habitat, as well as to alleviate flooding. These concerns were taken into account during the analysis of which resources should be included in the detailed analysis that appears in Chapter 4 of this document. A discussion of public involvement is included in Chapter 7, Public Involvement, Review, and Consultation.

3. Plan Formulation

The guidance for conducting civil works planning studies (Engineering Regulation (ER) 1105-2-100, Planning Guidance Notebook and Principles and Guidelines, 1983) requires the systematic formulation of alternative plans that contribute to the Federal objective. To ensure that sound decisions are made with respect to development of alternatives and ultimately with respect to plan selection, the plan formulation process requires a systematic and repeatable approach. This chapter presents the results of the plan formulation process. Alternatives were developed in consideration of study area problems and opportunities as well as study objectives and constraints with respect to the four evaluation criteria described in the Principles and Guidelines (completeness, effectiveness, efficiency, and acceptability). Figure 3-1 presents a summary of the plan formulation process that will be presented throughout this chapter.

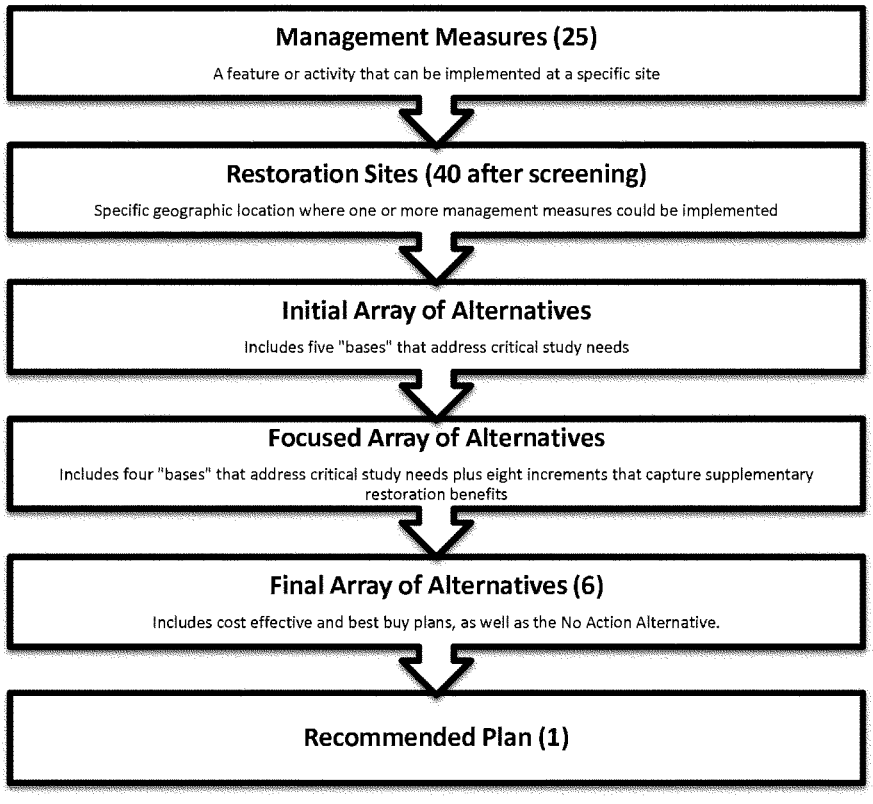


Figure 3-1. Plan Formulation Process

3.1 Management Measures

As part of the planning process for the study, the Project Delivery Team (PDT), in coordination with interested stakeholders and the public, developed a series of measures for consideration as potential elements of the project solution. A management measure is a feature or activity at a site that addresses one or more of the planning objectives and is a discrete element of a recommended project solution. The PDT identified 25 management measures during preliminary planning stages. Management measures for this study appear in the table below, along with the related objective(s) that each measure addresses. Measures include structural and non-structural features.

Table 3-1. Management Measures and Relationship to Planning Objectives

Measure	Objectives			
	Provide Year-Round Passage	Restore Side Channels and Tributaries	Restore Riparian and Floodplain Habitats	Improve Pool Habitats
New channel creation at the historical confluence	X			X
Large-scale sediment removal; environmental dredging	X			X
Spot dredge	X			X
Sediment traps	X			
Selective gravel removal on gravel bars (remove the largest sediment sizes at downstream end of gravel bars) to reduce stream power required to mobilize smaller sediments				X
Remove or breach levees to restore year-round fish passage near confluence	X			X
Wetland restoration - Remove or breach levees, dikes, or berms to reconnect floodplain wetland area			X	
Wetland restoration - Construct hydraulic features (e.g., embankments/water control structures) to improve hydraulic connection to reconnected floodplain wetland area			X	
Create salmonid spawning habitat			X	X
Reconnect and restore side channels, backwater areas, and tributaries		X	X	
Place large woody debris or engineered logjams			X	X
Install fish-passable weirs			X	
Install bank armor to stabilize riverbed sediments				
Plant riparian and estuarine vegetation (non-structural measure)		X	X	
Remove or minimize invasive species (non-structural measure)		X	X	
Culverts: add, remove, replace, or upgrade		X	X	X
Wetland restoration - raise roads, re-route roads, modify bridges or road prisms, decommission or remove roads to improve habitat availability and connectivity			X	

Rehabilitate bank lines: remove riprap, bulkheads, or hardened bank lines			X	
Place hard substrate for oyster attachment				
Install aeration system in Annas Bay				
Reconnect dendritic channels in estuary		X		
Riverbed and wetland vehicle exclusion (fence or barrier installation); non-structural measure				
Reroute power lines in estuary				
Fill estuary farm ditches				
Develop agricultural best management practices (non-structural measure)				

3.2 Screening of Measures

Screening is the process of eliminating, based on planning criteria, those measures that will not be carried forward for consideration. Criteria are derived for the specific planning study, based on the planning objectives, constraints, and the opportunities and problems of the study/project area. Preliminary criteria used to screen measures at this early stage are presented in the list below:

- Meets at least one planning objective
- Avoids planning constraints
- Access/land ownership considerations
- Size or scale is more conducive for local implementation

Table 3-2. Measures Screened from Further Evaluation

Measure Screened	Reason Screened			
	Does not meet at least one planning objective	**Does not avoid planning constraints**	**Access/land ownership considerations**	**Size or scale is more conducive for local implementation**
Place hard substrate for oyster attachment	X			X
Install aeration system in Annas Bay	X	X	X	
Reconnect dendritic channels in estuary				X
Riverbed and wetland vehicle exclusion	X			X
Reroute power lines in estuary	X		X	X
Fill estuary farm ditches	X			X
Develop agricultural best management practices	X			X

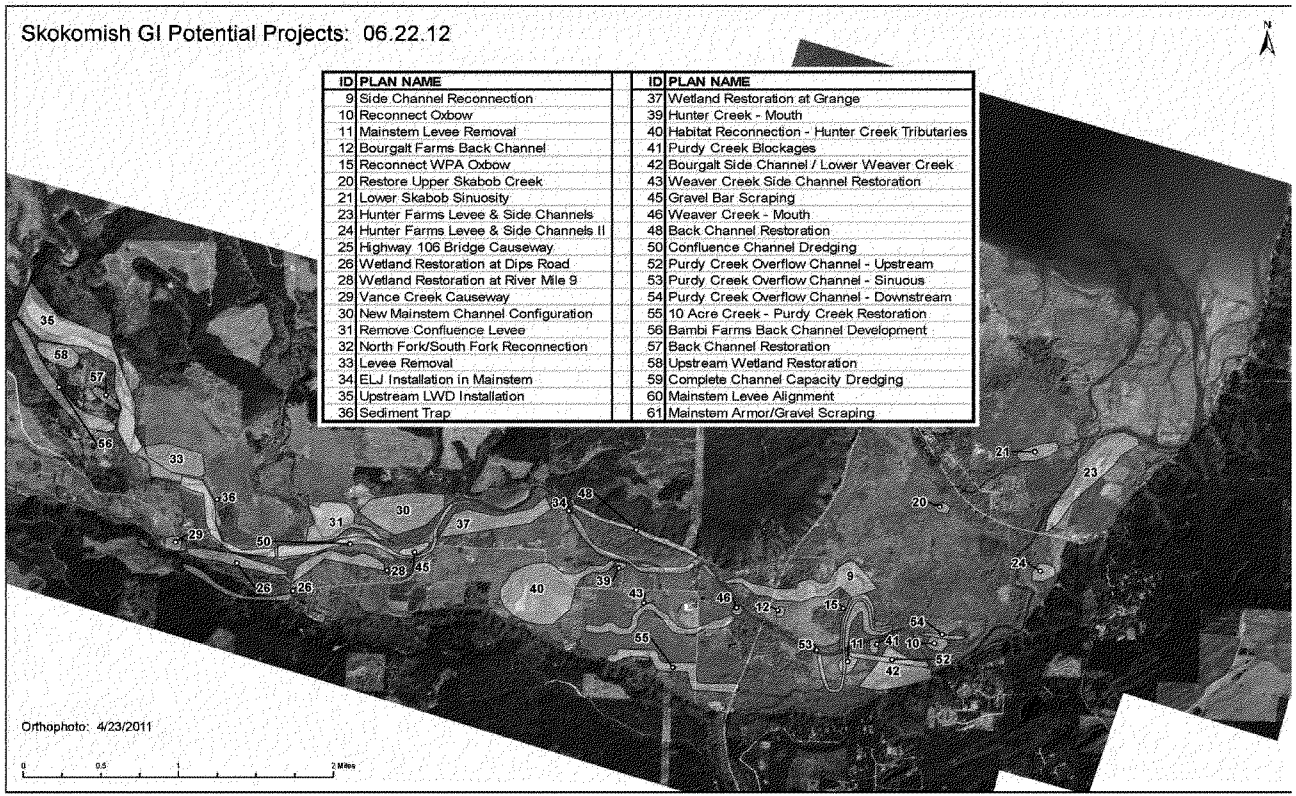
Based on these criteria, seven measures were not carried forward after preliminary screening leaving 18 measures for further consideration. Nearly all of the seven measures screened from further evaluation at this stage, listed in Table 3-2, were related to restoration of habitats in the estuary or nearshore of

the Skokomish River. The estuary and nearshore were included in early plan formulation activities; however, due to successful and ongoing restoration of these areas under the Estuary Restoration Act, these areas were removed from formal consideration within the feasibility study area.

3.3 Siting of Measures

After initial screening of measures was completed, remaining measures were analyzed for additional considerations including: (1) combinability, (2) dependability, (3) mutual exclusion, and (4) site identification for project implementation. The study team, non-Federal sponsors, local and regional stakeholders, and the public identified approximately 60 specific sites within the study area where one or more measures could address specific limiting factors. Sites were selected based on locations of severe degradation, physical features that will provide an opportunity to improve types of degradation, access, and consideration of other complimentary proposed projects outside the range of the feasibility study. Preliminary measures were assigned to sites using best professional judgment of those features that will best function at the site for intended benefits. Qualitative considerations of sustainability, operations and maintenance, costs, real estate, scale, risk and reliability of performance, and type of benefit needed were considered when applying measures to sites.

A second round of preliminary screening occurred prior to combining the potential restoration sites into an initial array of alternatives. The 60 sites were qualitatively screened based on two primary factors: (1) plans that have already received funding (or have submitted funding requests) to be constructed by Mason County, the Skokomish Indian Tribe, or other local entity prior to completion of the feasibility study; and (2) plans that could be better accomplished by a local entity (due to the size, scale, or nature of the plan), and not through the feasibility study. After this screening, 40 restoration sites remained for consideration. Figure 3-2 shows the potential project sites in the study area after preliminary screening.



ID	PLAN NAME	ID	PLAN NAME
9	Side Channel Reconnection	37	Wetland Restoration at Grange
10	Reconnect Oxbow	39	Hunter Creek - Mouth
11	Mainstem Levee Removal	40	Habitat Reconnection - Hunter Creek Tributaries
12	Bourgalt Farms Back Channel	41	Purdy Creek Blockages
15	Reconnect WPA Oxbow	42	Bourgalt Side Channel / Lower Weaver Creek
20	Restore Upper Skabob Creek	43	Weaver Creek Side Channel Restoration
21	Lower Skabob Sinuosity	45	Gravel Bar Scraping
23	Hunter Farms Levee & Side Channels	46	Weaver Creek - Mouth
24	Hunter Farms Levee & Side Channels II	48	Back Channel Restoration
25	Highway 106 Bridge Causeway	50	Confluence Channel Dredging
26	Wetland Restoration at Dips Road	52	Purdy Creek Overflow Channel - Upstream
28	Wetland Restoration at River Mile 9	53	Purdy Creek Overflow Channel - Sinuous
29	Vance Creek Causeway	54	Purdy Creek Overflow Channel - Downstream
30	New Mainstem Channel Configuration	55	10 Acre Creek - Purdy Creek Restoration
31	Remove Confluence Levee	56	Bambi Farms Back Channel Development
32	North Fork/South Fork Reconnection	57	Back Channel Restoration
33	Levee Removal	58	Upstream Wetland Restoration
34	ELJ Installation in Mainstem	59	Complete Channel Capacity Dredging
35	Upstream LWD Installation	60	Mainstem Levee Alignment
36	Sediment Trap	61	Mainstem Armor/Gravel Scraping

Figure 3-2. Initial Siting of Measures (40 sites after preliminary screening)

*Plan ID numbers 59, 60, and 61 are located along the entire river (RM 0-9) and are not identified by yellow polygons on this map.

3.4 Initial Array of Alternatives

An initial array of alternatives was formulated based on preliminary data collection and best professional judgment. The study team identified which of the 40 potential restoration sites address the critical needs of the study area. This exercise led to the development of an initial array of alternatives that include a "base" measure. The "bases" are key measures that address the critical needs of the study area (improve the quantity, quality, and complexity of pools and provide year-round fish passage) and meet the purpose and need for action. The "bases" are intended to be combined with other restoration measures to form alternatives. Developing alternatives around these base measures ensures the critical needs of the study area are addressed. An alternative cannot be considered complete, acceptable, efficient, or effective unless one of these bases is included. Increments will be added to these base alternatives to capture added benefits associated with restoration of additional habitat features. All increments identified in Table 3-5 are dependent on a base; dependencies and combinability relationships are indicated in Table 3-5. The initial array of "bases" includes the following:

Base #1: Riverbed Excavation (River Mile 0-9)

This base includes two primary measures located at site ID #59: large-scale sediment removal and placement of LWD. The goal of this base is to restore mainstem river habitat by removing accumulated sediment and constructing habitat features from RM 0 to RM 9. This base addresses the project objectives of improving the quality, quantity, and complexity of pools and restoring a year-round channel near the confluence to allow for year-round migration. The river channel would be deepened by 8 to 10 feet, which will restore the channel capacity to roughly a two-year return interval probability. The two-year capacity was chosen to mimic typical Puget Sound channels; a two-year capacity will provide similar habitats and biological processes found within less degraded channels in the Puget Sound region.

The increase in channel capacity would allow the placement of additional habitat features (engineered logjams and LWD) while reducing the frequency of overbank flooding and fish stranding. This base would include roughly two LWD jams per mile from RM 0-8, with more placement opportunities at the mouth. Dredging may also require the construction of 6 to 8 larger LWD jams to provide bank protection for high erosion risk sites near RMs 6 and 7. Approximately 40 to 50 single logs per mile could be placed depending on channel conditions.

This base would require the removal of approximately 2.5 million cubic yards from the mainstem channel. The post-construction deposition rate is predicted to be the same as the without-project rate, approximately 35,000 cubic yards (cy) per year. Maintenance at approximately 20-year intervals would be necessary to remove accumulated sediment and maintain capacity for a two-year flow. Dredged material would be placed in the estuary and nearshore zone of Annas Bay, which would constitute beneficial reuse of material and would provide suitable hard substrate for shellfish attachment.

The short-term construction impacts associated with riverbed excavation include significant turbidity in the river channel for the duration of construction, severe disturbance to spawning habitat of ESA-listed species, and risk of continued instability of gravel for several years after construction possibly preventing successful spawning and incubation. These effects are further discussed in Chapter 4.

Base #2: Confluence Channel Excavation

This base includes two primary measures located at site ID #50: spot-dredging and placement of LWD. The goal of this base is to lower the river thalweg to provide a continuous low flow channel during the late-summer base flow conditions to allow passage of migrating salmon. Fish passage would be restored between RM 7 and RM 9 of the Skokomish River mainstem, which is the reach that experiences subsurface flow during the late-summer/early fall low flow period. This base addresses the project objectives of improving the quality, quantity, and complexity of pools and restoring a year-round channel near the confluence to allow for year-round migration. To re-establish a continuous low flow channel, approximately 150,000 cy of sediment would be removed from the mainstem from RM 7.3 to RM 8.8. The alignment of the dredged channel would follow the thalweg to minimize disturbance of the channel and the dredging volume. The total length of excavation would be 7,000 feet. This excavation could increase the discharge capacity of the river channel by about 4,000 cubic feet per second (cfs) and lower flood elevations locally by up to one foot. However, additional capacity from RM 7.3 to RM 8.8 would not significantly affect lower mainstem channel capacity, and would produce only minor changes in downstream flood conditions. LWD would be placed in this reach to maintain the established channel path within the boundaries of the active river channel. Woody debris would also create deeper pools and hiding places, which are critical needs for fish in the system. This base addresses the project objectives on a much smaller scale than Base #1, focusing on improving channel capacity and habitat in the reach of the river where passage is most often blocked during the late-summer/early fall low flow period. Periodic maintenance may be necessary to remove sediment accumulations. The limited amount of dredged material would be disposed of offsite (versus placement in the estuary and nearshore zone of Annas Bay).

Base #3: North Fork/South Fork Confluence: Confluence Levee Removal

This base includes two primary measures located at site ID #31: removal of levees and placement of LWD. This base proposes removal of the 5,400-foot long levee on the north side of the mainstem near the original North Fork confluence, which would require removal of approximately 15,000 cy. This base primarily addresses the project objective of restoring a continuous low flow channel near the confluence and to a lesser extent the objective of improving the quantity, quality, and complexity of pool habitat in the river. South Fork flows would be diverted into the North Fork channel and reenter the mainstem at the confluence location. This would bypass the subsurface flow reach and provide improved fish migration. A portion of flood flows would stay in the old channel. Installed LWD would direct flow in the new channel and improve fish habitat. As described in Section 4.3.1.2 and 4.3.3.2, the combined discharges of the North and South Forks would be enough water to provide continuous surface flows during the late summer low flow period. It is anticipated that the new channel will aggrade, eventually meandering across the floodplain. This natural meandering process will develop a complex series of stream habitats that will be beneficial to salmon and other fish. This base is designed to work with natural river processes including aggradation to provide habitat benefits; therefore, it is anticipated that limited O&M will be required to maintain the channel.

Corps staff conducted a site visit in October 2013 and observed approximately five car bodies at the base of the western section of the Confluence Levee, which is locally referred to as "Car Body Levee". A

Phase II HTRW investigation was complete in July 2014. There were no sampling results that warranted further evaluation or investigation within the footprint of the recommended plan, including the Confluence Levee site. At this time, the cars are assumed to be solid waste that will be disposed of by the Non-Federal Sponsors at an appropriate disposal site. Please refer to Appendix I (HTRW Assessment) for additional information about the Confluence Levee investigation.

The short-term construction impacts associated with this base are expected to be temporary and minor. These effects are further discussed in Chapter 4.

Base #4: North/South Fork Confluence Channel

This base includes three primary measures located at site ID #30: spot-dredging, construction of a levee, and placement of LWD. The goal of this base is to restore the North Fork/South Fork confluence to its pre-2003 location at RM 8.4. This base addresses the project objective of restoring flow continuity for year-round passage near the confluence by increasing summer low flow. Approximately 50,000 cy of sediment would be removed from the mainstem and North Fork channels. LWD would be placed to maintain channel alignment and facilitate creation of pools and hiding places. The North Fork habitat would remain as quality backwater/rearing habitat for salmonids and other fish. Periodic maintenance may be necessary to remove sediment accumulations from the restored confluence. The limited amount of dredged material would be disposed of offsite (versus placement in the estuary and nearshore zone of Annas Bay).

Base #5: Riverbed Excavation (River Mile 3.5-9)

This base includes two primary measures located at site ID #59: large-scale sediment removal and placement of LWD. Dredging for Base #5 would start at RM 3.5 and continue upstream to RM 9. This base addresses the project objectives of improving the quality, quantity, and complexity of pools and restoring a year-round channel near the confluence to allow for year-round migration. The downstream limit was chosen because it will deliver the design discharge and associated bedload to a point where the river has some natural capacity to convey them to the mouth. It will channelize the flows through the reach between RMs 3.5 and 4 where bedload transport is at a minimum under existing conditions. For floods larger than the design discharge, flooding and low bedload transport will still occur between RMs 3.5 and 4. To assure the late summer connection to the South Fork, dredging must continue upstream past the old North Fork confluence to RM 9. If this base were implemented, channel capacity and flood patterns would remain unchanged downstream of RM 3.5.

Similar to Base #1, an increase in channel capacity would allow the placement of additional habitat features (engineered logjams and LWD) while reducing the frequency of fish stranding caused by overbank flooding, which may enhance recovery of listed species. This base would include roughly two LWD jams per mile from RM 3.5-8, with more placement opportunities at the mouth. Dredging may also require the construction of 6 to 8 larger LWD jams to provide bank protection for high erosion risk sites near RMs 6 and 7. Approximately 40 to 50 single logs per mile could be placed depending on channel conditions.

This base would require removal of approximately 1.9 million cubic yards from the mainstem channel. Similar to Base #1, periodic maintenance would be required to remove sediment accumulations. Dredged material would be placed in the estuary and nearshore zone of Annas Bay, which would provide suitable hard substrate for shellfish attachment constituting beneficial reuse of material.

The short-term construction impacts associated with riverbed excavation include significant turbidity in the river channel for the duration of construction, severe disturbance to spawning habitat of ESA-listed species, and risk of continued instability of gravel for several years after construction possibly preventing successful spawning and incubation. These effects are further discussed in Chapter 4.

Large Woody Debris

As noted in the descriptions above, all bases include placement of LWD. LWD is not a separable element of the bases. While the size, scale, and number of logjams to be installed vary among the bases, this measure was identified to be a critical habitat feature that should be included in any recommended plan in addition to the base. LWD has many benefits for juvenile salmon including increasing habitat complexity and number of pools, providing instream cover and predation refugia, and serves as a substrate for aquatic invertebrates that salmon rely on as a food source (Quinn 2005). Large accumulations of LWD also provide habitat for small mammals that serve as prey for owls and raptors, and perches for aquatic-oriented birds like belted kingfishers and American dippers. The general goal is to achieve approximately 64 logs, two to three feet in diameter and 15 to 30 feet long, per river mile based on recommendations found in Fox and Bolton (2007).

3.5 Evaluation of Initial Array

The initial array of bases was evaluated based on the decision criteria outlined in Table 3-3.

Table 3-3. Criteria for Evaluating the Initial Array of Bases

Evaluation Criteria	Metric / Threshold
Meets planning objectives	Number of objectives met
Avoids planning constraints	Yes / No
Environmental factors	Benefit to salmonids and other ESA-listed species Benefit to other fish and wildlife species Potential negative effects to salmonids and/or other habitat
Sustainability (ecological)	Low / Medium / High
Impact on fluvial geomorphic processes	Cubic yards of sediment to remove Discharge capacity
O&M requirements	Low / Medium / High

Table 3-4. Evaluation of Initial Array of Bases

Base #	Base Name	Base Description	Cubic Yards to Remove/Length of Excavation	Discharge Capacity (With-Project Condition)	Meets Study Objectives*	Benefits to Salmonids/Habitat	Impacts to Salmonids/Habitat	O&M Requirements	Sustainability
1	Riverbed Excavation (RM 0-9)	Dredge from RM 0 to RM 9 (complete mainstem dredge). Includes placement of LWD.	2.5 million cubic yards; RM 0 to 9	2-year flood capacity within the dredged reach	1, 4	Increases channel capacity to allow construction of additional in-channel habitat features; reduces fish stranding; may enhance recovery of listed species	Short-term construction impacts associated with large-scale dredging (risk of perhaps 2 to 3 years/spawning cycles)	High	Medium
2	Confluence Channel Excavation	South Fork channel dredged at confluence reach, RM 7.3 to 9.0. Includes limited placement of LWD.	150,000 cubic yards; RM 7.3 to 9.0; 7,000 ft.	Capacity increased by ~4,000 cfs within the dredged reach	1	Maintains two active channel habitats; maintains a continuous flow of water in S. Fork	Temporary disturbance of substrate reducing prey (aquatic insects) in this reach for up to 1 year	High	Medium
3	North Fork/South Fork Confluence: Confluence Levee Removal	Remove Confluence Levee on north side of mainstem near original North Fork confluence. South Fork flows would naturally divert into the North Fork channel and reenter the mainstem at the existing confluence location. Includes limited placement of LWD.	15,000 cubic yards/~5,400 feet	No Change	1	Improves fish migration in subsurface reach; allows for continuous passage for fish; levee removal restores river processes	Temporary construction disturbance reducing prey (aquatic insects) in this reach for up to 1 year; potential loss of North Fork habitat near mouth	Low	High
4	North Fork/South Fork Confluence Channel	Reconstruct confluence to return North Fork flows to the mainstem channel. Includes limited placement of LWD.	50,000 cubic yards	No Change	1	Provides continuity; North Fork habitat will remain as quality backwater/rearing habitat	Continued deposition in South Fork; cuts off high quality North Fork habitat; restricts habitat to a single active channel; prey reduction for 1 year	High	Low
5	Riverbed Excavation (RM 3.5-9)	Dredge from RM 3.5 to RM 9 (intermediate mainstem dredge). Includes placement of LWD.	1.9 million cubic yards; RM 3.5 to 9	2-year flood capacity within the dredged reach	1, 4 (smaller scale than Base #1)	Increases channel capacity to allow construction of additional habitat features; reduces fish stranding; may enhance recovery of listed species	Short-term construction impacts associated with large-scale dredging (risk of perhaps 2 to 3 years/spawning cycles)	High	Medium

*Study Objectives: (1) Provide year-round passage near confluence; (2) Restore side channels and tributary network; (3) Restore in-channel and floodplain habitats; (4) Increase quantity, quality, and complexity of pools

3.6 Focused Array of Alternatives

Based on an evaluation of the initial array of bases using the decision criteria, which appears in Table 3-4, the Corps PDT recommended carrying Bases #1, #2, and #5 forward into the focused array of alternatives because they meet the study objectives and have the largest anticipated benefits to species of concern in the Basin. In addition, the study sponsors requested that Base #3 be carried forward into the focused array because the Confluence Levee removal would allow natural river processes to be restored in a sustainable way. Thus, the focused array of bases includes the following:

- No-Action Alternative
- Base #1 (Riverbed Excavation: RM 0-9)
- Base #2 (Confluence Channel Excavation)
- Base #3 (Confluence Levee Removal)
- Base #5 (Riverbed Excavation: RM 3.5-9)

Base #4 was not carried forward for further analysis because directing North Fork flows into the original confluence area would disrupt high quality fish habitat that already exists in this reach. Bases #1, #2, #3, and #5 meet a greater number of study objectives and are anticipated to have greater positive effects to salmonid habitat compared to Base #4, which was not carried forward to the focused array. All bases carried forward to the focused array meet the purpose and need for action.

Increments

Increments were added to the focused array of four bases to capture supplementary benefits associated with restoration of additional channel and floodplain habitat features. Potential increments considered for addition to the bases were selected from the list of 18 proposed management measures and 40 potential restoration sites using best professional judgment. Of the approximately 40 potential restoration sites, the study team identified eight sites as high priority in-channel or floodplain increments that would optimize the environmental benefits for an alternative plan. Potential floodplain increments include removal of blockages at the mouths of tributaries, restoration of side channel habitat, creation of new side channels, and wetland restoration. A cost-effectiveness/incremental cost analysis (CE/ICA) determined the appropriate number and scale of cost effective increments. The combinability of projects to base plans is further described in Section 3.6.2 along with the overall CE/ICA framework for the study.

Management measures that have been identified as potential increments include upstream LWD installation, four side channel reconnections/restorations, and three wetland restorations; these measures could be constructed at eight high-priority sites identified by the PDT. All but one of these measures can be included as an increment to any of the bases carried forward in the focused array.

Table 3-5 includes key information about the proposed increments that could be added to the bases to capture added benefits associated with restoration of additional habitat features. Figure 3-3 shows the location of the focused array of bases and proposed increments within the study area.

Table 3-5. Proposed Restoration Increments

Project Site # (ID#)	Increment Name	Site Problem or Need	Increment Description	Increment to Base #	Dependencies
9	Side Channel Reconnection	Rearing and migration opportunities are significantly limited in this remnant river channel with a poor connection to the mainstem.	An abandoned channel that lies between RM 4 and 5.6 would be reconnected to the mainstem to provide high flow refuge and rearing habitat for fish. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would only be connected to the mainstem river during high discharges and would not convey water year round. During high river discharges, the reconnected channel would provide a low velocity refuge. During most of the year, the channel would provide pond habitat for fish rearing. Reconnecting the channel to the river could provide 45 acres of high quality, low velocity fish habitat. This increment would include planting of native vegetation.	1, 2, 3, 5	Stand Alone
26	Wetland Restoration at Dips Road	West Valley Road (located at the "Dips") acts as a physical barrier to riparian habitat connectivity.	The Dips Road relocation, located at RM 9.5-9.7, is intended to provide additional floodplain habitat and reduce the stranding potential for fish. A 3,700-foot section of the road between the Vance Creek and Swift Creek bridges would be relocated about 400 feet landward (south). This would place 17 acres of riparian forest on the riverward side of the road to develop into highly valued forested wetland. The roadbed would be partially removed. Where the road embankment is higher than the adjacent ground, the asphalt and roadbed material would be removed. Where the road is lower than adjacent ground only the asphalt would be removed. River sediments are expected to deposit in the remaining roadbed material and provide soil for vegetation to grow. This increment would include planting of native vegetation. This increment is considered a relocation and will be entirely non-Federal sponsor expense.	1, 2, 3, 5	Stand Alone
28	Wetland Restoration at River Mile 9	The river has been hydraulically disconnected from the floodplain by agricultural berms, restricting the connection to riparian and floodplain wetland habitats. Loss of connection between floodplain wetlands reduces available spawning, incubation, rearing, and over-wintering habitats. The berms also make it more difficult or impossible for juveniles that find their way onto the floodplain to return to the river when flows recede.	This wetland restoration increment, located from RM 8.3-9.2, is intended to reconnect and restore high quality wetland habitat. An existing agricultural berm will be breached and a new wetland embankment will be constructed landward (south) varying distances, generally around 200-300 feet. The breaches will allow for reconnection and improvement of a wetland in the floodplain, allowing flood waters to flow freely within the reconnected area and providing salmon access to the riparian habitat. While breaching the existing berm will provide reconnection of a wetland, construction of a wetland embankment is integral to achieving complete restoration benefits at this site. In addition to the berm breaches, a wetland embankment will be constructed to improve hydraulic conditions in the reconnected wetland area and is expected to hold water within the wetland at a greater depth and longer duration, thereby improving and expanding wetland conditions. The wetland embankment is a structural mechanism required to allow targeted reconnection to riparian wetlands multiple times a year; it is not a flood risk management feature. The wetland embankment contains flow during moderate winter storm events (approximately 6,000 cfs; these events occur multiple times a year), providing high flow refuge for fish as well as reconnection and restoration of high-value forested wetland during frequent, moderate winter storm events. The wetland embankment also diverts flows back into the river rather than across the entire floodplain to the south where there is no defined channel or ecologically beneficial habitat for salmonid species. Finally, the wetland embankment acts as a substitute streambank where none exists, providing an opportunity for the river to develop a secondary side channel over time. This increment would include planting of native grasses and trees to provide continuous vegetation cover in a buffer zone.	1, 2, 3, 5	Stand Alone
35	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of large woody debris in the upstream reaches of the Skokomish River.	This increment, located from RM 9-11, would include placement and installation of large woody debris. Small LWD jams could be used in this reach to increase meandering and bar formation and provide cover for salmon. Under either base alternative, this reach of the channel may be able to incorporate 6 to 12 jams per mile without adverse flooding or erosion effects. Because there is already some LWD in the channel, this reach would only require 30 to 40 new single logs per mile to satisfy the biological criteria.	1, 2, 3, 5	Stand Alone

Project Site # (ID#)	Increment Name	Site Problem or Need	Increment Description	Increment to Base #	Dependencies
37	Wetland Restoration at Grange	The river has been hydraulically disconnected from the floodplain by agricultural berms, restricting the connection to riparian and floodplain wetland habitats.	Similar to the River Mile 9 Wetland Restoration increment described above, this wetland restoration increment, located from RM 7.5-8, is intended to reconnect and restore high quality wetland habitat. An existing agricultural berm will be breached and a new wetland embankment will be constructed landward (south) up to 1,200 feet. The breaches will allow for reconnection of a wetland in the floodplain, allowing flood waters to flow freely within the reconnected area and providing salmon access to the riparian habitat. While breaching the existing berm will provide reconnection of a wetland, construction of a wetland embankment is integral to achieving complete restoration benefits at this site. The wetland embankment is expected to hold water within the wetland at a greater depth and longer duration thereby improving and expanding wetland conditions. This increment would include planting of native grasses and trees to provide continuous vegetation cover in a buffer zone.	1, 2, 3, 5	Stand Alone
39	Hunter Creek Mouth Restoration	There is a poor connection between the mouth of Hunter Creek and the mainstem.	This increment involves a small-scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river near RM 6.5.	2, 3	Stand Alone
40	Hunter Creek Tributary Restoration	Fish stranding commonly occurs at this site due to limited side channels off Hunter Creek; spawning and rearing opportunities are severely limited in Hunter Creek.	This increment involves the construction of tributary channels to Hunter Creek to provide additional fish rearing and refuge habitat. Hunter Creek is a perennial groundwater fed stream. The proposed restoration would consist of excavating small channels along existing swales down to slightly below the water table. The Hunter Creek channels would have a 4-foot bottom width and approximately 5-foot depth. The total length of channel would be approximately 21,250 feet. This increment would include planting of native vegetation.	1, 2, 3, 5	Dependent on Increment #39 (Hunter Creek Mouth Restoration) for Bases #2 and #3
43	Weaver Creek Tributary Restoration	Weaver creek lacks juvenile salmonid rearing habitat and experiences stranded fish during high flow events.	This increment involves the construction of tributary channels to Weaver Creek to provide additional fish rearing and refuge habitat. Weaver Creek is a perennial groundwater fed stream. The proposed restoration would consist of excavating small channels along existing swales down to slightly below the water table. The Weaver Creek channels would have a 4-foot bottom width and approximately 5-foot depth. The total length of channel would be approximately 27,110 feet. This increment would include planting of native vegetation.	1, 2, 3, 5	Stand Alone

*All increments are dependent on a base. No bases are combinable. Increment #39 (Hunter Creek Mouth Restoration) is not combinable with Base #1 or Base #5.

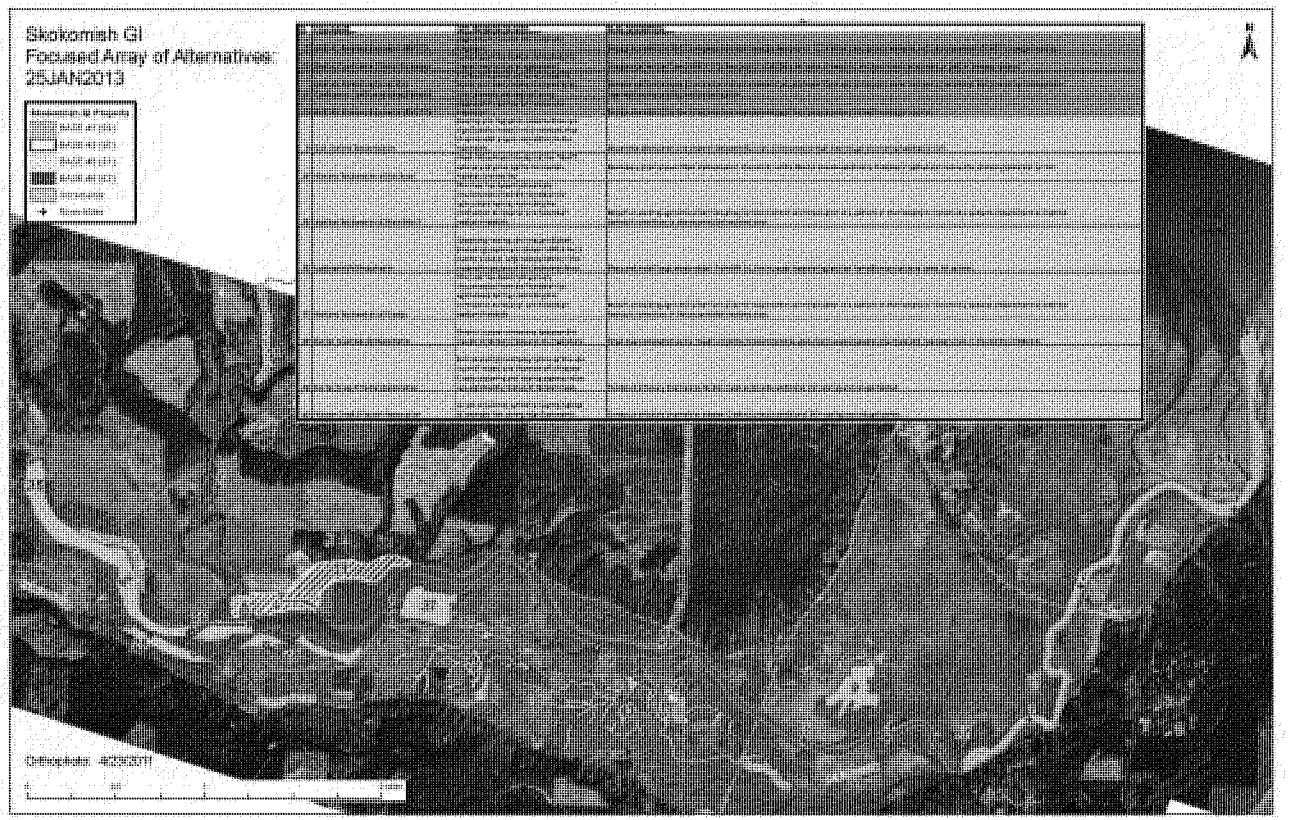


Figure 3-3. Focused Array of Bases and Potential Increments. Legend key: bases are shaded in blue in the table; increments are shaded in green. Bases will be combined with increments to form alternatives.

3.7 Evaluation of Focused Array of Alternatives

To effectively evaluate the focused array of alternatives, the PDT completed additional analysis including development of conceptual designs, development of parametric cost estimates, and evaluation of environmental outputs. All of the bases and increments selected for the focused array of alternatives were carried through these analyses. Based on these parameters, a CE/ICA was completed to help evaluate and quantify significant contributions or effects of individual plans. The following sections outline the assumptions and outcomes of this work in addition to the results of the CE/ICA.

3.7.1 Cost Estimates

The cost estimates for CE/ICA were based on the conceptual design drawings. Additional information developed by the PDT is incorporated into the estimate. The cost estimates were prepared using Micro-Computer Aided Cost Estimating System (MCACES) MII version 4, build 4. Some aspects of the dredging work associated with the project were developed using the most current version of the Corps of Engineers Dredge Estimating Program. The MCACES estimate carefully documents the basis of information used in development of costs, down to the lowest reasonable level.

The conceptual cost estimates summarized below were prepared at a Class 4 level; Per ER 1110-2-1302, these Class 4 estimates are generally associated with a conceptual level of design and were developed based on parametric designs and quantities developed by the PDT. Earthwork quantities used available topography using average end areas. Tree sizes were estimated by canopy size and LWD estimates used log counts and lengths. Certified Class 3 cost estimates were developed for the recommended plan based on feasibility-level designs. Final feasibility-level cost estimates are presented in Section 5.6 and Appendix K.

Table 3-6 shows the present value construction and real estate costs, computed interest during construction (IDC), periodic operations and maintenance (O&M) costs, total investment costs, and annualized costs for each base alternative and increment. It was assumed that the increments would require minimal maintenance; aiming for process-based restoration, in which human-made stressors are removed from the landscape, has an inherent goal of no O&M costs. Minimal maintenance for Base #3 and the increments is expected to be approximately $10,000 per year or less and focus on minor inspection and periodic wetland embankment maintenance activities. Based on the expected sediment deposition, Bases #1, #2, and #5 would require periodic sediment excavation to maintain channel capacity. For Bases #1 and #5, maintenance is estimated to occur every 20 years (see Section 4.3.2.2), or for two cycles during the period of analysis (in years 20 and 40). The shallower Base #2 channel would require more frequent maintenance to preserve the channel. Base #2 is expected to require maintenance every 10 years, or five cycles during the period of analysis (in years 10, 20, 30, 40, and 50). More detailed cost information appears in Appendix K.

Costs were annualized using the Institute for Water Resources (IWR) Planning Suite Annualization Tool (USACE certified version 2.0.6.0) using the construction cost, real estate cost, construction period (in months) for IDC computations, estimated O&M, the discount rate (3.75 percent), and a 50-year period of analysis. Costs are presented at the October 2013 price level.

Table 3-6. Average Annual Cost of Bases and Increments (Oct 2013 price level, 3.75% discount rate)

Project Site Number (ID #)	Project Name	Construction Cost (1,000s)	Real Estate Cost Estimate ($1,000s)	Interest During Construction ($1,000s)	Total Investment Cost ($1,000s)	Cost for periodic O&M / Frequency	Total Average Annual Cost ($1,000s)
59	Base #1: Riverbed Excavation (RM 0-9)	$141,391	$2	$7,173	$148,567	$43.4 M / Every 20 years (2x)	$8,035
50	Base #2: Confluence Channel Excavation	$14,017	$2	$65	$14,084	$6.2 M / Every 10 years (5x)	$1,153
31	Base #3: Confluence Levee Removal	$6,721	$741	$62	$7,525		$335
62	Base #5: Riverbed Excavation (RM 3.5-9)	$94,756	$2	$2,816	$97,575	$38.0 M / Every 20 years (2x)	$5,548
9	Side Channel Reconnection	$1,024	$2,069	$3	$3,096		$138
26	Wetland Restoration at Dips Road	$5,148	$97	$40	$5,285		$236
28	Wetland Restoration at River Mile 9	$2,250	$101	$14	$2,365		$105
35	Upstream LWD Installation	$870	$2,357	$3	$3,229		$144
37	Wetland Restoration at Grange	$2,722	$538	$17	$3,277		$146
39	Hunter Creek Tributary Mouth Restoration	$11	$193	$0	$204		$9
40	Hunter Creek Tributary Restoration	$4,190	$1,100	$13	$5,303		$236
43	Weaver Creek Tributary Restoration	5,318	$2,261	$25	$7,603		$339

3.7.2 Environmental Outputs

The Skokomish River Ecosystem Benefits Model is a habitat suitability index model, also called an ecosystem outputs (EO) model, accounting for the quality (suitability index score between 0.0 and 1.0) and quantity (area of restoration site) of available habitat for native salmonids, which are an indicator species for overall ecosystem health in the Pacific Northwest. Data published by the Washington Conservation Commission (Correa 2003) and USFWS (Peters et al. 2011) on the species' habitat requirements, preferences, and limiting factors were synthesized into a series of variables and suitability indices, which are mathematical representations of hypotheses regarding species-habitat relationships.

The EO model focuses on three key habitat requirements that most affect salmonid rearing, reproduction, and mortality in the Skokomish River – channel habitat quality, floodplain habitat quality, and channel capacity. Each key habitat requirement includes assessment metrics that were identified as indicators of the limiting factors. Channel habitat quality includes metrics for pools and woody debris to assess migration, resting, and rearing habitat. Floodplain habitat quality includes metrics for riparian cover and floodplain connectivity to assess refugia, feeding, and rearing habitat. Finally, the channel capacity factor is included to provide a score for reducing overbank flood probability of occurrence. In

aggrading rivers, lack of channel capacity causes displacement of juvenile and adult fish during overbank flows in which they become stranded in floodplain areas without access to return to the river. No entities have made an effort to quantify losses from stranding thus far; however, studies on other aggrading rivers in the region show a high correlation between high river flows and reduced survival of incubating eggs to reach migrant fry life stage (Seiler et al. 2003, Beamer et al. 2005). In the example from Beamer et al. (2005), egg-to-fry survival in decreased from 10% to 2% for the 0.2 ACE over a 70-year period. This metric is used as a surrogate for quantifying mortality due to stranding, which affects reproduction, adult and juvenile migration, and survival (see Figure 7 and Figure 8 in Appendix F). Table 3-7 summarizes the benefits for each base or increment to be carried forward for the CE/ICA. Complete documentation of the Skokomish River Environmental Benefits Model is presented in Appendix F.

Table 3-7. Environmental Outputs by Restoration Project

Project Site Number (ID #)	Project Name	Total Acres Affected	AAHU† (EO Model)	AAHU (Shellfish Substrate)	Total AAHU
59	Base #1: Riverbed Excavation (RM 0-9)	219 + 843 shellfish = 1,062	184.2	210.8	395.0
50	Base #2: Confluence Channel Excavation	26	17.5	n/a	17.5
31	Base #3: Confluence Levee Removal	68	45.9	n/a	45.9
62	Base #5: Riverbed Excavation (RM 3.5-9)	132 + 219 shellfish = 643	111.0	127.8	238.8
9	Side Channel Reconnection	45	25.7	n/a	25.7
26	Wetland Restoration at Dips Road	17	12.7	n/a	12.7
28	Wetland Restoration at River Mile 9	23	13.6	n/a	13.6
35	Upstream LWD Installation	107	82.9	n/a	82.9
37	Wetland Restoration at Grange	34	18.5	n/a	18.5
39	Hunter Creek Tributary Mouth Restoration	0.5	0.3	n/a	0.3
40	Hunter Creek Tributary Restoration	29	20.1	n/a	20.1
43	Weaver Creek Tributary Restoration	25	19.4	n/a	19.4

†Average Annual Habitat Units

As the study team developed conceptual designs and cost estimates for the bases, several disposal options were identified for the riverbed excavation bases. Placement of dredged material in the

Skokomish estuary and nearshore zone appeared as the most feasible disposal option (other options included disposal in a nearby quarry or open-water disposal). Appropriate technical experts have identified dredged material from the Skokomish River as suitable for placement. Placement of dredged material in approximately 800 acres of the estuary would create high quality shellfish habitat (i.e., hard substrate for oyster attachment) and would significantly reduce costs associated with transportation and disposal of up to 2.5 million cubic yards of dredged material outside the study area.

It should be noted that the EO model does not formally account for the benefits associated with placing dredged material in the estuary for shellfish attachment; the model only captures benefits related to channel habitat quality, floodplain habitat connectivity, and mainstem channel capacity to calculate Average Annual Habitat Units (AAHUs). To capture the approximate benefits associated with placement of hard substrate in the estuary for shellfish habitat, the study team developed a conservative estimate for the habitat quality change in the estuary and nearshore that would result from placement of dredged material. These outputs are presented in the "AAHU (Shellfish Substrate)" column of Table 3-7 and are fully described in the Economics Appendix (Appendix G). Habitat Units calculated by the EO model (presented in the "AAHU (EO Model)" column of Table 3-7 were added to habitat units calculated outside of the ecosystem benefits model (shellfish substrate) to determine total habitat units. The total outputs appear in the "Total AAHU" column of Table 3-7.

3.7.3 Cost Effectiveness and Incremental Cost Analysis

This section describes the model inputs for performing the CE/ICA using the IWR Planning Suite, version 2.0.6.0 (USACE certified model). The Corps' IWR developed this software to assist with the formulation and comparison of alternative plans. The software can assist with plan formulation by combining solutions to planning problems and calculating the additive effect of each combination, or "plan", by utilizing inputs on outputs (AAHUs), costs, and rules (combinability and dependency relationships) for combining solutions into plans. Plans are then compared in IWR Planning Suite by conducting CE/ICA, identifying the plans that are the best financial investments, and displaying the effects of each on a range of decision variables.

3.7.3.1 Cost Effectiveness Analysis

Multiple runs of CE/ICA were completed that included various sensitivity analyses. The complete CE/ICA results are presented in Appendix G. Cost effective plans are plans that provide a level of environmental output at the least cost. The CE/ICA results presented in this section include the additional shellfish substrate benefits that were discussed in Section 3.7.2. While the inclusion of these benefits in the analysis is an important factor, it should be noted that the array of best buy plans identified by the CE/ICA analysis does not change if CE/ICA is run without the inclusion of these additional benefits. Because inclusion of shellfish benefits more appropriately captures all possible benefits of the proposed restoration alternatives, they are presented in the CE/ICA results below.

The CE/CIA analysis evaluated 705 possible plan combinations. Of these, 60 plans (including the No-Action Alternative) were identified as cost effective. These plans are listed in Table 3-8 and displayed in Figure 3-4 as those plans that provide a given level of output at the lowest cost denoted by blue

triangles (cost effective plans) and red squares (best buy plans, refer to Section 3.6.3.2). Those plans that are not cost effective are denoted by clear circles.

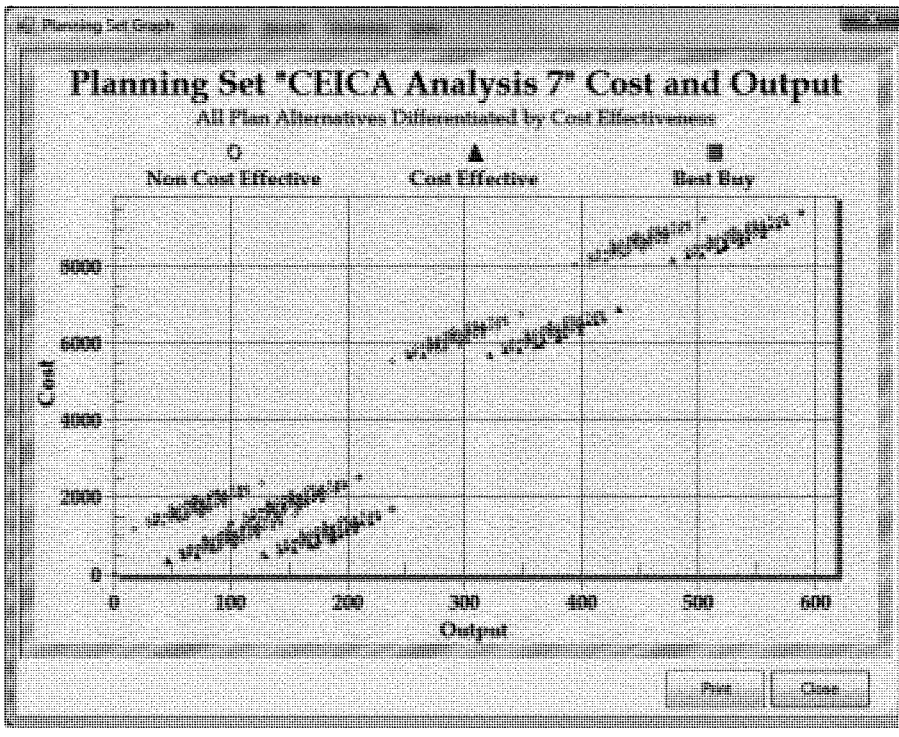


Figure 3-4. Cost Effectiveness Results

The table below outlines the 60 cost effective plans (including the No-Action Alternative) as identified using the CE/ICA analysis. Plans in bold represent "best buy" plans. The plans identified in color were carried forward into the final array of alternatives; this screening and evaluation process is described in subsequent sections of this chapter.

Table 3-8. Cost Effective Plans† (Oct 2013 price level, 3.75% discount rate)

Alternative #	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
1	**No-Action Plan**	**0.0**	**0.0**	**0.0**	**0**	
2	Base 3	45.9	0.0	45.9	335	7.30
3	Base 3+ Increment 39	46.2	0.0	46.2	344	7.45
4	Base 3+ Increment 28	59.5	0.0	59.5	440	7.39

Alternative #	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
5	Base 3+ Increments 28+39	59.8	0.0	59.8	449	7.51
6	Base 3+ Increment 9	71.6	0.0	71.6	473	6.61
7	**Base 3+ Increment 35**	**128.8**	**0.0**	**128.8**	**479**	**3.72**
8	Base 3+ Increments 35+39	129.1	0.0	129.1	488	3.78
9	Base 3+ Increments 35+28	142.4	0.0	142.4	584	4.10
10	Base 3+ Increments 35+28+39	142.7	0.0	142.7	593	4.16
11	Base 3+ Increments 35+9	154.5	0.0	154.5	617	3.99
12	Base 3+ Increments 35+9+39	154.8	0.0	154.8	626	4.04
13	Base 3+ Increments 35+9+28	168.1	0.0	168.1	722	4.30
14	Base 3+ Increments 35+9+28+39	168.4	0.0	168.4	731	4.34
15	Base 3+ Increments 35+9+37	173.0	0.0	173.0	763	4.41
16	Base 3+ Increments 35+9+37+39	173.3	0.0	173.3	772	4.45
17	Base 3+ Increments 35+9+39+40	174.9	0.0	174.9	862	4.93
18	Base 3+ Increments 35+9+28+37	186.6	0.0	186.6	868	4.65
19	Base 3+ Increments 35+9+28+37+39	186.9	0.0	186.9	877	4.69
20	Base 3+ Increments 35+9+39+40+28	188.5	0.0	188.5	967	5.13
21	Base 3+ Increments 35+9+37+39+40	193.4	0.0	193.4	1,008	5.21
22	Base 3+ Increments 35+9+28+37+26	199.3	0.0	199.3	1,104	5.54
23	Base 3+ Increments 35+9+28+37+39+40	207.0	0.0	207.0	1,113	5.38
24	Base 3+ Increments 35+9+28+39+40+43	207.9	0.0	207.9	1,306	6.28
25	Base 3+ Increments 35+9+37+39+40+43	212.8	0.0	212.8	1,347	6.33
26	Base 3+ Increments 35+9+28+37+39+40+26	219.7	0.0	219.7	1,349	6.14
27	Base 3+ Increments 35+9+37+39+40+43+28	226.4	0.0	226.4	1,452	6.41
28	Base 3+ Increments 35+9+37+39+40+43+28+26	239.1	0.0	239.1	1,688	7.06
29	Base 5+ Increment 28	124.6	127.8	252.4	5,653	22.40
30	Base 5+ Increment 9	136.7	127.8	264.5	5,686	21.50
31	Base 5+ Increment 35	193.9	127.8	321.7	5,692	17.69
32	Base 5+ Increments 35+28	207.5	127.8	335.3	5,797	17.29
33	Base 5+ Increments 35+9	219.6	127.8	347.4	5,830	16.78
34	Base 5+ Increments 35+9+28	233.2	127.8	361.0	5,935	16.44
35	Base 5+ Increments 35+9+37	238.1	127.8	365.9	5,976	16.33
36	Base 5+ Increments 35+9+40	239.7	127.8	367.5	6,066	16.51
37	Base 5+ Increments 35+9+28+37	251.7	127.8	379.5	6,081	16.02
38	Base 5+ Increments 35+9+28+40	253.3	127.8	381.1	6,171	16.19
39	Base 5+ Increments 35+9+40+37	258.2	127.8	386.0	6,212	16.09
40	Base 5+ Increments 35+9+40+37+28	271.8	127.8	399.6	6,317	15.81
41	Base 5+ Increments 35+9+28+40+43	272.7	127.8	400.5	6,510	16.25
42	Base 5+ Increments 35+9+28+40+43+37	277.6	127.8	405.4	6,551	16.16
43	Base 5+ Increments 35+9+40+37+28+26	284.5	127.8	412.3	6,553	15.89
44	Base 5+ Increments 35+9+40+37+28+43	291.2	127.8	419.0	6,656	15.89
45	Base 5+ Increments 35+9+40+37+28+43+26	303.9	127.8	431.7	6,892	15.96
46	Base 1+ Increment 35	267.1	210.8	477.9	8,179	17.11
47	Base 1+ Increments 35+28	280.7	210.8	491.5	8,284	16.85

Alternative #	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
48	Base 1+ Increments 35+9	292.8	210.8	503.6	8,317	16.52
49	Base 1+ Increments 35+9+28	306.4	210.8	517.2	8,422	16.28
50	Base 1+ Increments 35+9+37	311.3	210.8	522.1	8,463	16.21
51	Base 1+ Increments 35+9+40	312.9	210.8	523.7	8,553	16.33
52	Base 1+ Increments 35+9+28+37	324.9	210.8	535.7	8,568	15.99
53	Base 1+ Increments 35+9+28+40	326.5	210.8	537.3	8,658	16.11
54	Base 1+ Increments 35+9+40+37	331.4	210.8	542.2	8,699	16.04
55	Base 1+ Increments 35+9+40+37+28	345.0	210.8	555.8	8,804	15.84
56	Base 1+ Increments 35+9+28+40+43	345.9	210.8	556.7	8,997	16.16
57	Base 1+ Increments 35+9+28+40+43+37	350.8	210.8	561.6	9,038	16.09
58	Base 1+ Increments 35+9+40+37+28+26	357.7	210.8	568.5	9,040	15.90
59	Base 1+ Increments 35+9+40+37+28+43	364.4	210.8	575.2	9,143	15.90
60	Base 1+ Increments 35+9+40+37+28+43+26	377.1	210.8	587.9	9,379	15.95

†Plans in bold represent "Best Buy" plans.

3.7.3.2 Incremental Cost Analysis

An incremental cost analysis identified nine of the above plans as "Best Buy" plans, defined as those cost effective plans that provide the greatest incremental increase in output (benefits) for the lowest incremental increase in cost. These best buy plans are listed in Table 3-9 and displayed as a bar graph in Figure 3-5. Plans highlighted in color have been carried forward into the final array of alternatives, which changed during feasibility level design phase after release of the Draft FR/EIS. It should be noted that the Draft Feasibility Report/Environmental Impact Statement (January 2014) presented a different final array of alternatives than those identified below (the original final array of alternatives included #7, #23, #28, #45, and #60). This Final FR/EIS presents the latest results of the alternatives evaluation and screening process including a discussion of changes to alternatives in subsequent iterations of the planning process. The process used to carry these plans forward is described in the following sections.

Table 3-9. Incremental Cost Analysis: Best Buy Plans (Oct 2013 price level, 3.75% discount rate)

Alternative #	Plan Components	Total Output in AAHU's	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No-Action Plan	0.0	0				Best Buy 1	No
7	Base #3: Confluence Levee Removal +35	128.8	479	$3.71	$3.71	$10,754	Best Buy 2	No
11	Base #3: Confluence Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy 3	No
13	Base #3: Confluence Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy 4	No
18	Base #3: Confluence Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy 5	No
23	Base #3: Confluence Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy 6	No
27	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43	226.4	1,452	$6.41	$17.47	$32,602	Best Buy 7	No
28	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43 +26	239.1	1,688	$7.06	$18.58	$37,887	Best Buy 8	No
45	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	431.7	6,892	$15.96	$27.02	$154,623	Cost Effective	Yes
60	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	587.9	9,379	$16.00	$22.05	$210,434	Best Buy 9	Yes

As discussed in Section 3.8, Alternative #45 is cost effective only and does not appear as a best buy plan in Figure 3-5 or Figure 3-6.

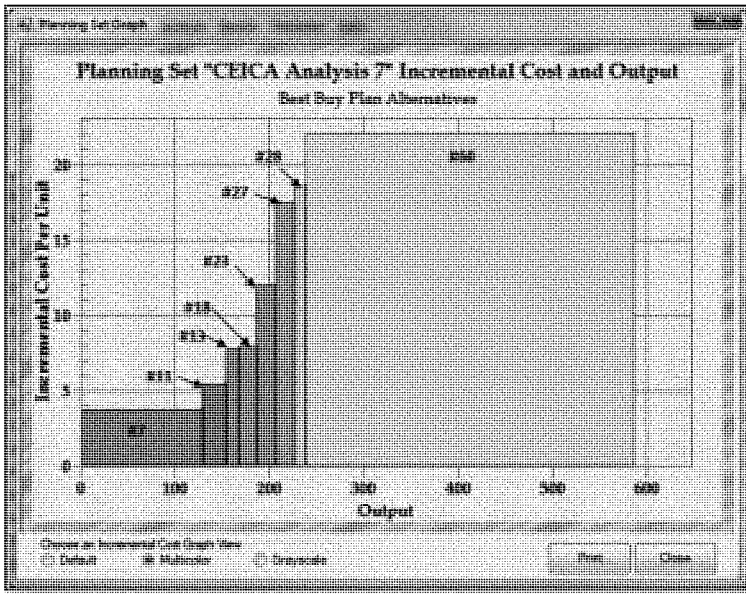


Figure 3-5. CE/ICA Results

3.7.4 Supplemental CE/ICA Analysis: Optimization of Wetland Embankment Sites

The study team completed additional evaluation and optimization of two sites that include proposed wetland embankment measures: Wetland Restoration at River Mile 9 and Wetland Restoration at Grange. These embankments were evaluated at two additional elevations (one lower and one higher which reasonably bracket the range of elevations to consider for optimization), as well as a "breach only" scenario (no embankment). The following scenarios were evaluated for each site:

- Without-project (No Action)
- With-project "original" scale scenario (original plan design, or average height of 5 ft for River Mile 9 and 6 ft for Grange)
- With-project "breach only" scenario (evaluated for benefits only but not carried to CE/ICA)
- With-project small-scale scenario (based on 6,000 cfs flow containment at each embankment site; approximate 2-3ft reduction in average height for each embankment)
- With-project large-scale scenario (approximate 1 ft increase in average height for each embankment)

For each site, a habitat model output score was derived using the methods outlined in Appendix F, Ecosystem Benefits Model Documentation. Parametric costs for each scenario were also developed. A CE/ICA analysis was conducted to determine cost effective and best buy alternatives for optimized plans at each site.

Supplemental Analysis Results: Breach Only Scenario

While the "breach only" scenario was evaluated for ecosystem outputs, these scenarios were not carried forward because they did not meet the planning objectives for the study. The following summarizes the habitat quantity (acres) and quality (HQI scores for riparian cover and connectivity) scoring using the methodology outlined in the EO model:

- The quantity score (acres) increased based on greater wetted areas once existing agricultural berms are breached.
- The quality score for riparian cover decreased based on GIS analysis conducted on the larger wetted areas to determine the proportion of perimeter with the buffer around the riparian area using the same methodology described in Appendix F, Ecosystem Benefits Model Documentation. There is no riparian zone in the farm fields south of the proposed wetland embankment alignment; these areas would not provide high-quality riparian zones and are not likely to develop native riparian wetland vegetation over time. Further, the perimeter of the wetted area includes a county road where no plantings could be installed.
- The quality score for connectivity is 0. This metric score is based on a two-way connection of flow into the reconnected riparian zone and diversion of flows back into the mainstem Skokomish River. This two-way connection would not exist under the "breaching-only" scenario.

While acreage increases for the "breach only" scenario for each embankment, the riparian cover score is lower than the without project condition score and this scenario does not achieve floodplain connectivity as reflected in connectivity scores of 0. Therefore, the "breach only" scenarios provide an increase in acreage of low quality habitat that is not of a habitat type identified as a problem or in need of restoration in this area and does not achieve the project goals and objectives.

Supplemental Analysis Results: Wetland Embankment Incremental Evaluation of Height

Cost and benefit information for Wetland Restoration at River Mile 9 and Grange were input into IWR Planning Suite and evaluated for cost effectiveness and incremental cost analysis. The results indicated two best buy plans (No Action/without-project and small-scale scenario) for each site. The original plan design and large-scale scenarios are not cost effective as the environmental output model was not sensitive to have an effect on benefits; therefore, they provide the same benefits as the small-scale scenario, but at an additional cost. Additional information is needed to confirm the embankment heights, but at this time it is likely that the optimum embankment heights fall within the range of heights between the small-scale and original recommended plan scale heights for each of the embankment sites. As described in Section 5.1.4 and 5.1.5, the small-scale wetland embankment scenario has ultimately been carried forward in the recommended plan. Risks and uncertainties associated with the small-scale wetland embankments are summarized in Section 5.12. Additional detail about this supplemental analysis is presented in Appendix G, Economics.

3.8 Final Array of Alternatives

The alternatives carried forward for detailed evaluation in the final array were chosen based on CE/ICA results, total cost, incremental cost, and ecological value added between increments. This step resulted in carrying forward six alternatives into the final array of alternatives. The final array of alternatives includes the No-Action Alternative, three Confluence Levee Removal alternatives, and two Riverbed Excavation alternatives.

Logic for screening was based on habitat types restored by each alternative. Side channel or tributary increments provide rearing and refuge habitats in an active channel setting. In contrast, the wetland restoration increments (located at River Mile 9 and the Grange) reconnect floodplain and riparian zones but do not directly provide an active channel habitat in the reconnected zone. Both of these types of increments provide important but slightly different ecosystem restoration benefits.

Alternative #11 was carried forward because it is the first alternative that includes reconnection of a side channel, identified as critical rearing and refuge habitat in the study area. Alternative #18 was carried forward because it includes two wetland restoration increments at River Mile 9 and the Grange; these increments improve floodplain habitat connectivity in critical forested riparian zones of the study area, providing benefits to all riverine life stages of salmonids by increasing available spawning, incubation, rearing, and over-wintering habitats as well as providing high flow refuge for fish during frequent winter storm events, and improving and expanding wetlands. Alternative #27 was carried forward because it represents one of the largest-scale Confluence Levee Removal alternatives with all but one increment (a road relocation) included in the plan. While Alternative #45 is cost effective only, it was carried forward into the final array of alternatives because it meets the critical needs of the study area while requiring a smaller extent of dredging compared to Alternative #60. Alternative #60 was carried forward because it is the largest-scale Best Buy Plan and represents the most significant Federal investment for the study.

Alternatives #7, #13, #23, and #28 were not carried forward into the final array of alternatives. While Alternative #7 represents the least cost best buy plan, it was not carried forward because it does not include side channel reconnections, wetland restoration increments or tributary restorations, which are all critical habitat types requiring restoration in the study area. Although Alternative #13 includes a side channel reconnection, it was not carried forward because it only includes a single wetland restoration increment (Wetland Restoration at River Mile 9); restoration and reconnection of floodplain habitat in two riparian zone wetlands represents a more complete alternative. Similarly, Alternative #23 was not carried forward because it only includes one of two tributary restoration increments, significantly limiting the area of tributary restoration in the study area. Hunter Creek and Weaver Creek are the only two perennial groundwater-fed streams in the lower Skokomish Basin and restoration of fluvial and biological processes in both tributaries represents a more complete alternative.

Finally, Alternative #28 was not carried forward into the final array of alternatives. The only difference between Alternative #27 (carried forward into the final array) and Alternative #28 is the inclusion of wetland restoration at Dips Road, a road relocation increment that is not a feature that could be cost-

shared as part of a proposed National Ecosystem Restoration Plan. This individual increment may be constructed by the non-Federal sponsors but was not carried forward as a best buy plan (Alternative #28) in the final array of alternatives. While the CE/ICA analysis presented in this report includes the Dips Road increment, Section 8.2 of the Economics Appendix (Appendix G) presents the results of a sensitivity analysis of CE/ICA that does not include the Dips Road increment. This sensitivity run removed the Dips Road increment and re-ran CE/ICA to determine whether the cost effective and incremental analysis results would change significantly without this feature. The analysis indicates that the final array of alternatives presented in this report are still considered to be cost effective and best buy plans.

Each alternative included in the final array meets the purpose and need for action. The final array of alternatives is described below and identified in Figure 3-6. As noted above, Alternative #45 is cost effective only and does not appear as a best buy plan in Figure 3-6.

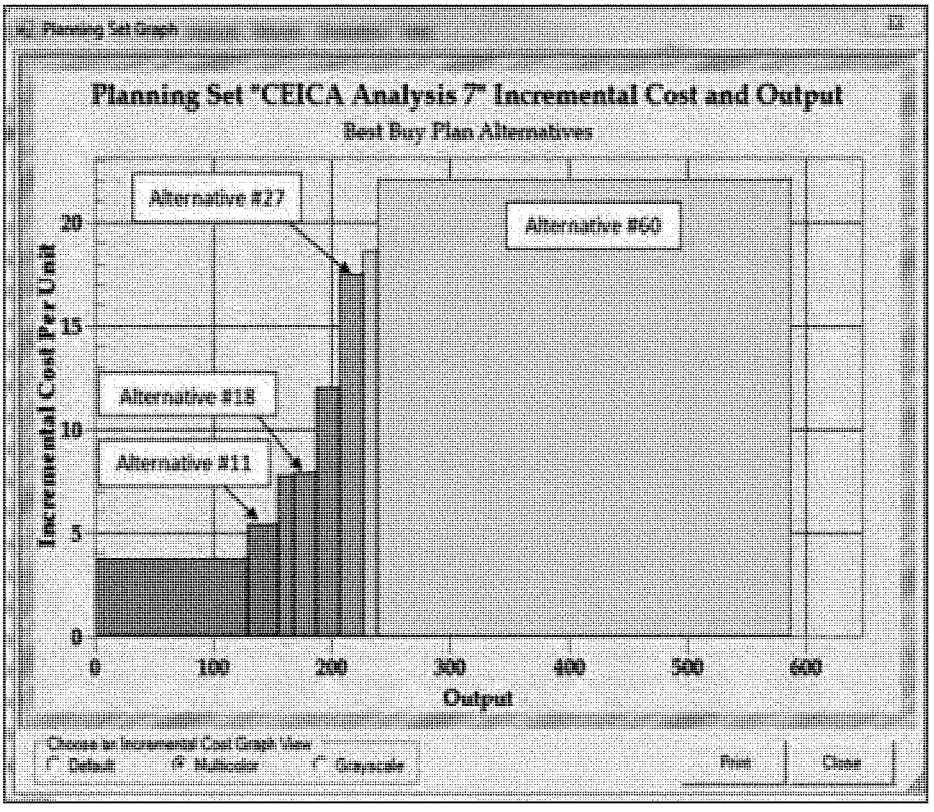


Figure 3-6. Final Array of Alternatives

No-Action Alternative*

Under the No-Action plan, which is synonymous with the "Future Without-Project Condition," the assumption is that no project would be implemented by the Corps to achieve the planning objectives. As described throughout Chapter 4, the Skokomish River will remain degraded under the No-Action Alternative. Habitat availability, quality, complexity, and connectivity will continue to deteriorate. As sediment continues to accumulate in the mainstem, upstream passage will continue to be delayed or completely blocked during summer low flows. The overall condition of the channel is anticipated to remain severely degraded; reduced holding pool quality and availability will continue to render adults vulnerable to predation/harassment, and reduced channel complexity will lead to more frequent and severe scouring of redds. Ultimately, the future without-project condition for fish in the mainstem and South Fork reaches of the study area is expected to remain in a severely degraded state and would not be able to support recovery of ESA-listed species.

Confluence Levee Removal Alternatives #11, #18, and #27

Three Confluence Levee Removal Alternatives were evaluated during this step of the planning process. Each plan represents a best buy plan identified during the CE/ICA. Alternative #11 is the first alternative that includes restoration of side channels, identified as critical habitat in the study area. Alternative #18 was carried forward because it includes two critical wetland restoration increments at River Mile 9 and the Grange; these increments improve floodplain habitat connectivity in critical forested riparian zones of the study area, providing benefits for all riverine life stages of salmonids by increasing available spawning, incubation, rearing, and over-wintering habitats as well as high flow refuge for flood survival. Alternative #27 was carried forward because it represents one of the largest-scale Confluence Levee Removal alternatives with all but one increment (a road relocation) included in the plan. The increments included in each scale of the Confluence Levee Removal Alternative are outlined in Table 3-10.

Table 3-10. Confluence Levee Removal Alternatives

Confluence Levee Removal (Alternative #11)	Confluence Levee Removal (Alternative #18)	Confluence Levee Removal (Alternative #27)
Base #3: Confluence Levee Removal	Base #3: Confluence Levee Removal	Base #3: Confluence Levee Removal
Increment #35: Upstream LWD Installation	Increment #35: Upstream LWD Installation	Increment #35: Upstream LWD Installation
Increment #9: Side Channel Reconnection	Increment #9: Side Channel Reconnection	Increment #9: Side Channel Reconnection
	Increment #37: Wetland Restoration at Grange	Increment #37: Wetland Restoration at Grange
	Increment #28: Wetland Restoration at River Mile 9	Increment #28: Wetland Restoration at River Mile 9
		Increment #39: Hunter Creek Tributary Mouth Restoration
		Increment #40: Hunter Creek Tributary Restoration
		Increment #43: Weaver Creek Tributary Restoration

The map shown below (Figure 3-7) indicates the location of the project features included in the largest Confluence Levee Removal Alternative carried forward in the final array (Alternative #27).

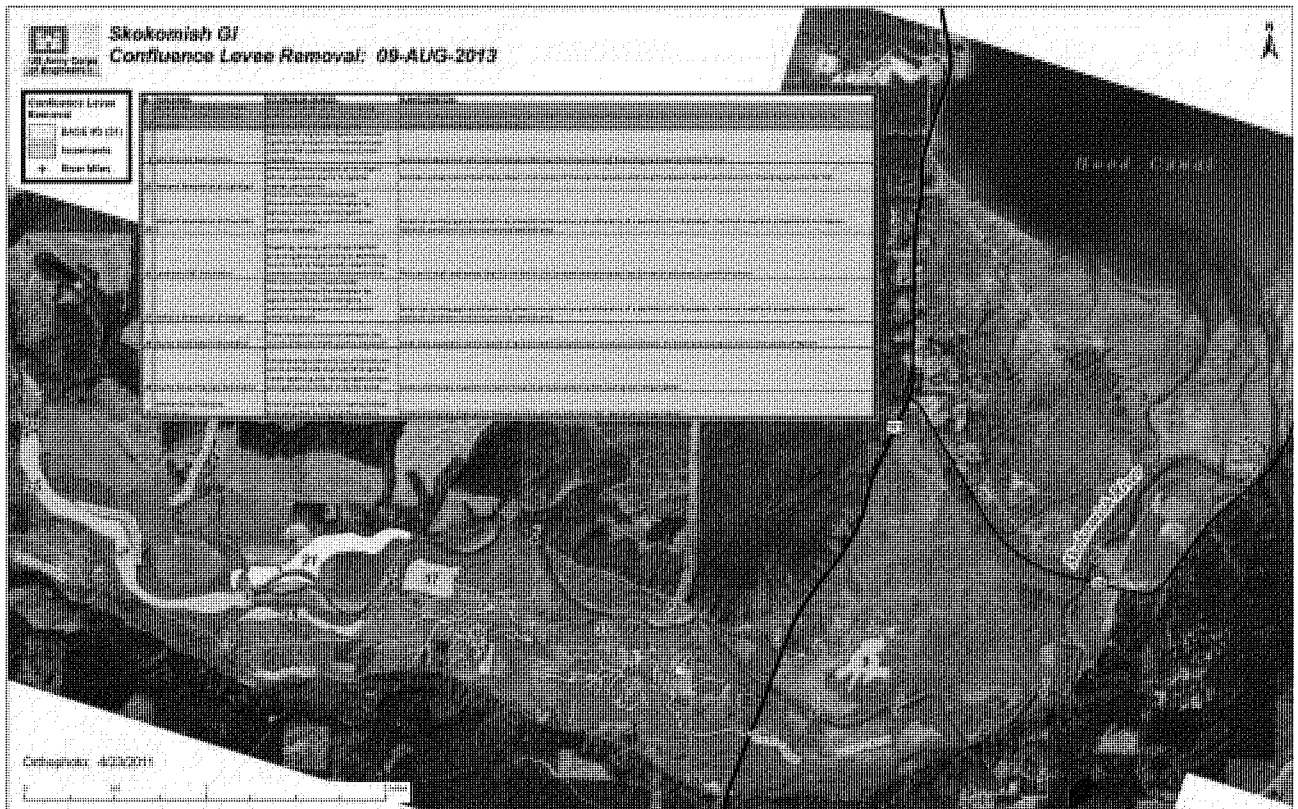


Figure 3-7. Confluence Levee Removal Alternative (Alternative #27)

Riverbed Excavation Alternatives #45 and #60

Two Riverbed Excavation alternatives were evaluated during this step of the planning process. Alternative #45 represents a smaller scale of riverbed excavation alternative. It should be noted that this plan is a cost effective plan only. The CE/ICA analysis did not indicate this plan is a best buy; however, it was carried forward to this stage of analysis because it meets the critical needs of the study area while requiring a smaller extent of dredging compared to Alternative #60. Alternative #60 represents the largest-scale best buy plan and represents the most significant Federal investment for this study.

The increments included in each scale of the riverbed excavation alternative appear in Table 3-11.

Table 3-11. Riverbed Excavation Alternatives

Riverbed Excavation (Alternative #45)	Riverbed Excavation (Alternative #60)
Base #5: Riverbed Excavation (RM 3.5-9)	Base #1: Riverbed Excavation (RM 0-9)
Increment #35: Upstream LWD Installation	Increment #35: Upstream LWD Installation
Increment #9: Side Channel Reconnection	Increment #9: Side Channel Reconnection
Increment #37: Wetland Restoration at Grange	Increment #37: Wetland Restoration at Grange
Increment #28: Wetland Restoration at River Mile 9	Increment #28: Wetland Restoration at River Mile 9
Increment #40: Hunter Creek Tributary Restoration	Increment #40: Hunter Creek Tributary Restoration
Increment #43: Weaver Creek Tributary Restoration	Increment #43: Weaver Creek Tributary Restoration
Increment #26: Wetland Restoration at Dips Road	Increment #26: Wetland Restoration at Dips Road

The map shown below (Figure 3-8) indicates the location of the project features included in the largest scale of the Riverbed Excavation Alternative (Alternative #60).

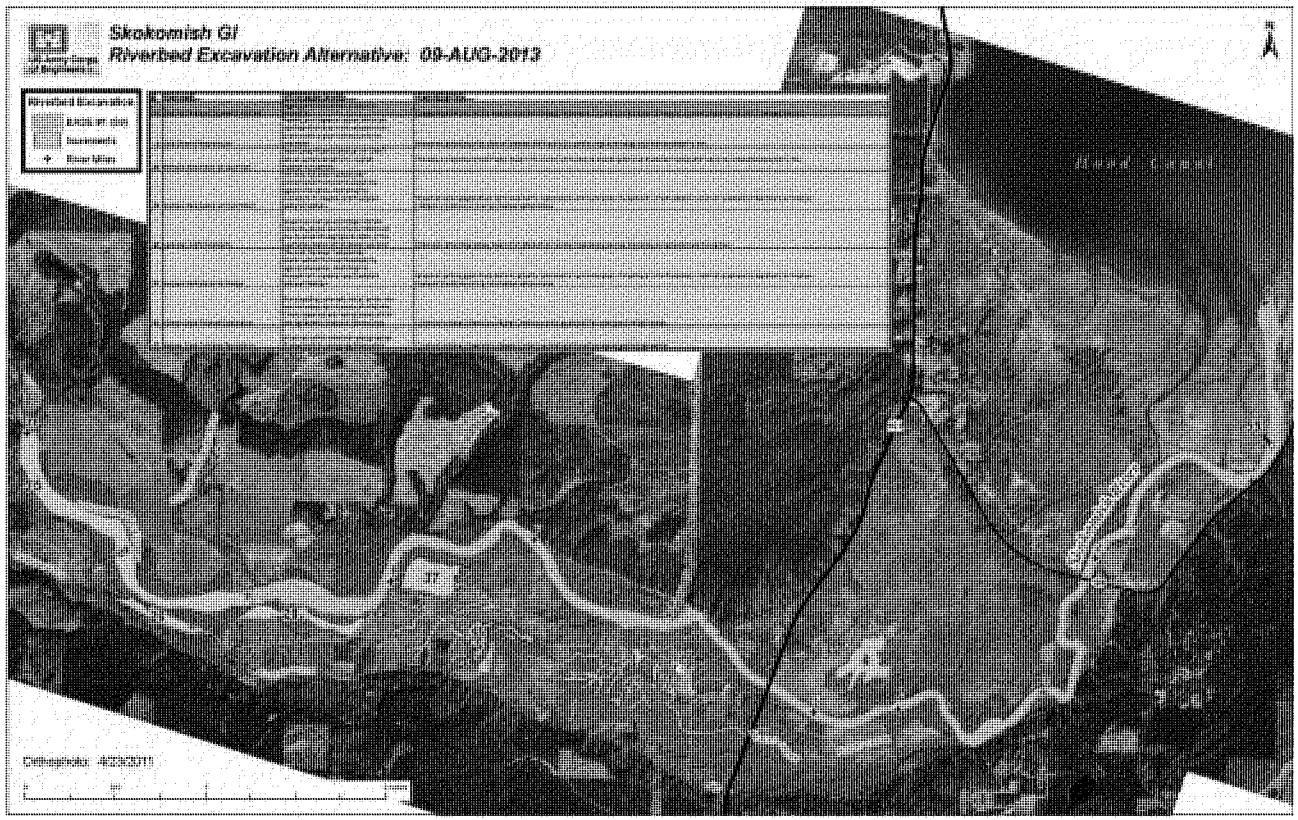


Figure 3-8. Riverbed Excavation Alternative (Alternative #60)

3.9 Evaluation and Comparison of Final Array of Alternatives*

Alternatives are evaluated by assessing or measuring the differences between each with- and without-plan condition and by appraising or weighting those differences. Evaluation consists of four tasks: (1) forecast the most likely with-project conditions expected from each alternative; (2) compare each with-project conditions to the without-project conditions and document differences between the two; (3) characterize the beneficial and adverse effects by magnitude, location, timing, and duration; and (4) qualify plans for further consideration. The following sections outline these steps and describe the final evaluation, comparison, and trade-off analyses to identify a recommended plan.

Plans were evaluated based on the following criteria: outputs and plan effects, contributions to the Federal objective (National Ecosystem Restoration - NER), the study goals and objectives, the Planning Guidance Notebook's four evaluation criteria (completeness, effectiveness, efficiency, and acceptability), and other criteria deemed significant by participating stakeholders. The following sections outline the results of the evaluation and comparison steps. The results of the evaluation and comparison of effects to significant resources are presented in Chapter 4 while evaluation of compliance with environmental protection requirements is presented in Chapter 6.

3.9.1 Outputs and Plan Effects

Table 3-12 summarizes the costs and beneficial environmental outputs for each alternative.

Table 3-12. Costs and Outputs of the Final Array of Alternatives (Oct 2013 price level, 3.75% discount rate)

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Average Annual Cost ($1,000s)
No-Action Alternative						
1	No-Action Plan	0	n/a	0	0	$0
Confluence Levee Removal Alternatives						
11	Confluence Levee Removal Alternative #11: *Base #3: Confluence Levee Removal* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration	154.5	n/a	154.5	220 In-Channel, Floodplain, & Capacity	$617
18	Confluence Levee Removal Alternative #18: *Base #3: Confluence Levee Removal* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9	186.6	n/a	186.6	277 In-Channel, Floodplain, & Capacity	$868

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Average Annual Cost ($1,000s)
27	Confluence Levee Removal Alternative #27: *Base #3: Confluence Levee Removal* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9 Increment 39 – Hunter Creek Tributary Mouth Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration	226.4	n/a	226.4	331.5 In-Channel, Floodplain, & Capacity	$1,452
Riverbed Excavation Alternatives						
45	Riverbed Excavation Alternative #45: *Base #5: Riverbed Excavation (RM 3.5-9)* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9 Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration Increment 26 – Wetland Restoration at Dips Road	303.9	127.8	431.7	412 In-Channel, Floodplain, & Capacity + 511 Shellfish = 923 Total Acres Restored	$6,892
60	Riverbed Excavation Alternative #60: *Base #1: Riverbed Excavation (RM 0-9)* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9 Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration Increment 26 – Wetland Restoration at Dips Road	377.1	210.8	587.9	499 In-Channel, Floodplain, & Capacity + 843 Shellfish = 1,342 Total Acres Restored	$9,379

3.9.2 Contributions to the Federal Objective (NER) and Study Objectives

Alternative plans were compared to each other with emphasis on benefits and impacts with respect to study goals, objectives, and NER objectives. Table 3-13 provides a summary of how each alternative plan meets the study objectives. Alternatives #11, #18, and #27 partially meet the planning objective of improving the quantity, quality, and complexity of pools in the Skokomish River; only Alternative #45

and #60 would fully achieve this objective. While improving pool habitat in the Skokomish River is an important objective that would help to address significant problems in the study area, it cannot be fully accomplished by implementing Alternatives #11, #18, or #27. In addition, Alternative #45 and #60 do not fully meet planning objectives due to environmental, real estate, and cost considerations. The analysis presented in Section 3.9.4 outlines these and other trade-offs between the alternatives.

Table 3-13. Comparison of Alternative Plans and Study Objectives

Objectives	Provide year-round passage near confluence	Restore side channel and tributary network	Improve quality and complexity of floodplain habitats	Improve quantity, quality, and complexity of pools
Alternative 1: No-Action	No	No	No	No
Alternative #11	Yes	Partially	Partially	Partially
Alternative #18	Yes	Partially	Yes	Partially
Alternative #27	Yes	Yes	Yes	Partially
Alternative #45	Yes	Yes	Yes	Yes
Alternative #60	Yes	Yes	Yes	Yes

3.9.3 Completeness, Effectiveness, Efficiency and Acceptability

Completeness, effectiveness, efficiency, and acceptability are the four evaluation criteria specified in the Council for Environmental Quality (CEQ) Principles and Guidelines (Paragraph1.6.2(c)) in the evaluation and screening of alternative plans. Alternatives considered in any planning study should meet minimum subjective standards of these criteria in order to qualify for further consideration and comparison with other plans.

Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.

Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.

Efficiency is the extent to which an alternative plan is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment.

Acceptability is the workability and viability of the alternative plan with respect to acceptance by State and local entities, tribes, and the public and compatibility with existing laws, regulations, and public policies.

Table 3-14. Comparison of Completeness, Effectiveness, Efficiency, and Acceptability

	Completeness	Effectiveness	Efficiency	Acceptability
Alternative 1: No-Action	No	No	No	No
Alternative #11	Yes	Yes	Yes	Yes
Alternative #18	Yes	Yes	Yes	Yes
Alternative #27	Yes	Yes	Yes	Yes
Alternative #45	Yes	Yes	No	Partially
Alternative#60	Yes	Yes	Yes	Partially

Alternative 1 (No-Action Alternative)*

The No-Action Alternative does not meet the completeness criterion because it does not provide any means to realize the planning objectives of this feasibility study.

The No-Action Alternative does not meet the effectiveness criterion because it does not achieve any of the planning objectives.

The No-Action Alternative is the least efficient alternative because it is not the most cost effective means of alleviating the problems and realizing the opportunities of the study area.

The No-Action Alternative is the least acceptable plan with respect to acceptance by State and local entities and the public.

Alternative #11 – Confluence Levee Removal

All actions required to achieve the planning objectives are accounted for in Alternative #11 and it is not significantly dependent on the actions of others. Alternative #11 is a complete plan that will enhance the overall goals of restoring the Skokomish River Basin by complementing other restoration efforts.

Alternative #11 is effective because it alleviates the specified problems and achieves the specified opportunities.

Alternative #11 is an efficient plan. It has low incremental costs and is considered a best buy plan.

Alternative #11 is acceptable. This alternative does not violate public laws or regulations.

Alternative #18 – Confluence Levee Removal

All actions required to achieve the planning objectives are accounted for in Alternative #18 and it is not significantly dependent on the actions of others. Alternative #18 is a complete plan that will enhance the overall goals of restoring the Skokomish River Basin by complementing other restoration efforts.

Alternative #18 is effective because it alleviates the specified problems and achieves the specified opportunities. Compared to Alternative #11, Alternative #18 includes more features that will contribute to restoring ecosystem structures, functions, and processes. Inclusion of two additional wetland restoration increments adds significant value to overall restoration goals of the study and meets planning objectives to a higher degree than Alternative #11. These increments improve productivity of all life stages of salmonids by increasing available spawning, incubation, rearing, and over-wintering habitats as well as providing high flow refuge for fish during frequent winter storm events, and are expected to hold water within the wetland at a greater depth and longer duration thereby improving and expanding wetland conditions.

Alternative #18 is an efficient plan. It has higher incremental costs compared to Alternative #11 but meets all the planning objectives to some degree.

Alternative #18 is acceptable. This alternative does not violate public laws or regulations.

Alternative #27 – Confluence Levee Removal

All actions required to achieve the planning objectives are accounted for in Alternative #27 and it is not significantly dependent on the actions of others. Alternative #27 is a complete plan that will enhance the overall goals of restoring the Skokomish River Basin by complementing other restoration efforts. This alternative can be considered more complete than Alternative #18 because it represents a more comprehensive restoration alternative; it restores one of the largest tributaries in the study area and reconnects a significant area of floodplain habitat.

Alternative #27 is more effective than Alternative #18 because it includes more features that will contribute to restoring ecosystem structure and function. Inclusion of two additional tributary restoration increments adds significant value to overall restoration goals of the study and meets planning objectives to a higher degree than Alternative #18.

Alternative #27 is an efficient plan. The incremental cost for this alternative compared to Alternative #18 is negligible (approximately $10/unit). This incremental cost is commensurate to the increase in habitat units (40 additional HUs) and acres restored (55 additional acres) compared to Alternative #18.

Alternative #27 is acceptable because it does not violate public laws or regulations. However, this alternative is not acceptable in terms of landowner willingness because there are insurmountable real estate issues associated with the Hunter and Weaver Creek tributary increments.

Alternative #45 – Riverbed Excavation

All actions required to achieve the planning objectives are accounted for in Alternative #45 and it is not significantly dependent on the actions of others. Alternative #45 is a complete plan that will enhance the overall goals of restoring the Skokomish River Basin by complementing other restoration efforts.

Alternative #45 is effective because it alleviates the specified problems and achieves the specified opportunities. However, this plan is less effective than Alternatives #11, #18, or #27 because there are significant short-term environmental impacts associated with construction activities for this plan as well as risks of longer-term impacts to salmon spawning habitat.

Alternative #45 is not efficient compared to Alternative #60. This alternative is a cost effective plan only and does not provide the greatest incremental increase in output (benefits) for the lowest incremental increase in cost.

Alternative #45 is partially acceptable. Resource agencies are not supportive of large-scale dredging for ecosystem restoration due to the anticipated significant short-term environmental consequences associated with construction of this plan as well as significant risk that salmon would not be able to find appropriate spawning habitat for one or more years as sediments stabilize and the river experiences higher channel-forming flows. This alternative does not violate public laws or regulations.

Alternative #60 – Riverbed Excavation

All actions required to achieve the planning objectives are accounted for in Alternative #60 and it is not significantly dependent on actions of others. Alternative #60 is a complete plan that increases channel

capacity throughout the most important part of the study area, RM 3.5-9. This alternative will enhance the overall goals of restoring the Skokomish River Basin by complementing other efforts.

Alternative #60 is effective because it alleviates the specified problems and achieves the specified opportunities. However, this plan is less effective than Alternatives #11, #18, or #27 because there are significant short-term negative environmental effects associated with construction activities for this plan as well as risks of longer-term negative effects to salmon spawning habitat.

Alternative #60 is a cost effective means of achieving the study objectives. Incremental costs of Alternatives #45 and #60 are nearly the same; however, due to significantly greater incremental costs compared to Alternative #27, Alternative #60 is a less efficient means of achieving study objectives.

Alternative #60 is partially acceptable. Resource agencies are not supportive of large-scale dredging for ecosystem restoration due to the anticipated significant short-term environmental consequences associated with construction of this plan as well as significant risk that salmon would not be able to find appropriate spawning habitat for one or more years as sediments stabilize and the river experiences higher channel-forming flows. This alternative does not violate public laws or regulations.

3.9.4 Trade-Off Analysis

Trade-off analysis is the procedure the Corps uses to identify the potential gains and losses associated with producing a larger or lesser amount of given outputs. The results of trade-off analysis inform the formulation, evaluation, comparison, and selection of the recommended plan. The study team identified several trade-offs between the Confluence Levee removal alternatives and the riverbed excavation alternatives. Although the final array of alternatives includes three scales of the Confluence Levee Alternative and two scales of the Riverbed Excavation Alternative, the following table summarizes the key trade-offs between the medium scale of the Confluence Levee Removal Alternative (Alternative #18) and the largest scale of the Riverbed Excavation Alternative (Alternative #60). Trade-off criteria were developed by the study team and generally relate to the following categories: cost considerations, types of habitat restored, positive and negative environmental impacts, and real estate considerations. The trade-off criteria were intended to highlight key differences among the alternatives to assist the study team in evaluating, comparing, and ultimately selecting a recommended plan.

Among the factors considered, this analysis identified key trade-offs between the alternatives. Additional trade-offs are presented in the environmental consequences documentation in Chapter 4.

The bases of the two Riverbed Excavation alternatives are considered to be highly engineered versus the more process-based restoration components included in the Confluence Levee Removal alternatives. While the Riverbed Excavation Alternative restores significantly more acres compared to the Confluence Levee Removal alternatives, provides benefits to shellfish, and allows for placement of habitat features like LWD in the mainstem river channel by directly increasing channel capacity, it has significant expected short-term environmental impacts and is cost-prohibitive in construction and O&M costs.

The benefits of river sediment excavation (Alternatives #45 and #60) are that providing the capacity for the 50% annual chance of exceedance (ACE) would greatly reduce the frequency of overbank flows and thereby reduce the problem of fish stranding on high ground after they are flooded out of the river and

then trapped with no channel access back into the river. However, such broad-scale alteration of the river bottom would cause significant short-term risks to salmon habitat; these are described in detail in section 4.4.1.2. As of yet, no entity or agency has been able to quantify the adult and juvenile fish stranding problem beyond the anecdotal reports from Skokomish Valley residents and local news media reports. Given the lack of quantification of the magnitude of the stranding problem and the level of potential environmental risks from riverbed excavation, it is difficult to weigh the risks versus benefits of Alternatives #45 and #60.

While Alternative #45 and #60 would have additional direct benefits to shellfish through the disposal of dredged gravel in the estuary, availability of real estate for disposal of dredged material in the estuary and avoiding negative effects to eelgrass beds in the estuary complicates the overall design and implementation of this alternative.

Table 3-15. Trade-Off Analysis

Trade-Off Criteria	No-Action Alternative	Confluence Levee Removal (Alternative #18)	Riverbed Excavation (Alternative #60)
Cost (Total First Cost)	$0	$19 million	$258 million
Total Habitat Units	0 AAHUs	187 AAHUs	588 AAHUs
Acres Restored	0 acres	277 acres (in-channel, floodplain, and channel capacity only)	1,342 acres (499 in-channel, floodplain, and channel capacity acres + 843 shellfish acres)
Cost Per Acre (total first cost divided by total acres)	$0	$70K	$192K
Direct benefit to shellfish or oysters	No	No	Yes (placement of dredged material in nearshore zone for shellfish attachment)
Directly increases channel capacity	No	No	Yes
Allows for placement of additional in-channel habitat features (LWD)	No	Yes, RM 9 to RM 11	Yes, RM 0 to RM 11
Addresses summer low flow reach; restores year-round channel near confluence	No	Yes	Yes
Improves habitat connectivity	No	Yes	Yes
Reduces fish stranding	No	Provides high flow refuge during frequent winter storm events; improves floodplain connectivity	Yes
Short-term negative environmental effects	None	Low	High
Sustainability	N/A	High	Medium
O&M	None	Minimal	Periodic re-dredging ($43M every 20 years)
Private property impacts	None	Low	High

Finally, construction and maintenance of the Riverbed Excavation alternatives are extremely cost prohibitive. Per Corps' cost-sharing policies for construction of ecosystem restoration projects, the non-

Federal sponsors would be required to contribute 35% of the construction costs with the Corps and would be responsible for all O&M activities associated with the alternative (estimated to be up to $80 million for the largest-scale riverbed excavation alternative). These non-Federal funding requirements are beyond the budget capacity of Mason County and the Skokomish Indian Tribe, and are also likely beyond the means of local or State grant opportunities. As such, the study sponsors do not have the financial capability to cost-share in construction of these alternatives or maintain them per Corps O&M requirements. If O&M cannot be sustained, it is anticipated that restoration benefits would be foregone at some time during the 50-year project life. Additionally, the requirement for maintenance (re-dredge the channel every 20 years) for the Riverbed Excavation alternatives would have similar short-term construction impacts as those experienced during initial construction (environmental impacts are discussed in Chapter 4), causing these alternatives to be less sustainable compared to the Confluence Levee Removal alternatives.

The base of all of the Confluence Levee Removal alternatives is a minimally engineered restoration solution and includes features that restore the ecosystem structures, functions, and processes of the study area. Confluence Levee Removal would restore fewer acres of habitat and would not provide direct benefits to shellfish. However, it improves habitat connectivity and restores a year-round channel near the confluence with minimal negative environmental effects. It also has lower construction costs and requires minimal O&M. Although this alternative does not allow for placement of additional in-channel habitat features like LWD because it does not directly increase channel capacity, additional floodplain increments (e.g., side channel reconnection) are warranted to create a comprehensive restoration solution.

The information developed by the CE/ICA and evaluation, comparison, and trade-off analyses have informed the decision-making process by helping to answer whether the proposed Federal investment of each alternative in the final array is justifiable and viable from a cost perspective; that is, whether the environmental benefit of the additional output in the next level of investment is worth its additional cost. Per the general decision-making guidelines outlined in Appendix E of ER-1105-2-100, the following factors assist in making it justifiable and viable from a cost perspective:

- Output target: Although a formal habitat unit target has not been identified for the study, the PDT has indicated that restoration of side channel and floodplain habitats adds significant value to the proposed alternatives. Additional investment to restore these critical habitat types are worth the relatively small cost of doing so; alternatives that include additional increments that propose restoration of floodplain or side channel habitats are worth the investment. The additional restoration of side channels and floodplain wetlands will have high returns in ecosystem functions.
- Cost affordability: Non-Federal sponsor implementation funds are a constraint. The Riverbed Excavation Alternatives are not affordable to the Non-Federal sponsors in terms of both construction costs and O&M requirements.
- Unintended effects: The Riverbed Excavation Alternatives have anticipated significant short-term environmental consequences associated with construction of this plan as well as significant risk that salmon would not be able to find appropriate spawning habitat for one or more years

as sediments stabilize and the river experiences higher channel-forming flows. Chapter 4 describes these environmental effects in more detail.

3.10 Summary of the Tentatively Selected Plan (Environmentally Preferable Alternative)*

The evaluation and comparison of alternatives led the study team to initially recommend Alternative #27 as the Tentatively Selected Plan (TSP) as well as the environmentally preferable alternative. Alternative #27 is environmentally preferable because it has the greatest quantity of Average Annual Habitat Units without the significant temporary construction impacts and environmental risk to salmon spawning habitat of Alternatives #45 and #60.

The TSP presented in the Draft FR/EIS (January 2014) included the removal of Confluence Levee, the installation of large woody debris, reconnection of a side channel, wetland restoration at two sites, and restoration of two tributaries. In subsequent coordination efforts between the Corps, the non-Federal sponsors, and local landowners in the study area, three increments that were originally included in the TSP are no longer being carried forward. The Hunter Creek Mouth (Increment #39), Hunter Creek Tributary Restoration (Increment #40), and Weaver Creek Tributary Restoration (Increment #43) are no longer included in the recommended plan due to a lack of landowner willingness. As the feasibility-level design phase was completed, these increments were determined to have insurmountable real estate and access issues that had not manifested earlier the analysis.

3.11 Summary of the Recommended Plan*

As described in the previous section, the TSP presented the Draft FR/EIS has been modified following agency, technical, and public review of the report as well as completion of feasibility-level design efforts. While the Draft FR/EIS presented the Corps' tentative proposal for a selected plan, this Final FR/EIS presents the Corps' recommended NER plan. Based on subsequent coordination efforts between the Corps, the non-Federal sponsors, and local landowners in the study area, Alternative #18 (Figure 3-9) is presented as the recommended plan. This best buy plan includes the same increments as the original TSP (Confluence Levee removal, installation of large woody debris, reconnection of a side channel, and two wetland restoration increments) but does not include the Hunter and Weaver Creek tributary restorations. While less comprehensive than the original recommended plan, Alternative #18 is still considered complete, acceptable, efficient, and effective, and it restores the critical needs of the study area (restores year-round flow for fish passage). Alternative #18 is a best buy plan, is economically justified, and is more acceptable in terms of landowner willingness/support.

Key considerations of the recommended plan are summarized below:

Total project cost: $19.3 million (October 2014 price level); $21.7 million (fully funded cost estimate to the midpoint of construction)

Acres restored: 277

Cost per acre: ~$70k/acre (October 2014 price level)

Total habitat units: 187

Habitat scarcity: The recommended plan restores nationally scarce habitats including those described in the U.S. Fish and Wildlife Service's Biological Sampling in the Skokomish River Basin (Appendix A).

Connectivity: The recommended plan fully restores a critical, direct physical connection of existing habitat areas (restoration of year-round flow near the confluence of the North & South Fork Skokomish River). The plan also provides critical life requisites including a migration corridor as well as rearing and refuge habitat for ESA-listed salmonids species.

Special species status: The recommended plan directly restores habitat for federally listed salmonid species including Chinook salmon, chum salmon, steelhead, and bull trout.

Hydrologic character: System hydrology is restored to the best attainable condition, but remains a limited factor in ecosystem health of the Skokomish River Basin.

Geomorphic condition: Geomorphology is restored to the best attainable condition, but remains a limiting factor in ecosystem health of the Skokomish River Basin.

Self-sustaining: The recommended plan is designed to be environmentally self-sustaining with little to no O&M costs.

Plan recognition: As described in Section 5.13, the recommended plan is one element of an integrated restoration effort in the entire Skokomish River watershed, contributing to a regional plan for restoration of the Skokomish River Basin.

Alternative #18 is the recommended plan, the National Ecosystem Restoration (NER) plan, and the agency preferred alternative as determined by all of the evaluation criteria discussed throughout Chapter 3. The NER plan reasonably maximizes environmental benefits considering cost effectiveness and incremental cost analyses, significance of outputs, completeness, efficiency, effectiveness, and acceptability. The NER plan is also more acceptable than the original TSP in terms of landowner willingness and constructability on available lands. The following chapters describe the direct, indirect, and cumulative environmental effects of each alternative including the recommended plan.

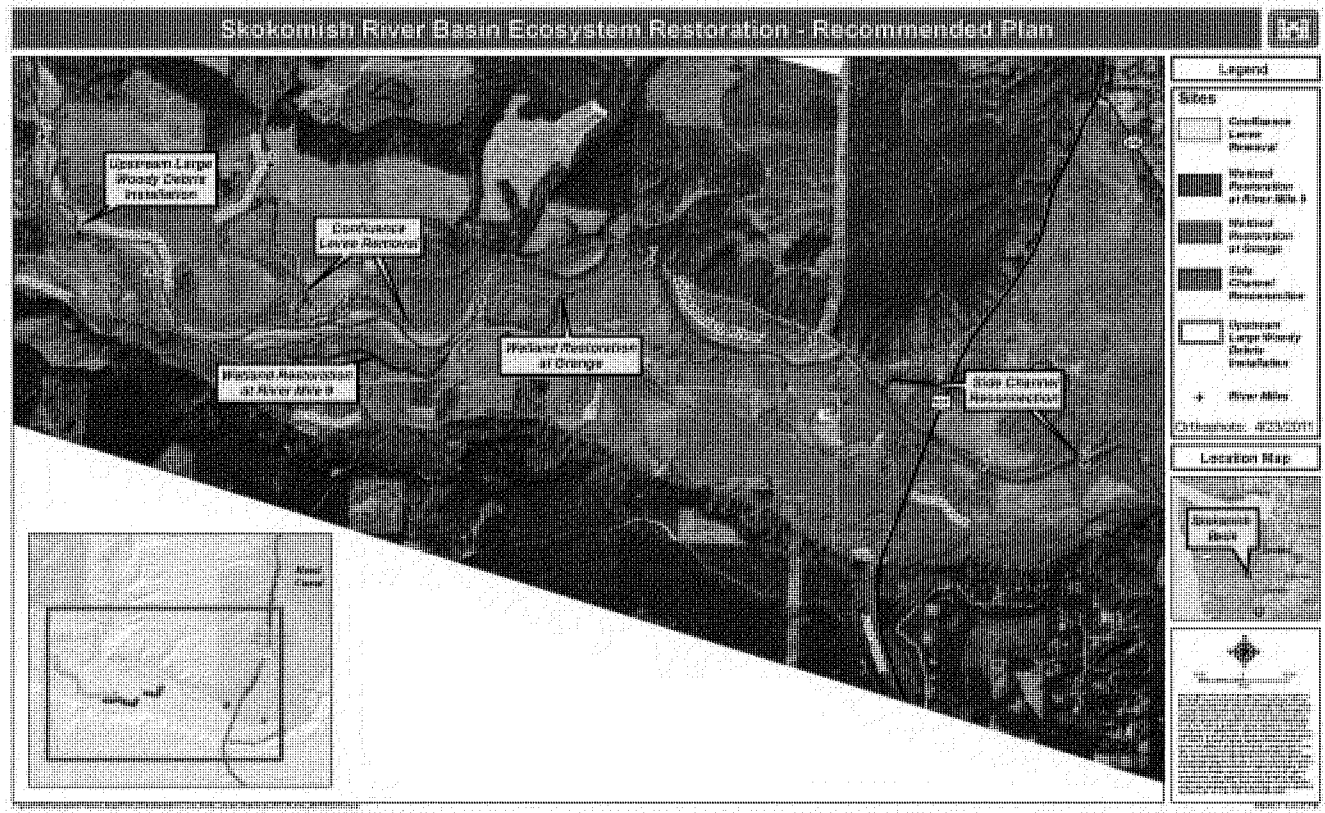


Figure 3-9. Recommended Plan

4. Affected Environment and Environmental Consequences of the Alternatives*

This chapter describes the existing conditions and future without-project conditions used for analysis during the Skokomish River Basin feasibility study, as well as the probable environmental outcomes of implementing each proposed alternative. Existing conditions are the physical, chemical, biological, and sociological characteristics of the study area. Characterizing resource conditions is critical for understanding the probable future condition of those resources (i.e. the future without-project condition) and for defining problems and opportunities. The assessment of environmental effects is based on a comparison of conditions with and without implementation of the proposed plan and a reasonable range of alternatives. In this case, the five action alternatives formulated through the screening process are grouped into two types: Confluence Levee Alternatives and Riverbed Excavation Alternatives and are compared to the No-Action Alternative. The No-Action Alternative and the two groups of action alternatives were analyzed for direct and indirect effects on each resource and whether those direct and indirect effects result in a significant adverse cumulative effect when added to other past, present, and reasonably foreseeable future actions. The analysis focuses only on significant resources that are potentially affected by the alternatives and have a material bearing on the decision-making process. The spatial scale of analysis focuses on the locations of the proposed sites to provide a comparison between the No-Action Alternative and the various scales of the two action alternatives. The time scale for analysis is a 50-year period beginning in 201S and extending to 2065.

Chapter 3 outlines the formulation and evaluation of alternatives. The final array of alternatives carried forward for the assessment of environmental effects in Chapter 4 is the following:

No-Action Alternative

Confluence Levee Removal Alternatives

Confluence Levee Removal (Alternative #11)	Confluence Levee Removal (Alternative #18)	Confluence Levee Removal (Alternative #27)
Base Alternative #3: Confluence Levee Removal	Base Alternative #3: Confluence Levee Removal	Base Alternative #3: Confluence Levee Removal
Increment #35: Upstream LWD Installation	Increment #35: Upstream LWD Installation	Increment #35: Upstream LWD Installation
Increment #9: Side Channel Reconnection	Increment #9: Side Channel Reconnection	Increment #9: Side Channel Reconnection
	Increment #28: Wetland Restoration at River Mile 9	Increment #28: Wetland Restoration at River Mile 9
	Increment #37: Wetland Restoration at Grange	Increment #37: Wetland Restoration at Grange
		Increment #39: Hunter Creek Mouth Restoration
		Increment #40: Hunter Creek Side Channel Restoration
		Increment #43: Weaver Creek Side Channel Restoration

Riverbed Excavation Alternatives

Riverbed Excavation (Alternative #45)	Riverbed Excavation (Alternative #60)
Base Alternative #5: Riverbed Excavation (RM 3.5-9)	Base Alternative #1: Riverbed Excavation (RM 0-9)
Increment #35: Upstream LWD Installation	Increment #35: Upstream LWD Installation
Increment #9: Side Channel Reconnection	Increment #9: Side Channel Reconnection
Increment #37: Wetland Restoration at Grange	Increment #37: Wetland Restoration at Grange
Increment #28: Wetland Restoration at River Mile 9	Increment #28: Wetland Restoration at River Mile 9
Increment #40: Hunter Creek Tributary Restoration	Increment #40: Hunter Creek Tributary Restoration
Increment #43: Weaver Creek Tributary Restoration	Increment #43: Weaver Creek Tributary Restoration
Increment #26: Wetland Restoration at Dips Road	Increment #26: Wetland Restoration at Dips Road

4.1 Resources Analyzed and Resources Screened from Detailed Analysis

Table 4-1 identifies the resources analyzed or screened from detailed analysis including a rationale for inclusion or exclusion. Resources were excluded from detailed analysis if they are not potentially affected by the alternatives or do not have a material bearing on the decision-making process.

Table 4-1. Resources Analyzed and Resources Screened from Detailed Analysis

Resource	Included in Detailed Analysis (Y/N)	Rationale for inclusion or exclusion
Hydraulics and Hydrology	Y	Problems identified center on the relationships among hydraulics, hydrology, and sedimentation. The alternatives require study of these characteristics. Local residents raised groundwater as a significant concern and it was reviewed in project screening.
Geomorphology and Sediment Transport	Y	Problems identified center on the relationships among hydraulics, hydrology, and sedimentation. Proposed alternatives require study of these characteristics.
Water Quality	Y	Riverbed excavation alternatives would have significant short-term effects to turbidity.
Air Quality	Y	Required to be analyzed as named in NEPA. This analysis appears in Chapter 6.
Greenhouse Gas Emissions	Y	Required to be analyzed by CEQ guidance (2010).
Climate Change and Sea Level Change	Y	USACE Engineering Circular 1165-2-212 requires feasibility studies to consider the sensitivity and adaptability of projects to sea level change. Predicted effects of climate change are described for the alternatives.
Underwater and Airborne Noise	N	Airborne noise from construction would attenuate by distance from the source to any sensitive receptors. Underwater noise from construction would occur when sensitive receptors would not be present, and in shallow water such that the sound waves would be attenuated quickly. Therefore, there would not be a significant impact.
Hazardous, Toxic, and Radiological Waste (HTRW)	Y	This analysis appears in Appendix I. The proposed action alternatives would not create any hazard to the public or the environment through transport, use, or disposal of hazardous materials. There are no CERCLA-regulated substances involved with any of the proposed restoration sites. The few cars at Confluence Levee have been present for decades and have not contaminated the surrounding area. Mason County contracted a consulting firm to test the soil for a Phase II HTRW investigation; results confirm that there is no hazardous or toxic waste resulting from the abandoned cars. Of the 33 samples taken at Confluence Levee, only 5 locations had detections of gasoline, all of which were below MTCA Method A Soil Cleanup Levels for Unrestricted Land Use. WDOE has provided a letter confirming that there are no active or proposed cleanup sites within the Skokomish River Basin.
Fish	Y	One of the proposed alternatives may have a significant negative effect to fish populations in the mainstem river channel. All alternatives would provide long-term significant benefits for fish populations.
Mammals	Y	Beaver, raccoon, river otter, mink, and other small mammals are associated with and dependent upon riparian and aquatic habitats.

Resource	Included in Detailed Analysis (Y/N)	Rationale for inclusion or exclusion
Birds	Y	The low levels of development in the Skokomish watershed have allowed many sensitive bird species to remain in their native habitat. The proposal is analyzed for its potential to disturb or displace birds.
Shellfish and other Macroinvertebrates	Y	Shellfish would likely benefit from the proposed ecosystem restoration. Two of the action alternatives may have a significant negative effect to benthic macroinvertebrates in the river.
Vegetation (Wetland, Riparian, Estuarine)	Y	Proposed action alternatives may affect size and type of wetlands, and may affect estuarine vegetation such as eelgrass.
Rare, Threatened, and Endangered Species	Y	Riverbed excavation alternatives may have a significant short-term impact on ESA-listed salmonid species.
Cultural Resources	Y	Potential exists for inadvertent discovery of cultural resources; discovery during construction could have an adverse effect to those resources.
Indian Trust Assets	Y	Riverbed excavation alternatives have a risk for negative effects to tribal resources through disturbance and potential harm to salmon.
Environmental Justice Communities	Y	Required to be analyzed by Presidential Executive Order. The result of this analysis appears in Chapter 6 Compliance with Environmental Statutes.
Aesthetics	N	None of the proposed alternatives will affect scenic resources or visual characteristics. Four segments of the South Fork Skokomish River have been proposed for designation as wild, scenic, or recreational under the Wild and Scenic Rivers Act; these sections are upstream from the study area and none of the alternatives would affect these reaches.
Land Use and Agricultural Resources	Y	Population in the study area is predicted to decline, and many area residents are likely to abandon agriculture as an economic base. The proposed alternatives area analyzed to determine whether there would be a significant effect on present or forecasted land use or agricultural resources across the study area.
Recreation Resources	N	Significant recreation activities (boating, camping, bicycling, hunting, etc.) occur outside the study area in the upper watershed or downstream from the study area in Annas Bay. The alternatives would not have more than a negligible effect on fishing activity within the study area.
Public Services and Utilities	N	None of the alternatives would have a substantial effect on electricity, water, wastewater and stormwater collection, sewer and solid waste, natural gas, oil/petroleum, or telecommunications services.
Public Health and Safety	Y	Public health and safety are a concern for any water resources project. The alternatives are analyzed to determine the scale and significance of effects.
Transportation and Traffic	Y	Construction may cause temporary disruptions to local traffic, and construction vehicles could require additional traffic controls for the duration of work.

4.2 Cumulative Effects Approach

Cumulative effects can result from the incremental effects of the proposed action when added to the effects of other past, present, and future actions, regardless of which government agency or private entity undertakes such actions. When effects that are individually minor combine over space or time, the cumulative effects can be significant. NEPA requires analyzing whether the incremental effect of the proposed action will cause a significant impact to the environment when added to past, present, and reasonably foreseeable future actions. This section will summarize actions that have affected the environment, and each resource in Sections 4.3 through 4.6 will be analyzed for whether it would accrue a significant adverse cumulative effect.

Past Actions

The Skokomish River channel has migrated within a narrow band along its present course for at least 400 years. The watershed remained relatively unaltered by human activity until Euro-American settlers

arrived in the mid-nineteenth century. During the last 150 years, there have been many changes to the environment along that alignment caused by both natural and anthropogenic factors. High bedload transport caused by the removal of LWD and disturbance of the stream banks, combined with altered depositional patterns caused by bank protection, side-channel closures, and flow regulation by the Cushman Project have caused riverbed aggradation and increased flooding. Logging and agricultural development have reduced riverbank riparian habitat and cleared LWD from the channel. The riverbank has been stabilized in places to protect roads and farmland. Land management has been geared toward agriculture and timber harvest. Significant land use and development including mining, logging, and fishing have altered the historical physical and biological characteristics of the Skokomish Basin. Table 4-2 outlines the historical timeline of significant events in the Skokomish Watershed.

Table 4-2. Skokomish Watershed Settlement and Development Historical Timeline

Decade	Event
Pre-1850	Only minor alterations of watershed by humans; homeland of Twana people
1850	Euro-Americans begin settling lower Skokomish floodplain
1860	Land clearing and agricultural development of lower Skokomish floodplain
late-1800's	Commercial and recreational fishing became popular among non-Tribal settlers
1899	Fish stocks had become so depleted that a hatchery was built on the river
1900	Logging of lower valleys; Logjam clearing; Log driving; Farm development continued
1910	Extensive logging of lower NF; State Route 106 (old State Road 21 and 14)
1920	Construction of Cushman dams; diversion of NF flow out of Basin at Cushman Dam No. 2 in 1930
1922	Hood Canal was closed to commercial fishing due to decreased salmon runs
1930	Clearcut logging begins on USFS lands in the SF; Diking within river delta for farm development; Channel straightening; River channel gravel mining; Highway 101 bridges built at Purdy Cr., Weaver Cr., north Skokomish overflow channel, and the Skokomish River; Evidence of aggradation in river.
1940	Creation of Shelton Cooperative Sustained Yield Unit (CSYU) Agreement on Simpson Timber and USFS lands in the SF (1946); logging accelerates
1940	Lower mainstem experiences 29 floods in 29 years between 1912 and 1941; Lower mainstem aggrades 1.5 feet
1950	Clearcutting in SF anticipating hydroelectric project; Diking in Vance Creek and lower river; Minimal aggradation in lower river between 1944 and 1964
1960	Extensive dike building; Accelerating road building and logging in the CSYU; Aggradation resumed in lower river
1970	Dike and revetment system lengthened and repaired; Road building and logging in CSYU occurring at high rates; Highway 101 bridge at Weaver Creek re-built
1980	Rapid logging of CSYU continues to early 1980s, then declines later in the decade; structural repairs and additions to various dikes made; Highway 101 bridges over the Skokomish and State Route 106 bridge rebuilt
1990	Logging on Olympic National Forest (ONF) lands in SF reduced significantly then essentially stopped (mid-1990's); Watershed restoration begins on ONF lands: over 200 miles of roads decommissioned or stabilized, 247 miles of upland soil stabilization, nearly 4 miles of instream restoration and riparian enhancement (Anderson et al. 2007); Extensive logging of second growth on Simpson lands; Forest and Fish Law enacted (1999); nearly 4 feet of aggradation since 1964 measured at Highway 101

Decade	Event
1999	Puget Sound Chinook Salmon, Hood Canal Summer-Run Chum Salmon, and the Coastal/Puget Sound Bull Trout listed as threatened under the Endangered Species Act; Corps GI Reconnaissance Study concluded.
2000	Logging of second growth timber on Simpson lands; Continued aggradation in lower river; Restoration work in upper SF to close logging roads; Bourgault/North channel and North channel oxbow restoration; LWD bank protection projects on the Skokomish mainstem, South Fork, and Vance Creek (2000-2012); Corps GI initiated; Cushman Dam settlement reached (2009)
2007	Puget Sound Steelhead listed as threatened under the Endangered Species Act.
2010	Cushman settlement agreement implemented; Floodplain restoration in South Fork by USFS; Estuarine restoration commences with dikes removed and borrow ditches filled on Nalley Island and Slough by the Skokomish Indian Tribe; Purdy Creek Bridge improved by WSDOT in 2009

Notes: NF = North Fork, SF = South Fork, CR = Creek
Sources: Peters et al. 2011, Barreca 2001, Smoker et al, 1952

Present Actions

The Skokomish Watershed Action Team (SWAT) is a diverse, informal partnership of government agencies, land managers, and others collaborating to restore the Skokomish watershed. In 2007, the SWAT designed a three-year action plan to implement over 40 projects in the upper and lower watershed at an approximate cost of $48.6 million. This action plan is currently being updated to identify restoration projects to be implemented from 2015 to 2020. Types of ecosystem restoration projects the SWAT has undertaken within the past 10 years include significant lengths of road decommissioning and stabilization, culvert replacements, in-stream large wood placement, riparian plantings, and control of invasive species. Similar actions are underway. The Skokomish Indian Tribe and Mason County have recently restored the estuary in three phases of construction to remove dikes and restore hydrology. A query of the WDFW Habitat Work Schedule and Recreation and Conservation Office (RCO) Project Information System (PRISM) databases reveal the following active projects within the study area: Phase 3 of estuary restoration; Southern Hood Canal Riparian enhancement along the mainstem Skokomish; floodplain restoration near Purdy Creek, near Highway 101 bridge, and at RM 8; Five Mile Creek LWD placement; removal of car bodies along the lower mainstem with riparian restoration; and riparian planting near Sunnyside Road (WDFW et al. 2013).

Skokomish Valley has remained relatively undeveloped for many years, and no significant building is occurring at the time of this analysis. Among the activities in the valley, aerial photography analysis reveals that the most significant land disturbances in the watershed over the past five years are large patches of clear-cut logging in the uplands.

Future Actions

Proposed ecosystem restoration projects that Olympic National Forest plans to implement include more road decommissioning, additional large wood in the South Fork, Pine Lake restoration, trail stabilization, prairie restoration, and thinning of overstocked forest stands to enhance wildlife habitat and biodiversity (USFS 2011a, 2011b). The WDFW Habitat Work Schedule and the Washington State RCO databases list the following proposed projects within the study area: Lower Skabob Creek restoration of

habitat complexity; Vance Creek LWD placement; Southern Hood Canal Riparian enhancement along the Skokomish Phase 2; placing engineered logjams after the confluence reach is restored; 150 acres of floodplain restoration at the confluence reach; and parcel acquisition for permanent protection of a side channel just upstream from the Highway 101 bridge (WDFW et al. 2013).

Planned developments within Skokomish Valley include adding 19 homes into the 746-acre property of Skokomish Valley Farms (Capitol Press 2013); these will be 40-acre parcels in which 35 acres will have a permanent agricultural easement. This farm qualifies for two programs under the Natural Resources Conservation Service's Environmental Quality Incentives Program: a permanent easement on land that is frequently inundated, as well as a five-year wildlife protection program. Approximately 24,000 trees have been planted under these programs (Capitol Press 2013).

Cushman Settlement Agreement

A settlement and relicensing agreement for Tacoma Power's Cushman Hydroelectric Project was signed in 2009. The agreement resolved a $5.8 billion damages claim and long-standing disputes over the terms of a long-term license for Cushman Dam. The licensing settlement agreement concludes nearly two years of negotiations and decades of contention between Tacoma Power, the Skokomish Indian Tribe, and the many State and Federal agencies that will oversee implementation of the terms of the agreement. Although the Corps is not a signatory of the Cushman Settlement Agreement, the terms outlined in the settlement have been considered in this report as actions undertaken by Tacoma Power in accordance with the settlement may have the potential to affect the existing and future without-project conditions of the Skokomish River. While multiple sections of this chapter outline the existing, future without-project conditions, and future with-project conditions under specific provisions of the Cushman Settlement, a summary of the key requirements of the agreement as they relate to this study are outlined below.

Current and future activities required by the Cushman Settlement occur primarily in the North Fork Skokomish River, which is outside the Corps' General Investigation study area. These activities include the construction of fish passage facilities, construction and operation of two fish hatcheries, construction of a new powerhouse at Cushman Dam No. 2, and recreation improvements near Lake Cushman. As described in Section 4.4.1.1., these activities would benefit separate stocks of fish that use different forks of the Skokomish River; habitat for the ESA-listed fish species that are found within the Corps' study area remains in a severely degraded state.

At this time, there are no confirmed activities required under the Cushman Settlement within the Corps' study area. Additionally, Tacoma Power is not yet required to develop or implement additional measures to address flooding, channel capacity, sediment transport, or habitat restoration within the Corps' study area. Any future action to be taken by Tacoma Power under the Cushman Settlement is dependent upon procedural and technical findings. Provisions in the Cushman Settlement limit the financial obligations for future action by Tacoma Power, so future activities would likely be smaller in scale and have only localized effects that are not expected to negatively affect the recommended plan. Additional funds provided by Tacoma Power in the future are unlikely to substantially increase mainstem channel capacity. If findings determine action by Tacoma Power is required on the mainstem

Skokomish River, activities must be approved by NMFS, BIA, USFWS, and the Skokomish Indian Tribe; Tacoma Power is also required to seek comments and recommendations from the Corps to ensure that any recommendations will be complementary to the recommended plan and will not affect the success or benefits accrued from the Federal (Corps) project.

Table 4-3 provides a summary of known and assumed components of construction of the base alternatives and increments. These construction components were used for the analysis of effects to environmental resources in the following sections.

Table 4-3. Summary of Construction Components Analyzed for Effects to Environmental Resources

	Project Features	Included in Alternative	Staging area cleared (acres)	Construction acres cleared (project footprint)	Material excavated	Material placed	Equipment on site (# calculated for schedule)	Estimated construction duration	Estimated number of truckloads (12 CY Truck)	Total haul distance
Bases	Riverbed Excavation (RM 0-9)	Alternative #60	3 Staging areas totaling: 30,000 SF 0.69 AC	219	2,684,000 cy O&M: 700,000 cy ea. 20 years	50 logs per mile	(1) 16" cutter head, pipeline dredge (3) 4 CY, Crawler, dragline crane (18) 18 CY, 6x6 off-road dump trucks (3) 3.2 CY, crawler, loader (3) Trailer mounted, 6'x20' grizzly screener	631 work days	199,728 + 65 (Staging area)	10-Mile cycle
Bases	Riverbed Excavation (RM 3.5-9)	Alternative #45	3 Staging areas totaling: 30,000 SF 0.69 AC	132	1,870,000 cy O&M: 600,000 cy ea. 20 years	50 logs per mile	(3) 4 CY, Crawler, dragline crane (18) 18 CY, 6x6 off-road dump trucks (3) 3.2 CY, crawler, loader (3) Trailer mounted, 6'x20' grizzly screener	363 work days	137,313 + 65 (Staging area)	10-Mile cycle
Bases	Confluence Levee Removal	Alternatives #11, 18, and 27	3 Staging areas totaling: 30,000 SF 0.69 AC	3.6	15,058 cy	30 logs	(3) 2 CY, Crawler, Excavators (12) 18 CY, 6x6 off-road dump trucks (3) 3.2 CY, crawler, loader (1) 75 HP, Dozer	107 total work days; 42 hauling days; minimal or no in-water work	714 + 65 (Staging area)	20-Mile cycle
Increments	Upstream LWD Installation	Alternatives #45 and 60 Alternatives #11, 18, and 27	3 staging areas totaling: 123,750 SF 2.84 AC	14	30,523 cy	80-100 logs 80-100 stones @ 5'diameter	(1) 2 CY, Crawler, Excavator (1) Log Skidder (1) 1.5 CY, Crawler, Excavator w/ Thumb	26 work days	~6 stone per truck ~3 rootwads per truck	20-Mile cycle
Increments	Side Channel Reconnection	Alternatives #45 and 60 Alternatives #11, 18 and 27	Staging areas assumed to be within footprint	0.8	3,614 cy	30 logs 30 stones to anchor logs	(6) 1.5 CY, Crawler, Excavator (4) 18 CY, 6x6 off-road dump trucks (1) 3.2 CY, Crawler,	10 work days	170	20-Mile cycle
Increments	Wetland Restoration at Grange	Alternatives #45 and 60 Alternatives #18 and 27	1 Staging area: 12,250 SF 0.28 AC	4	3,789 cy	27,134 cy	(3) 2 CY, Crawler, Excavators (12) 18 CY, 6x6 off-road dump trucks (3) 3.2 CY, crawler, loader (1) 75 HP, Dozer	63 work days No in-water work	2,992	20-Mile cycle
Increments	Wetland Restoration at River Mile 9	Alternatives #45 and 60 Alternatives #18 and 27	1 Staging area: 14,000 SF 0.32 AC	5.7	8,062 cy	19,891 cy	(3) 2 CY, Crawler, Excavators (12) 18 CY, 6x6 off-road dump trucks (3) 3.2 CY, crawler, loader (1) 75 HP, Dozer	63 work days No in-water work	2,396	20-Mile cycle
Increments	Hunter Creek Side Channel	Alternatives #45 and 60 Alternatives #18 and 27	1 Staging area: 10,000 SF 0.23 AC	29	Approx 75,000 cy	None	(6) 1.5 CY, Crawler, Excavator (4) 18 CY, 6x6 off-road dump trucks (1) 3.2 CY, Crawler, Loader	39 work days	6,493	20-Mile cycle
Increments	Huntar Creek Mouth	Alternatives #45 and 60 Alternatives #18 and 27	Staging areas assumed to be within footprint	0.5	Approx 200 cy	None	(6) 1.5 CY, Crawler, Excavator (4) 18 CY, 6x6 off-road dump trucks (1) 3.2 CY, Crawler, Loader	7 work days	16	20-Mile cycle
Increments	Weaver Creek Side Channel	Alternatives #45 and 60 Alternative #27	1 Staging area: 10,000 SF 0.23 AC	25	Approx 75,000 cy	None	(6) 1.5 CY, Crawler, Excavator (4) 18 CY, 6x6 off-road dump trucks (1) 3.2 CY, Crawler, Loader	47 work days	8,283	20-Mile cycle
Increments	Wetland Restoration at Dips Road	Alternatives #45 and 60	Staging areas assumed to be within footprint	17	1,800 cy at old road loc. 10,000-11,000 cy of organic material	11,000-12,000 cy	(1) 0.8 CY, wheel, loader (1) Excavator, pulverizer, 3,000 lb (1) 3.5 CY, wheel, loader (1) 1.5 CY, wheel, excavator (1) 2.7 ton, vibratory, double drum, roller (1) 135 HP, grader w/ blade (1) 250 hp, crawler, dozer (1) 10' wide, asphalt paver	99 work days No in-water work	3,274	20-Mile cycle

Note: After release of the Draft FR/EIS, the project underwent feasibility-level design. The primary changes relevant to this table are that the logjams are larger than those presented in the conceptual level design, and pile driving has been proposed for anchoring the larger logjams. The Corps will conduct further analyses during PED phase, such as the Wave Equation Analysis for Piles, and other on-site investigations to determine whether driving timber piles at these locations is feasible. Additionally, the staging areas that will be cleared and replanted were changed for Upstream LWD installation, Wetland Restoration at Grange, and Wetland Restoration at River Mile 9. These had been assumed to be within the project footprint of the conceptual level design, but have now been specifically delineated in the feasibility-level design.

4.3 Physical Environment

This section provides an analysis of the existing and future without-project condition of the significant physical resources in the study area, as well as how each alternative would affect these resources.

4.3.1 Hydrology and Hydraulics

A summary of the basin hydrology appears in this report and detailed analyses appear in the Skokomish River Flooding and Sedimentation Baseline report (Appendix H, Annex H-4). The Skokomish River drains approximately 240 square miles of forested terrain into Hood Canal. Three main tributaries contribute to the river system: the North Fork, the South Fork, and Vance Creek. Tacoma's Cushman Hydroelectric Project (Cushman Project), regulates the North Fork's flow, provides flood discharge reductions, and maintains year-round base flows in the 150 to 180 cfs range. The South Fork and Vance Creek are unregulated and provide most of the flood discharges. Average monthly discharges in the South Fork, at the USGS gage upstream of Vance Creek, range from less than 200 cfs in August and September to about 1,400 cfs in December and January. Downstream of the North Fork/South Fork confluence, average monthly discharge ranges from 250 cfs in August to 2,400 cfs in December. In recent years, North Fork and mainstem Skokomish summer base flows below the North Fork confluence have increased because of higher releases from the Cushman Project. Hunter and Weaver creeks are groundwater fed tributaries to the mainstem Skokomish River.

Channel capacity of the mainstem and South Fork Skokomish Rivers, as well as Vance Creek has been significantly reduced due to sediment accumulation. The mainstem has lost about 10,000 cfs of flow capacity since 1941 (Appendix H, Annex H-4). Typically, flooding occurs three to four times every year because of the low channel capacity. Along the south bank of the river, floodwater flows away from the river channel in the upper valley causing widespread, shallow flooding. The southern floodwaters flow southeast through Purdy Creek and rejoin the river downstream of Highway 101 near RM 3.5. The recently completed Purdy Creek bridge improved flood conveyance and should lower flood depths immediately upstream of Highway 101.

Flooding does not generally pose a life safety threat in the Skokomish Valley. Flooding occurs frequently and local residents have learned to cope with floodwaters. During the near record flood in December 2010, there were no reported injuries or deaths due to flooding. Most of the Valley would experience only shallow (less than three feet) flooding during a 1% annual chance of exceedance (ACE) flood event. Ponding areas fill repeatedly each year to depths of five to seven feet and are largely undeveloped.

There is not a continuous, competent, well-planned levee system along the Skokomish River. The levees, berms, and revetments were built by valley residents to combat local flood problems. The levees were built using available materials, and were constructed without engineering design. Most of the levees along the river were originally constructed in the 1950s and 1960s, and were raised or connected during the 1980s and 1990s. None of the levees are considered competent enough to provide reliable flood risk management, although they do provide some localized relief (less than a 2-year level of protection) from the frequent small floods that occur several times a year. The levees are approximately 4 to 6 feet high in some areas and should be considered to perform more like agricultural berms rather than fully

engineered levees. During a flood in 2003, the Confluence Levee was breached near RM 9, diverting the North Fork and moving the confluence downstream nearly 1 ½ miles to RM 7.7.

The sediment accumulation has altered flow conditions in the summer. The riverbed of the South Fork is higher than that of the North Fork near the old confluence at RM 9. Since the North Fork was diverted in 2003, the reduced summer discharges have contributed to all the South Fork flow going subsurface in the late-summer/early fall. This dry riverbed prevents access for ESA-listed fish to critical spawning habitat in the upper reaches of the South Fork.

A study of nine groundwater wells showed increases for six of the nine wells (Figlar-Barnes and Bullchild 2011). This investigation showed that since 1996, notable upward trends in these wells during a downward trend in rainfall suggests increases in overall groundwater levels in the Skokomish Valley that are not necessarily associated with rainfall. This report concluded that additional monitoring is required for a better understanding of groundwater trends.

Finally, the Cushman Settlement includes provisions for a minimum volume and distribution of flow releases to the North Fork as well as provisions to allow for releases of sediment transport flows (i.e., "flushing flows") to increase sediment transport in the mainstem Skokomish River. While the future without-project condition for hydrology and hydraulics includes the anticipated minimum flow releases now and in the future, the flushing flows are not assumed to be implemented in the future. Flushing flows were attempted in the past but this approach has been abandoned because (1) limited channel capacity causes downstream flooding when larger flushing flows are released, and (2) flushing flows that do not worsen downstream flooding are ineffective at transporting sediment throughout the system.

4.3.1.1 No-Action Alternative/Future Without-Project Conditions

Skokomish River hydrology is not expected to change significantly over the study period. Logging will likely continue in the South Fork and Vance Creek watersheds. Logging on Forest Service land could increase or decrease depending on Federal policy, but either course is unlikely to significantly influence seasonal or flood hydrology. The Cushman Project FERC license has been issued for a 50-year term, so North Fork hydrology should remain very similar to the existing conditions, at least through 2060.

Sediment accumulation is expected to continue to reduce channel capacities of the mainstem and South Fork Skokomish Rivers as well as Vance Creek. Flooding is expected to become even more frequent, but only small increases in flood depths are anticipated due to the broad floodplain in the valley. Continuing aggradation is expected to increase the frequency and duration of the subsurface flows in the South Fork and Vance Creek during the late summer. A channel avulsion that would create an entirely new channel is possible within 20 years (see Geomorphology and Sediment Transport, Section 4.3.2.1.). The Figlar-Barnes and Bullchild (2011) groundwater study did not offer speculation on future trends.

Finally, provisions in the Cushman Settlement are not expected to change the hydrology and hydraulics of the study area in the future without-project condition because potential future actions by Tacoma Power have not been identified, determined to be necessary from a legal or technical standpoint, and are not specifically described.

4.3.1.2 Action Alternatives/Future With-Project Conditions

Aspects common to both groups of action alternatives

Reconnecting the abandoned channel between RM 4 and 5.6 to the river would provide a high flow side channel. This channel carries overbank floodwaters, but is not directly connected to the river. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would be connected to the river only during high discharges and would not convey river flows most of the time.

Two wetland restoration increments, located at RM 7.5-8 and RM 8.3-9.2, are intended to provide additional floodplain habitat for fish and to expand the area of forested wetland adjacent to the river. The wetland embankments would be constructed landward (south) varying distances, around 200 to 300 feet between RMs 8.3-9.2, and up to 1,200 ft between RMs 7.5-8. This would place more riparian forest and floodplain ponds on the riverward side of the agricultural berm. The new wetland embankments are expected to hold water within the wetlands at a greater depth and longer duration thereby improving and expanding wetland conditions. Strategically located sections of the existing agricultural berms would be removed to allow floodwaters to flow freely within the restored wetland area. The wetland embankments will be constructed to improve hydrologic conditions in the reconnected wetland area. The wetland embankments are not flood risk management features; rather, they are a structural mechanism required to allow targeted reconnection to riparian wetlands multiple times a year. The wetland embankments contain flow during moderate winter storm events up to approximately 6,000 cfs (these events occur multiple times a year), providing high flow refuge for fish as well as reconnection and restoration of high-value forested wetland during frequent, moderate winter storm events. The wetland embankments also divert flows back into the river rather than across the entire floodplain to the south where there is no defined channel or ecologically beneficial habitat for salmonid species. The wetland embankments would not cause significant changes in the future with-project flooding conditions. These project components are included in all of the alternatives except for Alternative #11.

Small LWD jams would be placed in the South Fork from RM 9 to 11 to increase meandering and bar formation, and provide cover for salmon. The river channel in this reach is wider and has more flow capacity than the downstream river channels in the study area. The LWD jams would have small cross-sectional areas and be built parallel to flow to minimize the hydraulic disturbance. The channel may be able to incorporate 6 to 12 jams per mile without adverse flooding or erosion effects. During feasibility-level design, the Corps determined pile driving might be required for anchoring bar-apex logjams. Further investigation during PED phase will be conducted to determine whether pile driving is feasible at these locations. Installation of logjams will require implementation of specific best management practices (BMPs) for diversion and care of water, which will be determined in a later phase of design.

The construction of tributary channels to Hunter and Weaver Creeks, included in Alternatives #27, #45, and #60, would expand the valley's drainage network. The existing creeks are perennial groundwater fed streams. The proposed restoration would consist of excavating small channels along existing swales down to slightly below the water table. The new channels may facilitate faster drainage of floodwaters.

Finally, provisions in the Cushman Settlement are not expected to change the hydrology and hydraulics of the study area in the future with-project condition. As discussed in Section 4.2, any future action(s) taken by Tacoma Power as the result of technical and procedural findings are not anticipated to negatively impact the future success or function of the alternatives proposed in the Corps' study area.

Confluence Levee Removal Alternatives #11, #18, and #27

Removing the Confluence Levee and diverting the South Fork into the North Fork near the pre-2003 confluence would provide a year-round connection from the South Fork to the mainstem. Similar to the river conditions prior to the 2003 North Fork diversion, the combined discharges of the North and South Forks would be enough water to provide continuous surface flows during the late summer low flow period. The reach of the South Fork that runs subsurface in late-summer/early-fall would be abandoned during those low flow periods. These alternatives would have little effect on flooding since the South Fork channel would still convey flood discharges, and both sides of the river frequently flood in this location already. These alternatives would only have minor localized effects to groundwater. An analysis of potential effects to groundwater concluded that the actions proposed under all three scales of the Confluence Levee removal alternative would have no effect to groundwater. The study team's assessment is that elevated groundwater could be better addressed with Natural Resource Conservation Service (NRCS) BMPs on individual properties.

Riverbed Excavation Alternatives #45 and #60

Alternative #60, excavation of the mainstem and South Fork Skokomish Rivers from RM 0-9, would increase the channel capacity and is expected to greatly reduce the chances of the South Fork channel running subsurface in late summer/early fall. The riverbed excavation would average 8 to 11 feet deep. The river would be returned to a cross-section size similar to what may have existed in the early-1900s. The proposed excavation would produce a river channel with an approximate 50% ACE, or two-year flood capacity, considerably reducing the flood risk in the valley. Floods larger than the 50% ACE would still cause overbank flooding, but to a lesser degree than present. The increased channel capacity allows the placement of LWD habitat structures in the river without increasing the flood risks in the valley. Effects to groundwater would be minor and localized and dependent on localized geomorphology along the reaches of the river.

The smaller scale of this alternative, #45, is excavation of RM 3.5-9. This action starts just upstream of where the southern floodwaters re-enter the mainstem. It would provide 50% ACE flow capacity in the excavated reach and reduce flood risks in much of the valley. Downstream of RM 3.5, channel capacity and flooding would be unchanged. LWD habitat structures could be placed in the excavated reach of the river and flood risks would still be less than they are now.

For both alternatives #45 and #60, the excavated riverbed would have less capacity for subsurface flow (less gravel to transmit water through) and is expected to place the thalweg below the existing water table. Both of these factors should help to maintain surface flows in the mainstem and South Fork during summer low flow conditions.

Wetland restoration at Dips Road would not initially alter river geometry and thus would not affect river hydraulics. This location is one of the first in the study area to flood; to avoid increasing downstream flood risks, the wetland restoration features would be designed and built to allow flooding to occur similar to existing conditions.

Cumulative Effects

No significant adverse cumulative effects to hydrology or hydraulics are anticipated to accrue from any of the alternatives. The alternatives would not alter rainfall/runoff hydrology on restored USFS lands in the headwaters. Riverbed Excavation alternatives could work in conjunction with the new Highway 101 Purdy Creek Bridge to reduce flood risks.

4.3.2 Geomorphology and Sediment Transport

The Skokomish River Basin headwaters are typified by steep, rugged terrain carved by past glaciations. Numerous small mountain streams discharge into the three principal tributaries, which flow through deep, narrow valleys and gorges to the head of the Skokomish Valley. Channels in the valley have little bedrock control. Valley channel morphology ranges from wide and braided in the South Fork, to a narrow single thread throughout most of the mainstem.

The dominant geomorphic process within the study area is sediment aggradation in the South Fork and mainstem Skokomish Rivers. The total duration of active riverbed aggradation is unknown, but it has been documented that mainstem aggradation has been underway since at least 1965. It is likely that aggradation was underway prior to 1912 as the frequent flooding experienced at that time suggests an undersized channel already existed. The headwaters of the Skokomish basin contain large volumes of glacially derived unconsolidated sediment. During storms, gravel and cobbles eroded from landslide deposits and active river channels in the upper watershed are slowly transported to the Skokomish Valley channels as bedload. In the valley, the South Fork and mainstem Skokomish Rivers do not have enough stream energy to transport the incoming bedload to Hood Canal; thus, bedload sediment has accumulated in the channels causing them to aggrade.

Various human activities have altered geomorphic processes. Around the turn of the twentieth century, loggers cleared logjams, removed riparian trees, and transported logs in the Skokomish Valley river channels. Stream stabilization measures such as bank protection and side-channel closures have been constructed on Vance Creek and the South Fork and mainstem Skokomish Rivers to protect farmlands from erosion. The flood peak reductions from the Cushman Project have reduced bedload transport in the mainstem. The above actions have all contributed to altering the bedload transport and deposition in the South Fork, Vance Creek, and the mainstem Skokomish River.

The Skokomish River channels had an abundance of natural LWD. By the early 1900s, loggers and farmers had removed most of the natural LWD. Today, LWD typically lies along the channel margins where it has been transported by floodwaters. In-channel LWD suitable for fish habitat is scarce.

4.3.2.1 No-Action Alternative/Future Without-Project Conditions

Sediment deposition is expected to continue to aggrade the channels of the mainstem and South Fork Skokomish Rivers and Vance Creek. Abundant sediment sources in the upper watersheds can be

expected to supply sediment to the lower rivers throughout the project life. The amount of LWD in the river channels is expected to increase.

How floods and aggradation will interact to alter channel alignment is very uncertain. However, there is a substantial risk of a channel avulsion in the foreseeable future. While an unexpected event such as a large logjam could alter the river very rapidly, the most likely scenario is for the river channel to aggrade to a level where base flows would divert onto the floodplain. Locations with the highest risk of avulsion are near the old North Fork confluence (RM 8-9) and near the Purdy Creek confluence (RM 3.5-4).

The most likely location for an avulsion to originate is near the old North Fork confluence (near RM 8-9). The cause of an avulsion at this location would be the filling of the channel to elevations high enough to divert the winter base flows, approximately 800 to 1,000 cfs, onto the floodplain. The surfaces of some of the gravel bars in this reach are already near the top of bank elevations and are higher than the nearby floodplains. The channel is expected to continue to fill slowly, as has been occurring for decades, until the riverbed elevation exceeds the bankline elevation and then low flows could be diverted onto the floodplain. Based on the recent deposition rates, this could occur in about 20 years. There is a risk that the low flow channel could fill rapidly if a logjam blocks the channel during a flood. The flow could be diverted to either the south or north side of the main channel, depending on the depositional pattern. Given the uncertainty of river processes, the timing of an avulsion could be anytime from the next big storm to 20 years in the future.

An avulsion to the south at RM 8-9 would likely follow a path south and east across farmland toward Purdy Creek and re-enter the river near RM 3.5. This path has no defined channels and the river would have to undergo a long-term process of channel and riparian development. The river channel would likely be very unstable as erosion and deposition could cause the channel to meander. This avulsion would cut across Skokomish Valley Road, disrupting transportation in the valley. These types of effects would be anticipated unless the river was redirected to its original channel under emergency actions.

If an avulsion occurred to the north near RM 9, flow would combine with the North Fork and return to the existing channel near RM 7.3. This reach was an active channel in the 1930s before it was blocked. Portions of the South Fork winter base flows have already been diverted into the North Fork at this location. The existing (North Fork) channel would become unstable with the increased discharge and bedload from the South Fork. The combined channel is likely to aggrade and widen. As the combined channel aggrades, it is likely to meander across the northern floodplain, forming and abandoning gravel bars as it migrates. Eventually, the river may meander across the entire 1,000- to 2,000-foot wide floodplain between the old and new confluences and north of the existing channel. Based on the recent deposition rates in the vicinity, deposition could average 1 to 2 feet over this area in a 20-year period. Gravel bars covered approximately 170 acres in this area in 1938.

The second highest risk of an avulsion is near the Purdy Creek confluence (RM 3.5-4). The bedload volume reaching this location is much smaller than that reaching the North Fork confluence, yet the riverbed is aggrading here and has a very low capacity. When this channel fills, base flows will most likely divert to the wetlands on the north side of the river and return to the river at State Route 106 (RM 1.9). Based on the recent deposition rates, the timing of this diversion is estimated to be in the next 30

to 50 years. However, it could also occur quickly if a logjam blocks the channel. A logjam could accelerate a diversion by increasing deposition at a point or causing bank erosion that could erode through the natural levee along the north bank.

In addition to the near-term risk of avulsion in the future without-project condition, long-term projections show sediment will continue to travel from the upper to lower watershed. Sediment already in the upper watershed channels may take 20 to 160 years to travel downstream to the Skokomish Valley. Channel aggradation and instability can be expected to continue for the foreseeable future.

4.3.2.2 Action Alternatives/Future With-Project Conditions

Aspects common to both groups of action alternatives

Reconnecting the abandoned channel between RM 4 and 5.6 to the river would provide a high flow side channel. This channel carries overbank floodwaters but is not directly connected to the river. The direct connection would produce higher suspended sediment loads than this channel currently receives from overbank flows. This could cause some additional deposition along the channel. Most of this channel is heavily vegetated and erosion is not expected to be an issue. The Monitoring and Adaptive Management Plan (Appendix E) was refined during the feasibility-level design phase to include a component to determine whether deposition is occurring.

Two wetland restoration increments (included in all alternatives except for #11), located at RM 7.5-8 and RM 8.3-9.2, are intended to provide additional floodplain habitat for fish and to expand the area of forested wetland adjacent to the river. The wetland embankments would allow flooding to occur similar to existing conditions, thus there would be no significant change in sediment deposition or erosion. The riverbanks in this reach have been stable in recent years and are expected to continue to be stable with the South Fork diverted toward the northern floodplain. Section 5.12 includes additional discussion about the risks and uncertainties associated with future sediment deposition in the study area.

Small wood clusters as well as larger engineered logjams (ELJs) would be installed from RM 9 to 11 to increase low flow channel meandering, encourage mid-channel bar formation, and provide multiple types of habitat benefits for salmon. The volume of added wood will improve the quantity, quality, and complexity of pools in the Skokomish River to promote rearing success and provide year round fish passage. Three of the wood structure types are included in the design: bar apex ELJ, 5-log channel cluster, and single log placements. These features are intended to restore much of the missing habitat and channel complexity afforded by the historical wood load. Over the 50-year project life, additional LWD is likely to accumulate on some of the constructed LWD jams and some jams are likely to be abandoned as the river naturally migrates; it is likely that the natural formation and accumulation of LWD jams would influence geomorphic processes more than the installed jams.

The construction of tributary channels to Hunter and Weaver Creeks, included in Alternatives #27, #45, and #60, would expand the valley's drainage network. The proposed restoration would consist of excavating small channels along existing swales down to slightly below the water table. Small, steady flow rates and vegetated banks should keep erosion to a minimum along these tributary channels. The drainage of floodwaters could cause some erosion and possibly headcutting in some channels.

Confluence Levee Removal Alternatives #11, #18, and #27

Removing the Confluence Levee would divert much of the South Fork water and bedload into the existing North Fork channel. The abandoned reach of the South Fork would remain active during high flows. These alternatives would have a very similar geomorphic effect as the northern avulsion near RM 9 described in the Future Without-Project Conditions section above.

The South Fork is already depositional in this reach and bedload deposition is expected to quickly begin to aggrade the combined South Fork/North Fork channel. A large bedload supply, coupled with the downstream slope reduction and loss of water to the floodplains during high discharges contribute to aggradation in the channel. High discharges and sediment supplies will continue to come from the South Fork, as the North Fork is highly regulated by the Cushman project. Based on the recent deposition rates, the initial deposition rate in the combined channel could be in the 0.1 +/- 0.05 feet/year range. As the channel aggrades, it would meander across the floodplain, forming and abandoning gravel bars. This natural meandering process will develop a complex series of stream habitats that will be beneficial to salmon and other fish; the migration will renew channel habitats and recruit new LWD to the channel. During the 50-year project life, there could be two to three feet of deposition across the entire 1,000- to 2,000-foot wide floodplain between the old and new confluences and north of the channel. The levee removal and flow diversion would greatly reduce the risk of the avulsion to the south near RM 9 that is described in the Future Without-Project Conditions section above because the existing South Fork riverbed is 3 to 5 feet higher than the northern floodplain.

Removing the Confluence Levee would greatly reduce the avulsion potential to the southern floodplain described in the Future Without-Project Conditions section above.

Riverbed Excavation Alternatives #45 and #60

Alternative #60, excavation of the mainstem and South Fork Skokomish Rivers from RM 0-9, would increase channel capacity and increase the bedload transport potential. The riverbed excavation would average around 8 to 11 feet deep. The river would be returned to a cross-section size similar to what it may have been in the early-1900s. The proposed excavation would produce a river channel with an approximate 50% ACE flood capacity. The higher in-channel discharges would increase the bedload transport and reduce deposition from RM 9 downstream to Highway 101 (RM 5). The bankfull bedload transport at Highway 101 could increase from approximately 2,500 tons/day to around 10,000 tons/day. Between Highway 101 and RM 3.5 there would be a proportional increase in deposition, as the minimum bedload transport capacity (less than 200 tons/day) occurs just upstream on RM 3.5. Downstream of RM 3.5, bedload transport potential would increase, but transport would be limited by the amount of material available to be scoured from the riverbed. The average bedload deposition rate is expected to remain at about 0.08 to 0.14 feet per year, the range observed in recent years. At that deposition rate, sediment accumulation in the excavated channel would aggrade the riverbed by about two feet in 20 years, lowering the channel capacity from 50% ACE (17,500 cfs) to 75% ACE (13,500 cfs). It is recommended that maintenance be done at 20-year intervals to retain the design channel capacity. If the channel is not excavated to maintain the channel capacity, it could return to its pre-excavation

capacity in roughly 65 to 75 years. The excavation would allow the placement of LWD to form pool habitat. LWD jams would be small, typically four to six logs, and placed to encourage meandering and bar formation. A few LWD structures would be placed along the riverbank to reduce the risk of accelerated bank erosion due to the channel excavation.

Alternative #45 would involve excavation of RM 3.5-9. This would have the same channel dimensions as the longer excavation alternative, but would start just upstream of where the southern floodwaters re-enter the mainstem. As with the longer alternative, it increases the bedload transport and reduces deposition from RM 9 downstream to Highway 101 (RM 5). Between Highway 101 and RM 3.5 there would be a proportional increase in deposition. Downstream of RM 3.5, bedload transport potential would not change. The channel aggradation rates would be similar to the longer alternative and the channel could return to pre-excavated conditions in 65 to 75 years. The excavation would allow placement of LWD for habitat and bank protection along the deeper channel.

Wetland restoration at Dips Road would not initially alter river geometry and thus would not affect sedimentation or geomorphology. If the final design includes removal of the bank protection, then the river would be able to erode the bank and migrate south toward the new road. The new road would limit any channel migration to about 400 feet.

Cumulative Effects

No significant adverse cumulative effects to geomorphology or sediment transport are anticipated to accrue from any of the alternatives. Hydraulic effects of Alternative #60 could benefit sediment transport processes in estuary channels adjacent to the Skokomish Indian Tribe's restored estuarine habitats.

4.3.3 Water Quality

Water quality within the Skokomish River, tributaries, and estuary is influenced by the dominant land uses of the Basin, which are largely agricultural fields and livestock pastures with rural homes on septic systems. Water quality impairments such as fecal coliform, dissolved oxygen (DO), and temperature can affect salmonids and marine life, recreation opportunities, commercial fishing, tribal fishing, and cultural resource use rights. Recreational and commercial shellfish beds are an important resource at Annas Bay and are sensitive to the water quality affected by the land uses in the valley. Characteristic uses of the study area such as recreation, domestic water supply, and shellfish harvesting are commonly inhibited due to fecal coliform levels. Sources of fecal coliform pollution include humans, domestic animals, wild animals, and septic system failures due to flooding and high water tables. Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas as well as bacteria and nutrients from livestock can contribute to non-point source water pollution in the study area. Reduced vegetative cover in combination with aggradation have led to concerns about reduced DO levels and increased temperature in lower reaches of the river following review of past sampling data from near the Highway 101 Bridge (Peters et al. 2011). Two stream segments in the upper watershed upstream from the study area are on EPA's Clean Water Act Section 303(d) list; these are a segment of LeBar Creek and one reach of the South Fork Skokomish River listed for temperature impairment. One reach at the mouth of the

river is listed for fecal coliform bacteria. The identified cause is recreational anglers at the fishing access point from Highway 106 (Seattle Times 2009).

Hood Canal has exhibited the symptoms of hypoxia (inadequate DO) and monitoring data confirms that low DO conditions persist for extended periods (Correa 2009). Low concentrations of DO are causing increased stress to the ecosystem including extensive fish kills. Valuable species such as shellfish and Dungeness crabs may be adversely affected by hypoxic conditions. Restoring conditions to benefit these species is critical to overall health of the Skokomish River, Hood Canal, and ultimately Puget Sound.

4.3.3.1 No-Action Alternative/Future Without-Project Conditions

In the future without-project condition, fecal coliform levels will continue to be a concern in the lower Basin and pose a risk to public health. Operation of the Cushman Project for power generation, forestry practices, road building, construction of levees, agricultural practices, and other land use practices will continue to contribute non-point-source pollution (Correa 2003). The three fish hatcheries in the study area will continue to contribute point-source pollution. Changes to forestry, agricultural, or fish hatchery practices to reduce point and non-point pollution would occur outside Corps authorities. Continued nutrient input from humans, domestic and wild animals, and agricultural activities (livestock culture, hay production, etc.) may enter Hood Canal from the Skokomish River and tributaries, contributing to an ecological imbalance and low DO levels. Annas Bay may continue to experience hypoxia, which causes death to fish and marine bottom-dwelling species in the summer when DO levels become critically low.

4.3.3.2 Action Alternatives/Future With-Project Conditions

Aspects common to both groups of action alternatives

Construction work for ecosystem restoration projects in the Skokomish Valley may have a temporary negative effect to turbidity through the duration of construction. Turbidity is the primary water quality concern for determining whether the alternatives would have a significant impact. Short-term exceedances, such as up to 12 hours, of the state water quality regulations at WAC 410-201A do not typically constitute a significant impact. For activities that would cause prolonged elevated turbidity levels (e.g., longer than 24 hours), exceptional effort would need to occur to minimize effects.

Potential benefits of ecosystem restoration are that restored wetlands may assist with reducing pollution from the non-point sources through the added filtration that increased wetland area and quality would provide. Restoration would increase pool habitat, which would provide cooler water temperatures important for most aquatic species in the Pacific Northwest.

Confluence Levee Removal Alternatives #11, #18, and #27

Confluence Levee removal would have minimal or no in-water work; however, several of the increments would involve significant in-water disturbance of substrates and thereby cause turbidity in the channel. These include installation of LWD at the upstream end of the study area, reconnection of the side channel at RMs 4 and 5.6, and installation of LWD at the breach in Confluence Levee. During feasibility level design, installation of LWD increased in scope to include piles for anchoring larger groupings of logs, which means pile driving would be a temporary construction impact for water quality. Implementing these projects would cause localized turbidity during construction. The Corps would

implement all best management practices and adhere to fish work windows established by WDFW to minimize effects. Alternative #27 would have the greatest amount of turbidity during construction among the Confluence Levee Removal alternatives due to the tributary restoration increments for this Alternative, and Alternatives #11 and 18 would have much less in-water work. The Corps initiated coordination with the relevant natural resource agencies on the preferred methods for minimizing impacts related to LWD installation, primarily the methods for diversion and care of water. Coordination would continue during further design phases.

Among the post-construction benefits to water quality, the Hunter Creek and Weaver Creek increments, included in Alternatives #27, #45, and #60, would provide additional pool habitat, and improved flow through these tributary habitats may help to deliver cooler water into the mainstem. The levee removal site as well as all increments except for LWD placement would have riparian planting, which would improve shading of the river to help cool water temperature in the summer.

Risk of HTRW contamination from excavation of the old cars parked on the levee is believed to be extremely low based on surveys conducted by the Corps and a statement by WDOE that appears in Appendix L. A Phase II HTRW investigation was completed in July 2014. There were no sampling results that warranted further evaluation or investigation within the footprint of the recommended plan, including the Confluence Levee site. The cars are assumed to be solid waste that will be disposed of by the Non-Federal sponsors at an appropriate disposal site. Please refer to Appendix I (HTRW Assessment) for additional information; this topic is further discussed in Section 5.12 Risk and Uncertainties.

Riverbed Excavation Alternatives #45 and #60

Riverbed excavation would cause significant amounts of turbidity throughout the duration of the work, which would take from three to five years or longer to complete, depending on dredge productivity and timing limitations of fish work windows. This work would cause gill irritation and stress for all fish in the river over the relatively long-term duration of work. Sediments in the river are generally coarse, so plumes of turbidity would likely dissipate within the length of mixing zone that is allowed under State law, 300 feet downstream from the source (WAC 173-201A-400). Alternative #60 would take over 600 days of in-water work for dredging, and Alternative #45 would have roughly 350 days of in-water work for dredging. For estimates of excavation quantities and construction duration, see Table 4-3. The resulting channel morphology after construction of either Alternative #45 or #60 would likely have a vastly improved number of pools throughout the study area. This would allow cooler water temperatures in the depths of the pools.

Cumulative Effects

The short-term cumulative effects to water quality during and immediately following the Confluence Levee Removal alternatives would not be measurable, and would end as construction ended. Long-term cumulative effects are anticipated to be an overall benefit to water quality in the Skokomish Valley.

The short-term cumulative effects to water quality during construction of the Riverbed Excavation alternatives would be a temporary significant increase to turbidity due to the dredging action added to other degraded water quality conditions of high summer temperatures and increased fecal coliform

levels that occur in summer. Summertime water temperatures are high enough to cause stress to aquatic species, and the added stress of the significant amount of turbidity may cause mortality of fish and benthic invertebrates.

4.3.4 Greenhouse Gas Emissions

Estimating the total quantity of greenhouse gasses (GHG) that each alternative would produce would require extensive analysis and numerous assumptions about each site's final design and construction. Qualitative comparisons, however, can be drawn from a simplified estimation of GHG production. Emissions of carbon dioxide from hauling activities represent a significant fraction of GHG that would be produced under the various alternatives. Furthermore, all of the action alternatives feature significant hauling requirements for their completion. Therefore, the Corps performed a simplified estimation of GHG emissions for hauling activities for all alternatives and compared the results.

Table 4-4 shows the estimated volumes of materials to be excavated for each alternative, total gallons of diesel consumed, including an estimate of truck trips for material placement as well as for excavation hauling, and an estimate of carbon dioxide that would be produced by all truck trips. The estimate assumes that trucks hold 12 cy of material and have an average fuel efficiency of 6.5 miles per gallon of diesel. The estimate further assumes that haul routes for most activities are 20 miles round trip, and for hauling associated with dredging (Alternatives #45 and #60) that the haul routes are 10 miles round trip.

Table 4-4. Estimated Volumes of Excavated Material and Carbon Dioxide Produced by Hauling Activities

	Estimated cubic yards excavated material	Total gallons of diesel consumed	Tons carbon dioxide
No-Action Alternative	0	0	0
Confluence Levee Removal Alternatives			
#11	18,600	4,907	55.0
#18	125,620	43,583	487.7
#27	213,420	69,172	774.0
Riverbed Excavation Alternatives			
#45	2,180,220	318,407	3,563.0*
#60	3,014,220	425,375	4,759.9*

*Actual amounts of CO_2 for these alternatives are likely to be significantly higher than these figures; these figures do not include emissions from the hundreds of hours of operating dredge equipment.

To put these quantities into perspective, a passenger vehicle that travels 10,000 miles per year and burns diesel at a rate of 20 miles per gallon emits approximately 5.6 tons of carbon dioxide per year.

4.3.4.1 No-Action Alternative/Future Without-Project Conditions

GHG emissions would not be expected to increase or decrease as a result of the No-Action Alternative.

4.3.4.2 Action Alternatives/Future With-Project Conditions

Confluence Levee Removal Alternatives #11, #18, and #27

The estimated amount of carbon dioxide produced under these alternatives varies from approximately 55 tons to 774 tons. Alternatives #11, 18, and 27 are not expected to cause any substantial adverse cumulative impacts associated with global climate change, and there are no formally adopted NEPA thresholds of significance for GHG emissions.

Riverbed Excavation Alternatives #45 and #60

The estimated amount of carbon dioxide produced under these alternatives varies from approximately 3,500 tons to 4,800 tons. These figures likely significantly underestimate GHG emissions as they do not account for emissions associated with dredging operations. Alternatives #45 and 60 are not expected to cause any substantial cumulative impacts associated with global climate change, and there are no formally adopted NEPA thresholds of significance for GHG emissions.

Cumulative Effects

The potential effects of GHG emissions are by nature global and cumulative because they mix throughout Earth's atmosphere from various global sources. While the GHG releases from the proposed project will contribute to the GHG accumulating in Earth's atmosphere, an effect to global climate change would only occur when GHG emissions from all sources and sinks combine with the GHG emissions from the proposed actions on a global scale. Therefore, it is reasonable to assume that none of the alternatives for this project is large enough to have an appreciable effect on the climate because it would represent a very small portion of the total GHG emissions produced globally.

4.3.5 Climate Change and Sea Level Change

Climate change may cause unprecedented alterations to the hydrology and hydraulics in the Skokomish Basin. The basin's seasonal hydrology and flood conditions may be altered. The three main parameters of interest in this study are sea level change, altered hydrology, and increased sediment yields.

4.3.5.1 No-Action Alternative/Future Without-Project Conditions

USACE Engineering Circular 1165-2-212, 1 October 2011 (SLC Circular), requires feasibility studies to examine three scenarios to consider the sensitivity and adaptability of projects to sea level change (SLC). These scenarios include a low, intermediate, and high forecast of SLC for the period of analysis, which is 2015 to 2065. The guidelines require an active tide station with at least a 40-year record to estimate sea-level change for a project. Therefore, data from the National Oceanic and Atmospheric Administration (NOAA) tide station in Seattle, established in 1900, was used for the analysis, as data at the Union (local) Station has only been collected since 1996 and is of insufficient duration for developing sea level trends. The long-term trend for the Seattle station indicates the range of increases for the mouth of the Skokomish River are low 0.37 foot, intermediate 0.79 foot and high 2.15 feet. The effects predicted for global sea level change may be partially offset by vertical land rise of 0.6 foot at the mouth of the Skokomish River. A two-foot increase in average sea level would move the intertidal estuary environment landward about 1,000 feet. Higher sea level would increase the cross-sectional area and decrease velocities of estuary channels, resulting in a decrease in bedload transport to Hood Canal.

Skokomish Basin hydrology may change due to global climate change. Recent climate change projections for the Olympic Peninsula predict rising temperatures will cause more fall and winter precipitation to fall

as rain rather than snow, decreasing winter snow packs. Those projections indicate that such a change in precipitation would increase winter stream flows and reduce summer base flows. Because the Skokomish Basin already receives most of its precipitation as rain, this shift in runoff is expected to be moderate. Climate change could make winter flooding even more frequent in the valley. Any reductions in summer base flows in the South Fork or Vance Creek could aggravate the summer/fall subsurface channel conditions in both streams. In the North Fork and mainstem Skokomish River, the climate change effects may be partially offset by the regulated discharges from the Cushman Project.

Climate change caused increases in winter storm discharges would result in increased bedload inflow and channel aggradation. Channel aggradation would be accelerated and potential for avulsions could develop earlier. The magnitude and timing of any increase in aggradation would depend on the unknown magnitude of the climate change related hydrologic changes.

4.3.5.2 Action Alternatives/Future With-Project Conditions

Confluence Levee Removal Alternatives #11, #18, and #27

Sea level change would not affect the Confluence Levee removal alternatives, as none of the proposed actions are within the estuary.

Climate change influences on flooding with the Confluence Levee removal alternatives would be similar to those in the without-project condition (No-Action Alternative). The summer/fall subsurface channel would not occur on the South Fork, as the combined North Fork/South Fork discharges should be enough to maintain a flowing stream in the new combined channel. Subsurface channel conditions on Vance Creek would be similar to the future without-project conditions. Increased storm discharges and bedload inflows would accelerate the sediment deposition in the combined South Fork/North Fork channel formed by the Confluence Levee removal. Increased suspended sediment inflows would also increase deposition in the reconnected channel at RM 4-5.6 and in the riparian areas of the two wetland restoration sites (RM7.5-8 and RM 8.3-9.2).

Riverbed Excavation Alternatives #45 and #60

Higher sea levels would increase the cross-sectional area and decrease velocities of the estuary channels, resulting in a decrease in bedload transport to Hood Canal. The RM 0-9 channel excavation would likely experience some reduction in bedload transport near the mouth due to sea level change. In the RM 3.5-9 excavated channel, sea level change would not directly affect bedload transport, but the natural channel downstream of RM 3.5 would experience a reduction in bedload transport similar to that expected for the without-project conditions (No-Action Alternative).

Increases in winter storm discharges are expected to result in increased bedload and suspended sediment inflow. Deposition in the reconnected channel at RM 4-5.6 and in the riparian areas of the two wetland restoration sites (RM 7.5-8 and RM 8.3-9.2) would depend on the magnitude of the increase in flood discharges. Higher discharges generally produce higher suspended sediment loads that would cause higher deposition; however, the higher suspended sediment load would be countered in the excavated channel by the reduced frequency of flooding.

Climate change effects on flooding with the channel excavation alternatives would be less than those in the without-project condition. The increased channel capacity provided by the excavated channel would reduce the frequency of flooding. The risk of lower summer/fall discharges causing a subsurface channel on the South Fork would be low, as the excavated channel bottom is expected to be below the groundwater table. Subsurface channel conditions on Vance Creek would be similar to the without-project conditions.

Increased storm discharges and bedload inflows would accelerate the sediment deposition in the excavated channels. The channel aggradation rates would be higher than current rates and the channels could likely return to pre-excavation conditions in less than 65 years. Increased suspended sediment inflows would also increase deposition in the reconnected channel at RM 4-5.6 and in the riparian areas of the two wetland restoration sites (RM 7.5-8 and RM 8.3-9.2).

4.4 Biological Environment

The Skokomish River Basin is a diverse landscape with abrupt changes in elevation, making the watershed home to a variety of different habitat types and wildlife resources. Located in the Olympic Mountain Range, the Skokomish Basin is somewhat geographically isolated and not as diverse as the river basins in the neighboring Cascade Mountain Range. Over the last 150 years, there have been significant alterations to the habitats of the Skokomish watershed. Subsequently, wildlife populations, distribution, and diversity have been similarly affected. Much of the Basin's species composition (wildlife and vegetation), structure (trees, snags, soil, and tree canopy), as well as some physical processes (evapotranspiration, surface and subsurface flow of water) have been altered at a very large scale. See Appendix A, Peters et al. 2011, for a comprehensive analysis of biological baseline conditions of aquatic habitats, and Appendix C, Anchor QEA 2011 for a brief description wildlife in the study area.

During feasibility-level design, the Increments of Hunter Creek mouth, Hunter Creek Side Channel, and Weaver Creek Side Channel were eliminated from the proposed action due to landowners' objections to these project components. The Final Recommended Plan does not include these Increments.

4.4.1 Fish and Wildlife

Fish resources in the study area

The Skokomish River system hosts at least 22 species of fish (Watershed Management Team 1995; Peters et al. 2011). Nearly half of these are in the Salmonidae family, which includes salmon, trout, and char. Species present include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), rainbow trout/steelhead (*O. mykiss*), sea-run and resident cutthroat trout (*O. clarki*), bull trout (*Salvelinus confluentus*), and mountain whitefish (*Prosopium williamsoni*) (Peters et al. 2011). Sockeye salmon (*O. nerka*) and pink salmon (*O. gorbuscha*) were historically found in the Skokomish River but have been functionally extirpated (Peters et al. 2011). Five species of sculpin (*Cottus* sp.) inhabit the river, including prickly (C. *asper*), coast range (C. *aleuticus*), riffle (C. *gulosus*), reticulate (C. *perplexus*), and shorthead sculpin (*C. confusus*). River lamprey (*Lampetra ayrsi*), western brook lamprey (*L. richardsoni*), and Pacific lamprey (*L. tridentata*) occur in the Basin (Peters et al. 2011). Three-spined sticklebacks (*Gasterosteus aculeatus*) are abundant. Species associated with the estuarine

and nearshore habitat include shiner perch (*Cymatogaster aggregata*), surf smelt (*Hypomesus pretiosus*), Pacific staghorn sculpin (*Leptocottus armatus*), and starry flounder (*Platichthys stellatus*).

Two WDFW hatcheries, George Adams and McKernan, release hatchery Chinook, coho, chum, and steelhead into the Skokomish River Basin. The two facilities release approximately 3.8 million Chinook, 300,000 coho, 8.5 million chum, and 34,000 steelhead annually (Peters et al. 2011). A third hatchery, Eels Springs, raises cutthroat trout, rainbow trout, and kokanee salmon (i.e., land-locked sockeye salmon; [*O. nerka*]) for put-and-take fisheries in local lakes (Peters et al. 2011).

Salmonid species can have separate stocks, also called runs, within a single river system. Table 4-5 is a summary of the stocks known to occur in the Skokomish watershed, including those that are functionally extinct but that may still have a few representatives each year.

Table 4-5. Salmonid Stocks that Occur in the Skokomish Watershed with Their Spawning Timing and Locations Summarized from Peters et al. (2011)

Species and stock designation	Spawning timing	Spawning location
Chinook – Fall/summer	Sept-Oct	Mainstem, S. and N. Forks, Purdy, Weaver, Vance Creeks
Chinook – Spring (extinct)	July	Mainstem, S. and N. Forks, Purdy, Weaver, Vance Creeks
Chum – upper Skok late fall	Dec-Jan	Most tributaries and lower 5 miles of N. Fork
Chum – lower Skok fall	Nov-Dec	Purdy and Weaver Creeks, and lower mainstem
Chum – summer (extinct)	Mid-Sept to mid-Oct	Lower watershed
Coho	Oct through March	Most tributaries, N. Fork, Vance Creek
Steelhead – summer	Feb to April	S. Fork canyon reach
Steelhead – winter	Mid-Feb to Mid June	Mainstem and S. Fork
Bull trout – South Fork stock	Mid-Sept through Dec	Use S. Fork and all tributaries, but specific spawning locations are unknown
Cutthroat (sea-run)	Late winter through spring, peak in Feb	Small tributaries

Riffle and side channel habitats are important for lamprey spawning. Lamprey larvae are most abundant where the stream channel is relatively deep (0.4–0.5 m), gradient is low (<0.5%) and the riparian canopy is open (Torgerson and Close 2004). Ammocoetes (juvenile lamprey) rear in reaches where spawning occurred (Pletcher 1963). At finer scales, larval occurrence corresponds positively with low water velocity, pools, and suitable burrowing habitat (Roni 2002; Pirtle et al. 2003; Torgerson and Close 2004; Graham and Brun 2005). Prickly sculpin and coastrange sculpin typically inhabit the lower reaches with prickly sculpin inhabiting pools and other slow-water habitats while coastrange sculpin inhabit riffles and other fast-water habitats. Riffle sculpin and reticulate sculpin usually occur in middle reaches in a variety of habitat types. Shorthead sculpin typically occur at higher elevations than the other four species.

Degraded conditions continue to affect fish populations in the study area. Habitat requirements for the Salmonidae family make a good surrogate for overall ecosystem health when considering the full range of anadromous fish habitat requirements, including off-channel habitats, food web interactions, and

spatial relationships among habitats. Each salmonid species differs in the timing of critical life history events and the way it uses various habitats, but all of the anadromous fish in the system have the same basic requirements:

- Adequate water quality and appropriate water temperatures
- Balanced sediment budget
- Stable spawning gravels
- Pools and in-stream structure including large boulders and logs
- A functional riparian zone
- Connected freshwater migratory and refuge habitats
- A complex of healthy estuarine and nearshore habitats to allow transition from freshwater to seawater

These habitat requirements are the focus of the discussion of future without-project conditions (No-Action Alternative) and effects of the alternatives on fish species in the study area.

All of these critical factors were found to be compromised or lacking to some extent in the study area. Much of the degradation originates from alteration of the river environment by the removal of LWD, channel realignments, bank protection, aggradation in the channel, changes in flows, and disconnection of access for fish into aquatic habitats in the floodplain and off-channel wetlands.

As discussed in Section 4.3.1, the lack of channel capacity for even the one-year return interval discharge causes displacement of fish during overbank flows. Effects of this are that the adults may become stranded in floodplain areas where they die before spawning, or they are forced to spawn in areas that become dewatered killing the eggs; additionally, the offspring that do survive in isolated ponds are unable to return to the river to rear and migrate out to sea. Those that remain in the channel have little refuge habitat and are therefore forced downstream to the lower river and estuary where they become vulnerable to predators or are unable to survive in saltwater as they have not yet smolted (changed physiology for saltwater life stage).

Along with reduced channel capacity, significant aggradation causes the river to flow subsurface during the summer months. Subterranean flow occurs in the South Fork and lower Vance Creek and significantly affects fish. In recent years during the late summer and early fall, no surface hydraulic connection has existed between the mainstem and the South Fork and Vance Creek (USACE 2000). Lack of access to upstream habitat means a drastically reduced area for spawning and blocked migration for fish moving to upstream or downstream reaches. Another characteristic of the Skokomish River is that the removal of large wood decades ago and the filling of pools due to wood removal and sedimentation have significantly reduced the variety of habitat types. This reduction in habitat complexity leads to reduced resilience of the river's salmon populations (Waples et al. 2009). The Ecosystem Benefits Model developed to quantify benefits of the alternatives includes a detailed description of habitat limiting factors for salmonids in the Skokomish watershed (see Appendix F).

<u>Bird and mammal resources in the study area</u>

Beaver (*Castor Canadensis*), raccoon (*Procyon lotor*), river otter (*Lontra canadensis*), mink (*Neovison vison*), and many other small mammals are associated with and dependent upon riparian and aquatic

habitats. Beavers live along rivers, streams, and ponds and build lodges of tree branches and mud to live in, or they may build burrows in the banks of rivers. They primarily eat tree bark and cambium, which is the soft tissue under tree bark. Favorite species include willow, maple, birch, cottonwood, and alder; all of these are common riparian species in the study area. Beavers are territorial and live in small family colonies. Raccoons live in riparian zones and have a widely varying diet as omnivores. They rinse their food as they eat and are therefore reliant on shoreline habitat of rivers and lakes. River otters live exclusively in riparian habitat and usually occupy bank dens that beavers have abandoned. Their diet is primarily aquatic animals such as crayfish, frogs, and fish. River otters live in family groups of 4 to 8 individuals. Mink live in forested areas near rivers, lakes, and marshes; they dig dens in riverbanks or use hollow logs or abandoned beaver dens as dwellings. Mink are carnivores and target a variety of other riparian species by spending a lot of time swimming and diving.

Bird species associated with the river corridor include the following:

- Bald eagle (*Haliaeetus leucocephalus*)
- Osprey (*Pandion haliaetus*)
- Great blue heron (*Ardea herodias*)
- Raven (*Corvus corax*)
- Belted kingfisher (*Megaceryle alcyon*)
- American dipper (*Cinclus mexicanus*)

Other species groups found in the river corridor and adjacent forested riparian zone include waterfowl, woodpeckers, and songbirds.

Riparian zones represent a small component of the complete watershed landscape in western states; however, they provide essential habitat for more species of breeding birds than any other habitat type (Knopf et al. 1988). The primary factor affecting bird populations in the study area is the past timber harvest activities, which was the dominant land use around the South Fork Skokomish River from the 1920s through the 1990s. Additionally, the width of the forested riparian zone has decreased in many areas as land was cleared for timber harvest, farming, and residences.

4.4.1.1 No-Action Alternative/Future Without-Project Conditions

The Skokomish River will continue to face numerous limiting factors for fish. Major problems affecting salmon survival and migration will continue. Habitat availability, quality, complexity, and connectivity will continue to deteriorate. Winter high flows will continue to transport both juvenile and adult salmon out of the river, stranding them in the floodplain to die. As sediment continues to accumulate in the mainstem, upstream passage will continue to be delayed or completely blocked during summer low flows. The overall condition of the channel is anticipated to remain severely degraded; reduced holding pool quality and availability will continue to render adults vulnerable to predation/harassment, and reduced channel complexity will lead to more frequent and severe scouring of redds. Ultimately, the future without-project condition for fish in the mainstem and South Fork reaches of the study area is expected to remain in a severely degraded state and would not be able to support recovery of ESA-listed species.

Salmon return to spawn in the streams and tributaries where their parents spawned and where they spent the first months of their lives. Therefore, the stocks that use the North Fork habitat (the area of the basin affected by the Cushman Settlement) are largely distinct from the populations that use the mainstem and South Fork reaches of the Skokomish River. For this reason, the Cushman Settlement will benefit mainly the North Fork stocks of fish. While the Cushman Settlement will benefit the estuary and lower eight miles of River, conditions will not significantly improve the habitat of the entire recommended plan area. The recommended plan includes off-channel habitats and tributaries that are not affected by the Cushman Settlement. Additionally, the ESA-listed runs of fish that use habitat upstream from the confluence will still encounter severely degraded habitat conditions. The summer low-flow blockage problem is upstream from the confluence and therefore requires attention that the Cushman Settlement measures do not address. The Cushman Settlement measures are complementary to, but independent from the action alternatives described in this chapter.

Birds and mammals associated with the riparian zone will continue to endure the reduced total area of the width of the riparian buffer without attempts to remove levees to widen the area available for hydrologic connection to the river.

4.4.1.2 Action Alternatives/Future With-Project Conditions

Confluence Levee Removal Alternatives #11, #18, and #27

Construction for removal of the Confluence Levee would have no in-water work and minimal disturbance for fish as machinery works on the riverbank above the water; however, temporary culverts or stream crossings for machinery to access the levee will be necessary. Construction work for the increments associated with all three alternatives would involve some in-water work and would there for have short-term disturbance to fish species such as sculpin, lamprey, and steelhead that are still present during the fish work window that is timed for when juvenile salmon are absent, 15 July to 15 September. Turbidity is the primary concern for stress to fish species. Background turbidity during the summer is typically very low. Construction methods would employ best management practices to minimize turbidity. For duration of construction for each increment, see Table 4-3.

Confluence Levee removal would resolve the problem of the river going subsurface in the summer months by providing a bypass to this reach as the South Fork combines with the North Fork. The benefit of this year-round connection for fish is that adult salmon migrating upstream would have access to their spawning areas and would not have to endure delays to migration and the complete blockage of access to critical spawning habitat. The proposal has potential for increasing spawning productivity by reducing stress and increasing accessibility.

Birds and mammals associated with the riparian zone would greatly benefit from the increased area of wetlands and the width of the riparian zone afforded by breaching the agricultural berms and constructing wetland embankments under Alternatives #18 and 27. Since many of these species rely directly or indirectly on salmonid populations, the improved salmonid habitat would thereby influence improvement to bird and mammal habitat and diets. Construction of the action alternatives may temporarily disrupt activities or displace wildlife, but would not occur during nesting season, which is early March to mid-July for the many bird species that nest within the study area. Birds and mammals

would endure short-term disruption during construction but would see long-term benefits of ecosystem restoration. The agency preferred alternative, #18, includes the net gain of 51 acres of forested riparian zone from the wetland restoration increments, so benefits to birds and mammals would be substantial, but not as great as those for Alternative #27.

Riverbed Excavation Alternatives #45 and #60

Alternatives #45 and #60 would have substantial short-term detrimental effects to all fish species in the Skokomish River due to the wide-scale sediment excavation. These alternatives are designed to remove the top 8 to 10 feet of riverbed sediments for 9 miles in #60 and for 5.5 miles in #45. This work would remove the benthic macroinvertebrates that serve as the primary food source for most fish, and would potentially kill most of the sculpin and lamprey species present in the length of channel that would be dredged. Construction would adhere to fish work windows, but these are timed to protect salmon that are in the channel only during juvenile and adult life stages. Sculpin and lamprey inhabit the river throughout their lives, and are less capable of avoiding dredge machinery. Steelhead rear in the river for the first 1 to 3 years of their lives and would therefore be present during dredging. Loss of these fish populations could take many years to recover.

Such broad-scale alteration of the river bottom would cause substantial risk to salmon habitat. Salmon spawn throughout the lower 12 miles of the river and in-stream sediment removal directly alters the channel geometry and risks leaving morphology unfavorable to salmonids. Some risks include the following: salmon have a narrow range of parameters for spawning depth, velocity, and substrate size (Bjornn and Reiser 1991), and therefore may not find appropriate spawning habitat for one or more years as sediments stabilize and channel morphology adjusts (Kondolf et al. 2002); disturbed substrate has a lower velocity threshold for scour of eggs incubating in the gravel (NOAA Fisheries 2004); and such significant quantity of gravel removal can reduce the amount of water that flows through the hyporheic zone, which can lead to elevated water temperatures without the cooling effect of intragravel flow. Many other biological consequences are associated with sediment extraction from streams (Collins 1995, Kondolf et al. 2002).

Risks to juvenile salmonids in the nearshore zone from placement of dredged material would involve risk of loss of some area of eelgrass although impacts to eelgrass would be avoided to the maximum extent practicable. Other risks include turbidity, although construction would be timed for the season when juvenile salmon are least likely to be present. The change in substrate size from fine sand and mud to coarse river sediments could cause a shift in species use of the area, or avoidance of this substrate type; however, the area proposed for dredged material placement does not cover the entire estuary, so sand and mud habitat would still be available in the center and north reaches of the estuary.

Benefits of river sediment excavation for both Riverbed Excavation alternatives are that providing the capacity for the 50% ACE would greatly reduce the problem of fish stranding on high ground after being flooded out of the river and then trapped with no channel access back into the river. Additionally, the increased flow capacity would allow for placement of LWD habitat structures throughout the excavated reach of river without exacerbating flooding in the valley. Dredging would also resolve the problem of flow going subsurface in the late summer.

Birds and mammals associated with the riparian zone would greatly benefit from the increased area of wetlands and the width of the riparian zone afforded by the wetland restoration increments under Alternatives #45 and #60. Since many of these species rely directly or indirectly on salmonid populations, the improved salmonid habitat would thereby influence improvement to bird and mammal habitat and diets. Construction of the action alternatives may temporarily disrupt activities or displace wildlife, but would not occur during nesting season, which is early March to mid-July for the many bird species that nest within the study area. Birds and mammals would endure short-term disruption during construction but would see long-term benefits of ecosystem restoration.

Cumulative Effects

Cumulative effects of Alternatives #11, #18, and #27 are assumed to be countervailing to the history of development in the Skokomish Valley and are expected to be additive to the benefits of all other restoration effort that has occurred in the estuary and upper watershed.

Short-term effects of Riverbed Excavation pose a significant risk to all fish species, and especially to salmon that may not find suitable spawning habitat for an unpredictable number of years. This potential negative effect would be added to the list of events in Table 4-2 that have caused environmental degradation around the Skokomish watershed. Long-term cumulative benefits of Riverbed Excavation are assumed that increased channel capacity would significantly reduce stranding of juvenile and adult salmon such that they may be able to rebuild their populations to some degree above the low numbers that have endured for at least a decade. Similar to the Confluence Levee Removal alternatives, the benefits of the Riverbed Excavation alternatives would be additive to all other restoration work around the watershed.

4.4.2 Shellfish and other Macroinvertebrates

Shellfish

The Annas Bay estuary area contains a rich shellfish resource that is used by tribal, commercial, and recreational harvesters. Shellfish species common in Annas Bay include Dungeness (*Cancer magister*) and red rock (*Cancer productus*) crabs; butter (*Saxidomus giganteus*), manila (*Venerupis philippinarum*), littleneck (*Protothaca staminea*), and purple varnish (*Nuttallia obscurata*) clams; and Pacific oysters (*Crassostrea gigas*) (Dethier 2006; WDFW 2013a). The WDFW Priority Habitats and Species database has a record of geoduck in narrow bands along the shorelines around Annas Bay (WDFW 2013b). These native and non-native species are associated with the intertidal and subtidal zones; crabs and oysters dwell on the substrate surface while the clams bury themselves at various shallow depths. The substrate preferences range from mud and sand to gravel and rocks (Dethier 2006).

Shellfish resources have been declining due to reduced availability of suitable substrate for shellfish attachment in the estuary as well as high fecal coliform levels in Annas Bay and Hood Canal. The Washington State Department of Health downgraded 300 acres on the east side of Annas Bay growing area from *Approved* to *Prohibited* in August 2005 based on high fecal coliform bacteria levels. Mason County was therefore required by RCW 90.72.045 to establish a shellfish protection district and program

to address the cause of the pollution. The Corps' feasibility study area includes a significant portion of the shellfish protection district (Figure 4-1).

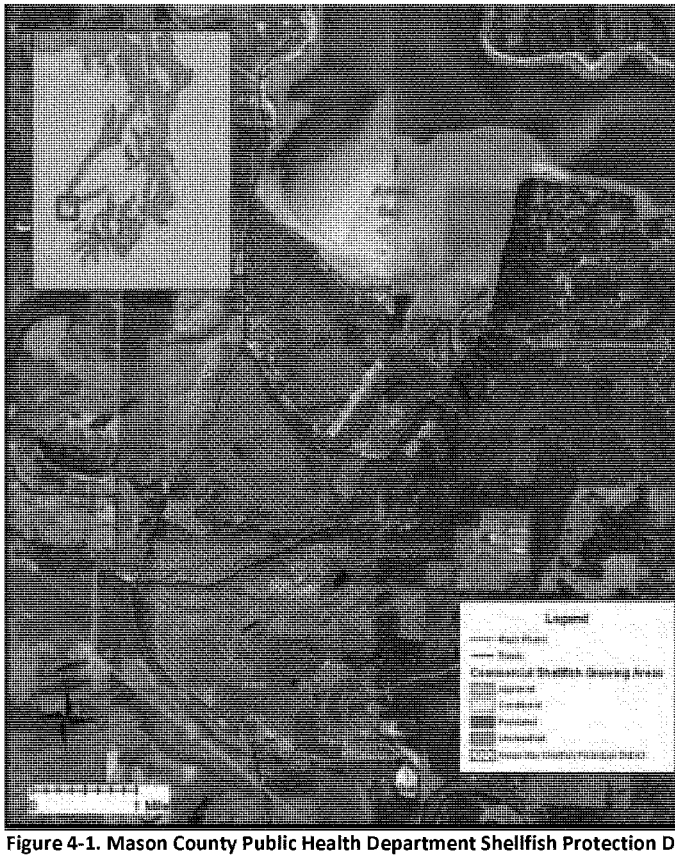


Figure 4-1. Mason County Public Health Department Shellfish Protection District and designations of shellfish harvest areas in the Skokomish River estuary and extended nearshore area

Benthic Macroinvertebrates

The freshwater benthic macroinvertebrates of concern in this feasibility study are the aquatic insects that dwell in the substrate of the river and tributaries. The five orders of insects that typically inhabit Pacific Northwest freshwater habitats are the black flies including mosquitoes (Diptera), caddisflies (Trichoptera), mayflies (Ephemeroptera), stoneflies (Plecoptera), and true bugs (Hemiptera). Dragonflies and damselflies (Odonata) are associated with wetlands and pools at the edges of streams as well. These aquatic insects provide critical ecosystem services such as the following (Allan 1995):

- Breaking down detritus inputs from riparian vegetation (shredders)

- Removing excess algae from rocks and other surfaces (scrapers)
- Water filtration by collecting suspended particles (collector-filterers)
- Mixing bottom sediments (burrowers)
- Population control of other invertebrates (predators)
- Serving as key food sources for fish, birds, and other aquatic-oriented animals (prey)

USFWS conducted biological monitoring for this feasibility study, which revealed that the aquatic insect population is generally healthy, but that long-lived species populations are very low (see Appendix A, Peters et al. 2011).

4.4.2.1 No-Action Alternative/Future Without-Project Conditions

Shellfish – The crabs, clams, and oysters in Annas Bay may continue the recent population declines that have been occurring due to reduced suitable substrate. Local work to reduce fecal coliform will slowly improve conditions. Given multiple confounding factors, it is difficult to predict with any confidence what the shellfish populations could be through the 50-year study period.

Benthic Macroinvertebrates – The aquatic insect community in the river is not expected to change as no activities are planned for the reach of river in the study area that would cause shifts in population or community structure. Aggradation and/or frequent flooding may be the cause of the dearth of long-lived species, and these two characteristics are not expected to change in the 50-year study period. Recent restoration in the estuary is anticipated to improve the community structure of the benthic macroinvertebrates found there.

4.4.2.2 Action Alternatives/Future With-Project Conditions

Confluence Levee Removal Alternatives #11, #18, and #27

Shellfish – None of these alternatives would be expected to have a significant effect on the shellfish populations, although improved water quality expected from Alternatives #18 and 27 may be of benefit to shellfish. Without the 51 acres represented by the wetland restoration sites, Alternative #11 does not include enough wetland restoration to provide water quality benefits that would reach the estuary.

Benthic Macroinvertebrates – All three Confluence Levee Removal alternatives would have measurable, localized improvements in numbers and diversity of the aquatic insect communities. This may have a positive effect upstream and downstream from the restoration sites; however, ability to quantify improvements decreases with distance from the restored area. Alternative #27 would see the greatest improvement as this alternative has the most increments. Alternative #11, would provide the least improvement of all the alternatives. The agency preferred alternative, #18, would see substantially greater productivity than #11 due to the 51 acres of wetland restoration.

Riverbed Excavation Alternatives #45 and #60

Shellfish – For Alternatives #45 and #60, sediment excavated from the river would be strategically placed at specific locations in the lower intertidal and subtidal areas of the estuary and adjacent nearshore zone. Material would be placed to create swales that are two to eight feet high over an area that is approximately 800 acres. Alternative #60 disposal quantity would be nearly 2.7 million cubic

yards, and Alternative #45 would be less at just under 1.9 million cubic yards. The grain size distribution of this dredged and disposed material would be beneficial for the shellfish species that attach to the substrate, such as oysters and mussels. Other benthic invertebrates in the estuary would be expected to recover within about one year (Bolam and Rees 2003).

Benthic Macroinvertebrates – Alternatives #45 and #60 would have substantial negative effects to the aquatic insect populations in the river. Dredging effectively removes and kills nearly all aquatic insects within the dredged channel, and insects that remain in the channel are subjected to the settling of fine sediments that become suspended during the dredging work (Kondolf et al. 2002). Recolonization across the many miles of river would take varying amounts of time depending on species mobility and trophic habits (Mackay 1992). A direct effect of such widespread removal of the benthic macroinvertebrates that dwell among the substrate is that any fish remaining in the river that were not killed during dredging would have little to no food source available. Additionally, the young salmon that emerge from redds the following spring will have extremely poor feeding conditions as their primary food sources would not likely have had enough time to recover to previous abundance.

Cumulative Effects

Cumulative effects that would accrue for shellfish and benthic macroinvertebrates with implementation of any of the action alternatives are the improved water quality from restoration of wetlands, which would add to the efforts of Mason County Public Health Department to improve water quality for the Shellfish Protection District. The Riverbed Excavation Alternatives would have additional direct benefits to shellfish through the disposal of dredged gravel in the estuary. However, the negative effects from riverbed excavation for benthic macroinvertebrates would have significant cumulative effects for salmonid species that already face greatly reduced and degraded habitats in the channel and floodplain.

4.4.3 Vegetation (Wetland, Riparian, Estuarine)

The Skokomish watershed's topography is widely varied, consisting of steep mountain slopes, moderately sloping foothills, and flat valley bottoms, which causes a corresponding variation in vegetation throughout the Basin. Logging and forest management for timber production have caused large-scale alteration of flora and fauna. Effects include reduction of habitat diversity, fragmentation of the landscape, and soil disruption that led to mass wasting. Mass wasting can completely alter the vegetation potential of the land; plant communities that colonize these sites are usually much different from the preceding mature communities. Logging and road construction effects are felt throughout the Basin; however, the proposed action focuses on aquatic habitats. This section therefore focuses on the riparian, wetland, and estuarine habitats for analysis of the future with and without-project conditions.

Agricultural conversion of the Valley began in the late 1800s with removal of large Douglas fir and cedar trees that were cut and floated down the Skokomish River to Hood Canal. By the early 1900s, most of the Skokomish River floodplain had been cleared of timber and converted to pastureland, reducing the amount of riparian forest along the river. By 1995, about 2,700 acres in the study area had been converted to agriculture and urban uses (USFS 1995).

Wetland Vegetation

The Lower Skokomish Basin is one of the few areas in the Hood Canal area to increase in wetland coverage over the last 20 years. Since the study area is an extremely large geographic area, the inventory of wetland habitats was conducted by using existing aerial topography surveys, color infrared imagery, and field-verification methods. A thorough assessment of the entire study area using the Corps' standard three-parameter approach was not practical, as it would be extremely labor-intensive and cost-prohibitive to conduct formal wetland delineations on the entire area. The analysis resulted in mapping 231 individual wetland habitat polygons covering 4,553 acres within the study area and an additional 995 acres of subtidal wetland in the Skokomish river delta. In addition to areas of development including the Skokomish Tribal Reservation, there are 1,640 acres of agricultural lands in the study area. Of these 1,640 acres, about 216 acres (13 percent) are wetlands.

Riparian Vegetation

Riparian zones have a diverse selection of vegetation including an overstory of red cedar, cottonwood, alder, and Douglas fir as well as an understory of salmonberry, snowberry, Indian plum, swordfern, blackberry, willow, and various grasses. In addition to preventing pollution and stabilizing bank erosion, the diverse vegetation of the riparian zone sustains a wide variety of fauna. The fish and wildlife that live in the stream and along riverbanks are very dependent on the zone for their food and habitat requirements. Suitable habitat characteristics including LWD, riparian vegetation, and aquatic vegetation are necessary for providing refugia from predation and optimal growth for juvenile salmon. Riparian vegetation provides shade to keep water temperatures lower during summer months.

Although there are pockets of good riparian vegetation in the mainstem Skokomish, approximately 62% of the mainstem is sparsely vegetated, has been cleared for agriculture, has a riparian buffer less than 66 feet wide, and does not provide LWD recruitment necessary to maintain structurally diverse channels (WDFW and PNPTT 2000). Deciduous trees dominate the riparian areas where historically the riparian corridor was mixed forest (Correa 2003). Riparian vegetation appears to be degraded within the Skokomish Basin, with the greatest degradation occurring in the lower Skokomish reach and in mainstem channels relative to upstream tributaries. The Skokomish River's riparian zones consist of younger tree age classes with higher percentages of hardwoods and reduced LWD potential (U.S. Dept. of Agriculture 1995). The Skokomish mainstem, Weaver Creek, Hunter Creek, and the lower South Fork Skokomish have poor riparian conditions (Correa 2003).

The U.S. Forest Service, Mason Conservation District, and Mason County Weed Board have efforts underway to control and eradicate invasive species in the Skokomish watershed. Some of these species include reed canary grass, Japanese knotweed, and tansy ragwort among others. Some of these efforts include assistance to private property owners.

Estuarine Vegetation

The Skokomish River has the largest estuary and intertidal delta in the Hood Canal Basin. The delta includes a broad estuarine wetland complex and supports extensive submerged aquatic vegetation including eelgrass beds. Analysis of historical maps indicates that emergent vegetation dominated up to 75 percent of the estuarine wetlands in the Skokomish delta (Collins and Sheikh 2005). Estuarine scrub-shrub wetlands comprised about 13 percent of the complex, compared to current wetland maps

showing no scrub-shrub wetlands in the complex (Collins and Sheikh 2005). Recent projects have breached dikes around islands in the lower estuary to restore tidal inundation of historic salt marsh areas. These breached areas make up the majority of the estuarine wetlands across the delta.

Eelgrass (*Zostera marina*) is the most common native vegetation in intertidal and subtidal beach habitats and embayments of Puget Sound. Large eelgrass beds can grow on the fringes of large river deltas where the salinity is high enough and sediment supply is sufficient. Biological diversity of eelgrass beds is much higher than that of surrounding areas because the three dimensional structure provides substantial habitat value. Eelgrass meadows support many small vertebrate and invertebrate organisms that provide prey for larger species, including juvenile salmon and sea-going trout that use the area heavily for feeding and protective cover during their outmigration. Eelgrass beds provide habitat for other fish, adult and larval crabs, great blue herons, crustaceans, and many other kinds of marine life. Eelgrass serves an important spawning substrate for Pacific herring (Penttila 2007). Additionally, eelgrass supplies organic material to nearshore areas, and its roots stabilize sediments.

The Skokomish estuary has about 17% less eelgrass compared to historical conditions (Jay and Simenstad 1996). Recent sampling shows Annas Bay has approximately 10 acres of eelgrass coverage (WDNR 2009). Based on data collected from 2000 to 2008, the Washington Department of Natural Resources (WDNR) places Hood Canal in a category of high concern for eelgrass decline; however, the sampling location in Annas Bay showed no evidence of decline as of 2008 (WDNR 2009), and has actually been increasing in coverage area according to the 2010 surveys. One of WDNR's survey results of the extent of eelgrass coverage is shown in Figure 4-2.

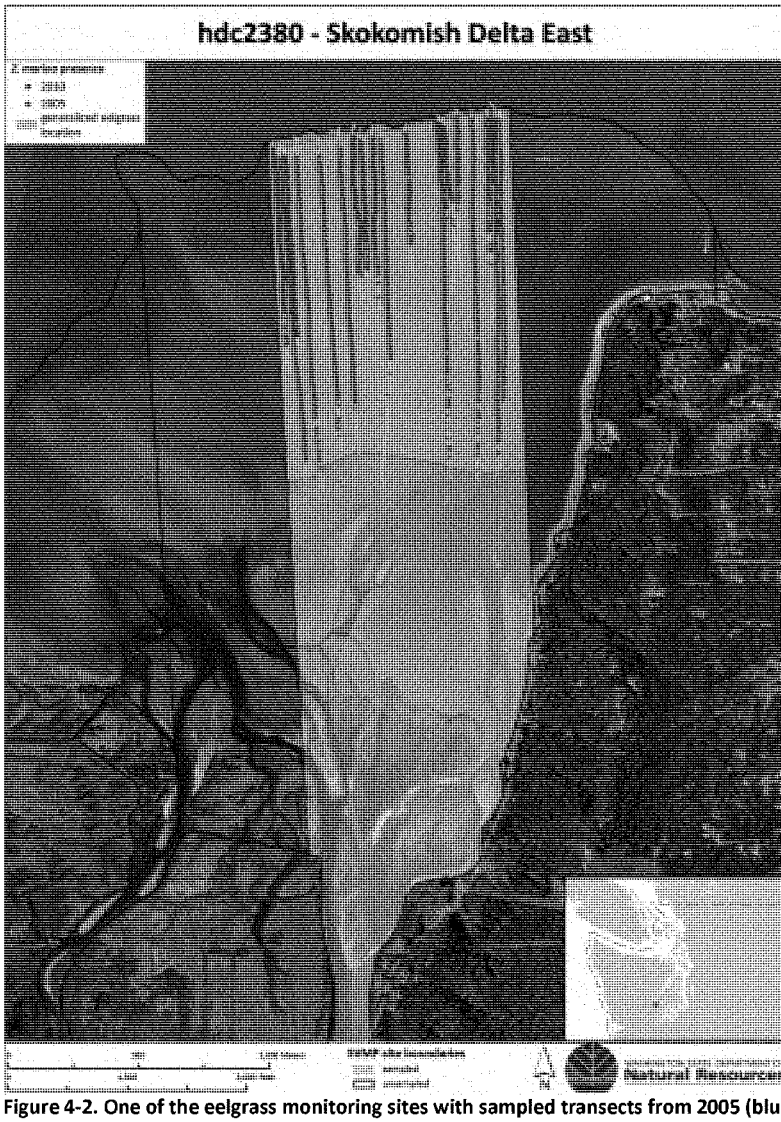


Figure 4-2. One of the eelgrass monitoring sites with sampled transects from 2005 (blue) and 2010 (red). Image courtesy of Washington Department of Natural Resources.

4.4.3.1 No-Action Alternative/Future Without-Project Conditions

Wetlands in the study area may continue their trend of increasing in area even without directed restoration efforts to restore or increase their area and quality.

In the higher elevations, riparian zones are recovering as improved forestry practices focus on increasing riparian buffers and providing vegetated corridors. However, without restoration actions in valley, the upper watershed improvements will not be realized in the lower river. Local entities are expected to undertake various vegetation enhancement projects to address the loss of riparian vegetation. Mason Conservation District is employing invasive species removal and riparian restoration efforts in the Skokomish Valley including working with Washington Conservation Corps crews to inventory and treat Japanese knotweed. Efforts to restore native riparian vegetation are focused on a 70-acre Conservation Reserve Enhancement Program buffer and a 43-acre floodway easement. In addition, approximately 25 to 30 acres have been planted on Skokomish Farms, WDNR, and Skokomish Reservation lands. However, due to the large percentage of privately owned lands, the extent to which these actions can comprehensively restore vegetation depends on the willingness of private landowners to participate in the restoration projects. With no large-scale changes planned to improve riparian vegetation on the tributaries and the mainstem, riparian vegetation is anticipated to remain in poor condition.

Estuarine emergent marshes will slowly continue to improve due to the restoration efforts of the Skokomish Indian Tribe and Mason County at dike breaching in the estuary. Without the proposed restoration efforts, eelgrass around Hood Canal is expected to continue its decline, although the eelgrass meadow in the Skokomish estuary may remain the same size or continue its trend of expansion (WDNR 2009).

4.4.3.2 Action Alternatives/Future With-Project Conditions

Confluence Levee Removal Alternatives #11, #18, and #27

Construction impacts to vegetation from Alternative #27 would be temporary clearing of approximately 1.15 acres of upland vegetation bordering on riparian zones for staging areas for the base and all increments in this alternative. The area of wetland vegetation displaced due to construction of the two wetland embankments is approximately 2.7 acres for wetland restoration at Grange and approximately 2.3 acres for wetland restoration at River Mile 9. Alternative #18 would have 0.92 acre of uplands cleared for staging areas and the same impacts to wetlands as Alternative #27. Alternative #11 would have 0.28 acre of wetland vegetation temporarily disturbed and no wetlands filled for wetland embankments. The Corps selected staging areas based partly on avoidance of large trees and would replant all staging areas at the end of construction. Vegetation would be expected to reach preconstruction conditions within approximately three years. Therefore, all staging areas would be temporary impacts, and the construction of the two wetland embankments for Alternatives #18 and #27 would have 5 acres of wetland function loss in their footprint with a 51-acre net gain in forested riparian wetlands. This impact represents a change since the release of the Draft FR/EIS. These wetland impacts were determined during feasibility-level design in which the footprint of the wetland embankments expanded to accommodate for a shallow backslope of each structure to prevent erosion during over-topping.

The proposed actions would have great benefits to riparian and wetland vegetation. Implementation of Alternative #27 would involve creation or improvement of 242 acres of mixed riparian and wetlands habitats. The proposed restoration would result in improvement of existing wetland and riparian zones

and connection of uplands to riverbank, creating new riparian zones and large areas of wetlands through wetland restoration projects. Restoring wetlands by breaching existing agricultural berms and constructing wetland embankments at River Mile 9 and Grange would reconnect 19 acres and 32 acres of forested wetland riparian zone respectively. Alternative #18 would provide the same types of improvements, but to less acreage at 200 total acres of wetlands and riparian zone improved or created. Alternative #11 would provide reconnection of 68 acres of riparian uplands at the location of the Confluence Levee removal, and the side channel reconnection would provide increased inundation of 44 acres of wetland. None of the alternatives would affect more than one acre of invasive species in the Skokomish Valley, and none of the alternatives would increase invasive populations. None of these three alternatives would have any effect on eelgrass in the estuary.

Riverbed Excavation Alternatives #45 and #60

Both of these alternatives would have the same acreage of staging areas at approximately 1.15 acres. Construction impacts to vegetation would be the same as described for the Confluence Levee Removal alternatives. Alternatives #45 and 60 include all of the increments; therefore, both would affect 5 acres of wetlands for wetland embankments, but would improve the same acreage of wetland and riparian vegetation as Alternative #27 at approximately 242 acres. None of the alternatives would affect more than one acre of invasive species in the Skokomish Valley, and none of the alternatives would increase invasive populations. Riverbed excavation could have negative effects to eelgrass in the estuary from significant amounts of turbidity caused by the dredging action. This would cause reduced photosynthesis during the growing season and may cause some burial of eelgrass.

Cumulative Effects

The Corps anticipates no adverse cumulative effects to vegetation from any of the alternatives. Restoration of riparian and wetland vegetation in the Skokomish Valley would add to the work of the USFS in the Federal forestlands in the upper watershed and to the 1,000 acres of estuarine restoration that the Skokomish Indian Tribe and Mason County have achieved. The proposed restoration would provide an important connection between these two valuable habitat types in the Skokomish Basin and would therefore have a cumulative benefit to overall biodiversity of the vegetation communities.

4.4.4 Rare, Threatened, and Endangered Species

Nine species identified under the ESA as endangered or threatened potentially occur in the study area: four fish species, four bird species, and rare sightings of killer whales (USFWS 2010a; NOAA-NMFS 2009, 2010). These species are presented in Table 4-6. No federally listed plants, invertebrates, amphibians, or reptiles are found in the study area (USFWS 2010a; NOAA-NMFS 2009, 2010). The Corps conducted ESA Section 7(a) consultation as part of the EIS process. Effects determinations are included in the following descriptions of effects of the alternatives. All effects from this Federal action are covered under two Biological Opinions as described in Chapter 6.

The existing condition and future without-project condition (No-Action Alternative) for each confirmed or likely ESA species are discussed below, followed by analysis of effects in the future with-project condition (action alternatives) for the broader group of species.

Table 4-6. Federally Listed, Proposed, and Candidate Species that May Occur in the Study Area

Common Name (*Scientific name*)	Federal Listing Status/ Critical Habitat	Year Listed	Potential for Occurrence	Effect Determination of the recommended plan / agency preferred alternative
Northern spotted owl (*Strix occidentalis caurina*) /1	Endangered / Designated	1990	Likely	No effect
Marbled murrelet (*Brachyramphus marmoratus*) /1	Endangered / Designated	1992	Likely	No effect
Streaked horned lark (*Eremophila alpestris strigata*) /1	Threatened / Designated	2012	Unlikely	No effect
Western yellow-billed cuckoo DPS (*Coccyzus americanus*) /1	Proposed/ None designated	2001	Unlikely	No effect
Southern Resident killer whale (*Orcinus orca*) /2	Endangered / Designated	2003	Unlikely	No effect
Puget Sound Chinook Salmon ESU (*Oncorhynchus tshawytscha*) /2	Threatened / Designated	1999	Confirmed	Likely to adversely affect
Hood Canal Summer-Run Chum Salmon ESU (*Oncorhynchus keta*) /2	Threatened / Designated	1999	Extirpated from System	No effect*
Puget Sound Steelhead DPS (*Oncorhynchus mykiss*) /2	Threatened / Proposed	2007	Confirmed	Likely to adversely affect
Coastal/Puget Sound Bull trout DPS (*Salvelinus confluentus*) /1	Threatened / Designated	1999	Confirmed	Likely to adversely affect

/1 USFWS 2010a
/2 NMFS 2009
*NMFS confirmed that summer chum are considered extirpated from the Skokomish River and stated that there is no need to consult on this species for projects in the Skokomish River (Matt Longenbaugh, pers. comm. 2014).

Northern Spotted Owl

Northern spotted owls inhabit old growth or late successional coniferous or mixed conifer-hardwood forests, and the Skokomish watershed is within their range. The only report of spotted owls recorded in the WDFW (2013b) database is a sighting in 1994 at Frigid Creek, a tributary to the North Fork Skokomish River. No critical habitat is located within five miles of the study area. In the future without-project condition, northern spotted owl populations are expected to continue to decline due to habitat loss, reduction in prey, and competition for home range from other species such as the barred owl.

Marbled Murrelet

Marbled murrelets occur in the Hood Canal region in small numbers compared to the more northern areas of Puget Sound. Marbled murrelets nest in mature and old growth forests and forage in deeper water of entrance channels of rocky shores, estuaries, and protected bays where they dive in pursuit of prey fish such as Pacific herring, sand lance, and surf smelt. Critical habitat includes upland forested stands used for nesting, but does not include marine water. Marbled murrelets have been observed within their designated critical habitat in forested areas upstream from the study area (WDFW 2013b).

Recent trends indicate a continued steady decline of marbled murrelets, with a decrease in population of eight percent from 2000 to 2009 in Puget Sound and the Strait of Juan de Fuca (USFWS 2009). The

2010 population estimate for Puget Sound and Strait of Juan de Fuca was around 4,000 (Pearson et al. 2011). Population declines occur through habitat loss from timber harvest and natural events such as wildfires, insect outbreak, and windthrow in their terrestrial environment, and harmful algal blooms, declining prey availability (forage fish), and catastrophic events such as oil spills in their marine environment. In the future without-project condition, marbled murrelet population declines may occur through habitat loss and catastrophic events beyond the scope of this feasibility study, such as oil spills.

Streaked Horned Lark

The historical breeding range for Streaked horned lark extended from southern British Columbia through the Puget lowlands and Washington Coast south to the Willamette and Rogue River valleys. These birds nest on bare ground in sparsely vegetated sites that are mostly grassy, such as prairies, coastal dunes, fallow agricultural fields, and seasonal wetlands. There are no historical breeding records for Mason County and this species is considered not likely to occur in the study area.

Yellow-billed cuckoo

This migratory bird had a range across much of North America, but is now limited primarily to the eastern and central United States with a few populations in the West. The preferred breeding habitat is open lowland deciduous woodlands with clearings and shrubby vegetation, especially near rivers and streams with nests in willows and cottonwoods of long contiguous riparian zones. Yellow-billed cuckoos are not expected to occur in the study area because their habitat requirements are not present.

Puget Sound Chinook salmon

Puget Sound Chinook salmon are ESA-listed as threatened (NMFS 2005). Critical habitat was designated throughout Puget Sound and its tributaries in 2005. Puget Sound populations are largely summer/fall runs; however, the Skokomish River once supported a run of spring Chinook salmon. The stock was reported in decline as early as 1950, but still used the lower five miles of the South Fork and 13 miles of the North Fork. Nehlsen et al. (1991) reported the stock extinct in 1991. This extinction is likely due to overfishing and the construction of the Cushman Dams (James 1980), which blocked access to a major component of their habitat and altered hydraulic patterns in the system (Skokomish Indian Tribe and WDFW 2010). Fall/Summer Skokomish Chinook were classified as threatened as a component of Puget Sound Chinook ESA listing in 1999, and this status was reaffirmed in 2005 (70 FR 37160); they were designated as their own stock in WDFW's 2002 Salmonid Stock Inventory (SASSI) based on geographic location and have been rated as depressed.

According to Peters et al. (2011), for the last several years, fewer than 100 fall Chinook were documented in the South Fork. Juvenile Chinook were observed in the mainstem, tributaries, and off-channel pond habitats in the Skokomish Valley. Juvenile Chinook were common in the estuary and were quite abundant (i.e., 55,000) compared to their observed abundance in freshwater habitats, despite the fact that a very small portion of the estuary was sampled. This suggests that a majority of juvenile Chinook in the system may be migrating directly to the estuary without rearing in the freshwater environment, likely due to the severe lack of appropriate pool habitat.

Although a recovery plan is in place, poor habitat conditions continue to affect Chinook in the study area. The lack of LWD, poor riparian corridors, and riverbed aggradation have reduced channel capacity to critically low levels in several locations. Summer low flows can block adult migration, resulting in an unsuccessful migration to spawning grounds. Eggs are susceptible to smothering by sediment or scouring during floods. In the future without-project condition, fall Chinook numbers in the North Fork may increase due to actions from the Cushman Dam settlement agreement. Habitat conditions on the South Fork, Vance Creek, and mainstem will continue to degrade, leading to a decline in fall Chinook numbers and potential extirpation from these areas. The Skokomish Indian Tribe and Mason County have collaborated to accomplish significant restoration in the estuary, but without complementary restoration of the freshwater habitat, this effort will have limited success at restoring Chinook numbers.

Hood Canal Summer-Run Chum Salmon

Hood Canal summer-run chum salmon were listed as threatened in March 1999; this status was reaffirmed in 2005 (70 FR 37160). Critical habitat was designated in September 2005. Today, summer-run chum are extirpated from the Skokomish River. A few adults are observed in the mainstem each year, but are not enough to be described as a self-sustaining population. In the future without-project condition, summer-run chum are not anticipated to recover in the Skokomish River.

Puget Sound Steelhead

Puget Sound steelhead were listed as a threatened species in May 2007 (72 FR 26722); critical habitat is under development. An estimated 300 to 400 winter steelhead occur in the South Fork but there are no credibly documented summer steelhead in this area (Peters et al. 2011; Skokomish Tribe 2011). In the future without-project condition, steelhead numbers may increase in the North Fork due to actions from the Cushman Dam settlement agreement. South Fork, Vance Creek, and mainstem habitat conditions would continue to degrade due to the excessive sediment input and lack of LWD. This is expected to continue the decline in steelhead numbers downward from the 1,000 natural adult winter steelhead in the Skokomish River.

Bull Trout

The Coastal/Puget Sound bull trout was listed as a threatened species in November 1999 (64 FR 14307); critical habitat was designated in September 2005 (USFWS 2005) and revised in 2010 (USFWS 2010b). The Skokomish River Watershed hosts three distinct stocks of bull trout, a fluvial population in the South Fork, a lacustrine-adfluvial population in Lake Cushman, and a fluvial population in the upper North Fork (Peters et al. 2011). Bull trout in the Skokomish River watershed do not appear to be anadromous (Correa 2003) indicating that they are almost entirely dependent on freshwater habitats throughout their life histories (Brenkman et al. 2007; Peters et al. 2011). It is thought they can be found in all reaches of the watershed below anadromous barriers.

Bull trout populations above Lake Cushman are healthy and are not likely to face habitat limiting factors in the foreseeable future. Bull trout numbers may remain stable on the North Fork due to actions from the Cushman Dam settlement agreement. The depressed South Fork population could improve in the future without-project condition due to reduced logging activities, decommissioning of logging roads,

and other restoration activities in the upper watershed; however, positive effects of restoration activities may not be fully realized without complementary restoration action in the lower watershed.

4.4.4.1 No-Action Alternative/Future Without-Project Conditions

In the future without-project condition, ESA-listed salmonid species will continue to face obstacles within the mainstem migration corridor including the following: spawning at less than optimal sites due to variable gravel movement; inability to gain access to the upper watershed to spawn due to continued blockage of key migration corridors; winter high flows transporting juvenile and adult salmon out of the river; and high water temperatures in the summer and early fall affecting various salmon species during rearing and migration seasons. The degraded and absent riparian zone vegetation is not expected to see improved conditions without breaching the agricultural berms, constructing new wetland embankments to improve wetland hydrology, and adding plantings. Continued loss of high quality rearing and off-channel habitat is anticipated during low flows due to sediment deposition at the mouths of tributaries.

The No-Action alternative would have no effect on the listed bird species.

4.4.4.2 Action Alternatives/Future With-Project Conditions

Aspects common to both groups of action alternatives

Marbled murrelets would likely only be flying high over the action area in transit between aquatic foraging areas and roosts in the upper watershed and the other listed bird species are not expected to be in the action area. None of the proposed action alternatives would be expected to affect the behaviors or habitats of the four listed bird species. Therefore, the Corps has determined that there would be *no effect* to these species.

Confluence Levee Removal Alternatives #11, #18, and #27

Construction effects to listed salmonid species may involve some turbidity during in-water construction; however, the Corps would adhere to fish work windows that are timed to protect salmon. The fish work window for the Skokomish River is 15 July to 15 September. This period may be adjusted based on consultation with the natural resource agencies such as WDFW, NMFS, and USFWS. The Confluence Levee removal will have minimal or no in-water work, and each of the increments will have an in-water work duration that will not exceed the duration of the fish work window. Construction methods would employ all best management practices to minimize turbidity. Although the fish work window extends to September 15, it is likely that adult Chinook salmon would be present for their spawning migration beginning in early September. Additionally, bull trout and steelhead have potential for early and sub-adult life stages to be present in the river system year-round. Due to the threshold for adverse effects being determined to occur even when it occurs to very few fish, the Corps has determined that the in-water work required for this project is *likely to adversely affect* Chinook, steelhead, and bull trout. Effects would occur to only a very low number of fish and would not likely be lethal. Effects would be temporary disturbance or displacement, and temporary stress from turbidity. The project is *not likely to adversely affect* critical habitat for these species.

Fisheries managers and scientists have determined that Hood Canal summer chum have been extirpated from the Skokomish River watershed; however, there is interest in re-introducing a run from other

genetic sources around Hood Canal rivers, so critical habitat remains designated in the Skokomish River. Therefore, the Corps has determined there would be *no effect* to Hood Canal summer chum salmon from this alternative, and the action is *not likely to adversely affect* critical habitat.

Alternatives #11, 18, and 27 would benefit the listed salmonid species by resolving the problem of blocked spawning migration by providing a year-round connection to upstream spawning areas. Alternative #27 provides the greatest acreage of improved or reconnected riparian zones, wetlands, and aquatic habitats that would benefit all listed salmonid species. Alternative #18, the agency preferred alternative, although smaller in scope than #27, still includes the substantial increase of 51 acres in forested riparian zone wetlands that would be reconnected to the river through construction of the wetland restoration increments, which is a significant benefit over Alternative #11.

Riverbed Excavation Alternatives #45 and #60

Increasing channel capacity to reduce the frequency of over-bank flooding is assumed to reduce the acknowledged fish-stranding problem in which adult and juvenile salmonids escape the river channel in sheet flow across roads and agricultural fields and have no pathway back to the river or other off-channel aquatic habitat. While direct mortality from stranding has been regularly observed in the Skokomish Valley during winter floods, not much has been researched regarding long-term consequences of stranding on population dynamics (Nagrodski et al. 2012).

Riverbed excavation has potential for high risks to the listed salmonids and their critical habitat. Dredging poses a risk of negative effects from turbidity and direct mortality for juvenile salmonids present in the river channel during dredging. After construction, there is risk that the resulting channel morphology would not support favorable spawning conditions (Collins 1995). The sediment excavation work would need to be designed to mimic preferred spawning conditions to the greatest extent practicable.

Due to the substantial loss of benthic invertebrates from dredging and risk of significant negative effects to spawning habitat, the Corps has determined that these alternatives would *likely adversely affect* the listed salmonid species and would constitute an *adverse modification of critical habitat.*

Cumulative Effects

Aggradation of the Skokomish River has multiple causes as described in Bureau of Reclamation (2009) and briefly summarized in Section 4.2 of this report. The extensive sediment excavation proposed for the Riverbed Excavation alternatives would have a countervailing effect in an attempt to reduce the environmental consequences of reduced channel capacity. The post-construction risk of lack of suitable spawning habitat for several years may have an additive effect to the habitat limiting factors that have reduced salmon populations in this watershed. The Confluence Levee Removal alternatives would have no significant negative cumulative effects. Combining removal of the Confluence Levee with the wetland restoration at River Mile 9, which is included in Alternatives #18 and #27 but not Alternative #11, would have a significant cumulative benefit of widening the channel migration zone and enhancing forested riparian wetlands because these two project features are directly across the river from each other.

4.5 Cultural Resources

Cultural resources are locations on the physical landscape of past human activity, occupation, or use and typically include archaeological sites such as lithic scatters, villages, procurement areas, resource extractions sites, rock shelters, rock art, shell middens; and historic era sites such as trash scatters, homesteads, railroads, ranches, logging camps, and any structures or buildings that are over 50 years old. Cultural resources include traditional cultural properties, which are aspects of the landscape that are a part of traditional lifeways and practices and are considered important to a community.

Very little cultural resource survey has occurred within the study area; however, a cultural resource survey was conducted for specific project components of the TSP for the feasibility study. To compare the alternatives and identify potential impacts to cultural resources, the Corps reviewed previous inventory reports and site forms, historic maps, ethnographic literature, and did a "windshield" survey in 2009 to characterize the nature of the resources present in the basin and to determine whether there were any historic structures or other clearly visible resources that should be avoided during alternative development. The Corps requested information about cultural resource concerns from the Skokomish Indian Tribe's Tribal Historic Preservation Officer in a meeting in 2010 and gathered information from local residents through oral histories later that year (Montgomery and Lahren 2011). A Corps archaeologist attended the Public Scoping meeting held on October 7, 2010 and one of the informal scoping meetings discussed in section 7.1. A cultural resource survey was conducted January 2015. Results of these efforts are summarized below and additional information about cultural resources in the study area appears in the Cultural Resources Appendix (D).

According to the Washington Department of Archaeology and Historic Preservation's (DAHP) online database WISAARD (last queried January 2015), seven cultural resource inventories have occurred in the study area since 1995. The database lists all archaeological sites that have been officially recorded and sent to DAHP. The majority of inventories known to have occurred in the study area have been small in scale, typically under three acres, or linear surveys that simply bisected the study area. Most of the inventory in the study area has clustered around Hood Canal. The study area has 17 recorded archaeological sites. Eleven of these are prehistoric sites. Shell middens and small lithic scatters are the predominant site types. Historic era sites consist of the remains of two bridges and small domestic refuse scatters without clear temporal markers. Of those 17 recorded archaeological sites, only three are recorded within 1.50 miles of project components that make up the TSP.

A cursory review of information reveals that the survival of buildings and structures from the earliest settlement period is limited. Not surprisingly, extensive flooding, logging, and later agricultural pursuits have swept away many of these properties. A "windshield" survey of the valley's most accessible structures and buildings suggests that those that remain are products of accelerated agricultural growth in the early part of the twentieth century, the general period 1920-1940. There is also the strong possibility that some of these homes and agricultural buildings are the products of pattern books or "pre-cut and assemble" building packages selected from local hardware stores and shipped by train.

In addition to the archaeological and structural inventories, Bouchard and Kennedy (1994) completed an extensive ethnographic study of the Basin. They interviewed 22 Skokomish tribal members in 1991-1992 and identified 72 areas of tribal concern. Bouchard and Kennedy's study built off of previous work in the

area such as Dr. W.W. Elmendorf's ethnography *The Structure of Twana Culture* (1960), Edward Curtis's (1913) volume on the Salishan Tribes of the Coast, and T.T. Waterman's (1920) collection of over 120 Twana place names in the vicinity of Hood Canal.

A cultural resources survey was conducted in January 2015 for the TSP. This consisted of walking the River Mile 9/Grange agricultural berm (locally referred to as the River Mile 9 Levee) and shovel testing the proposed wetland embankment alignment at River Mile 9 and Side Channel Reconnection at RM 5.6. Subsurface shovel probing was only conducted on property where the landowner had signed right of entry. In addition to the subsurface shovel probes, the Confluence Levee (locally known as Car Body Levee) and the River Mile 9/Grange berm were recorded. No significant cultural material was identified during the subsurface investigation. Based on the Corps internal guidelines for flood control systems and structures, the Corps has determined that the Confluence Levee and the River Mile 9/Grange berm are not eligible for listing on the National Register of Historic Places (NRHP). Though both the Confluence Levee and the River Mile 9/Grange berm are fifty years of age, these structures are a ubiquitous type of flood control structure and are not distinguished for their engineering value. In addition, both the Confluence Levee and the River Mile 9/Grange berm show clear loss of essential integrity due to loss of linear continuity due to breaches and both structures are experiencing erosion. While both the Confluence Levee and the River Mile 9/Grange berm were built to protect agricultural fields from flooding, these structures did not play a central role in the agricultural development of the Skokomish River Valley. Finally, neither the Confluence Levee nor the River Mile 9/Grange berm can provide additional cultural information beyond what is already known.

4.5.1.1 No-Action Alternative/Future Without-Project Conditions

Without an ecosystem restoration project, conditions would remain the same within the Skokomish River Valley. Flooding would still occur and the groundwater may continue to rise. To date, a small number of archaeological sites have been identified and recorded within the Skokomish River Valley. Within the project area, no archaeological sites were identified on the parcels that were surveyed. Three historic age properties – the River Mile 9 Levee, the Grange Levee, and the Confluence levee – were recorded and determined not eligible for listing on the National Register of Historic Places. However, due to lack of land owner permission not all of the project area was able to be surveyed. Therefore, it is unknown what effects may occur to unrecorded archaeological sites that may exist within the project area. Taking no action toward ecosystem restoration in the Skokomish Valley would have no effect to the sites identified in the project area thus far.

4.5.1.2 Action Alternatives/Future With-Project Conditions

Both NEPA and the National Historic Preservation Act (NHPA) require that Federal agencies consider impacts to cultural resources; however, the NHPA specifies the process by which Federal agencies determine the significance of these resources and assess a project's effects. The NHPA considers impacts to "historic properties" as opposed to "cultural resources". A historic property is defined as a cultural resource that has met certain standards of age, integrity, and significance. The phrase "adverse effect" (used in the NHPA) and "significant impact" (used in NEPA) are not equivalent terms but are similar in

concept. Impacts to cultural resources are typically examined in terms of how the project will impact the qualities that make the resource eligible for listing on the National Register of Historic Places (NRHP).

The cultural resources survey did not find any significant cultural resources and the Corps has determined that no historic properties will be affected. The Corps will require additional cultural resource surveys to be conducted once the landowner permission has been received for project components that will affect private property (e.g. proposed access routes for the LWD/ELJ placement).

Section 304 of the NHPA prohibits Federal agencies from publicly disclosing specific information about cultural resources that could lead to their harm through vandalism or looting regardless of their eligibility. Therefore, specific site locations are not discussed in this analysis.

Confluence Levee Removal Alternatives #11, #18, and #27

Removal of the Confluence Levee would require three staging areas with a total of less than one acre of ground disturbance. Ethnographic literature suggests that the confluence of the north and south forks with the mainstem has a higher potential for containing archaeological sites. Elmendorf (1960) referenced a campsite near the Confluence Levee; however, it was not in use in the 1930s and archaeological evidence has not been discovered at the junction. The staging area would be placed to avoid adversely affecting any significant cultural resources. The Confluence Levee may be over 50 years old; however, based on the Corps' internal guidelines for flood control systems and structures, the Corps has determined that the Confluence levee is not eligible for listing on the NRHP.

In general, projects that are proposed within the river channel or that have little ground disturbance have less potential for adversely affecting cultural resources. Of the eight proposed increments, the installation of LWD at RM 9-11, the reconnection of the side channel between RM 4 and 5.6, and restoring the mouth of Hunter Creek have little potential to affect historic properties because there is little likelihood that sites exist within each project footprint.

The wetland restoration increments at Grange and RM 9 (included in #18 and #27) would involve construction of new features on the landscape, so in addition to direct impacts within the construction footprint and staging areas, the wetland embankment could indirectly adversely affect surrounding historic properties by changes in the viewshed. Other considerations include the area in front of the newly constructed features that would be more exposed to erosion and changes in soil moisture that could affect buried archaeological materials. Cultural resource monitoring would be required during construction for the following locations: construction of the wetland embankments at River Mile 9 and at Grange, and the channel reconnection locations at RM 4 and RM 5.6. While the channel reconnection location at RM 4 was not surveyed, both channel reconnection locations are relict channels of the Skokomish River and reconnection would involve re-excavating the former inlet and outlet of the relict channels. In addition, excavation would only be deep enough to allow water to pass into the channel during higher flows.

For the proposed wetland restoration at the Grange, the Corps would conduct a cultural resources report if this project component were to move forward through the next phase of design. The placement of the Upstream LWD will be within the current Skokomish River channel. Proposed access

routes currently include private property and will be finalized during PED phase. The Corps will conduct a cultural resources survey when the proposed locations of the Upstream LWD and access routes are finalized in PED phase.

Riverbed Excavation Alternatives #45 and #60

In general, in-water work such as dredging has little likelihood of directly impacting archaeological sites or historic structures. However, changes in channel capacity and morphology could lead to changes in rates of bank erosion and flooding, which have potential to indirectly impact archaeological sites, historic structures, or important aspects of traditional cultural properties (TCPs).

For Alternatives #45 and #60, sediment excavated from the river would be placed within the lower intertidal and subtidal areas of the estuary and adjacent nearshore zone. Of the 17 recorded sites within the basin, 10 have been recorded along the edges of Hood Canal and within the estuary. Prehistoric sites associated with the Twana, and historic era sites associated with the establishment of Nalley's Ranch, logging, and early commerce are expected to be present. Placement of dredged materials within the estuary would need to be coordinated to avoid impacts to significant cultural resources. Potential impacts associated with the eight proposed increments would be the same as discussed above.

The Hunter Creek side channel and the Weaver Creek side channel would require excavating small channels along existing swales and therefore could affect sub-surface archaeological materials adjacent to the creeks. The most likely resources to be present include short-term prehistoric and historic campsites, middens, and historic refuse areas. Due to the nature of the proposed projects, indirect impacts to surrounding historic properties are not likely.

Cumulative Effects

The proposed undertakings evaluated in this document would contribute to the overall restoration projects proposed by the SWAT and others and should lead to a general improvement in ecological functions. Many of the areas identified as important to the Twana were related to fishing; therefore, any improvement in fisheries would have a beneficial effect on fishing related TCPs within the area.

4.6 Social and Economic Resources

This section presents an overview of major socioeconomic characteristics and trends within the study area, including demographics and economics.

4.6.1 Indian Trust Assets

In addition to the Federal government's responsibilities under NHPA, the Federal government must consider the effects its actions may have on American Indian traditions and cultural practices. The Federal basis of a tribe's legal status rests within the context of U.S. Constitutional provisions for Federal government's powers for treaty making with other sovereign nations, and American Indian tribes' inherent sovereignty.

The Skokomish Indian Tribe, with other Tribes and bands of the Twana, Clallam, and Chimakum peoples, signed the Treaty of Point-No-Point with the Federal Government on January 26, 1855. The Skokomish Indian Reservation was formed through this treaty and required these Indians to move to the current

reservation location at the mouth of the Skokomish River. The reservation boundaries were expanded by executive order in February 25, 1874 and the current location consists of 4,950 acres, with nearly 2,700 acres of residential areas and many tribal government services. Today, many tribal members continue to work within the region's fishing and logging industries. In an attempt to diversify its economy, the Tribe has purchased property for economic development (including the operation of a local casino) and resource enhancement, as well as for housing. The Tribe operates its own businesses including a tribal hatchery and a gas station/convenience store.

The priorities of the Skokomish Indian Tribe are protection of the marine, freshwater, and land resources of Hood Canal that are the backbone of the Tribal economy and spiritual beliefs. One of the treaty-reserved rights is the ability to conduct fishing and hunting activities on all U&A locations. Hunting, fishing, and gathering are central to the cultural and economic existence of the Tribe and its members. Acquisition of food through hunting, fishing, and gathering is part of a complex culture that emphasizes the concept that all of life is interrelated. Fish, wildlife, and other natural resources sustain the cultural and spiritual identity of the community in addition to providing economic stability for present and future generations.

In addition to salmon, shellfish have been a mainstay of the Skokomish Indian Tribe for thousands of years. Clams, crab, and oysters were readily available for harvest year-round. The rapid decline of many western Washington salmon stocks, due in large part to habitat loss from the region's burgeoning human population, has pushed shellfish to the forefront of many tribal economies. Today, the Annas Bay estuary contains a significant shellfish resource used by Tribal, commercial, and recreational harvesters. However, shellfish resources have been declining due to reduced availability of suitable substrate for shellfish attachment in the estuary as well as high fecal coliform levels in Annas Bay and Hood Canal.

Along with hunting, fishing, and gathering, the intricate basketry and artwork of the Skokomish Indian Tribe is widely renowned and culturally significant. Until the 1930s, the Twana women from the Skokomish Indian Reservation harvested sweetgrass (*Scirpus americanus*) from the estuary for making baskets and other items. Industrial and agricultural development in western Washington estuaries has all but eliminated sweetgrass, and only a few remnants of the Skokomish sweetgrass were found outside of the estuary dike system by the 1970s.

4.6.1.1 No-Action Alternative/Future Without-Project Conditions

In the future without-project condition (No-Action Alternative), U&A fishing areas and fisheries resources will continue to degrade. As salmon populations continue to decline and shellfish habitat is lost, the cultural and spiritual identity of the Tribe would be significantly impacted.

4.6.1.2 Action Alternatives/Future With-Project Conditions

Confluence Levee Removal Alternatives #11, #18, and #27

Removal of the Confluence Levee will create a year-round connection from the mainstem to the North Fork and will solve the issue of the river going subsurface in the summer months. All three alternatives would benefit salmon and consequently would have a positive effect for tribal fisheries. Alternatives #18 and 27 include wetland restoration by breaching the agricultural berms at Grange and River Mile 9 and

constructing wetland embankments, which would provide an additional 51 acres of forested riparian zone reconnection to the river. Alternative #11 does not include these two project components and therefore lacks a significant opportunity to increase the channel migration zone, improve and expand forested wetlands, and provide salmon habitat and reduce fish stranding during floods. These alternatives would have a minimal effect to other tribal trust resources such as game and sweetgrass.

Riverbed Excavation Alternatives #45 and #60

While both riverbed excavation alternatives would address the issue of fish stranding, the removal of sediments would have significant detrimental effects to all fish species in the Skokomish River due to its effects on benthic macroinvertebrates that serve as the primary food source as well as spawning areas. The placement of gravels within the estuary would benefit shellfish; however, placement of the gravel would need to be coordinated to avoid affecting the last stands of sweetgrass in the estuary. This alternative has a high risk of negative effects on tribal resources.

Cumulative Effects

The preferred alternative's benefits to fish and wildlife would have a beneficial effect on fishing related traditions and cultural practices and these benefits are assumed to be cumulative when added to other ecosystem restoration efforts around the Skokomish River watershed.

4.6.2 Land Use and Agricultural Resources

Section 4.2 provides a summary of past land uses and events that have influenced the present conditions of the valley. Many of the farm properties have been held within families for multiple generations. Current land uses in the study area are primarily farming and cattle grazing along with rural-residential areas. Non-residential structures in the study area include schools, barns and other farming-related buildings, tribal services buildings such as a health clinic and administrative offices, a fish hatchery that covers roughly six acres, a fire station, the local Grange Hall, and a church. The area surrounding the lower river and estuary is reservation land for the Skokomish Indian Tribe.

4.6.2.1 No-Action Alternative/Future Without-Project Conditions

The future without-project conditions shows potential for continuing a shift in types of agricultural land uses based on crops that can tolerate increasing frequency of inundation and slow drainage, or changes in groundwater levels. Flooding is expected to become more frequent, but only small increases in flood depths are anticipated due to the broad floodplain in the valley. Taking no action toward ecosystem restoration would have no effect on land use or agricultural resources.

4.6.2.2 Action Alternatives/Future With-Project Conditions

Aspects common to both groups of action alternatives

The action alternatives would not involve any condemnation of properties or takings by the government, and no sites would move forward without necessary land ownership or easements in place. Project components would not occur without willingness of the affected property owners.

The Upstream LWD project component would involve the need for permanent road easements along existing dirt road pathways as well as flowage easements across parcels that area already inundated by

the existing river channel. These are not anticipated to cause any change to present land uses or prevent economic benefits of future property uses.

The two wetland restoration increments, included in all alternatives except #11, will require perpetual easements. Breaching existing berms and constructing wetland embankments would contain floodwater within an expanded area of forested riparian wetland and would cause small acreages of infrequently harvested agricultural fields to revert to forested riparian wetland. This constitutes a change of approximately 10 acres from farmland to uncultivated riparian zone wetland at the River Mile 9 wetland embankment location.

The area surrounding the Side Channel Reconnection increment is abandoned farm fields that have not been cultivated in more than 20 years. No change to the land use is anticipated from opening the inlet and outlet channels at this site.

Confluence Levee Removal Alternatives #11, #18, and #27

Construction access for Confluence Levee Removal would require a permanent road easement along existing dirt road pathways and a temporary work area easement. The opened flowage area will convert the upland levee soils and vegetation to wetland soils and will be planted with species tolerant of frequent inundation. These features are not anticipated to cause any change to present land uses or prevent economic benefits of future property uses.

Riverbed Excavation Alternatives #45 and #60

Alternatives #45 and #60, excavation of the mainstem and South Fork Skokomish Rivers, would increase the channel capacity and would produce a river channel with an approximate 50% ACE, or two-year flood capacity, considerably reducing the frequency of overbank flooding in the valley. Floods larger than the 50% ACE would still cause overbank flooding, but to a lesser degree than present. This would have benefits for agricultural uses in the valley, but it is unknown to what degree the reduced inundation would allow a shift in types of crops.

Cumulative Effects

No significant cumulative effects to land use and agricultural resources are anticipated to accrue from any of the alternatives.

4.6.3 Public Health and Safety

NEPA requires the consideration of public safety in any Federal proposal. Public safety is a primary concern for any Federal water resources project. The following features under consideration have relevance for public safety: wetland embankments, engineered logjams, and temporary river crossings within the construction zones.

4.6.3.1 No-Action Alternative/Future Without-Project Conditions

The future without-project conditions would have the same level of public assurances of health and safety as the existing conditions. Flooding is expected to become even more frequent, but only small increases in flood depths are anticipated due to the broad floodplain in the valley. Taking no action toward ecosystem restoration poses no risk or benefit toward public health and safety.

4.6.3.2 Action Alternatives/Future With-Project Conditions

Aspects common to both groups of action alternatives

Each action alternative contains ecosystem restoration features that must be designed to maintain public safety. The ELJs, clusters, and single anchored logs in the Upstream LWD component will be designed for the appropriate level of risk for their loss or mobilization, typically a recommended safety factor of two in most situations, which is expected to remain in place through large floods. The two wetland restoration sites that include wetland embankment features at Grange and River Mile 9 would not change the existing flooding conditions in the study area. While the goal for the new wetland embankments is to cause water retention on the riparian and floodplain wetlands and direct flow back to the river, this retention is only up to river flows of around 6,000 cfs, which is a moderate storm event that occurs multiple times per year. The wetland embankments are designed for overtopping with a shallow backslope to prevent erosion. These wetland embankments are included in all of the alternatives except for #11.

Confluence Levee Removal Alternatives #11, #18, and #27

Removal of Confluence Levee has been determined to pose no additional risk of flooding populated areas. Temporary river crossings would be installed for construction access to remove Confluence Levee, but these would not be open to public access and construction limits would be tightly controlled.

Riverbed Excavation Alternatives #45 and #60

Alternative #60, excavation of the mainstem and South Fork Skokomish Rivers from RM 0-9, would increase the channel capacity. The proposed excavation would produce a river channel with an approximate 50% ACE, or two-year flood capacity, considerably reducing the flood risk in the valley. Floods larger than the 50% ACE would still cause overbank flooding, but to a lesser degree than present.

The smaller scale of riverbed excavation, Alternative #45, is excavation of RM 3.5-9. This action starts just upstream of where the southern floodwaters re-enter the mainstem. It would provide 50% ACE flow capacity in the excavated reach and reduce flood risks in much of the valley. Downstream of RM 3.5, channel capacity and flooding would be unchanged.

Cumulative Effects

No significant negative cumulative effects to public health and safety are anticipated to accrue from any of the alternatives. Riverbed Excavation alternatives could work in conjunction with the new Highway 101 Purdy Creek Bridge to reduce flood risks.

4.6.4 Transportation and Traffic

Two highways are located in the study area: US Highway 101 (US-101) and State Route 106 (SR-106). The principal arterial road, Skokomish Valley Road, runs the length of the Skokomish Valley and provides the primary access to residences and farms in the study area. Skokomish Valley Road is the most frequently flooded road, which affects access for valley residents. Public transit is limited to bus service in the Skokomish Valley. Commute times average around 29 minutes for Skokomish Valley residents, which is greater than the national average of 25 minutes and most residents commute by car alone

(Census 2013). Average daily traffic volume through the study area for US-101 is 5,800 and for SR-106 is 1,600 (WSDOT 2013a); US-101 is classified as a rural-principal arterial (WSDOT 2013b). US-101 is designated a Highway of Statewide Significance by the Transportation Commission (WSDOT 2009).

4.6.4.1 No-Action Alternative/Future Without-Project Conditions

In the future without-project condition, inundation of local roads in the study area will continue to be a problem. The pattern of flooding may have a slight increase in depth and frequency across the floodplain. Traffic and commute times in the study area are not expected to change substantially as US-101 is a rural-principal arterial, which provides access to rural Washington coastal communities away from urban centers. The level of service (LOS) for US-101 is Class C, or stable flow, at or near free flow (WSDOT 2010). Population in the Skokomish Valley has been declining due to a building moratorium and frequent flooding in the basin, and development and population growth is not expected to increase.

4.6.4.2 Action Alternatives/Future With-Project Conditions

For analysis of effects to transportation and traffic in the study area, the Corps used guidance from the California Environmental Quality Act (CEQA) to assist with determining levels of significance of impacts (State of California and Bureau of Land Management 2010). Under CEQA, the proposed project would have a significant impact if it would cause an increase in traffic that is substantial in relation to the existing traffic load and capacity of the street system; exceed, either individually or cumulatively, an LOS standard established by the regional transportation planning organizations; result in inadequate emergency access; or result in closure of a major roadway (arterial or collector classification) to through traffic as a result of construction activities with no suitable or alternative route available.

<u>Confluence Levee Removal Alternatives #11, #18, and #27</u>

Confluence Levee removal would cause temporary impacts during construction, with approximately 17 truck trips per day over 42 working days for material hauling. Additional temporary traffic increases for each alternative depend on the number of increments, construction sequencing, and quantity of hauling, but are assumed to range from an additional 10 hauling days (17 truck trips per day) for Alternative #11 to approximately 70 additional hauling days for Alternative #27 work (see Table 4-3, Summary of construction components analyzed for effects to resources). Temporary traffic delays will depend on the construction sequencing, timing, and intensity. Trucks are assumed to have up to a 20-mile round-trip cycle to and from the study area. Traffic control structures may be required for restoration work along Skokomish Valley Road and US-101 for each alternative.

Residents may experience minor delays (less than 5 minutes) as they commute around the study area on local roads. Construction activities are not expected to cause significant increases in traffic and delay on US-101 and SR-106. These alternatives are not expected to cause an increase in traffic that is substantial in relation to the existing traffic load and capacity of the system; result in closure of a major roadway to through traffic with no suitable or alternative route available; nor meet thresholds for any of the other CEQA impact significance criteria. Given the CEQA criteria and the assumed impacts, these alternatives are not expected to cause significant temporary or long-term effects to traffic and transportation.

<u>Riverbed Excavation Alternatives #45 and #60</u>

Riverbed Excavation Alternatives would cause temporary impacts during construction, with approximately 300 or more truck trips per day over 631 working days for #60 and 363 working days for #45. Trucks for dredged material disposal have a shorter round-trip cycle of 10 miles, while the increments are assumed to have up to a 20-mile cycle to and from the study area. The project increment Dips Road would relocate a portion of Skokomish Valley Road and may reduce traffic delays associated with flooding. Traffic control structures may be required for restoration work along Skokomish Valley Road and US-101 for both of these alternatives.

Residents may experience longer delays (greater than 5 minutes) as they commute to and from the study area on local roads. Construction activities will increase traffic and may cause traffic delays on US-101 and SR-106 with an estimated 10 percent increase in traffic within the study area. Alternatives #45 and 60 are assumed to require periodic dredging to maintain channel capacity approximately every 20 years, or two periodic dredge cycles over the period of analysis. Periodic sediment excavation is expected to be 30 to 40 percent of the initial construction and would cause temporary traffic and transportation delays. Given the CEQA criteria and the assumed impacts, Alternatives #45 and 60 are expected to cause significant temporary effects to traffic and transportation as part of initial construction and periodic maintenance.

Cumulative Effects

No cumulative effects from implementation of the preferred alternative are anticipated to occur as permanent changes to transportation and traffic in the Skokomish Valley.

5. Recommended Plan – Agency Preferred Alternative

The Corps' objective in ecosystem restoration planning is to contribute to national ecosystem restoration (NER). Contributions to NER (outputs) are increases in the net quantity and/or quality of desired ecosystem resources. The NER Plan must reasonably maximize ecosystem restoration benefits compared to costs, consistent with the Federal objective. The selected plan must be shown to be cost effective and justified to achieve the desired level of output.

5.1 Description of the Recommended Plan (NER Plan)

The annual costs and benefits of the recommended plan (Alternative #18) using planning level cost estimates are shown in Table 5-1. Features included in the recommended plan range from 23 acres to 107 acres restored with costs ranging from approximately $1.9 to $6.1 million per feature. The total area of the proposed sites included in the recommended plan is approximately 277 acres restored. The average annual habitat units are estimated at 186.6, total annual cost using feasibility-level cost estimates are estimated at $824,000 (October 2014 price level, 3.375% discount rate), and the total estimated costs of the recommended plan using a more detailed cost estimate is approximately $19,343,000 at the October 2014 price level (Section 5.5 outlines the recommend plan cost estimate).

Table 5-1. Recommended Plan Components (October 2014 price level, 3.375% discount rate)

Plan ID	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Real Estate Parcels Affected	Total Annual Cost ($1,000s)
18	Base Alternative #3: Confluence Levee Removal	45.9	0	45.9	68	8	$177
	Increment 35 – Upstream LWD	82.9	0	82.9	107	37	261
	Increment 9 – Side Channel Reconnection	25.7	0	25.7	45	22	79
	Increment 28 –Wetland Restoration at River Mile 9	13.6	0	13.6	23	21	153
	Increment 37 –Wetland Restoration at Grange	18.5	0	18.5	34	17	154
	Totals for Recommended Plan	**186.6**	**0**	**186.6**	**277**	**105**	**$824**

No costs or features (local betterments) over the NER Plan have been identified for implementation.

The following sections describe the key design elements included in each of the components of the recommended plan.

5.1.1 Confluence Levee Removal

The Confluence Levee Removal, located in the vicinity of the North Fork and South Fork confluence (RM 9), removes approximately 5,400 linear feet of levee and diverts flow from the South Fork into the North Fork through a small (300-foot) diversion channel (Figure 5-1). The diversion channel is designed to pass all flow up to a typical winter flow of approximately 2,000 cubic feet per second (cfs). A number of

engineered logjams and single log structures will be placed adjacent to the diversion to assist in keeping low flows in the diverted channel and to prevent the main channel from migrating around the diversion. This wood will also encourage recruitment and aid in formation of the newly diverted channel. The diverted flows are expected to do geomorphic work downstream of the diversion for many years after the project, as high flows will split between the existing and new flow paths. The existing terrain will erode and existing vegetation will be altered as a new, larger active channel forms in the area. This process will be allowed to occur naturally over time.

Some project benefits will commence within the first year after construction, and other components of restoration will accrue more slowly. For example, in the first high flows of the first winter following Confluence Levee removal, the South Fork will already be diverting into the diversion channel, and higher flows will activate the established main channel where the bar-apex logjams will initiate habitat formation. In the summer following removal of Confluence Levee, migrating adult salmon will find a year-round channel for migration to critical spawning grounds for the first time since approximately 2004. Benefits of plantings will accrue over time as it takes roughly 3-7 years for some shrubs to become mature and longer for taller trees to grow.

Levee construction has affected the process of channel dynamics that create more complex habitat than what levees allow. Removal of Confluence Levee will alleviate a channel constriction that is more than a mile long. This action will remove the blockage to upstream and downstream fish passage and allow salmon access to spawning grounds. The river will be able to follow a more natural path, which will allow its forces to influence channel morphology. Over time, riparian wetlands will develop more fully on the north side of the river, which will enhance habitat for birds and mammals associated with the riparian and river corridor such as beavers, mink, river otters, as well as bald eagles and osprey that target fish as a prey base.

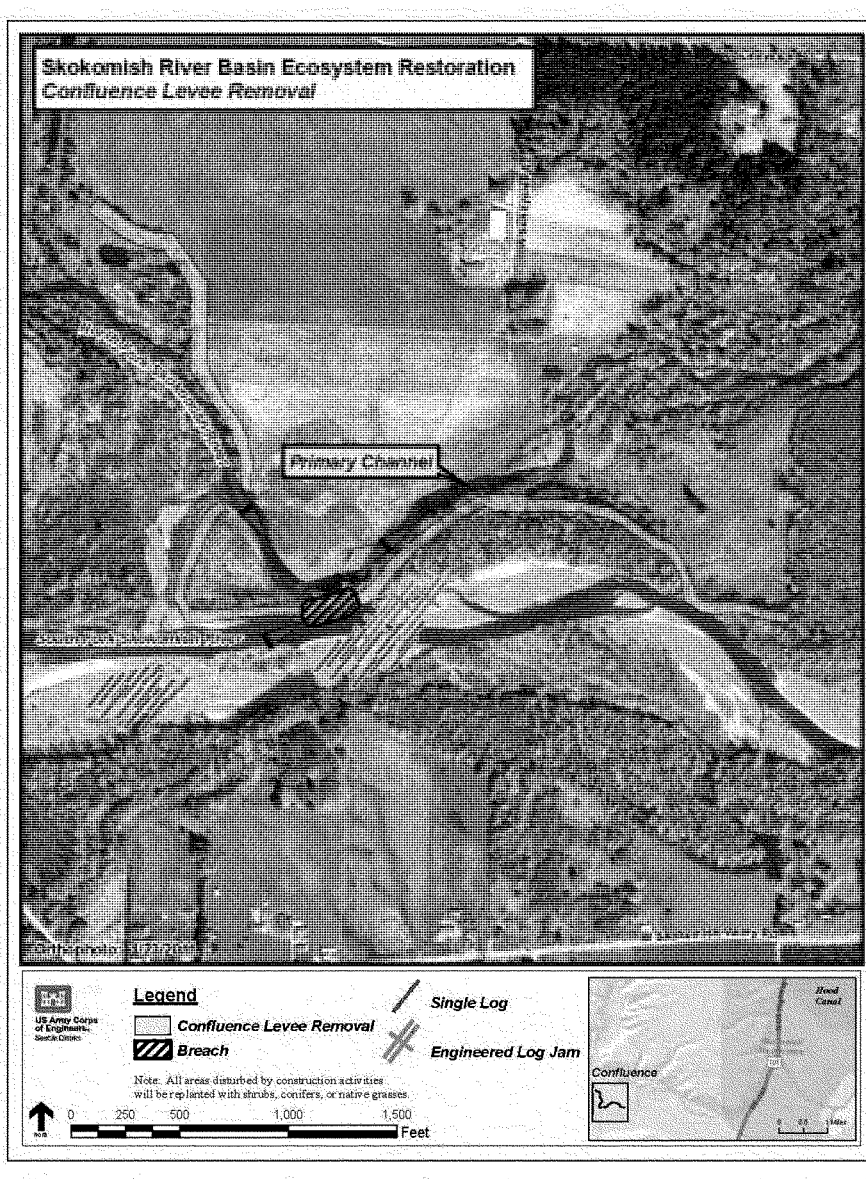


Figure 5-1. Confluence Levee Removal

5.1.2 Upstream Large Woody Debris

This plan component, located from RM 9-11, would include placement and installation of large woody debris (Figure 5-2). As described in Appendix H, multiple wood structure types are included in the design: bar apex engineered logjams, 5-log channel clusters, and single log placements. These large woody debris installations are intended to restore much of the missing habitat and channel complexity afforded by the historical wood load. All wood included in the South Fork has been preliminarily located and designed with stable anchoring. Location and size of wood structures will be refined in preconstruction engineering and design (PED) phase as additional LIDAR and channel surveys are obtained.

The LWD for this project will be supplied by the non-Federal sponsors. The source material has not been determined at this time; however, similar LWD projects in the Skokomish basin have used trees from managed timber-production forests as part of routine land management. The most probable source for LWD for this project would be privately owned forests managed for timber production in the North and South Fork Skokomish watersheds. Trees could also come from a permitted logging operation for clearing or selective thinning, or from private land that will be cleared for development. Another source for other past projects was from forestland used for enhancement of elk browse habitat in which tree removal provided an environmental benefit to the largest mammals in the watershed.

The ecosystem processes of forest succession and large woody debris recruitment have been curtailed in this basin due to human activities. Large woody debris is severely lacking throughout the study area as a direct result of channel clearing. Installation of logs and logjams will restore this vital ecosystem component and renew the process of woody debris accumulation at the structures. This action will directly improve fish habitat and will create and maintain channel characteristics resembling nearby watersheds that are far less disturbed due to their location within Olympic National Park. The large woody debris will provide substrate for aquatic insects and structure for aquatic-oriented mammals. The logjam structures will also create pools for rearing and refuge habitat for juvenile and adult salmon, which will help with their survival and productivity.

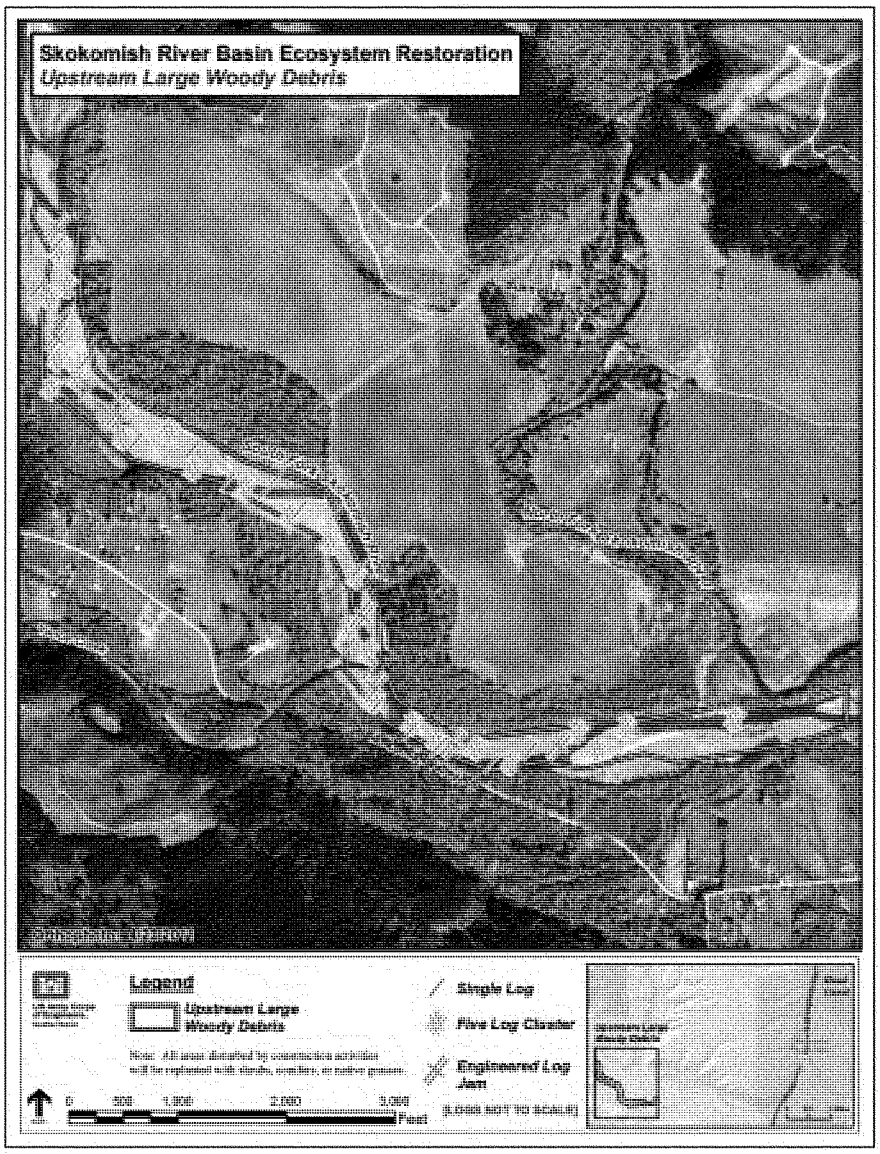


Figure 5-2. Upstream Large Woody Debris

5.1.3 Side Channel Reconnection

This component will reconnect an abandoned channel that exists between RMs 4 and 5.6 (Figure 5-3). Restoration will involve constructing improvements to the channel inlet and outlet. The reconnected channel would only be connected to the river during moderate discharges and would not convey water year round. The inlet is located directly downstream from a large natural logjam at RM 5.7 and was placed to provide for a stable connection to the mainstem Skokomish River that is not likely to accumulate significant wood. At the downstream end of this site, the channel would be reconnected through an existing outlet that presently backwaters at the lowest flow. A small number of 5-log bank clusters will be placed at the inlet and outlet to provide for stable banks and refuge for salmonids. The existing Highway 101 Bridge is near this site and is estimated to be adequate in width and height to convey flows associated with this restoration project.

Floodplain connectivity for fish and wildlife is a critical component of the riverine ecosystem. Human activities have led to many disconnections of these habitats. Opening the 44 acres of wetlands that were once the main channel of the river will provide a vast area of habitat connected for fish, which will greatly expand the prey base for birds and mammals that consume fish such as river otters and great blue herons. The area will serve as over-wintering habitat for coho salmon, which will also enhance productivity of a key resource for recreational and tribal fishing the Skokomish River.

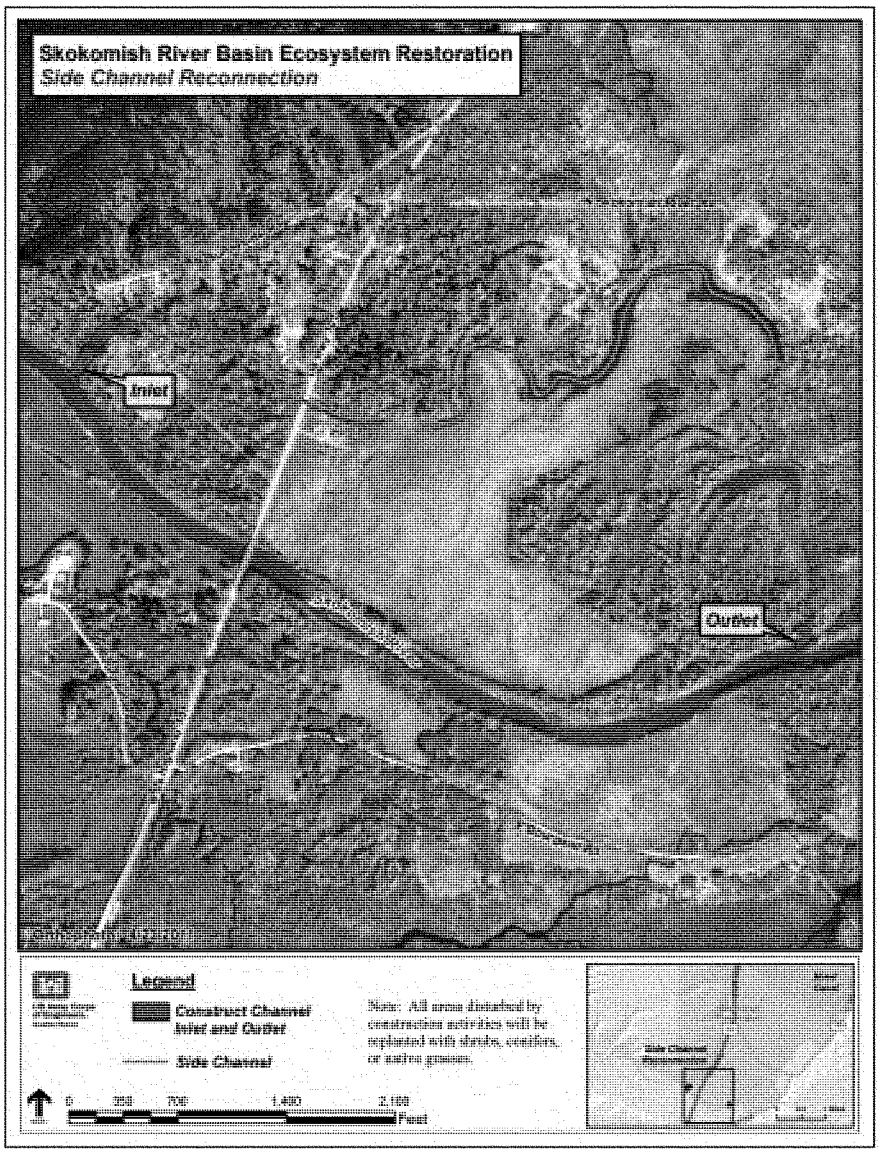


Figure 5-3. Side Channel Reconnection

5.1.4 Wetland Restoration at River Mile 9

This wetland restoration increment, located from RM 8.3-9.2, is intended to reconnect and restore high quality wetland habitat (Figure 5-4). An existing agricultural berm will be breached and a new wetland embankment will be constructed landward (south) varying distances, generally around 200-300 feet. The breaches will allow for reconnection and restoration of a wetland in the floodplain, allowing flood waters to flow freely within the reconnected area and providing salmonids access to the riparian habitat. While breaching the existing berm will provide reconnection of a wetland, construction of a wetland embankment is integral to achieving complete restoration benefits at this site. In combination with the berm breaches, a wetland embankment will be constructed to maintain hydraulic conditions in the reconnected wetland area.

The wetland embankment is a structural mechanism which is necessary to allow targeted reconnection to riparian wetlands multiple times a year; it is not a flood risk management feature but is integral to the function of the riparian wetland. The wetland embankments contain flow from frequent winter storm events (approximately 6,000 cfs), providing high flow refuge for fish as well as reconnection and restoration of high-value forested wetland.

The height and alignment of the proposed wetland embankments are designed to meet ecological criteria established by fisheries biologists from the Corps, Skokomish Indian Tribe, and USFWS. The embankments are designed to direct water to flow through the reconnected areas and back into the river, ensuring two-way flow in the reconnected area. The wetland embankments are also designed to generally contain flows up to approximately 6,000 cfs (frequent winter storm events), allowing flow depths of 1-3 feet to be consistently held in the riparian wetland area, ultimately allowing hydric soils to develop and favoring native wetland vegetation. Designing for a lesser flow (i.e., smaller than 6,000 cfs) would not provide sufficient depth of flows over the reconnected wetland; hydric soils would not develop over time and flows may not reach the riparian zone targeted for restoration. Therefore, project objectives would not be met under this scenario.

The existing agricultural berms to be breached range from approximately 5-8 feet in height at both locations. The proposed wetland embankment at River Mile 9 is approximately 4,370 linear feet in length and varies in height along its alignment from 0-4.5 feet in height with an average height of approximately 2 feet over the existing variable terrain. These heights reflect the outcomes of the supplemental analysis conducted on the embankment site as presented in Section 3.7.4, and are consistent with the small-scale wetland embankment which was identified as a best buy plan for that site. Height variation of the embankments is based on the natural topography in the study area. Some areas of the embankments are taller where the structure crosses depressions, while some areas of the embankments are lower in height where high ground is crossed. Foundation soils in the low areas are loose fine-grained soils so an overbuild was included in the design to account for future settlement.

The proposed wetland embankments are located on the landward edge of existing riparian zones. The embankments reconnect the existing area of forested wetland that is currently cutoff from the river channel, while avoiding cleared farm fields that do not provide high-quality riparian zones and are not likely to develop native riparian wetland vegetation due to lack of hydric soil conditions. The embankments are also aligned to divert flows back into the mainstem Skokomish River rather than

across the floodplain to the south where there is no defined channel or ecological beneficial habitat for salmonids and other aquatic species. The alignment also captures depressions in the riparian zone, which would attract and support river otters, beavers, and mink.

This action will improve productivity of all riverine life stages of salmonids by increasing available spawning, incubation, rearing, and over-wintering habitats. These types of benefits are only achieved if the existing berm is breached and a new wetland embankment is constructed, as both measures are integral to restoring the wetland area in the floodplain. Construction of the new wetland embankment would serve to hold overbank flows on the site at slightly greater depth and longer duration, which would improve and expand wetlands as well as provide fish a pathway back to the river. The restored wetland and forested areas would export invertebrates and organic material as well as provide direct refuge habitat during high flows. This type of off-channel habitat is crucial to overwintering juveniles such as coho and steelhead, which use inundated wetlands to escape high winter flows. Off-channel habitats are also used as predator refugia by juvenile salmonids, and some adult salmon species utilize off channel habitat for spawning. The existing agricultural berms located in the study area can make it more difficult or impossible for juveniles that find their way onto the floodplain to return to the river proper when flows recede, so restoration and reconnection of riparian wetlands provides critical ecological benefits to nationally significant resources. Finally, the wetland embankments will not only serve the purpose of restoring and improving wetland habitat, but would also prevent fish stranding for most of the moderate winter storm events.

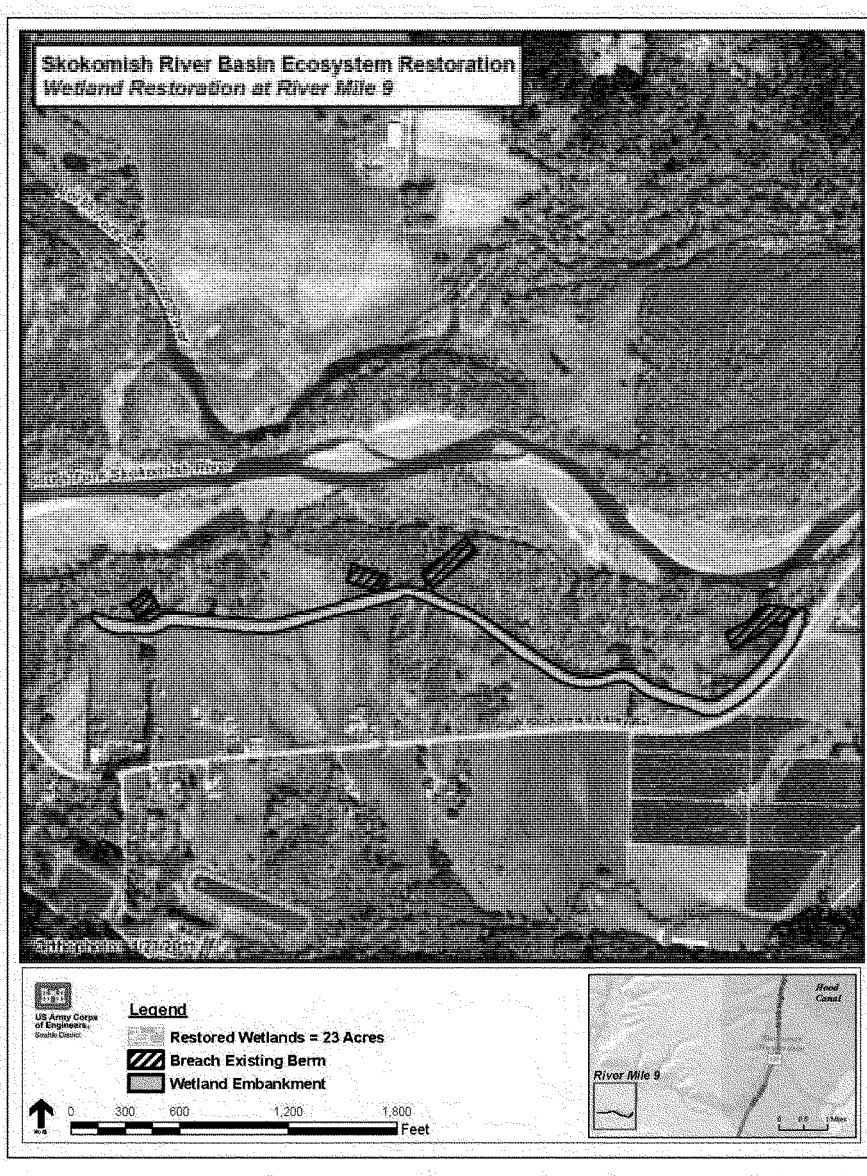


Figure 5-4. Wetland Restoration at River Mile 9

5.1.5 Wetland Restoration at Grange

Similar to the River Mile 9 Wetland Restoration increment described above, this wetland restoration increment, located from RM 7.5-8, is intended to reconnect and restore high quality wetland (Figure 5-5). An existing agricultural berm will be breached and a new wetland embankment will be constructed landward (south) up to 1,200 feet. The breaches will allow for reconnection of a wetland in the floodplain, allowing flood waters to flow freely within the reconnected area and providing salmonid access to the riparian habitat. While breaching the existing berm will provide reconnection of a wetland, construction of a wetland embankment is integral to achieving complete restoration benefits at this site.

The height and alignment of the proposed wetland embankments are designed to meet ecological criteria established by fisheries biologists from the Corps, Skokomish Indian Tribe, and USFWS. The embankments are designed to direct water to flow through the reconnected areas and back into the river, ensuring two-way flow in the reconnected area. The wetland embankments are also designed to generally contain flows up to approximately 6,000 cfs (frequent winter storm events), allowing flow depths of 1-3 feet to be consistently held in the riparian wetland area, ultimately allowing hydric soils to develop and favoring native wetland vegetation.TThe proposed wetland embankment at Grange is approximately 2,750 linear feet in length and varies in height along its alignment from 0-6.5 feet in height with an average height of approximately 4 feet over the existing variable terrain. These heights reflect the outcomes of the supplemental analysis conducted on the embankment site as presented in Section 3.7.4, and are consistent with the small-scale wetland embankment which was identified as a best buy plan for that site. Height variation of the embankments is based on the natural topography in the study area. Some areas of the embankments are taller where the structure crosses depressions, while some areas of the embankments are lower in height where high ground is crossed. Foundation soils in the low areas are loose fine-grained soils so an overbuild was included in the design to account for future settlement.This action will improve productivity of all riverine life stages of salmonids by increasing available spawning, incubation, rearing, and over-wintering habitats. These types of benefits are only achieved if the existing berm is breached and a new wetland embankment is constructed, as both measures are integral to restoring the wetland area in the floodplain. Construction of the new wetland embankment would serve to hold overbank flows on the site at slightly greater depth and longer duration, which would improve and expand wetlands as well as provide fish a pathway back to the river. The restored wetland and forested areas would export invertebrates and organic material as well as provide direct refuge habitat during high flows. This type of off-channel habitat is crucial to overwintering juveniles such as coho and steelhead, which use inundated wetlands to escape high winter flows.

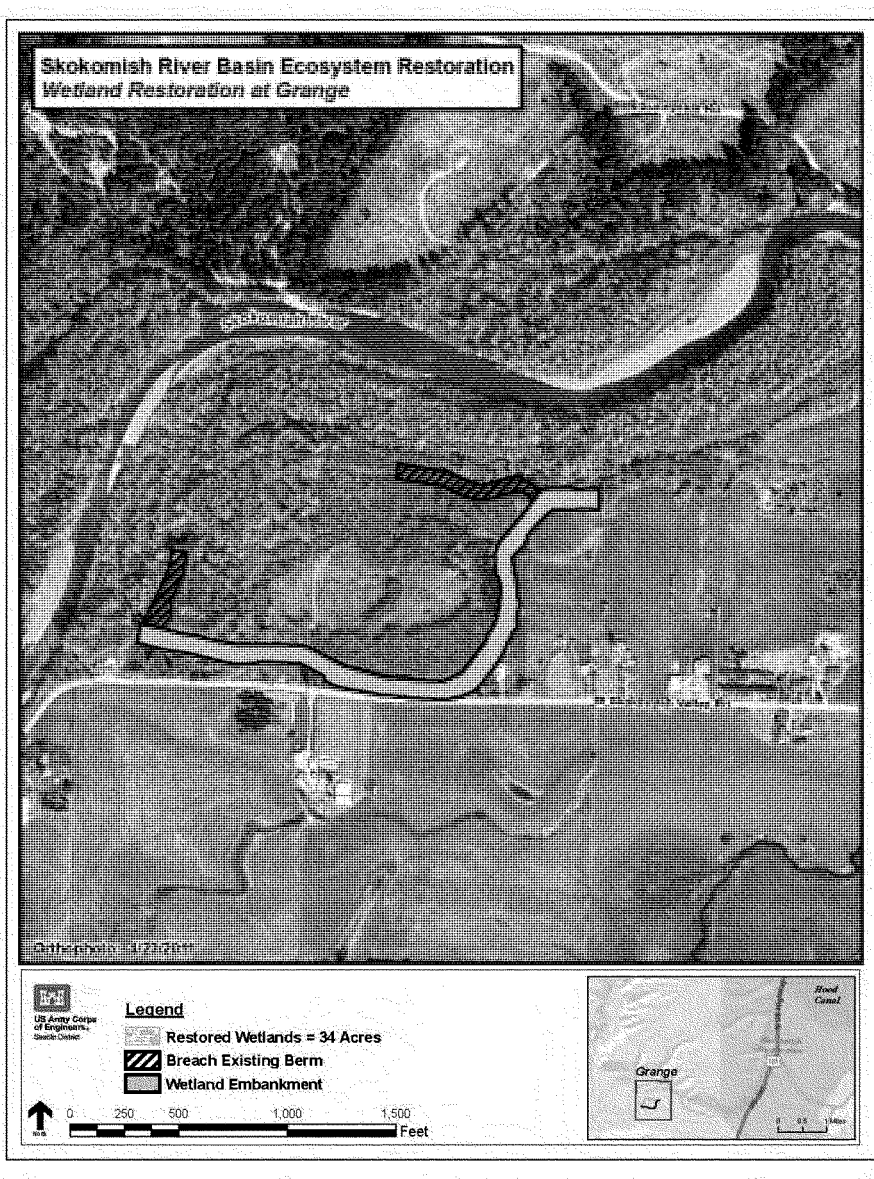


Figure 5-5. Wetland Restoration at Grange

5.2 Effects of the Recommended Plan

Corps policy establishes four accounts to facilitate the evaluation and display of the effects of the recommended plan. These accounts are National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). These four accounts encompass all significant effects of plan implementation, including economic, socioeconomic, and environmental effects that must be considered in water resources planning. Effects of the recommended plan in the four evaluation accounts are displayed in Table 5-2.

Table 5-2. Evaluation of the Recommended Plan

Evaluation Accounts	Recommended Plan / NER Plan: Alternative #18 Confluence Levee Removal
National Economic Development Account	
Flood Risk Management	The combined effects of the recommended plan are not anticipated to significantly reduce flood risk in the study area. However, projects are designed to ensure flooding is not made worse for people, property, or infrastructure in the study area.
Commercial Navigation	No significant difference expected between with- and without-project conditions.
Recreation	A marginal improvement is expected between with- and without-project conditions.
Commercial/Recreational Fishing	A marginal improvement expected between with- and without-project conditions.
Regional Economic Development Account	Improvement to the health of the Skokomish River will support local-based recreation, fishing, and tourism businesses. Additional RED benefits are associated with job creation and income during construction of the project.
Environmental Quality Account	Refer to 4.4, 4.5, and 4.6 for a discussion of ecological, cultural, and aesthetics attributes.
Other Social Effects Account	Opportunities for participation of affected groups were provided in each phase of the planning process.

5.3 Design and Construction Considerations

The study team has taken a risk-based approach to the level of design developed in the feasibility phase. The designs included in this FR/EIS (Appendix H) are detailed enough to support certifiable cost estimates and defensible Section 902 cost limit. The study team has identified the necessary studies and data collection to be performed during PED phase to manage specific risks and uncertainties. A full description of each site, proposed construction features, risk/uncertainty, and additional studies to be completed in PED appears in Appendix H.

The study team coordinated with the relevant natural resource agencies during feasibility-level design phase, which commenced after release of the Draft FR/EIS and the Agency Decision Milestone. This coordination process began with a meeting to present preliminary designs to representatives from USFWS, NMFS, WDFW, and the Bureau of Reclamation as well as the non-Federal sponsors. Following the meeting, the Corps sought further input from these agencies as the designs were refined. The Corps incorporated recommendations from the natural resource agencies into the feasibility-level designs presented in Appendix H. Some of these recommendations included planting species and spacing,

ensuring designs avoid fish stranding, using established roads and open areas for access and staging and avoiding vegetation removal, and to increase the size of the large wood structures from what was proposed in the conceptual designs.

In addition to coordination with natural resource agencies, the study team and non-Federal sponsors met with landowners during the feasibility-level design phase. As described in Section 3.10, landowner input during the feasibility-level design phase led the study team to remove increments from the tentatively selected plan based on insurmountable real estate or access issues that had not manifested earlier in the analysis. The Corps and non-Federal sponsors will continue to coordinate with landowners as designs are finalized in the PED phase.

5.4 Fish and Wildlife Coordination Act Considerations

Compliance with the Fish and Wildlife Coordination Act (FWCA) is documented in Chapter 6. The Draft Coordination Act Report includes several recommendations from USFWS for minimizing negative effects and maximizing restoration benefits. USFWS pointed out the following recommendations the Corps should address during project design:

- Any remaining sections of Confluence Levee and the other levee breach/removal increments may pose a stranding risk to fish; therefore, all of the levee material should be removed.
- LWD installations can have unintended consequences of locking a channel in place preventing natural migration.
- A planted riparian buffer is critical to the success of added productivity.
- The recommended plan should include effort toward returning the river to its reference condition of island-braided morphology.
- The Corps should either collect sufficient data to show benefits outweigh the impacts of excavation at Hunter Creek mouth, or remove this project component from the plan.
- The Corps should evaluate whether the areas proposed for floodplain restoration at Grange and River Mile 9 could be expanded to facilitate natural channel migrations and riverine processes.

The Final Coordination Act Report confirms that the Corps considered all of the recommendations during feasibility level design phase. To further incorporate advice from the natural resource agencies into designs, the Corps held an interdisciplinary design coordination meeting inviting the design team, USFWS, WDFW, NMFS, Reclamation, WDOE, and the local sponsors on September 23, 2014. In the months following this meeting, the Corps sought further advice from the natural resource agencies on best practices and methods for installations of LWD and methods for diversion and care of water during construction. It was determined that most of these decisions are highly dependent on site-specific conditions and would need to be determined as detailed designs are developed in the PED phase. The Corps evaluated the risk of fish stranding at the wetland restoration sites in which agricultural berms will be strategically breached but not completely removed. The Corps concluded that the wetland embankments that will be constructed will not only serve the purpose of restoring and improving wetland habitat, but would also prevent fish stranding for most of the moderate winter storms. In addition, the Corps evaluated whether these areas could be expanded by moving the alignment of the

wetland embankments landward away from the river. At this time, landowners are willing to allow only portions of properties to restore wetland conditions, but not their entire properties.

The design for Confluence Levee is to remove all levee material down to the natural grade at this site. Regarding LWD installations, the Corps will use design assistance from technical experts to maximize benefits and avoid inappropriate design given the reach being restored. The Corps will re-plant all areas of the riparian zone that are disturbed or excavated during construction; plantings will include native shrubs and conifers. Regarding a braided-island plan form, during feasibility-level design phase, the Corps incorporated bar-apex logjams into the Upstream LWD project component, which are anticipated to assist with this type of habitat formation. The design for the wetland restoration increments at River Mile 9 and Grange is to breach the agricultural berms at strategic locations based on the direction of water flow and to construct new wetland embankments for longer periods of inundation in which fish stranding risk would be evaluated and minimized. These wetland embankments will contain moderate winter storms that would otherwise escape as sheet flow across the valley to the south valley wall. By retaining these river flows on the wetland restoration sites, the areas will experience geomorphic change and potentially develop highly valuable side channel habitat that would remain connected to the mainstem of the river. Excavation at Hunter Creek mouth was eliminated during the feasibility-level design phase.

The Final Coordination Act Report included a final recommendation regarding Increments #28 and #37, which are the Wetland Restoration at Grange and River Mile 9. At the time of coordination with USFWS for the Final Coordination Act Report, Alternative #11 was the selected plan. After receipt of the Final Coordination Act Report, the Corps re-evaluated these wetland restoration increments and selected Alternative #18 as the Recommended Plan, which now includes the wetland restoration increments and is better aligned with recommendations from USFWS.

5.5 Real Estate Considerations

Approximately 105 parcels of varying sizes and public/private ownership lie within the project footprint of the recommended plan. Based on the Gross Appraisal, dated February 4, 2015, the real estate values for the affected lands of the project total $1,467,000 (not including contingency).

As discussed in Section 5.11.1, the primary non-Federal Sponsors for the project are Mason County and the Skokomish Indian Tribe. The Washington State Department of Natural Resources (WDNR) has also indicated their willingness to be a co-signer of the Project Partnership Agreement (PPA) for the sole purpose of providing the Skokomish riverbed land (RM 9-11) in fee. As a result, the realty interests identified for the required project lands consist of standard estates, i.e., Fee Simple, Perpetual Road Easement, Channel Improvement Easement, and Temporary Work Area Easement.

5.6 Cost Estimate

Based on October 2014 price levels, the estimated total project first cost is $19,343,000, which includes monitoring costs of $374,000 and adaptive management costs of $127,000. The fully funded cost estimate to the midpoint of construction is $21,712,000. In accordance with the cost share provisions in Section 103(c) of WRDA of 1986, as amended {33 U.S.C. 2213(c)}, the Federal share of the total project cost is estimated to be $12,573,000 and the non-Federal share is estimated to be $6,770,000, which

equates to 65% Federal and 35% non-Federal. The non-Federal costs include the value of lands, easements, rights of-way, relocations, and dredged or excavated material disposal areas (LERRD) estimated to be $1,687,000, or 9% of total project cost. Table 5-3 outlines the project first costs of the recommended plan.

Table 5-4 displays the cost share of the recommended plan.

Table 5-3. Recommended Plan Cost Summary (October 2014 price level)

	Total Estimated First Cost (October 2014 price level)
Construction Item	
01 Lands & Damages (LERRD)	$1,687,000
Elements	
06 Fish & Wildlife Facilities	$12,806,000
06 Monitoring	$374,000
06 Adaptive Management	$127,000
Subtotal	***$14,994,000***
30 Planning, Engineering and Design (PED)	$2,545,000
31 Construction Management	$1,804,000
Total Estimated Cost	**$19,343,000**

Table 5-4. Project Cost Share of Recommended Plan (October 2014 price level)

	Federal ($1,000s)	Non-Federal ($1,000s)	Total ($1,000s)
Ecosystem Restoration			
Lands & Damages		$1,687	$1,687
Fish & Wildlife Facilities	$12,806		$12,806
Monitoring & Adaptive Management	$501		$501
Planning, Engineering & Design	$2,545		$2,545
Construction Management	$1,804		$1,804
Cash Contribution/Reimbursement	($5,083)	$5,083	$0
Total Project Cost Share	**$12,573**	**$6,770**	**$19,343**
Total Project Cost Share (%)	***65%***	***35%***	***100%***

5.7 Monitoring and Adaptive Management*

The Corps' Implementation Guidance for Section 2039 of the Water Resources Development Act (WRDA) of 2007 defines monitoring as "the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits" (USACE 2009a). Even the most strategically planned restoration actions can yield unexpected results. Monitoring

includes documenting and diagnosing these results especially in the early, formative stages of a project, providing information useful for taking corrective action. In this way, monitoring reduces the risk of failure and enables effective, responsive management of restoration actions.

The Monitoring and Adaptive Management Plan (Appendix E) provides a plan for evaluating the effectiveness of proposed restoration actions and for developing corrective actions if management measures are not meeting performance metrics. At the state of project planning during which the monitoring plan was written, the tentatively selected plan that went through feasibility-level design was used for the description of monitoring methods and potential adaptive management efforts. Refinements can be made during the PED phase concerning the exact project features, monitoring elements, and adaptive management opportunities. Proposed monitoring protocols follow those used in monitoring other restoration projects in Puget Sound and the Pacific Northwest (Heitke et al. 2010, Crawford 2011).

Effectiveness monitoring provides data to determine whether projects are meeting their objectives. The Corps will use decision criteria to evaluate project performance for the degree of success, or for the need for corrective actions. Details and uncertainties will be addressed in PED phase, and refinements can be made to this monitoring and adaptive management plan, including a revised cost estimate.

The plan outlines a 10-year monitoring period per guidance associated with the Water Resources Development Act of 2007. As described in Section 5.12, there is residual risk of channel migration beyond a 10-year period after construction. To maintain ecological performance after the initial 10-year monitoring and adaptive management period, LWD structures and/or minor channel excavations could be used to maintain the South Fork diversion and an actively flowing channel. In addition, LWD structures could also be used to supplement habitat in the river. These types of activities could supplement the scope of the monitoring and adaptive management plan and could be presented in a long-term monitoring and adaptive management plan. However, any additional monitoring required beyond 10 years will be a non-Federal responsibility. The Corps will continue to provide recommendations for monitoring and adaptive management timeline, activities, and budget with the cost-sharing non-Federal sponsors as needed.

5.8 Summary of Cumulative Effects of the Recommended Plan (Agency Preferred Alternative)*

The overall cumulative effects of the recommended plan would be synergistic benefits to all aquatic species through process-based restoration in the lower Skokomish River. The benefits of increasing the number and size of in-channel pools, placing enough LWD to mimic quantities in nearby more natural rivers, reconnecting aquatic habitats in the adjacent floodplain, and greatly increasing the acreage of riparian zones and wetlands along the river will provide significant benefits to fish and wildlife habitat, especially for salmon species. As an indicator species in Pacific Northwest ecosystems, the Corps assumes benefits to salmon would accrue for all other fish, wildlife, and plants in the study area. A synergistic effect is expected because salmon are also a keystone species that over 100 other fish, wildlife, and invertebrate species benefit from directly. These benefits would combine with the more than 1,000 acres of restored estuarine habitat at the downstream end of the study area, as well as the improving forested habitat in the upper watershed; the estuarine and upper watershed restoration

actions are led by other local, State, or Federal entities and complement the Corps' preferred alternative. The reach of river proposed for restoration in this feasibility study is a critical link between these habitats.

5.9 Summary of Environmental Consequences*

The following sections summarize the analysis provided in Chapter 4 on the potential environmental effects from implementation of the recommended plan (agency preferred alternative).

5.9.1 Unavoidable Adverse Environmental Effects

To facilitate the construction of all of the proposed restoration measures of the recommended plan, some adverse environmental effects, most only temporary, could occur within the project area. The following list summarizes adverse environmental effects that are more fully described in Chapter 4:

- Temporary, minor, and localized degradation of water quality from increases in turbidity during in-water work.
- Temporary, minor disturbance to fish and aquatic insects through increased turbidity and construction activity in the water.
- Temporary clearing of upland and riparian vegetation for access and staging areas.
- Fill of up to 5 acres of wetland where wetland embankments are constructed, which is offset by a net gain of 51 acres of wetlands by these increments; plus another 1 acre of disturbance to wetlands for the Side Channel Reconnection inlet
- Temporary and localized disruptions to traffic caused by construction vehicle access to worksites.

5.9.2 Irreversible and Irretrievable Commitment of Resources

The environmental analysis includes identification of "any irreversible and irretrievable commitments of resources, which would be involved in the preferred alternative should it be implemented." This clause in NEPA refers to the use of nonrenewable resources and the effects that the use of these resources have on future generations. Irreversible effects primarily result from use or destruction of a specific resource (e.g., energy and minerals) that cannot be replaced within a reasonable period. Irretrievable resource commitments involve the loss in value of an affected resource that cannot be restored because of the action (e.g., extinction of a species or the disturbance of a cultural site).

As an ecosystem restoration project, the proposed Federal action is designed to have little or no irreversible and irretrievable commitment of resources. The recommended plan would result in an irreversible use of fossil fuels to execute the construction of the habitat restoration. Machinery types were estimated during the cost estimate work for the alternatives analysis and these are listed in Table 4-3 in Chapter 4. All construction effects are assumed to be short-term reductions in fish, aquatic insect, and plant resources, which would recover their abundances in a relatively short period.

5.9.3 Relationship between Short-Term Uses and Long-Term Productivity

Chapter 4 of this document evaluates the direct, indirect, and cumulative effects that could result from the alternatives. The environmental analysis also looks at the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity. For the

recommended plan, "short-term" refers to the temporary phase of construction of the proposed project, while "long-term" refers to the 50-year period of analysis of the proposed project and beyond.

Construction of the recommended plan would result in minor, short-term construction-related impacts within small parts of the project area and would include to some extent interference with local traffic, minor limited air emissions, and increases in ambient noise levels, negligible disturbance of fish and wildlife, and increased turbidity levels. These impacts would be temporary and would occur only during construction, and are not expected to alter the long-term productivity of the natural environment.

The recommended plan would enhance the long-term productivity of the natural communities throughout the study area by facilitating the growth and productivity of riparian zones and wetlands and the invertebrates, fish, and wildlife that use these habitats. The recommended plan would improve the critical habitat limiting factors for salmonids. Benefits to fish populations would have long-term benefits for recreational and tribal fishing in the study area. Long-term beneficial effects of the recommended plan would vastly outweigh the short-term impacts caused by construction activities.

5.9.4 Areas of Controversy and Unresolved Issues

The recommended plan has no unresolved issues that must be addressed prior to construction. A significant proportion of public comments submitted at the public scoping meeting indicated that flood risk reduction is a major concern for Skokomish Valley residents. Since that time, an unfavorable cost-benefit analysis led to removal of the flood risk management portion of the feasibility study. Valley residents continue to request government action to alleviate flooding problems in the valley. The proposed Federal action and alternatives analyzed in this FR/EIS focus only on the ecosystem restoration problems and opportunities.

As described in Section 3.10, landowner input during the feasibility-level design phase led the study team to remove increments from the tentatively selected plan based on insurmountable real estate or access issues that had not manifested earlier in the analysis. While landowners are generally supportive of the remaining increments included in the recommended plan, the Corps and non-Federal sponsors will continue to coordinate with landowners as designs are finalized in the PED phase.

5.10 Mitigation for Adverse Environmental Effects*

No compensatory mitigation is included in the recommended plan as none is required. This section summarizes efforts to avoid and minimize the minor effects of the proposed construction. Implementation of the recommended plan would involve three ecosystem restoration sites with only minor construction activities in the aquatic environment, primarily for temporary culvert installation for access. Each of the proposed sites would have negligible, short-term construction related effects. All of these minor and temporary effects can be avoided and minimized through construction designs and standard best management practices (BMPs). Specific measurable and enforceable measures would be developed for each site based on the specific effects of the project. The Corps would require construction contractors to adhere to BMPs to protect water quality. Standard construction stormwater BMPs can be incorporated into site designs, operational procedures, and physical measures on site. There are no legal requirements to mitigate for GHG emissions; however, BMPs are available for fuel and material conservation during construction.

5.11 Implementation Requirements and Permits

The following sections outline the requirements for implementation of the recommended plan.

5.11.1 Non-Federal Sponsor

Mason County and the Skokomish Indian Tribe are the cost-sharing non-Federal sponsors of the study. Both sponsors have provided letters of reaffirmation indicating their support of the recommended plan, as well as statements of financial capability to partner with the Corps in PED and construction activities. The Corps will request additional letters of intent prior to execution of a design agreement (DA) and project partnership agreement (PPA).

The Washington State Department of Natural Resources (WDNR) claims ownership of the riverbed for River Mile 9-11 of the Skokomish River. As a result, WDNR has indicated that they will be a co-signatory of the PPA for the sole purpose of providing aquatic lands associated with the Upstream Large Woody Debris project increment.

5.11.2 Institutional Requirements

The schedule for project implementation is dependent on project authorization. After project authorization, the project would be eligible for construction funding. The project would be considered for inclusion in the President's budget based on national priorities, magnitude of the Federal commitment, economic and environmental feasibility, level of local support, willingness of the non-Federal partner to fund its share of the project cost, and the budget constraints at the time of funding. Once Congress appropriates Federal construction funds (earliest anticipated fiscal year is 2017), the Corps and the non-Federal partner(s) would enter into a DA and eventually a PPA. The DA would define the Federal and non-Federal responsibilities for completion of final designs for the project. The PPA would define the Federal and non-Federal responsibilities for implementing, operating, and maintaining the project.

5.11.3 Operation, Maintenance, Repair, Rehabilitation, and Replacement Requirements

After completion of construction, the non-Federal sponsor(s) will assume O&M responsibility for the entire project footprint. The non-Federal sponsor is responsible for all long-term project operations, maintenance, repairs, replacements, and rehabilitations following completion of construction. O&M costs have been estimated for the base measure and increments recommended in the proposed plan.

Aiming for process-based restoration, in which human-made stressors are removed from the landscape, has an inherent goal of no O&M costs. The features included in the recommended plan are intended to be environmentally self-sustaining. The recommended plan does not require specific channel forms or habitats to be maintained over the project life, thus avoiding the need for frequent O&M to correct minor changes. Based on feasibility-level designs and associated modeling, it is assumed that the recommended plan will require minimal maintenance only (approximately $10,000 per year) with O&M activities focusing on minor inspection of the upstream LWD features and periodic maintenance of the wetland embankments at the River Mile 9 and Grange wetland restoration sites. As described in Section 4.3.1.2 and 4.3.3.2, the combined discharges of the North and South Forks would be enough water to provide continuous surface flows during the late summer low flow period. It is anticipated that the new

channel will aggrade, eventually meandering across the floodplain. This natural meandering process will develop a complex series of stream habitats that will be beneficial to salmon and other fish. This base is designed to work with natural river processes (including aggradation) to provide habitat benefits. As described in Section 5.12 below, future aggradation is not expected to be detrimental to project goals; therefore, it is anticipated that limited O&M will be required to maintain the new combined North Fork/South Fork channel near the confluence levee removal as well as the reconnected wetland areas. Detailed O&M manuals will be developed for each site during the PED phase.

5.11.4 Schedule

The Corps will officially request the non-Federal partner(s) to acquire the necessary real estate immediately after the signing of the PPA. The advertisement of the construction contract will follow the certification of the real estate. The final acceptance and transfer of the project to the non-Federal partner(s) will occur after delivery of an operations and maintenance manual and as-built drawings.

5.12 Risk and Uncertainty

The PDT has used a risk and uncertainty-based strategy in their approach to formulating the project from the early stages of the study. Risks and uncertainties associated with the formulation of alternatives, development of conceptual designs and cost estimates, quantification of environmental benefits, and assumptions associated with selection of a recommended plan are captured in the study's risk register. Key risks or uncertainties associated with the recommended plan include the following, along with the strategy to reduce risk as the study continues:

Quantities for Wetland Embankment Measures

Risk and Cause: Given the results of the supplemental cost effectiveness and incremental cost analyses performed for the two wetland embankment sites at River Mile 9 and Grange (summarized in Section 3.7.4), it is likely that the optimum embankment height necessary to achieve the ecosystem restoration function falls within the range of heights between a small-scale (average height of 2-4 feet) increment and original recommended plan (average height of 5-6 feet) increment. The elevation change for the embankment increments of 2 to 3 feet, on average, between the current recommended embankment height and the lower scale embankment height is within the margin of error of the existing terrain data used to develop the embankment heights.

Evaluation: The Cost Schedule Risk Analysis (CSRA) for the project has identified risks associated with the variability in existing survey/LIDAR data with varying resolution (ranging approximately 6 to 10 feet depending on location and density of vegetative cover). Cost contingencies reflect the uncertainty in optimized wetland embankment height, quantities of material required for construction, and PED costs to include additional survey and hydraulic analysis to refine the size and scale of the measures.

Future Risk Management: Additional survey data and LIDAR will be obtained during the PED phase. Additional hydraulic modeling will also be conducted to refine the optimum embankment elevations to achieve the desired ecosystem functions. PED costs include estimates for both

obtaining new survey data and performing necessary engineering analysis to refine the wetland embankment elevation.

Aggradation and Future Channel Migration

Risk & Cause: Sediment deposition is one of the key considerations for project sustainability. Sediment deposition is expected to continue to aggrade the channels of the mainstem and South Fork Skokomish Rivers, as sediment is transported to the lower rivers throughout the project life. Future aggradation may cause channel migration in the study area.

Evaluation: The study team completed 2-dimensional hydraulic modeling of the entire study area, 1-dimensional sediment transport modeling of the confluence area, and sediment transport analysis of the reconnected wetland areas during feasibility-level design.

Results: As described in Section 4.3.2.2., deposition in the combined North Fork/South Fork channel is expected to be around 0.1 foot/year, which is similar to that in the existing South Fork channel. Over time, the channel is expected to aggrade and meander across the 1,000 to 2,000 foot wide northern floodplain. Spreading deposition across the northern floodplain would reduce the initial deposition rate, resulting in a long term deposition rate of approximately 0.02 foot/year (or approximately 1 foot during the 50-year project life). This would result in an active riverbed 2-4 feet lower than the existing South Fork channel at the end of the 50-year period. Over a long-term analysis (10-50 years), the natural migration of the new channel will renew channel habitats and recruit new LWD to the channel. This natural meandering process will develop a complex series of stream habitats that will be beneficial to salmon and other fish.

As described in Section 5.11.3, the confluence levee removal aims to provide year-round fish passage by removing a human-made stressor (the Confluence Levee) from the river. The goal of this action is to provide a continuous flowing channel that will evolve naturally over time. No specific channel forms or habitats are required to be maintained over the project life. Only minimal O&M is expected to be required because 1 foot, or even 2 feet, of sediment accumulation will not cause the river to move away from the new mainstem channel as the existing South Fork riverbed will remain 2-4 feet above the new channel. For this area, the likelihood of unacceptable deposition occurring was determined to be low or none.

The Confluence Levee removal would greatly reduce the risk of the avulsion to the south near RM 9. To further reduce this risk, a large levee could be constructed along the south side of the river between RM 7 and 11. The levee would confine the river to the new mainstem channel, regardless of rate or amount of sediment deposition. However, this would result in a large takings area due to the transfer of floodwaters within the Skokomish Valley and would not achieve the process-based restoration goals established by the study team. Thus, inclusion of a large levee as a feature to minimize risk of future aggradation or channel migration is not recommended.

Maintenance to include sediment removal is not anticipated to be required at the Grange or River Mile 9 Wetland Restoration sites. The majority of bedload (i.e. gravel, cobbles, and boulders) will pass through the diversion to the re-connected North and South Forks, thereby bypassing the reach

where the proposed wetland restoration sites are located. The probability of aggradation resulting from movement of fine material (i.e., smaller than gravel, cobbles, and boulders) into the re-connected wetland areas at Grange and River Mile 9 is very low; 2D modeling indicates that flows will keep these fine sediments mobile, reducing the likelihood of aggradation in the wetland restoration areas.

The Side Channel Reconnection inlet is elevated above the riverbed to avoid the bedload transport. There may be some suspended sediment deposition near the side-channel entrance, but this should require only infrequent O&M action, which is accounted for in the existing O&M estimate (approximately $10,000 per year).

Summary: Even with continued sediment accumulation, the study team has determined that residual risk to long-term accrual of environmental benefits associated with the recommended plan within the study area is low. In addition, the risk of an avulsion to the south near RM 9 is greatly reduced in the with-project condition.

Future Risk Management: Monitor the project; implement adaptive management strategies as needed.

Landowner Willingness

Risk & Cause: There may be unwilling landowners located within the project footprint.

Future Risk Management: Continue formal and informal landowner outreach; refine construction footprints based on real estate needs.

Cushman Dam Settlement Agreement / Future Actions Required of Tacoma Power

Risk & Cause: Based on future technical and procedural findings, Tacoma Power may be required to implement restoration or flood risk management actions within the Corps' study area in the future. Because these actions have not been identified or determined to be necessary, and are not specifically described, the future with-project condition and future without-project condition remains somewhat uncertain.

Evaluation: The assumptions for project conditions are described in this report and will be revisited as future actions by Tacoma Power are confirmed (refer to Sections 2.6 and 4.2 for additional information regarding the Cushman Dam Settlement Agreement).

Summary: Potential future action(s) taken by Tacoma Power as the result of technical and procedural findings are not likely to negatively impact the success or function of the recommended plan, as Tacoma Power is required to seek comments and recommendations from the Corps to ensure that any future actions will be complementary to the recommended plan and will not affect the success or benefits accrued from the Federal (Corps) project. Additionally, provisions in the Cushman Settlement limit the financial obligations for future action by Tacoma Power, so future activities would likely be smaller in scale and have only localized effects that are not expected to negatively affect the recommended plan.

Future Risk Management: Continue close coordination with the Skokomish Indian Tribe and Tacoma Power.

5.13 Complementary Restoration Actions for Local Implementation

There is a strong, united effort by Federal, State, and local agencies as well as the Skokomish Indian Tribe for restoration of the Skokomish River Basin. Various Federal and State agencies as well as local entities are working within their individual authorities and within specific areas of the Basin to implement restoration activities throughout the upper and lower watersheds. Section 4.2 outlines present and future actions to restore the Skokomish River Basin; these actions are compatible with the Corps' recommended plan and capture synergies associated with process-based restoration.

Through ongoing collaborations, the Corps and non-Federal sponsors have continually reviewed all potential options for restoration work across the entire basin. This collaboration and coordination among the Corps, Mason County, Skokomish Indian Tribe, and key stakeholders/landholders will continue to ensure any future proposed actions will not negatively affect the recommended plan. The Corps and non-Federal sponsors are continuing to coordinate both formally and informally to ensure the sustainability of all proposed restoration projects within the Skokomish River Basin. To ensure the sustainability of the recommended plan, best practices have (and will continue to be) encouraged and/or required. For example, modern State and Federal forestry regulations require environmentally sound logging practices that will limit any adverse impacts to the recommended plan. The Cushman Settlement Agreement provides a new flow regime intended to improve the North Fork and main stem environments and does not contain any provisions that would reduce the benefits of the recommended plan. Project landowner agreements will also contain provisions to support the sustainability of the recommended plan. The Corps and Non-Federal sponsors will continue to assess the applicability of legal and policy mechanisms (e.g., memoranda of understanding) and will seek to implement these types of mechanisms if applicable in the future.

In addition to the proposed present and future restoration projects outlined in Chapter 4, the study team, non-Federal sponsors, local and regional stakeholders, and the public identified approximately 60 specific sites within the study area where one or more measures could address various limiting factors. As Section 3.3 describes, sites were selected based on locations of severe degradation, physical features that will provide an opportunity to improve types of degradation, access, and consideration of other complementary proposed projects outside the range of the feasibility study. These proposed projects are generally smaller in scale and could be easily implemented by a local entity. These projects are generally compatible with the Corps' recommended plan and further restore the structures, functions, and processes of the Skokomish River. Members of the Corps PDT will continue to be available to Mason County and the Skokomish Indian Tribe to ensure any proposed actions will not adversely affect the Federal investment in restoration of the Skokomish River Basin.

Finally, the recommended plan is one element of an integrated restoration effort in the entire Skokomish River watershed. The recommended plan recommends restoration of the lower Skokomish River, which is complementary to, yet independent from, restoration actions in the upper watersheds (the Upper South Fork and North Fork) and estuary. Attainment of benefits associated with the

recommended plan is not dependent on restoration activities led by the USFS in the Upper South Fork. Similarly, implementation of proposed flow regimes at Cushman Dam, construction of fish passage facilities or hatcheries in the North Fork, or other activities required by the Cushman Settlement are independent of the Federal action, but will complement the recommended plan. The synergistic efforts of those involved in restoration of the entire Skokomish River watershed will produce positive, cumulative effects across the Basin.

6. Compliance with Environmental Statutes

This chapter provides documentation of how the recommended plan (agency preferred alternative) complies with all applicable Federal environmental laws, statutes, and executive orders.

6.1 National Environmental Policy Act

The National Environmental Policy Act (NEPA) (42 U.S.C. §4321 et seq.) commits Federal agencies to considering, documenting, and publicly disclosing the environmental effects of their actions. NEPA documents must provide information regarding the proposed action and alternatives, the environmental impacts of the alternatives, appropriate mitigation measures, and any adverse environmental impacts that cannot be avoided if the agency implements the proposal. Agencies are required to demonstrate that decision makers have considered these factors prior to undertaking actions, which is documented in signing a Record of Decision for Environmental Impact Statements such as this one. The FR/EIS is the primary vehicle to achieve NEPA compliance for the proposed project. Before preparing the Draft FR/EIS, the Corps published a Notice of Intent to prepare an EIS in the Federal Register on 24 September 2010, and held a public scoping meeting 7 October 2010. The Corps published the Draft FR/EIS for a 45-day public comment period that ran from February 21 through April 7, 2014. All public comments received appear with Corps responses in Appendix M. Following publication of this Final version of the FR/EIS and a 30-day wait period, the Assistant Secretary of the Army for Civil Works will sign a Record of Decision, while the Chief of Engineers will sign the Corps-required Chief's Report.

6.2 Endangered Species Act of 1973

The Endangered Species Act (ESA) (16 U.S.C. §1531-1544), Section 7(a) requires that Federal agencies consult with the NMFS and USFWS, as appropriate, to ensure that proposed actions are not likely to jeopardize the continued existence of endangered or threatened species or to adversely modify or destroy their critical habitats. The Corps coordinated with NMFS and USFWS to ensure the protection of those threatened and endangered species under their respective jurisdictions and to anticipate potential negative effects that may result from the project.

The proposed Federal action is compliant with ESA based on two separate Programmatic Biological Opinions. Project designs incorporate all necessary components to comply with the requirements of the Programmatic Biological Opinion for Fish Passage and Restoration Projects (FPRP) issued in 2008. For species under the jurisdiction of USFWS, the Corps submitted a Specific Project Information Form and received a verification letter on February 20, 2015 that the project is compliant with the FPRP Biological Opinion.

For species under the jurisdiction of NMFS, approval authority is granted to the State of Washington in the ESA Section 4(d) Rule, Limit 8 Programmatic Biological Opinion (See Appendix L for approval authority) for projects in the State's Habitat Restoration Program (HRP). The Corps received a letter from NMFS dated February 3, 2015 confirming their approval of the HRP under the ESA Section 4(d) Rule, Limit 8, as administered by the Washington Recreation and Conservation Office (RCO). NMFS also stated their agreement that the project fits within the HRP. The Corps certifies that the project is

consistent with all of the elements of the Habitat Restoration Program 4(d) Rule, Limit 8 Programmatic Biological Opinion and communicated this to the Washington Recreation and Conservation Office. The project occurs within the Puget Sound Salmon Recovery Region covered in this Biological Opinion, and the proposed Federal action is listed in the Mid Hood Canal Chinook Recovery Planning Chapter of the Puget Sound Salmon Recovery Plan. The Corps received a letter from the Washington Recreation and Conservation Office on February 17, 2015 providing their approval of the project's ESA coverage under the 4(d) Limit 8 Programmatic Biological Opinion. See Appendix L for compliance documents.

6.3 Clean Water Act of 1972

The project is in compliance with the Clean Water Act.

Section 401 – Any project that requires a Federal license or permit, which may result in any discharge into waters of the United States or wetlands, or mechanized clearing of wetlands, requires a water quality certification from the State agency or from EPA. For the Upstream LWD, Confluence Levee removal, wetland restoration sites with construction of wetland embankments, and the inlet channel of the Side Channel Reconnection components of the recommended plan, WDOE has Section 401 authority. The outlet channel of the Side Channel Reconnection project component is entirely on Skokomish Indian Tribe reservation land and is therefore under the jurisdiction of EPA.

This project will have approximately 6 acres of wetland fill and vegetation disturbance to construct the new wetland embankments at the wetland restoration sites at Grange and River Mile 9 and to excavate the inlet channel at the Side Channel Reconnection. Individual Section 401 review is required for the Corps to obtain a 401 Water Quality Certification.

The Corps coordinated the feasibility level design of all project components with WDOE including via meeting invitations, e-mail consultations for construction methods to protect water quality, and a site visit to determine extent of wetland impacts. The feasibility-level designs include standard BMPs to protect water quality and these are accounted for in the cost estimate. Based on experience with the standard methods in the proposed design, there is no expectation for costs of water quality protection to substantially increase due to any conditions that may appear in the 401 certification. All proposed construction components and methods are standard ecosystem restoration methods used in Pacific Northwest ecosystems.

The Corps verified with WDOE that all standard project design documentation (e.g. NEPA document, 95% design drawings, water quality monitoring plan) are required for their review to certify that State water quality standards will not be violated. The Corps will continue to coordinate project designs with WDOE and provide all necessary documentation to WDOE and EPA as it is developed during PED phase. These documents will be prepared in advance of finalizing PED, which will ensure that the Corps obtains Section 401 Water Quality Certification from both agencies well in advance of signing the Project Partnership Agreement. All applicable water quality standards will be met.

Section 402 – The National Pollutant Discharge Elimination System (NPDES), controls discharges into waters of the United States. NPDES permits contain industry-specific, technology-based, and/or water-quality-based limits, and establish pollutant monitoring and reporting requirements. EPA has established

a program to address stormwater discharges. These regulations require that facilities or construction sites with stormwater discharges from a site that is one acre or larger apply for an NPDES permit.

The proposed Federal action will have greater than one acre of temporary clearing for construction and will therefore require obtaining a Section 402 NPDES permit. The Corps will fulfill this obligation by obtaining a Construction General Stormwater Discharge Permit during PED phase prior to construction when the site-specific environmental protection plans are developed. These plans include a Diversion and Care of Water Plan, Spill Prevention and Clean-up Plan, and a Temporary Erosion and Sedimentation Control Plan. The Section 402 permit requires identification of the Certified Erosion and Sedimentation Control Lead personnel, which is not identified until immediately prior to construction and is therefore not available in feasibility phase.

Section 404 – The Corps administers regulations under Section 404(b)(1) of the Clean Water Act, which establishes a program to regulate the discharge of dredged and fill material into waters of the U.S., including wetlands. The Corps has evaluated potential project-induced effects subject to these regulations during feasibility-level design. Appendix L includes a completed 404(b)(1) evaluation.

6.4 Coastal Zone Management Act of 1972

The Coastal Zone Management Act (CZMA) of 1972 as amended (16 U.S.C. §1451-1464) requires Federal agencies to carry out their activities in a manner that is consistent to the maximum extent practicable with the enforceable policies of the approved State Coastal Zone Management Program (CZMP). The aim of the act is to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone." Ecology is the agency in the State of Washington that has an approved CZMP, therefore Ecology has authority for Federal consistency review with the 15 coastal counties. In compliance with State law, Mason County has developed its own Shoreline Master Program under the State Shoreline Management Act. The project is fully consistent with the enforceable polices of Mason County's Shoreline Master Program. The Corps prepared a CZMA Consistency Determination during feasibility-level design phase according to the relevant county code (see Appendix L).

The Corps will submit the CZMA Consistency Determination to WDOE for their review at the same time as submission of all of the documents required for Clean Water Act Section 401 review. WDOE's concurrence with the CZMA Consistency Determination is contingent upon receipt of a 401 Water Quality Certification. The Corps will continue coordination with WDOE throughout PED to ensure the project meets requirements for 401 certification as a prerequisite for WDOE concurrence on the CZMA Consistency Determination.

6.5 Clean Air Act of 1972

The Clean Air Act (CAA) as Amended (42 U.S.C. §7401, et seq.) prohibits Federal agencies from approving any action that does not conform to an approved State or Federal implementation plan. Three agencies have jurisdiction over air quality in the project area: EPA, WDOE, and the Olympic Region Clean Air Agency. The EPA sets standards for concentrations of pollutants in outdoor air and the State establishes regulations that govern contaminant emissions from air pollution sources.

The air-pollutant concentrations in the study area are consistently below the National Ambient Air Quality Standards. Mason County (which includes the study area) does not have a non-attainment area. Air quality for the study area is rated 8.8 on a scale of 0 to 10 where 10 is the best indicator of air quality. Proposed action alternatives are predicted to have a negligible contribution to pollutants; however, the effect would be only during construction and would not be expected to exceed the ecological or human tolerance standards, nor change the rating of 8.8. Construction activities associated with the NER plan will create air emissions, but the emissions are not expected to affect implementation of Washington's CAA implementation plan and would have no lasting effect on the study area. The Corps' assessment is that the Recommended Plan will have temporary and minor effects, but no substantial impact.

6.6 National Historic Preservation Act of 1966

The National Historic Preservation Act (NHPA) and its implementing regulations 36 CFR §800 provides a regulatory framework for the identification, documentation, and evaluation of cultural resources that may be affected by Federal undertakings. Under the Act, Federal agencies must take into account the effects of their undertakings on historic properties (cultural resources that have been found to be eligible for listing in the National Register of Historic Places) and afford the Advisory Council a reasonable opportunity to comment on such undertaking. Additionally, a Federal agency shall consult with any tribe that attaches religious and cultural significance to such properties.

To meet the Agency's responsibilities under NHPA, the Corps consulted with the Washington State Historic Preservation Officer (SHPO) and the Skokomish Indian Tribe. In addition, the Corps conducted a cultural resources survey of project components for the TSP. Due to the majority of the project components occurring on privately owned property, the cultural resources survey was only conducted on property where landowners had signed rights of entry. The cultural resources survey conducted in January 2015 did not identify any significant cultural resources. Based on the Corps' internal guidelines for flood control systems and structures, the Corps has determined that the Confluence Levee and the River Mile 9/Grange agricultural berm are not eligible for listing on the National Register of Historic Places (NRHP). Though the Confluence Levee is fifty years of age, this levee is a ubiquitous type of levee and is not distinguished for its engineering value. In addition, the Confluence levee shows clear loss of essential integrity due to loss of linear continuity due to breaches and it is experiencing erosion. While the Confluence levee was built to protect agricultural fields from flooding, this levee did not play a central role in the agricultural development of the Skokomish River Valley. Finally, the Confluence Levee does not provide additional information beyond what is already known.

The Corps has determined a finding of *no historic properties affected* and will require monitoring during construction for the Side Channel Reconnection locations at RM 4 and RM 5.6. The placement of the Upstream LWD will be within the current Skokomish River channel. Proposed access routes currently include private property and will be finalized during PED phase. The Corps will conduct a cultural resources survey when the proposed locations of the Upstream LWD and access routes are finalized in PED. The Corps began consulting with the Washington SHPO in November 2013. At that time, the Corps was in the process of identifying the TSP and invited the SHPO to participate in the preparation of a Programmatic Agreement (PA). At that time, the Corps believed that a PA would be the most

appropriate course of action. Over the course of feasibility-level design development, the Corps had the opportunity to conduct cultural resources fieldwork. On February 9, 2015, the Corps sent a letter to the Washington SHPO that provided project updates, the results of the cultural resources fieldwork and provided the Corps determination of *no historic properties affected* with monitoring required during construction. In addition, the Corps informed the SHPO that future cultural resources surveys will be conducted (if necessary) as the project moves forward for areas where the project will affect private landowners. The SHPO concurred with the Corps determination of *no historic properties affected* in a letter dated February 10, 2015 and requested a draft of the monitoring plan for review prior to the start of construction (Appendix L). In addition, the Corps sent a letter on February 9, 2015 to the Skokomish Indian Tribe that provided project updates and described the results of the cultural resources survey. The Skokomish Indian Tribal Historic Preservation Officer responded by email on February 18, 2015 and concurred that no historic properties would be affected and agreed that construction monitoring should take place (Appendix L).

6.7 Federal Trust Responsibility

The Federal trust responsibility to Native American Tribes arises from the treaties signed between them. Under Article VI, Clause 2 of the U.S. Constitution, treaties with the Tribes are the supreme law of the land, superior to State laws, and equal to Federal laws. In these treaties, the United States made a set of commitments in exchange for tribal lands, including the promise that the United States would protect the tribe's people. The Supreme Court has held that these commitments create a trust relationship between the United States and each treaty tribe, and impose upon the Federal government "moral obligations of the highest responsibility and trust." The scope of the Federal trust responsibility is broad and incumbent upon all Federal agencies. The U.S. government has an obligation to protect tribal land, assets, and resources that it holds in trust for the Tribes, and a responsibility to ensure that its actions do not abrogate Tribal treaty rights.

The Skokomish Indian Tribe has had representation in this feasibility study planning phase as one of the two non-Federal sponsors. The study team anticipates that the proposed ecosystem restoration would have significant benefits to ecosystem and fisheries resources, which are of economic and cultural value to the Tribe, and is consistent with the Tribe's treaty rights.

6.8 Executive Order 13175 Consultation and Coordination with Indian Tribal Governments

Executive Order 13175 reaffirmed the Federal government's commitment to a government-to-government relationship with Indian Tribes, and directed Federal agencies to establish procedures to consult and collaborate with tribal governments when new agency regulations would have tribal implications. The Corps has a government-to-government consultation policy to facilitate the interchange between decision makers to obtain mutually acceptable decisions. In accordance with this Executive Order, the Corps has engaged in regular and meaningful consultation and collaboration with the Skokomish Indian Tribe throughout the course of the study.

6.9 Bald and Golden Eagle Act of 1940

The Bald and Golden Eagle Protection Act (16 U.S.C. §668-668c) applies to Corps civil works projects through the protection of bald and golden eagles from disturbance. Construction activities associated

with the proposed actions have potential to disturb bald and golden eagles due to the presence of heavy machinery and elevated noise levels. The Corps will develop an eagle monitoring plan during the next phase of design, and will minimize construction effects by surveying each site for nests and roosts prior to and during construction, and, if nests and/or roosts are nearby, will coordinate with USFWS. Review of the WDFW database of Priority Habitats and Species showed there are no recorded eagle nesting sites within two miles of the project area.

6.10 Fish and Wildlife Coordination Act of 1934

The Fish and Wildlife Coordination Act (FWCA) of 1934 as amended (16 U.S.C. §661-667e) provides authority for the USFWS involvement in evaluating effects to fish and wildlife from proposed water resource development projects. It requires that fish and wildlife resources receive equal consideration to other project features. It requires Federal agencies that construct, license, or permit water resource development projects to consult with the USFWS, NMFS, and State resource agencies regarding the effects to fish and wildlife resources and measures to mitigate these effects. Section 2(b) requires the USFWS to produce a Coordination Act Report that describes fish and wildlife resources in a project area, potential negative effects of a proposed project, and recommendations for a project. The draft report includes the USFWS positions and recommendations. This draft document and a planning aid letter pursuant to FWCA are in Appendix L. The Corps considered these recommendations and implemented further coordination during feasibility level design phase. The design changes are described in this Final FR/EIS and in the Final Coordination Act Report received from USFWS on February 27, 2015, which appears in Appendix L. Subsequent to receiving the Final Coordination Act Report, the Corps reconsidered USFWS' strong recommendation for the restoration plan with a greater scope and have added the wetland restoration increments back into the plan. Further recommendations will be incorporated during the PED phase.

6.11 Magnuson-Stevens Fishery Conservation and Management Act of 1976

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 et. seq.) requires Federal agencies to consult with NMFS on activities that may adversely affect Essential Fish Habitat (EFH). The objective of an EFH assessment is to determine whether the proposed action(s) "may adversely affect" designated EFH for relevant commercial, federally managed fisheries species within the proposed action area. EFH includes those waters and substrate necessary for fish spawning, breeding, feeding, or growth to maturity. The assessment describes conservation measures proposed to avoid, minimize, or otherwise offset potential adverse effects to designated EFH resulting from the proposed action. Although habitat disturbance may have temporary adverse effects to designated EFH for salmonids, the conservation measures that the Corps will include as part of the proposed site design to address ESA concerns have been determined adequate to avoid, minimize, or otherwise offset potential adverse effects to the EFH. The proposed restoration sites would result in long-term benefits to salmonids, but are not anticipated to have any effect on EFH of the coastal pelagic species or groundfish. The Programmatic Biological opinion for ESA Section 4(d) Limit 8 includes the results of the consultation on likely effects on Essential Fish Habitats (EFH) pursuant to Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act. It includes no conservation recommendation. All measures to avoid, minimize, or otherwise offset potential adverse effects to EFH

are already included in the proposed project or as permit conditions. See Appendix L for compliance documents related to ESA Section 4(d) Limit 8.

6.12 Marine Mammal Protection Act of 1972

The Marine Mammal Protection Act (MMPA) of 1972 (16 U.S.C. §1361-1407) restricts harassment of marine mammals and requires interagency consultation in conjunction with the ESA consultation for Federal activities. The preferred alternative would have no effect to marine mammals. In the event that changes in design would affect marine mammals, the Corps would consult with NMFS on effects to marine mammals. The Corps would implement all practicable conservation measures and adhere to a marine mammal monitoring plan as needed.

6.13 Migratory Bird Treaty Act of 1918 and Executive Order 13186 Migratory Bird Habitat Protection

The Migratory Bird Treaty Act (16 U.S.C. §703-712) as amended protects over 800 bird species and their habitat, and commits that the U.S. will take measures to protect identified ecosystems of special importance to migratory birds against pollution, detrimental alterations, and other environmental degradations. EO 13186 directs Federal agencies to evaluate the effects of their actions on migratory birds, with emphasis on species of concern, and inform the USFWS of potential negative effects to migratory birds. Implementation of the preferred alternative will not have any negative effects to migratory bird habitat. Neo-tropical migratory birds that use the forested riparian zone in the river corridor will benefit from any levee removal actions that increase the forested area adjacent to the river. The Corps will continue to coordinate with USFWS through the PED phase.

6.14 Wild and Scenic Rivers Act of 1968

The Wild and Scenic Rivers Act (Public Law 90-542; 16 U.S.C. 1271 et seq.) establishes a National Wild and Scenic Rivers System to preserve, protect, and enhance the wilderness qualities, scenic beauties, and ecological regimes of rivers and streams. Any construction within 100 feet of a scenic stream requires a scenic streams permit. Four sections of the South Fork Skokomish River are designated as "wild", "scenic", or "recreational"; however, these segments are several river miles upstream from the study area. All of the proposed restoration work would occur several miles away in the lower mainstem Skokomish River and would not affect the protected reaches or any aspect of their designations.

6.15 Executive Order 12898 Environmental Justice

Executive Order 12898 directs Federal agencies to take the appropriate steps to identify and address any disproportionately high and adverse human health or environmental effects of Federal programs, policies, and activities on minority and low-income populations. The Corps has analyzed the potential effects of the alternatives on communities in the Skokomish Valley and found that there would be no disproportionately high and adverse human health impacts to any environmental justice communities. Further, the Tribe as a community protected under this Executive Order has been actively engaged in the study and environmental review process.

6.16 Executive Order 11990 Protection of Wetlands

The purpose of Executive Order 11990 is to "minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands". To meet these objectives, the order requires Federal agencies, in planning their actions, to consider alternatives to wetland sites and limit potential damage if an activity affecting a wetland cannot be avoided. The preferred alternative would have the overall effect of enhancing wetlands and increasing their total area in the Skokomish Valley.

6.17 Executive Order 11988

Executive Order 11988 requires Federal agencies to recognize the significant values of floodplains and to consider the public benefits that would be realized from restoring and preserving floodplains. It is the general policy of the Corps to formulate projects that, to the extent possible, avoid or minimize adverse impacts associated with use of the base floodplain and avoid inducing development in the base floodplain unless there is no practicable alternative that meets the project purpose. Per the procedures outlined in ER 1165-2-26 (Implementation of Executive Order 11988 on Flood Plain Management), the Corps has analyzed the potential effects of the recommended plan on the overall floodplain management of the study area. The proposed action is in the base floodplain and there are no practicable alternatives to the action as the entire feasibility study area is within the base floodplain. The public has been advised of the proposed action and the Corps has requested their comments on the recommended plan. Chapter 4 outlines beneficial and adverse effects of the action. A discussion of benefits to natural floodplain values including restoration of fish and wildlife values (e.g., wetlands, marshes, and related natural habitat) is also included in Chapter 4. The action is not likely to induce development in the floodplain, as Mason County already imposes stringent restrictions on development within the study area (refer to Section 2.6 for more information regarding development ordinances). The Corps has recommended the plan that is most responsive to the study's planning objectives and is consistent with the requirements of this Executive Order.

The recommended plan will not cause significant changes in future with-project flood conditions compared to future without-project conditions. Coordination with the Federal Emergency Management Agency (FEMA) is ongoing; the Corps will formally submit a no-rise certificate to FEMA during the PED phase as H&H modeling continues to be refined.

6.18 Farmland Protection Policy Act

Congress passed the Farmland Protection Policy Act (FPPA) because of substantial decreases in farmland acreage. The purpose of the Act is to minimize the extent to which Federal actions contribute to the unnecessary and irreversible conversion of farmland to nonagricultural uses. Projects are subject to FPPA requirements if they may irreversibly convert farmland (directly or indirectly) to nonagricultural use and are completed by a Federal agency or with assistance from a Federal agency. None of the farmland in the Skokomish Valley has been designated as prime and unique farmland under the FPPA.

7. Public Involvement, Review, and Consultation

Stakeholders, agencies, and the public are integral in providing input for defining restoration opportunities, objectives, constraints, and for developing restoration strategies that support development of the range of alternatives to be analyzed for feasibility and environmental compliance. Public involvement activities and agency coordination are summarized in this chapter.

7.1 Public Involvement Process

Corps Planning Policy and NEPA emphasize public involvement in government actions affecting the environment by requiring that the benefits and risks associated with the proposed actions be assessed and publicly disclosed. In accordance with NEPA public involvement requirements (40 CFR 1506.6) and Corps Planning Policy (ER 1105-2-100), opportunities were presented for the public to provide oral or written comments on potentially affected resources, environmental issues to be considered, and the agency's approach to the analysis. Efforts to involve the public included a public scoping meeting, soliciting relevant information from the public, holding a number of informal public meetings, and explaining procedures of how interested parties can get information on the planning process.

7.1.1 Public Scoping Meeting

Scoping is a critical component of the overall public involvement program to solicit input from affected Federal, State, and local agencies; tribes; and interested stakeholders. The scoping process provides early and open means of determining the scope of issues (problems, needs, and opportunities) to be identified and addressed in the DFR/EIS. The Skokomish scoping process was conducted jointly with Mason County and the Skokomish Indian Tribe.

To announce the start of the feasibility phase, a Federal notice of intent (NOI) was issued to residents, Federal, State and local agencies, Tribal governments, and interested groups and was published in the Federal Register on September 24, 2010. The recipients were invited to comment on the results of the earlier completed reconnaissance study and to provide input to the feasibility study, including the scoping of the environmental issues that should be addressed throughout the study. The NOI announced a public scoping meeting, which was held on October 7, 2010 at Mason County Public Works, 100 West Public Works Drive, Shelton, Washington. An open house ran from 4:00 p.m. to 7:00 p.m., with a presentation and opportunity for formal public comment at 5:30 p.m. The public scoping meeting aimed to provide an overview of the Skokomish feasibility study, identify project purpose and need, identify preliminary measures, and describe the NEPA process.

During the comment period, the Corps received 28 comments; three comment forms and one photo were submitted during the scoping meeting, nine verbal comments were given during the scoping meeting, eight letters were mailed, and eight email messages were submitted. Comments included several themes, primarily agriculture, aquatic ecosystem restoration/channel restoration, Cushman Dam, flooding, habitat (specific organisms or animals), and sediment management. A complete list of public comments from the scoping period is contained in Appendix M.

7.1.2 Draft Feasibility Report / EIS Public Review

The public comment period, during which any person or organization may comment on the Draft FR/EIS, is mandated by State and Federal laws. For the Skokomish study, the Draft FR/EIS public comment period ran for 45 days beginning February 21, 2014 and ending April 7, 2014. The Study Team hosted one public hearing in the study area on March 20, 2014. In addition to accepting comments during the public hearings, comments were accepted via mail, fax, and email. The Corps considered all comments received during the comment period. The complete list of comments regarding the Draft FR/EIS and the Corps' responses are included in Appendix M of this Final FR/EIS.

7.2 Agency and Tribal Government Consultation and Coordination Process

Preparation of the Draft and Final FR/EIS was coordinated with appropriate Federal, State, and local interests as well as environmental groups and other interested parties.

7.2.1 Federal Agencies

Several Federal agencies participated in early study activities, particularly in the process of identifying problems and opportunities in the basin. The Bureau of Reclamation has provided information critical to understanding the geomorphology and sediment transport processes of the river. The Corps has briefed the NMFS Restoration Center Northwest on the study as NMFS continues to express interest in the study's progress. The Corps contracted a baseline study through USFWS to conduct biological sampling throughout the study area. Additionally, the Corps coordinated with USFWS in compliance with the FWCA. The Council for Environmental Quality regulations for implementing NEPA encourage agencies to formally agree to "cooperating agency" status, thus ensuring their expertise will be applied when formulating feasible alternative plans. Prior to the Feasibility Scoping Meeting, NMFS and USFWS expressed willingness to consider a cooperating agency role; although they declined upon formal invitation, both agencies remain actively involved in the study.

7.2.2 State Agencies

The Corps has coordinated with the WDFW to seek input on potential restoration projects and has sought information regarding shellfish and eelgrass habitat from the WDNR. Further consultation with WDFW and WDOE occurred during feasibility level design phase to seek their input on maximizing benefits and minimizing impacts of the proposed action. The Corps consulted with the DAHP regarding cultural resources and will conduct monitoring during construction per the SHPO's requirement.

7.2.3 Indian Tribes

The Corps has engaged in formal and informal coordination with the Skokomish Indian Tribe throughout the feasibility phase. The Skokomish Indian Tribe has had a critical role throughout the feasibility study as one of the two non-Federal sponsors (Mason County is the other). Tribal coordination will continue throughout the feasibility phase, PED phase, and construction in accordance with Executive Order 13175 Consultation and Coordination with Indian Tribal Governments.

7.3 Additional Coordination and Consultation

The following Federal and State agencies, tribal partners, and non-governmental organizations have been involved during the feasibility study:

- National Marine Fisheries Service
- U.S. Fish and Wildlife Service
- U.S. Bureau of Reclamation
- Washington Department of Fish and Wildlife
- Washington Department of Natural Resources
- Washington Department of Archaeology and Historic Preservation
- Washington Recreation and Conservation Office
- Washington Department of Ecology
- Puget Sound Partnership
- Washington Salmon Recovery Funding Board
- Northwest Indian Fisheries Commission
- Skokomish Watershed Action Team
- Hood Canal Coordinating Council
- Taylor Shellfish Company
- Green Diamond Resource Company
- Tacoma Public Utilities

7.4 Peer Review Process

In 2011, the PDT developed the Review Plan for the Feasibility Study of the Skokomish River Basin, Mason County, Washington (Peer Review Plan; USACE 2011), which the Corps Ecosystem Restoration Planning Center of Expertise (ECO-PCX) approved. Peer review was designed to meet all pertinent Corps policies (e.g. Engineering Circulars [EC] including EC 1165-2-214; USACE 2012). This plan requires external review of the project's technical reports as well as the Draft and Final FR/EIS. The Skokomish study has adhered to this guidance and completed multiple rounds of District Quality Control (DQC) and Agency Technical Review (ATR) on feasibility phase deliverables. The Draft FR/EIS went through DQC, ATR, and Independent External Peer Review (IEPR). The DQC, ATR, and IEPR reports are submitted with the Final FR/EIS. The IEPR report will also be posted for public access and transmitted to Congressional committee.

In accordance with guidelines set by the Corps for planning and ecosystem output models (e.g., ER 1165-2-501 and EC 1105-2-412, Seattle District requested approval for one-time use of a planning model. The model review plan was submitted to the ECO-PCX in March 2013. The complete model documentation report (Appendix F) has undergone peer review by the ECO-PCX and was approved for one-time use on October 8, 2013.

8. Recommendations

The following language outlines the Corps' recommendations for project approval and authorization for implementation.

I recommend that the recommended plan for ecosystem restoration for the Skokomish River Basin project area as generally described in this report be authorized for implementation as a Federal project, with such modifications thereof as in the discretion of the Commander, USACE may be advisable. The estimated project first cost of the recommended plan is $19,343,000 (October 2014 price level), which includes monitoring costs of $374,000 and adaptive management costs of $127,000. Minimal operations, maintenance, repair, rehabilitation, and replacement (OMRR&R) expenses are estimated at $10,000 per year. The Federal portion of the estimated first cost is $12,573,000. The non-Federal sponsors' portion of the required 35% cost share of total project first costs is $6,770,000. The non-Federal partners shall, prior to implementation, agree to perform the following items of local cooperation:

1. Provide 35 percent of total project costs as further specified below:

   1.a. Provide the required non-Federal share of design costs;

   1.b. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs;

   1.c. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the project;

   1.d. Provide, during construction, any additional funds necessary to make its total contribution equal to 35 percent of total project costs;

2. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds are authorized to be used to carry out the project.

3. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;
4. Shall not use the project or lands, easements, and rights-of-way required for the project as a wetlands bank or mitigation credit for any other project;

5. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;
6. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;
7. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;
8. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;
9. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;
10. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);
11. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal

Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

12. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;
13. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and
14. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

The recommendations contained herein reflect the information available at this time and current departmental policies governing the formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of the national civil works construction program or the perspective of higher levels within the executive branch. Consequently, the recommendations may be modified before they are transmitted to Congress for authorization and/or implementation funding. However, prior to transmittal to Congress, the State of Washington, interested Federal agencies, and other parties will be advised of any significant modifications in the recommendations and will be afforded an opportunity to comment further.

JOHN G. BUCK
Colonel, Corps of Engineers
District Commander

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SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX A

BIOLOGICAL SAMPLING IN THE SKOKOMISH RIVER BASIN

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

U.S. Fish and Wildlife Service

Biological Sampling in the Skokomish River Basin, Washington: Army Corps of Engineers General Investigation

July 2011

By Roger Peters, Zhuozhuo Li, Scott Sanders, Roger Tabor, Carrie Cook-Tabor, and Paul Bakke

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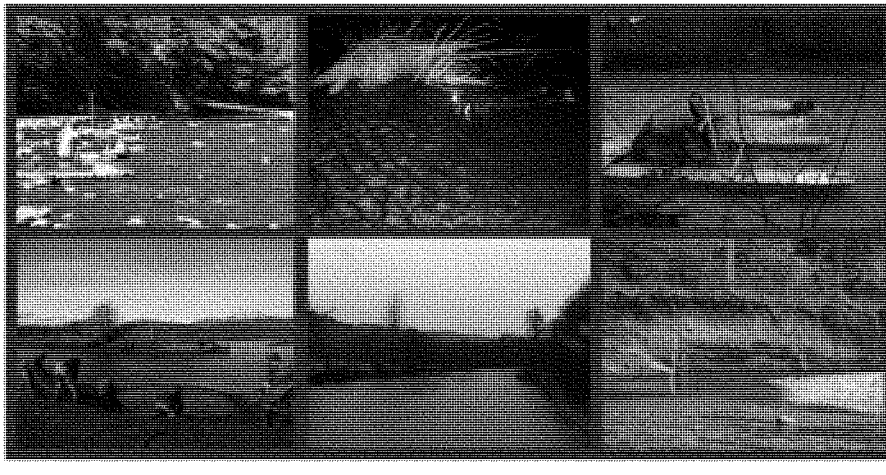

Sponsored by U.S. Army Corps of Engineers, in cooperation with the Skokomish Tribe, Mason County and U.S. Geological Survey

Biological Sampling in the Skokomish River Basin, Washington: Army Corps of Engineers General Investigation

By

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Figure 1. Stream network of the Skokomish Basin along with that portion of the watershed accessible to anadromous salmon (i.e., anadromous zone). Data collection for this project was collected in the anadromous zone and the estuary only, with the exception of one macroinvertebrate and periphyton sample collected above Lake Cushman on the North Fork Skokomish (see Chapter 9). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD). 7

Figure 2. Example of the stable vegetated islands hypothesized to exist in the upper South Fork Skokomish, lower South Fork Skokomish below the Canyon, lower Vance Creek below the Canyon, and lower mainstem just below the North Fork Skokomish confluence. This map shows a vegetated island approximately one mile downstream of the canyon on South Fork Skokomish River (General Land Office) GLO Surveyor map from July 1875). The canyon is located at the top of the map with Vance Creek shown at the bottom of the map (Modified from Skokomish Indian Tribe and WDFW 2010). 16

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Acronyms

AI	Admiralty Inlet
ANOSIM	Analysis of Similarities
AW	Average Water Depth
BC	Braided Channel
BFW	Bankfull Width
B-IBI or BIBI	Benthic Index-of-Biotic-Integrity
BOR	Bureau of Reclamation
BP	Before Present
BVSTEP	A routine in Primer that compares the rank correlation between two triangular similarity matrices.
BW	Backwater
C	Confined channel
CPUE	Catch Per Unit Effort
CSYU	Cooperative Sustained Yield Unit
DO	Dissolved Oxygen
DW	Deep water
ELJ	Engineered Logjam
EMAP	Environmental Monitoring and Assessment Program
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FERC	Federal Energy Regulatory Commission
FWS	U.S. Fish and Wildlife Service
GI	General Investigation Study
GIS	Geographic Information System
GLO	General Land Office
HCB	Hood Canal Bridge
HCCC	Hood Canal Coordinating Council
HSRG	Hatchery Scientific Review Group
HWY	Highway
IBI	Index of Biotic Integrity
JDF	Strait of Juan de Fuca

LDP	Large Debris Pile
LWD	Large Wood
MC	Main Channel
MDS	Multi-dimensional scaling
NF	North Fork (Skokomish River)
NMFS	National Marine Fisheries Service
NNFSF	New North Fork South Fork Skokomish study reach
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelemetric Units
NWIFC	Northwest Indian Fisheries Commission
OC	Overflow Channel
ONFSF	Old North Fork South Fork Skokomish study reach
PCA	Principal Component Analysis
PIT	Passive Integrated Transponder
PMP	Project Management Plan
PNPTT	Point No Point Treaty Tribes
PR	Point of Release
RKM	River Kilometer
RVM	River mile
RM	River Mouth
SASSI	Salmon and Steelhead Stock Inventory
SC	Side Channel
SD	Standard Deviation
SE	Standard Error
SF	South Fork (Skokomish River)
SFV	South Fork (Skokomish) Vance study reach
SSHIAP	Salmon and Steelhead Habitat Inventory
SR	State Route
SW	Shallow Water
TAG	Technical Advisory Group
TMDL	Total Maximum Daily Load
TFW	Timber-Fish-and-Wildlife

U	Unconfined Channel
USACE	U. S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator coordinate system
WDF	Washington Department of Fisheries (currently Washington Department of Fish and Wildlife
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington Department of Ecology
WFPB	Washington Forest Practices Board

Summary

Background

The U.S. Army Corps of Engineers (USACE) and its partners, the Skokomish Indian Tribe and Mason County (local sponsors), funded the U.S. Fish and Wildlife Service (FWS) to collect biological data throughout the Skokomish Basin as part of the feasibility phase of their Skokomish River Basin Ecosystem Restoration and Flood Risk Management General Investigation Study (Skokomish GI or GI). The purpose of the GI is to restore proper natural function to the Skokomish Basin while reducing flood damages to valley residents. Specific objectives are to 1) maintain a sustainable river alignment; 2) maintain agricultural use in the river valley; 3) provide flood protection in the valley; 4) maintain a sustainable groundwater table; 5) restore spawning, rearing, and migration habitats for salmonids; 6) restore, where possible, the natural complexity of the aquatic and riparian ecosystem; 7) assess, and if needed, improve water quality critical to fish survival and migration, 8) reduce sedimentation and altered sediment transport processes; and 9) monitor the projects and use adaptive management where necessary. Some potential actions resulting from this project include levee and dike removals and/or setbacks, sediment control structures, reconnecting side channels or oxbows, riparian planting, and dredging sections of the river channel. The goal of these projects will be to increase fish habitat availability, complexity, connectivity, and stability, and to decrease or lessen floods damages.

Work described in this report address the first two tasks of the Skokomish GI Project Management Plan (PMP), collection of existing research and data (Task 1) and physical data collection (Task 2). The purpose of Task 1 is to determine what information exists, consolidate that information into a usable and informative form, and determine data gaps. The purpose of Task 2 is to collect information that is lacking.

Based on initial efforts to complete Task 1, it became evident that descriptive information is lacking for juvenile salmonids and overall ecosystem health in this system. For example, information on simple life history traits such as distribution, outmigration timing, and community structure of primary and secondary producers (i.e., periphyton and benthic invertebrates) are lacking. The data collections and assessments described in this report are focused on goals developed in conjunction with the USACE, Skokomish Indian Tribe, and Mason County. These goals include obtaining information on juvenile fish life history traits and ecosystem health within the Skokomish Basin. In addition, the data collected during this investigation will provide information regarding general habitat availability, the seasonal distribution and abundance of fish in the river and its estuary, outmigration timing of salmonids in this system, and the species composition of primary and secondary producers. These data are useful in determining the overall health of the Skokomish Basin and in planning ecosystem restoration and flood risk management projects.

Data collection for this study was completed from June 2008 through September 2009, which means the data cannot describe year-to-year variability. Data collection was completed for eight major themes including habitat condition; fish distribution and abundance; winter survival; winter diet composition in different habitats; overall Skokomish Basin production and

outmigration timing; estuarine use, timing, and residency; early estuarine and marine migration and survival; and primary and secondary species composition.

This report is organized as a watershed assessment; however, nearshore areas adjacent to the Skokomish estuary were not included since they are outside the scope of this project. The introduction provides the necessary background to understand the need and scope of the project. A study description describes the Skokomish Basin and its geology, climate, and biological community. Next, are two sections describing the physical and biological characteristics of the Skokomish Basin. Each of these sections firsts presents existing information, followed by results from the new data collection. Within the biological characteristics section, individual species of salmonids are discussed. This discussion is organized around their general habitat requirements, historic adult salmonid distribution and population trends, specific juvenile habitat requirements, a summary of existing information, and results from the new data collections. A short summary of limiting factors is provided for each species. The final section of the report is a discussion of overall limiting factors and recommended habitat restoration measures. A companion set of appendices describe the methods used to collect and analyze new data for the Skokomish GI.

Skokomish Basin Condition: Physical Characteristics

The Skokomish River originates in the southeastern Olympic Peninsula of Washington State and flows southeast, emptying into Annas Bay at the southern end of Hood Canal. The river drains a watershed area of approximately 622 km^2 (240 mi^2). The Skokomish Basin consists of the estuary, the mainstem and the following three primary sub-basins: the North Fork Skokomish- 305 km^2 (117 mi^2), South Fork Skokomish - 331 km^2 (128 mi^2), and Vance Creek - 61 km^2 (24 mi^2). The Skokomish watershed has variable terrain ranging from alluvial and glacial valley bottoms and relatively gentle slopes to rugged and steep terrain with near vertical side slopes. Soil depths in the Skokomish Basin are shallow except in the river valleys, where sediment may be hundreds of feet deep. The climate is a temperate marine climate with wet winters and dry summers. Annual rainfall in the Skokomish Basin varies from 152 cm in the lower valley to 304 cm in the headwaters.

Natural and anthropogenic disturbances influence the watershed. Significant natural disturbances include flooding, mass wasting, fire, and wind-throw, although mass wasting is also influenced by anthropogenic causes such as logging and associated road building. Other anthropogenic influences include river and estuarine diking, road building, riverine dredging, hydroelectric dams, and general development.

The interaction of the physical characteristics of the Skokomish Basin and watershed processes combined to form the main factors limiting adult and juvenile salmon habitat in the watershed – channel aggradation, or an increase in overall sediment in the river. The six primary factors that have influenced channel aggradation are mass wasting events, flow reduction, channel destabilization due to large wood removal and riparian clearing, channel confinement through levee construction, channelization through straightening, bank armoring and dredging, and constriction by bridge embankments. The combination of these six factors results in increased sediment supply to the channel, reduced sediment transport capabilities, and reduced stable floodplain storage for sediment.

Mass wasting appears to have increased in the Skokomish Basin as a result of logging and associated road building, based on landslide inventories. However, it is still unclear how much this has contributed to the current level of aggradation in the lower South Fork Skokomish and the Skokomish mainstem. It is possible that much of the sediment that has entered the river in the upper watershed has not yet reached the lower watershed. These sediments could thus become available in the future to induce future aggradation in the lower mainstem, unless they can somehow be stabilized in the upper and middle reaches.

The second cause of aggradation is reduced flows resulting from the Cushman hydroelectric project, which has reduced the rivers ability to transport its sediment load. This project, on the North Fork Skokomish River, has historically diverted significant proportions of the North Fork Skokomish discharge (i.e., up to 96%) directly to Hood Canal. These reductions have also been significant (80%) during important high sediment transport discharges such as bankfull discharge. Thus, the rivers ability to transport sediment downstream of the confluence of the North Fork Skokomish with the South Fork Skokomish has been seriously reduced since the 1920s. However, this impact has likely been mitigated as a result of a new flow regime resulting from the new Federal Energy Regulatory Commission (FERC) license agreement implemented in July 2010. This agreement calls for greater minimum base flows and more importantly a 'normative flow regime' that will increase discharges below the projects during freshets to facilitate sediment transport. This should increase the sediment transport capabilities of the system.

Levee construction along the lower mainstem has impacted sediment transport and storage. The levees isolate the river from its floodplain, resulting in suspended sediment that would have been stored in the floodplain to be stored in the channel in the rivers lowermost reaches, and eliminating the rivers ability to store coarse sediment in secondary channels through channel avulsion and migration processes. Levees also cause flood flows to backwater upstream of the constriction, resulting in increased coarse sediment deposition and subsequent channel aggradation upstream from the levees. This aggradation usually results in bank erosion, which further increases sediment supply to the channel.

Large wood removal early in the twentieth century coupled with clearing of riparian old growth conifer forests for farming and wood production likely resulted in destabilization of an island braided channel morphology, converting it to the wider single-thread or braided morphology seen today. This channel evolution would have released large amounts of coarse and fine sediments stored as stable floodplain deposits, and would have reduced the sediment transport efficiency of the river, resulting in aggradation.

Channelization, including the straightening and widening of the channel for flood conveyance, though poorly documented, is known to have been done, particularly in the mid twentieth century. Channel straightening increases the slope and channel widening increases the flow cross section, achieving a temporary increase in hydraulic capacity. However, a wide, planar channel bed cannot transport sediment as effectively as a natural channel with a deeper thalweg and a lower width to depth ratio. Thus, channelization likely set the stage for increased aggradation in these reaches as well.

Constriction of the channel and floodplain by bridge embankments causes backwatering during peak flow events, resulting in aggradation upstream of the bridge. Floodplain constriction reduces the ability of the river to deposit suspended sediment on the floodplain, making these

sediments more available to be deposited in-channel further downstream where the slope is decreased, particularly in the zone influenced by tidal action. Bridge embankments also cut off secondary channels which formerly served as deposition sites for coarse sediment during floods.

Channel aggradation has two potential impacts to salmonid populations; channel instability which can scour redds and reduced habitat quality in terms of pool frequency and depth, and large wood cover. Data within the Skokomish Basin are lacking to make a definitive conclusion regarding the impact of scour on salmonid populations in the system. However, increased scour-related mortality has been observed in other systems with impaired sediment supply and sediment transport equilibrium. This issue was not evaluated in this study, but should be a high priority data gap in future assessments.

Past habitat data collections have concluded that pool and large wood cover are somewhat impaired in the system. In general pool frequency and large wood (LWD) abundance is low. In general, habitat quality improves as you move up the Skokomish Basin and as you move from the mainstem to the tributaries. Pool frequencies have been rated poor in the South Fork Skokomish, but fair or good in tributaries, except Church Creek. Large wood cover levels were not adequate to provide good quality cover in nearly one-third of the sites sampled historically.

Increased sediment supplies, reduced flows, and levees have also had a significant effect on estuarine habitat. The delta has become steeper, resulting in the loss of important intertidal and eelgrass habitat. This has also reduced the mesohaline mixing zone, which is an important transition area for juvenile and adult salmonids as they transition between freshwater and seawater. Diking and filling has also resulted in the loss of tidal channels and vegetated wetlands.

We collected new data throughout the Skokomish Basin, but our efforts were limited to habitats below barriers to anadromous fish migration (i.e., anadromous zone) and included tributaries, lateral habitats, off-channel habitats, and the estuary. Data was collected using a stratified approach, moving from large spatial scales to successively finer scales. Existing Geographic Information System (GIS) data, barrier information, and consultation with professional biologists was used to estimate the extent of the anadromous fish zone. Based on this analysis, there is approximately 132 km of anadromous fish habitat in the Skokomish Basin. Just over half of this habitat (55.4%) was classified as mainstem habitat and the rest (44.6%) as tributary habitat. A majority of the habitat was also classified as low gradient (<1%) and unconfined, with very little classified as having gradients greater than 4%. In addition, 4.1 km of the lower mainstem was estimated to lie within the stream estuary ecotone, the transition zone between the river and its estuary.

Instream habitat data was collected from 21 study reaches (22 km) during the summer of 2008 and 24 study reaches (22 km) during the winter of 2009. As expected, the majority of the available habitat existed in the main channels. However, braided channel habitat (channels separated by unvegetated islands) was the next most common and side channel (channels separated by islands with mature vegetation) and backwater habitats were found in low proportions. Overall, deep water habitats commonly associated with pools made up between 25% and 44% of the habitat. However, deep water habitats were absent or in low abundance in several study reaches. In addition, deep water habitats, which are very important habitats during the winter, were in lowest abundance during that period. Fine wood and vegetative cover was

the most common cover element available in the reaches we evaluated. Large wood and large wood debris piles were present at intermediate levels to other cover elements. Overhead cover and undercut banks were relatively uncommon.

We identified 28 different off-channel pond complexes through evaluation of aerial photographs. These ponds had a total surface area of 20.3 hectares and a perimeter of 29,499 m. The ponds ranged in size from 0.08 to 4.96 hectares and averaged 0.7 hectares. We sampled 14 different pond sites located in six different ponds during the summer and 20 sites located in 7 different ponds during the winter. Two of the ponds, within the anadromous zone were determined to not be accessible to juvenile salmonids, one due to the level of vegetation in the pond, and the other was in the middle of an agricultural field and lacked access channels to the river or its tributaries. One pond was determined to lie outside the anadromous zone due to its location on a terrace and the lack of obvious egress channels to the river or its tributaries.

Based on the habitat assessment, the tributary junctions, especially the Vance Creek and South Fork Skokomish confluence are the most degraded portions of the watershed. These areas are the most effected by land use practices throughout the Skokomish Basin and several of these areas, including lower Vance Creek, go subsurface during late summer and early fall due to sediment aggradation. This has the potential to block the upstream migration of adult salmon, thereby significantly reducing habitat availability for their progeny. These areas are also likely to be susceptible to scour which can severely impact salmon redds and juvenile salmon overwintering in the substrate.

Skokomish Basin Conditions: Biological Characteristics

We collected data for periphyton and macroinvertebrate community structure in the Skokomish to assess ecosystem health. Samples were collected from 29 locations throughout the Skokomish Basin including the North Fork Skokomish, South Fork Skokomish and 5 different tributaries. Taxa richness, the total number of unique diatom taxa found at a given site, averaged 32 species and was slightly greater in mainstem sites than tributary sites. The Shannon diversity ($base_2$) averaged 3.31. Scores for the three biocriteria metrics generally indicated good to excellent ecosystem health, with only one site, Pine Creek, receiving a score of poor.

Macroinvertebrate abundance and community structure generally indicated good habitat quality. Macroinvertebrate abundance (mean of 6,835 individuals per sample) generally indicated values of waters in good conditions with high primary and secondary productivity. Taxa richness, the total number of unique taxa at each site, was generally moderate to high across all sites (mean 48). Shannon's index averaged 2.86.

Scores for the Benthic Index-of-Biotic-Integrity (B-IBI or BIBI) developed for Puget Sound lowland streams and larger western Washington Rivers indicated moderate to high overall biological integrity throughout the Skokomish Basin. B-IBI scores for tributaries were more commonly rated as having higher biological integrity than mainstem sites. Although B-IBI scores generally indicated healthy community structure, long-lived macroinvertebrate taxa and shredder macroinvertebrates were somewhat low. This could be due to a lack of channel roughness caused by high embeddedness, the quality of interstitial spaces in the steam bed, lack of habitat complexity, scour effects of highly mobile river bottom, lack of wood boles or other habitat features that long-lived species use as special refugia during high flows. In addition,

there was a lack of snails, pea clams, and crustaceans in the system, which are generally common in mid- to low-elevation stream in western Washington.

Twenty-three species of fish have been identified in the Skokomish Basin. A majority of these species are salmonids. We observed 15 species of fish in freshwater environments during our sampling, including 3 introduced species, common carp, largemouth bass, and brook trout. Salmonid species observed included Chinook, coho, chum, rainbow/steelhead, cutthroat, and bull trout. Coho salmon were numerically the dominant species of salmonid in the system.

Juvenile salmonid distribution and abundance, which was identified as a data gap by the Skokomish GI sponsors, is obviously influenced by adult salmon distribution and abundance. Four fish species, Puget Sound Chinook salmon, Puget Sound steelhead, Hood Canal Summer chum, and bull trout have been listed under the Federal Endangered Species Act. Thus, abundance for these species is expected to be low. The distribution of Chinook salmon is often limited in the South Fork Skokomish and Vance Creek due to the channel going subsurface. Adult chum salmon also appear to be restricted to the lower sections of the South Fork Skokomish due to the first canyon in this system. They spawn in most of the tributaries to the Skokomish River, with the heaviest concentrations in the lower 7.6 km of the North Fork Skokomish. Coho salmon spawn in most of the tributaries, with the highest concentrations in the lower North Fork Skokomish and Vance Creek. They appear to have been restricted historically to the lower portions of the South Fork Skokomish due to the first canyon. However, we observed juvenile coho salmon in the upper South Fork during our study, suggesting that adults were able to migrate through the Canyon the fall prior to our surveys (2007). Steelhead and bull trout adults are the most widely distributed salmonids in the Skokomish Basin. They appear to use most tributaries as well as the upper reaches of the South Fork Skokomish and Vance Creek.

Juvenile salmon have a diverse array of freshwater and estuarine habitat requirements which vary by species and life history strategies within species. However, the basic requirements can be summarized as 1) stable gravel with ample flow of water with high dissolved oxygen levels and appropriate temperatures for egg incubation and early rearing, 2) high quality freshwater habitat for early and potentially extended rearing, 3) connected freshwater migratory habitats, and an estuarine environment to allow transition from freshwater to sea water. These requirements have been described for the species of juvenile salmon expected to be present in the Skokomish Basin.

Data for the status and distribution of juvenile Chinook salmon in the Skokomish River is limited to outmigration data in Skabob Creek and estuarine sampling. We observed Chinook salmon in mainstem, tributary, freshwater, the stream-estuary ecotone, and the estuary during our sampling efforts. Juvenile Chinook were more common in the mainstem then tributary and pond habitats. Their distribution was limited to the lower Skokomish Basin, generally below the first canyon in the South Fork Skokomish and Vance Creek, and their distribution was greater in the winter than during the summer. However, this difference may have been an artifact of our sample sites.

We estimated that 239,511 Chinook salmon migrated past the screw trap between mid-March and late July. A majority (93%) of these fish were hatchery parr and smolts. Naturally produced Chinook salmon smolts migrate from the Skokomish River primarily in January and February. However, small numbers were observed outmigrating from March through July. Hatchery smolts emigrated from mid-May when they were released from the hatchery through

July. Both naturally produced and hatchery produced Chinook salmon were caught in low numbers, although we caught seven times as many hatchery Chinook than wild Chinook.

The timing of estuary use is consistent with that observed during outmigration, extending from January through August. Juvenile Chinook salmon catch per unit effort (CPUE) in the estuary was generally low and was dominated by hatchery Chinook. We could only calculate one population estimate for juvenile Chinook salmon in the Nalley Island section of the estuary. The estimate for this sampling event, which occurred May 27, 2009, was 55,104 individuals (95% Confidence Interval: 20,099 to 133,080). In general, hatchery Chinook arrived at the estuary later in the year, apparently due to hatchery release strategies, and left the estuary sooner than their unmarked, presumed wild counterparts.

Juvenile Chinook salmon distribution and abundance appear to be limited most by the stability of their incubation environment. We saw relatively few juvenile Chinook salmon in the freshwater rearing habitat, in outmigration sampling, and in the estuary. Adult Chinook salmon were distributed throughout the Skokomish Basin as a result of higher than normal late summer discharges, and an adult supplementation program initiated by the Skokomish Indian Tribe and Washington Department of Fish and Wildlife (WDFW), which resulted in adults being trucked into the upper South Fork Skokomish. The fact that we saw so few individuals suggests that reproductive success or incubation survival was relatively low. This could be due to poor reproductive fitness of hatchery Chinook salmon spawning with naturally produced adults or scour occurring during high flows.

Juvenile chum salmon generally migrate to sea shortly after emergence. Thus, their freshwater rearing requirements are largely incubation and early rearing. We found no information on the freshwater distribution and abundance of juvenile chum salmon in the Skokomish River. We observed chum salmon in mainstem, tributary, and pond freshwater habitats in the lower Skokomish Basin below the South Fork Skokomish canyon. However, we observed chum above the first canyon in Vance Creek, which contrasted observations for juvenile Chinook salmon. Unlike Chinook salmon, they did not use the entire North Fork Skokomish up to the lower Cushman dam.

We estimated 52,179 chum salmon migrated downstream during screw trap sampling between mid-March through July. However, it appears that our estimates were significantly biased and underestimated production since 10 million chum were released from hatcheries in the Skokomish River during this period. Peak daily chum salmon migration occurred from late-January through mid-July, peaking in mid-February. There was a second large peak in mid-April following the hatchery release. Out-migrating chum salmon averaged 42 mm in fork length and grew throughout the season. Chum salmon caught immediately after the hatchery release, and presumably hatchery chum (chum are not marked prior to release from the hatchery) were much larger than the chum caught immediately prior to the hatchery release.

Juvenile chum salmon were the most numerous salmonid caught in the estuary. They were present from February through June, peaking in mid-May. The difference in peak outmigration and estuary residence suggests that juvenile chum salmon held in the stream-estuary ecotone or adjacent estuary prior to entering the Nalley Island section of the estuary, highlighting the potential importance of this habitat.

Coho salmon generally rear in freshwater for a year before migrating to sea. Thus, they have greater freshwater requirements than either Chinook or chum salmon. In contrast, they

generally move through the estuary quicker than Chinook or chum salmon. Juvenile coho salmon were observed in tributary, mainstem, and pond habitats. They had a much greater distribution than either Chinook or chum salmon. They were observed in the upper South Fork Skokomish above the series of canyons. Juvenile coho salmon were also numerically the dominant salmonid present in the Skokomish Basin. However, their abundance decreased dramatically from summer to winter.

We estimated that 352,603 coho fry and smolts migrated downstream during our outmigration sampling, with unmarked fish comprising 80% of the total. Coho fry were more numerous than coho smolts, accounting for 51% of the total. Wild coho smolt outmigration was estimated at 87,639. Both coho fry and smolts were caught during our entire outmigration sampling (January through July). Fry outmigration peaked in late-April and early-May, while smolt migration peaked from mid-May through mid-June. Hatchery coho smolt outmigration peaked in mid-April, immediately after release. The size distribution of coho salmon caught during the outmigration sampling was bimodal due to the presence of fry and smolts in the outmigration sampling. Fry were generally less than 60 mm, while smolts were generally between 80 and 100 mm fork length.

Coho salmon were captured in the estuary from April through September, with peak abundance occurring from mid-May through late-June. Unmarked coho salmon were present in the estuary before and after (i.e., longer) their marked counterparts. Coho fry as small as 50 mm were frequently observed in the Nalley Island section of the Skokomish estuary. Thus, coho fry use both the stream-estuary ecotone and the estuary during the summer. However, their absence during the fall and early winter suggests that they potentially migrate back upstream into the lower mainstem or off-channel habitats present in the lower river during the winter. Thus, the stream-estuary ecotone and the estuary appear to be extremely important for juvenile coho salmon in this system.

Juvenile coho salmon appear to be limited by freshwater winter rearing habitat. They were present in large numbers during the summer 2008 surveys, suggesting better incubation success than Chinook salmon. However, their numbers decreased dramatically during the winter and we estimated less than 100,000 smolts were produced. The lack of winter pool habitat would contribute significantly to the observed reduction from summer to winter

Juvenile steelhead are the most dependent salmonid species on freshwater habitat of all anadromous species in the Skokomish River. They spend up to three years in freshwater before migrating to sea. Juvenile steelhead are found throughout the Skokomish Basin in relatively low densities. They also had the greatest distribution of any juvenile salmonid species, being present in the upper reaches of the South Fork Skokomish, North Fork Skokomish, McTaggert Creek, and Vance Creek.

We caught very few steelhead in outmigration sampling. However, they were caught from early February through July, when sampling was terminated. A majority of the steelhead caught were unmarked. Based on body size, we caught fish that appeared to be from three different age classes (0+, 1+, and 2+).

We did not capture any steelhead in our estuary sampling. Results from acoustic tagging suggest that steelhead migrate through the lower river relatively quickly (generally less than 5 days). Steelhead smolts use the nearshore habitat of Hood Canal as more than just a migratory corridor, and generally spend approximately 2 weeks travelling from the mouth of the

Skokomish River to the Hood Canal Bridge. Survival through the lower river is generally high (>80%) for wild fish, but much lower (<50%) for their hatchery counterparts.

Steelhead appear to be limited by overwinter habitat conditions. Steelhead typically spawn in the spring after most of the large freshets which would scour their redds. In addition, outmigration, estuarine, and early marine survival (through Hood Canal) appear to be relatively high. The lack of winter pool habitat and unstable channels likely limit production, since steelhead use pool habitats during the winter, and often hide in the substrate during daylight hours during the winter.

The biological community has also potentially been influenced by hatchery activities in the Skokomish Basin. Two of the three hatcheries in the watershed produce Chinook, coho, and chum salmon that are released into the Skokomish Basin on-station fry or smolt releases. Significant out of basin stocks have been reared and released into the Skokomish Basin historically. The impact of these out of basin stocks on the fitness of natural spawned salmon in the Skokomish Basin is unknown. Hatchery fish released into the system compete with naturally produced fish, may increase predation on naturally produced fish which can impact their subsequent survival. Finally, hatchery adults that return successfully may spawn with wild fish; potentially reducing the fitness of the natural offspring. This is a particular concern with Chinook salmon which stray in large numbers to the lower South Fork Skokomish and Vance Creek and can contribute significantly to the number of naturally spawning fish.

Based on the information compiled in this report, it appears that the primary factor limiting juvenile salmonid distribution and abundance in the Skokomish Basin is excessive sedimentation and aggradation. Although not measured specifically in this report, scour and/or burial of redds of fall spawning salmonids and low overwinter survival of freshwater dependent species such as coho and steelhead appear to limit production. Scour could be the result of the disequilibrium between sediment input and sediment transport in the system. The excessive sediment would also result in poor pool frequency and/or quality, which we observed in our habitat surveys.

We recommend a process based approach of restoration that reduces sediment inputs, reduces artificial channel constrictions, provides floodplain storage for sediments, stabilize active channel sediment, and ample discharges to transport existing sediment. Sediment inputs would be reduced by controlling anthropogenic sources of sediment in the system, improving and decommissioning roads in the Skokomish Basin, reducing logging associated mass wasting events, and stabilizing existing mass wasting areas. Reductions in artificial channel constrictions and increased floodplain storage of sediment can be obtained by levee removal and/or significant setbacks. Active channel stability can be increased through the introduction of large wood, especially engineered logjams. Active monitoring of the new FERC license agreement for the operation of the Cushman hydroelectric facility will help determine if the prescribed flows are adequate for sediment transport requirements in the system.

Introduction

The U.S. Army Corps of Engineers (USACE) is currently in the feasibility phase of the Skokomish River Basin General Investigation (Skokomish GI or GI). The purpose of the GI is to investigate and formulate a solution to address ecosystem restoration and flood risk management in the Skokomish Basin. The goal of the GI is to restore proper natural function to the Skokomish Basin while reducing flood damages to valley residents. Specific objectives are to 1) maintain a sustainable river alignment, 2) maintain agricultural use in the river valley, 3) provide flood protection in the valley, 4) maintain a sustainable groundwater table, 5) restore spawning, rearing, and migration habitats for salmonids, 6) restore, where possible, the natural complexity of the aquatic and riparian ecosystem, 7) assess, and if needed, improve water quality critical to fish survival and migration, 8) reduce sedimentation and altered sediment transport processes, and 9) monitor the projects and use adaptive management where necessary. A current conditions report will be prepared as part of the feasibility phase of the GI. The current conditions report will outline the current conditions of the Skokomish Basin as it relates to the goals of the project and is completed by examining existing information, identifying information gaps, and collecting additional information to address identified information gaps.

The Skokomish GI requires the evaluation of both physical and biological information, including channel geomorphology, hydrology, sediment transport, aquatic community structure, and physical habitat before a plan is evaluated and eventually recommended. From an aquatic community structure and habitat perspective, adequate information exists for the spawning distribution and abundance of adult salmonids throughout the Skokomish Basin. However, information related to the community structure of aquatic primary (periphyton) and secondary (invertebrates) producers, juvenile salmonid life history traits, and general habitat availability is lacking. This information is critical to develop strategies to meet the sponsors' objective of ecosystem restoration and to plan flood risk management in a manner consistent with the restoration objective. This study, developed in conjunction with agency and tribal staff, reviewed existing information and collected additional biological and habitat data. The purpose of this data collection was to provide information for aquatic community structure, general habitat availability, and juvenile salmon life history traits, including distribution, abundance, outmigration patterns, and estuarine use.

Watershed and/or river management and ecosystem restoration planning requires a thorough understanding of watershed processes, community structure, ecology, habitat conditions, and habitat requirements of biota. Watershed assessments generally evaluate landscapes, physical processes, and land-use factors influencing riverine ecosystems (Beechie et al 2003). Beechie et al. (2003) suggest that watershed assessments be used to estimate historic and current smolt production based on habitat conditions, and identify causes of habitat loss and restoration actions necessary to recover those habitats. Several assessments of watershed condition, fish habitat conditions and limiting factors focusing, in part or completely, on the Skokomish Basin have been completed (e.g.; Watershed Management Team 1995; KCM 1997; ME2 Environmental Services 1997; Correa 2003). However, many of these assessments were limited in scope (i.e. habitat focus) or were restricted to summarizing available information. Thus, information for current conditions in the Skokomish Basin is limited.

Flooding has always occurred in the Skokomish Basin, but several studies (Jay and Simenstad 1996, Stover and Montgomery 2001, Bountry 2009, USACE 2010) have concluded

that it has been exacerbated during the last century. Increased flooding is probably a result of channel aggradation, which has been exacerbated by increased sediment delivery, levee construction, and instream flow manipulations resulting from human activities in the Skokomish Basin (USACE 2010). These issues are discussed briefly here and in more detail later in this report. Extensive logging and associated road building in the upper South Fork Skokomish and Vance Creek sub-basins has resulted in increased landslides, thereby increasing sedimentation in the river. This situation has been exacerbated in the lower river, by the construction of levees in the floodplain, which constrict flows and limit sediment transport (Bountry et al. 2009). In addition, the ability of the Skokomish River to transport sediment has been decreased historically as a result of water diversions that occur at two City of Tacoma Hydroelectric Project Dams, Federal Energy Regulatory Commission (FERC) #460. However, a new settlement agreement between the Skokomish Tribal Nation and Tacoma Public Utilities will reduce future diversions (Cushman Project 2009). The alteration of these three processes (flow regime, sediment delivery and sediment transport/storage) has resulted in approximately 1.6 meters of aggradation during the last 40 years. This aggradation has reduced channel conveyance to the point that overbank flow near the Highway (HWY) 101 bridge that historically occurred at 13,000 cfs now occurs at 4,100 cfs (Bountry et al. 2009). However, overbank flows occur at only 2,500 cfs downstream of the HWY 101 Bridge (Karl Erickson, USACE, Personal Communication).This reduced conveyance means there is a 90% chance of overbank flow during a given year (USACE 2010). Channel aggradation and increased frequency in overbank flows has negatively influenced aquatic communities, including salmonids and their habitats.

The status and distribution of adult salmonids, which will obviously influences subsequent juvenile distribution, is relatively well known. This information is summarized in Salmon and Steelhead Stock Inventories (SASSI) completed from the early 1990's through 2006 (SASSI 1992, 2002, 2006). Salmon production in the Skokomish Basin has been reduced from historic levels (Watershed Management Team 1995). Twelve salmonid stocks have been identified in the Skokomish Basin (SASSI 1992, 2002, 2006). Of these, 3 are listed as healthy, 2 as depressed, 2 as extinct (Nehlsen et al. 1991), and 5 are listed as unknown. Four salmonid species in the Skokomish Basin are part of population segments that have been listed as threatened under the Endangered Species Act (ESA). These include Puget Sound Chinook (*Oncorhynchus tschawytscha*) (1999, Federal Register Volume 64, 14308); Hood Canal Summer Chum (*O. keta*) (1999, Federal Register Volume 64, 14508); Coastal-Puget Sound, Washington bull trout (*Salvelinus confluentus*) (1999, Federal Register Volume 64, 58910); and Puget Sound steelhead (2007, Federal Register Volume 72, 26722). Stock status is based on yearly spawning ground surveys completed by WDFW and the Skokomish Indian Tribe.

Relative to adult salmonids, little is known about juvenile salmonids and their habitats in the Skokomish Basin. The distribution of juvenile salmonids can be inferred from the spawning distribution of adults, although juvenile salmonids can move upstream upon emergence (e.g. Kaya 1989). In addition, relatively little information exists regarding the habitat requirements of juvenile salmonids in relatively large river channels. This is an important factor in the Skokomish Basin since a majority of the available habitat is mainstem habitat. This is because limited tributary habitat is available due to natural anadromous barriers which occur short distances upstream of the tributary mouths in this Skokomish Basin (Watershed Management Team 1995). This lack of information resulted in this topic being identified as an important information gap during the initial phases of the GI.

Information regarding the community structure of lower trophic levels is also lacking. The U.S. Fish and Wildlife Service (FWS) collected invertebrate data from two reaches in the Skokomish Basin in the mid 1990's, one in the North Fork Skokomish (NF) above Lake Cushman and one in the lower Skokomish River (Celedonia 2004). Based on this survey, aquatic health was rated as excellent in the North Fork Skokomish, above Cushman Dam and fair in the lower Skokomish mainstem. However, this data is relatively old and may not accurately represent current conditions.

This study will provide important information to help fill the information gaps described above. The information is critical for planning ecosystem restoration and flood risk management measures consistent with ecosystem restoration. In addition, this data will establish baseline conditions in the Skokomish Basin which can be used to assess the influence of future projects resulting from proposed alternatives in this GI. This is a critical need for evaluating the effectiveness of riverine restoration projects, which is often lacking in most restoration assessments (Pess et al. 2005).

The objectives of this study were to: 1) identify potential limiting factors to juvenile salmon production within the Skokomish Basin; 2) identify seasonal distribution, abundance and survival; 3) estimate Skokomish Basin production; 4) determine smolt out-migration timing; 5) evaluate estuarine use and residence time of juvenile salmon; and 6) evaluate the community structure of periphyton and aquatic invertebrates. A literature review was completed to gather existing information for the Skokomish Basin to address the objectives described above. Potential limiting factors will be identified by assessing seasonal distribution, abundance, and survival throughout the Skokomish Basin. This information will help identify potential bottlenecks in production and/or survival. Distribution, abundance, and survival data was collected using a combination of seasonal snorkel and habitat surveys, along with Passive Integrated Transponder (PIT) tagging and subsequent recapture surveys. Skokomish Basin production estimates were completed using the information collected during the habitat and snorkel surveys, as well as limited fyke netting and screw trap data collected in the lower river. This trapping also provided information regarding out-migration timing in this system. Estuarine use and residence timing was assessed using beach and purse seining. The community structure of primary and secondary producers was evaluated by collecting samples throughout the Skokomish Basin.

This report is organized into several sections which generally summarize existing information for the Skokomish watershed and new field data collected as part of the GI. This information will be used to identify factors limiting juvenile salmonids in the Skokomish watershed; identify additional information needs; and guide potential restoration activities. The report sections are organized into six parts: 1) a description of the study area, including a general description of the stream network, geology, climate, and fish assemblage; 2) a general overview of the disturbance regime and their relationship to physical processes in the Skokomish Basin; 3) a description of historic and current habitat data, 4) historic and current stock status of each species in the watershed; 5) a comparison of the general habitat requirements of juvenile salmonids; 5) a description of juvenile salmon seasonal distribution and abundance throughout the watershed, outmigration timing and abundance, and timing and relative abundance in the estuary; and 6) a summary of current conditions, factors limiting juvenile salmonids in the Skokomish Basin based on these current conditions, and recommended restoration activities.

Detailed descriptions of the methods used for new data collection and general results are provided in companion set of appendices.

Skokomish Basin Condition: Physical Characteristics

The physical characteristics of the Skokomish Basin are characterized in this section of the report, including the physical setting (i.e., drainage, geology, and climate), disturbance regime (natural and management), and resulting fish habitat conditions. The descriptions of the physical setting and disturbance regime are relatively brief in an effort to generally familiarize the reader with the general attributes of the watershed and the physical processes influencing the watershed. It is not our intent to provide an in depth fluvial geomorphology investigation in this section of the report since this information has been examined in detail in several reports (i.e., USFS 1995, ME2 1997, Correa 2003, Bountry et al. 2009, Skokomish Tribe and WDFW 2010, USACE 2010). The primary purpose of this section is to provide a brief summary of these conditions and summarize how these factors have influenced habitats for fish and other aquatic organisms. This is completed by providing a brief summary of the physical setting, natural physical processes and management activities that influence the watershed, the interaction of these two factors, summarizing past habitat data collection and summary efforts, and summarizing the new data collected as part of the GI.

Drainage Area

The Skokomish River originates in the southeastern Olympic Peninsula of Washington State and flows southeast, emptying into Annas Bay at the southern end of Hood Canal (Figure 1). The river drains a watershed area of approximately 622 km^2 (240 mi^2). The Skokomish Basin consists of the mainstem, three primary sub-basins: the North Fork Skokomish 305 km^2 (117 mi^2), South Fork Skokomish 331 km^2 (128 mi^2), and Vance Creek 61 km^2 (24 mi^2), but also includes several smaller tributaries with an additional 416 km (260 mi) of stream habitat. New habitat data collected as part of the GI was collected throughout the Skokomish Basin, but was limited to habitats below barriers to anadromous fish migration (i.e., anadromous zone) and included tributaries, lateral habitats, and off-channel habitats. No new habitat data was collected in the estuary for the GI. As a result of these criteria, approximately 123 km (76 mi) of the 514 km (319 mi) of stream habitat in the Skokomish Basin, was included in the area where new data collection was completed for the GI (Williams et al. 1975).

The Skokomish estuary consists of the mouth of the Skokomish River and its delta that is tidally influenced. It is the largest and most complex river estuary in Hood Canal. The Skokomish estuary has undergone significant change since the mid-1800, when land clearing was initiated to convert the land to agricultural and residential uses. Much of the estuary was completely diked by the 1930's significantly reducing the total estuary area. However, estuarine restoration in the form of extensive dike removal and burrow ditch filling has occurred since 2007, partially restoring some of this lost habitat.

In addition to direct alterations resulting from diking, the Skokomish estuary has also been influenced by indirect alterations resulting from water diversions and increased sediment delivery in the upper basin (Jay and Simenstad 1996). These alterations have resulted in tidal influence in the mainstem that reaches approximately 5.6 to 6.4 km upstream of the mouth (Skokomish Indian Tribe and WDFW 2010, citing Marty Ereth, former Skokomish tribal biologist, personal communication), significantly less than historic values. Data presented in this

report suggests that tidal influence may actually have shifted even further downstream (see Biological Characteristics section for details). They have also resulted in finer substrate in the inner delta (Jay and Simenstad 1996).

Collins and Sheikh (2005) used a regional process-based classification scheme to classify tidal wetlands in Puget Sound. They classified the Skokomish estuary along with estuaries of major rivers with river deltas and tidal freshwater floodplains in major glacial troughs. These systems were characterized by broad low gradient valleys created by sub-glacial fluvial erosion (Collins and Sheikh 2005). Bortleson et al. (1980) classified habitat conditions in the Skokomish estuary broadly as intertidal and subaerial. Collins and Sheikh (2005) also classified intertidal wetland habitats within Puget Sound and determined that approximately 70 percent of the Skokomish estuary composed of emergent estuarine wetlands (~70%) with the remaining wetlands classified as scrub-Shrub wetlands.

The mainstem Skokomish River flows from the confluence of the North and South Fork Skokomish River through the broad, alluvial Skokomish Valley before entering Hood Canal via the relatively large estuary described above (Todd et al. 2006). This section of river has been relatively dynamic in recent years. As stated above, tidal influence in the mainstem appears to be shifting downstream (Skokomish Tribe and WDFW 2010). In addition, the confluence of the North Fork Skokomish and South Fork Skokomish was altered in 2004 when the North Fork Skokomish became blocked with sediment and large wood, resulting in a channel avulsion. The channel of the North Fork Skokomish overtopped a levee and connected to an historic channel, now entering the mainstem Skokomish River at river kilometer (RKM) 12.9 (river mile (RVM) 8) (at the mouth of the old Richert Springs inlet), downstream of its previous confluence.

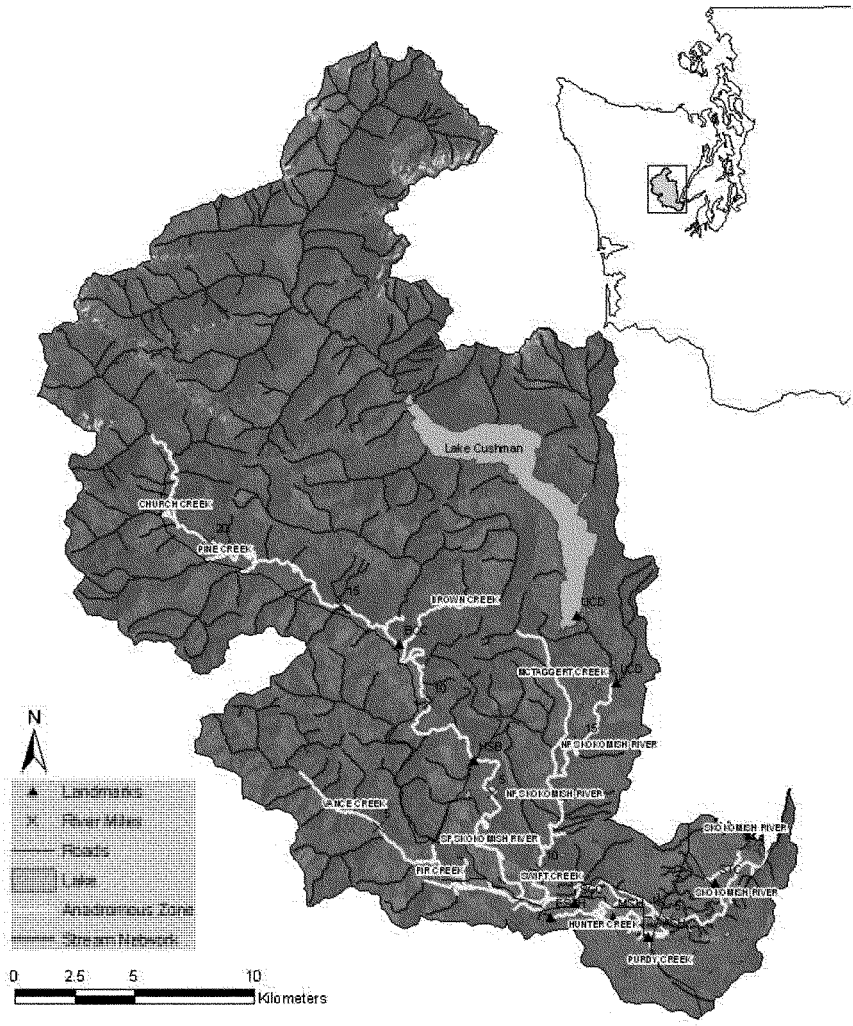

Figure 1. Stream network of the Skokomish Basin along with that portion of the watershed accessible to anadromous salmon (i.e., anadromous zone). Data collection for this project was collected in the anadromous zone and the estuary only, with the exception of one macroinvertebrate and periphyton sample collected above Lake Cushman on the North Fork Skokomish (see Chapter 9). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

The mainstem below the confluence is low gradient (slope less than 0.0024 ft/ft; Bountry et al. 2009), when compared to all other sections of the river network, and has an extensive floodplain. However, the river has been hydraulically disconnected from this floodplain in many areas, by levees, bank armoring, and channelization (BOR 2007). Land-use in this section of river is primarily agriculture and private residence, including the Skokomish Indian Reservation. Significant tributaries of this section of river include Hunter Creek, Weaver Creek, and Purdy Creek. These are mainly spring fed systems that all enter the mainstem between RKM 5.8 (RVM 3.6) and RKM 12.7 (RVM 7.9) (WDFW and PNPTT 2000).

The North Fork Skokomish drains approximately 305 km^2 (118 mi^2), but is impounded at RKM 27.7 (RVM 17.3) by the first of two City of Tacoma Dams, which creates the 40 ha (100 acre) Kokanee Reservoir. The much larger Cushman Dam is located 2.7 km (1.7 mi) further upstream, creating the 1,619 ha (4,000 acre) Cushman Reservoir, which expanded a pre-existing natural lake. An additional 17.7 km (11 mi) of river lies upstream of Cushman Reservoir. This section of river is contained mainly within Olympic National Park and is characterized by steeply wooded hillsides and a deeply incised canyon. The impoundment at Kokanee Reservoir blocks anadromous fish passage, while the Cushman Dam has historically diverted approximately 80% of the North Fork Skokomish flow directly to Hood Canal. However, a recent legal agreement will initiate trap-and-haul passage for salmon and significantly reduce water diversions to Hood Canal (Cushman Project 2009). One main tributary, McTaggert Creek, joins the North Fork Skokomish below Kokanee Reservoir. Land-use in the North Fork Skokomish consists of Olympic National Park, commercial timber production, and limited private residence and agricultural use below Kokanee Reservoir.

The South Fork Skokomish drains an area of approximately 331 km^2 (128 mi^2) and can be broadly characterized into four sections: the lower portion from the confluence up to the canyon at RKM 8.0 (RVM 5), the canyon portion which extends from RKM 8 (RVM 5) upstream to RKM 16.1 (RVM 10), a wide alluvial valley section from RKM 16.1 (RVM 10) to RKM 37.8 (RVM 23.5) and a final canyon which stretches from RKM 37.8 (RVM 23.) another 8 KM to the headwaters. The lower portion is characterized by a wide, alluvial valley with significant human influence related to residential and agriculture properties. The canyon section is a steep, bedrock dominated gorge that reaches 120 meters deep in places and is only 18 meters wide at its narrowest point (TAG 2003). There are steep cascades within this section (RKM 8.9-10.5; RVM 5.5-6.5) that have been identified as a barrier to upstream migration for some species of salmon (WDF 1957). The upper valley section is generally unconfined and has a moderate gradient (typically, 0.013; M2, 1997). Land use in this section is dominated by commercial timber harvest and associated road building. The upper canyon is also a steep gradient bedrock gorge that lies within Olympic National Park. The South Fork Skokomish originates in Olympic National Park, flows through U.S. Forest Service (USFS) and Green Diamond Resources (formerly Simpson Timber) property, and then through agriculture and private residential areas (WDFW and PNPTT 2000). Land-use in this sub-basin is commercial timber harvest, agriculture and residential. Several tributaries enter the South Fork Skokomish including Vance, LeBar, Cedar, Pine, and Church Creeks. The largest tributary to the South Fork Skokomish is Vance Creek, entering at RKM 1.3 (RVM 0.8), while the remaining tributaries enter the upper portions of the South Fork Skokomish. These upper Skokomish Basin tributaries are all relatively short streams with anadromous gradient blockages generally within the first mile. The exception is Browns Creek which has more than 4.8 km (3 mi) of anadromous habitat.

Vance Creek, which enters the South Fork Skokomish at RKM 1.3 (RVM 0.8), has a drainage area of 61 km^2 (23.8 mi^2). Vance Creek flows through a broad valley with moderate gradient for the first 6.4 km (4 mi) and then abruptly steepens until an anadromous barrier (10 m falls) at RKM 11.4 (RVM 7.1) (TAG 2003). Vance Creek originates on USFS land and then flows through Green Diamond Resources timber land before entering agricultural and residential land. Land-use in this sub-basin is dominated by commercial timber production.

Geology

Bedrock in much of the Skokomish watershed consists of submarine basalt flows dating from the Eocene Epoch, approximately 37 to 50 million years ago, which have been uplifted due to tectonic plate movement. The uppermost headwaters, however, are underlain by marine sedimentary slates, mudstones, and sandstones of similar age, which originally formed part of the accretionary wedge associated with the subduction zone. Superimposed on this bedrock, are hundreds of feet of sediments deposited by Pleistocene continental glaciation, which overran the Southeast corner of the Skokomish Basin, from the area around Lake Cushman, reaching inland from the Hood Canal about 8 miles in the vicinity of Vance Creek. Alpine glaciation, originating in the Olympic Mountains, likewise filled portions of the middle and upper watershed with glacial sediments. Fluvial erosion during the centuries since the Pleistocene has cut into these sediments, creating the broad alluvial valleys of the lower South Fork Skokomish and mainstem, and the much narrower alluvial valley comprising the middle portions of the South Fork Skokomish. Each of these alluvial segments remain bounded by high terraces of glacial sediment, which can be eroded by the river channel where it impinges on the valley sides. Soil depths for the watershed as a whole are generally less than one meter, except in the valleys of the lower river, where glaciation and fluvial deposition has accumulated over 30 meters of sediment in some places, particularly in the southern portion of the watershed (WDFW and PNPTT 2000).

Although these glacial processes and the sediments they deposited occurred more than 14,000 years ago, they are important to understanding how management activities and climate change can influence the current river channel. An excellent description of this relationship is described in detail by the Skokomish Tribe and WDFW (2010). Recently deglaciated landscapes go through a paraglacial period which is characterized by unstable conditions that persist until glacial sediments are essentially removed from the basin or become stable (Ballantyne 2002). The morphology of rivers within this geomorphic setting was historically an interaction between valley floor forests composed of large conifer trees and large in-channel logjams, which typically created a stable, island-braided river channel (Collins et al. 2003). Channel avulsions are the main mechanism of channel migration in these systems; however, these typically result in the main channel re-activating relic channels. Thus, these systems can attain a relatively stable state that will transport the sediment load or even accommodate long-term storage of alluvial sediment in the channel migration zone without disruption of its morphological pattern, and can sustain complex aquatic habitat in the process. It is known from studies in similar river systems, however, that these systems are sensitive to external perturbations which can re-activate paraglacial sediment transport (Ballantyne 2002), resulting in unstable channel conditions and re-mobilization of floodplain sediment sources. Perturbations capable of destabilizing the system include altered sediment load or hydraulic energy (such as triggered by climate change, forest harvest, increased road density, tectonic movements, etc.) or loss of the logjams and large conifer

trees that stabilized the floodplain islands and comprised the source for large wood recruitment (Skokomish Tribe and WDFW, 2010).

Climate

The climate in the Skokomish Basin can be described as a temperate, marine climate with wet winters and dry summers. This climate supports a diverse flora and favors the growth of trees (WDFW and PNPTT 2000). Due to its location on the east side of the Olympic Mountain Range, there is a precipitation gradient from the headwaters down to Hood Canal. The extreme upper portions of the watershed receive nearly 304 cm (120 inches) of rain annually, while areas near Hood Canal receive approximately 152 cm (60 inches) of rain annually.

Long-term climate change is underway in the Pacific Northwest, including the Skokomish drainage (Mote 2003). These changes are especially important in watersheds which contain headwaters at intermediate elevations commonly known as the transient snow zone. The transient snow zone can shrink appreciably in response to relatively small increases in winter temperatures, which alters the pattern of runoff and the severity of peak flows (Cuo et al. 2008). This area is relatively large in the Skokomish Basin, which suggests that a relatively large change in precipitation from snow to rain has occurred and will likely continue to spread in the Skokomish Basin (Knowles et al. 2006), meaning that runoff shifts from spring and summer to mid-winter, and that peak flow magnitudes increase. This change in precipitation type will thus subsequently influence sediment transport and channel stability (see below for more details).

Hydrology

Historically, sub-basins in the Skokomish River had three different flow regime patterns that were directly related to the influence of snowmelt, including strong, weak, and no snowmelt influence (Skokomish Tribe and WDFW 2010). These varied flow regimes combine to provide the flow regime of the Skokomish Basin as a whole. Historically, peak runoff in the watershed occurred during the winter when precipitation is at its highest and a second, smaller peak occurred during the spring as mountain snow melted. The South Fork Skokomish and Mainstem, however, do not display this bimodal pattern of runoff, showing significant peaks only in only the winter season (England, 2007). Flows declined after the spring snowmelt reaching base flows in August or September. A peak flow of 36,600 cfs was observed on November 23, 1990 (USGS 2008) and base flows in the mainstem are approximately 205 cfs, based on 90% exceedence values from 1943-2008. However, lower sections of both the South Fork Skokomish and Vance Creek, where sediment aggradation has occurred, often go dry during summer base flow.

The current flow regime varies considerably from this historic regime (Skokomish Tribe and WDFW 2010). The primary peak runoff still occurs during the winter and flows still decline to base flows in August or September. However, the magnitude of the second spring runoff appears to be decreasing both in the South Fork Skokomish and North Fork Skokomish (above Cushman), and is completely absent below the two dams in the North Fork Skokomish (England 2007). This could be the result of changes in forest cover resulting from historic intensive logging in the watershed (South Fork Skokomish) or long-term climate change (Cuo et al., 2009;

Skokomish Tribe and WDFW 2010). Climate change appears to be the primary factor influencing hydrology (Skokomish Tribe and WDFW 2010), since the regime has shifted in both sub-basins, and little logging has occurred in the North Fork Skokomish above Lake Cushman (the gauge used for this assessment by Cuo et al.). The influence of climate change on hydrologic patterns may include higher annual maximum, fall, winter and early spring streamflow, but lower summer flow (Cuo et al. 2009, Mantua et al. 2010). Reductions in base flows from historic levels have been observed in the Skokomish Basin (Skokomish Tribe and WDFW 2010).

Peak discharges in the Skokomish Basin appear to be changing from historic values, although the available reports must be interpreted carefully. As mentioned above, climate change models predict increases in peak discharges in the Skokomish Basin. However, peak discharges are reduced from historic values in the mainstem Skokomish River due to water diversions at the Cushman dam (The Skokomish Tribe and WDFW 2010). England (2007) reports that there is an increasing trend in maximum flows in the North Fork Skokomish (1925-2006, 1967-2006) above the dams and in the mainstem Skokomish River (1944-2006, 1976-2006), which has recorded flows during the diversion period due to dam operation. Peak flow trends in the gage on the South Fork Skokomish are more difficult to discern due to its much shorter period of record (England 2007). These increasing trends in peak flow magnitude are evident in many stream gage records throughout Washington, including the Skykomish, Duckabush, Dungeness (England, 2007) and Stehekin Rivers (Bakke, 2009).

Regardless of how peak flows have changed from historic levels, it is quite clear that the channel's ability to convey those discharges has been reduced relative to historic values. Historic channel capacity at the HWY 101 Bridge was 13,000 cfs, but is currently approximately 4,100 cfs (Bountry et al. 2009). This is equivalent to a 1.1 year event and has a 90% chance of being exceeded during a given year (USACE 2010). Overbank flows occur at even lower discharges of only 2,500 cfs downstream of the HWY 101 Bridge (Karl Erickson, USACE, personal communication). Thus, channel capacity appears to be less than one-third of historic values, thereby increasing the frequency of overbank flow in the valley.

Disturbance Regime

Disturbance in the watershed can be categorized as either natural or anthropogenic (human influenced). The influence of these disturbances on the watershed will be determined in large part by the geology and hydrology of the system. The primary natural disturbances in the Skokomish watershed include flooding, mass wasting, fire, windthrow, insects and disease, non-native invasive plant species, and climate change. Each of these natural disturbances can result in increases in the other natural disturbances to some degree. However, climate change has the potential to influence the frequency and intensity of all of these natural disturbances (i.e., by influencing temperature and hydrology).

Mass wasting events and flooding are caused by a combination of physical attributes of the watershed, such as its topography and soil composition. The steep slopes of the upper Skokomish Basin, level of precipitation, relatively large size of the transient snow zone, and shallow soils, result in slopes that are prone to mass wasting events and flooding. These natural

disturbances have also been exacerbated by anthropogenic influences, which are discussed in more detail later.

Fires have always influenced the Skokomish watershed (USFS 1995, ME2 Environmental Services 1997). The last large fire occurred in 1834, which burned approximately 4% of the watershed (1,102 ha; 2,500 acres). An extremely large fire hasn't occurred in the Skokomish Basin since approximately 1701, when about half (13,759 ha, 34,000 acres) the watershed was burned. It appears that large fires occurred approximately once every 200 years prior to the 1701fire (USFS 1995, ME2 Environmental Services 1997). It's likely that stable watershed processes and associated channel conditions occurred between these fires and that this stability was not impacted greatly by the fire in 1834. Current fire management in the watershed varies depending on land ownership. Naturally occurring fires within Olympic National Park are monitored but not actively extinguished by fire crews. All fires occurring on the Olympic National Forest, on the other hand, are extinguished as soon as possible (USFS 1995).

There have been a number of different human impacts in the watershed, which vary with regard to the location where they occur. Logging and associated road building has occurred throughout the watershed, except within the boundaries of Olympic National Park. Other human impacts, which have been more common in the lower mainstem, include land conversion from forest to agriculture, removal of large wood from the channel, estuarine diking, riverine levee construction, dredging and channelization, and general development, which all combine to reduce floodplain connectivity. Two dams constructed on the North Fork Skokomish have altered the rivers hydrology and block anadromous fish passage. In addition, there are three fish hatcheries in the lower watershed, George Adams, McKernan, and Eels Springs.

Interaction of Physical Characteristics and Processes

The interaction of various physical characteristics and processes in the watershed has resulted in the main factor that limits habitat for both adult and juvenile salmon (and people) in the watershed: channel aggradation, or an increase in the overall sediment in the river channel, with its associated syndrome of morphological characteristics and changes to channel processes. Channel aggradation causes a host of problems affecting salmonid habitat. In this section, we will provide a brief overview of the factors which have contributed to aggradation, as a prelude to discussing its effects on salmonid habitat. To provide perspective, we will summarize the historic narrative of anthropogenic modifications to the watershed, and include a brief discussion of the sensitivity of a river channel in this geomorphic setting to alterations of the physical processes that determine channel structure, function, and stability.

Hypotheses for triggering aggradation and increased flooding in the Skokomish River commonly fall into the following six categories (Bountry et al., 2009; Skokomish Indian Tribe and WDFW, 2010):

1. Rapid deforestation in the form of clearcut logging, resulting in an increased sediment load;
2. Removal of large wood pieces and logjams, and clearing of riparian zone old-growth forest, resulting in conversion of an island-braided system to a less-stable braided system, triggering release of stored floodplain sediments;

3. Reduction in flow from the North Fork Skokomish due to the operation of Cushman dam, resulting in reduced sediment transport capacity in the lower mainstem;
4. Channelization of the river channel using riprap, crib structures, cabled logs, and removal of large wood, resulting in temporary improved hydraulic capacity, but reduced sediment transport efficiency;
5. Confinement of the channel by levees, resulting in backwatering of some areas, translation of depositional zones in a downstream direction, in-channel deposition of suspended sediments in low gradient areas, and loss of storage of coarse sediments in secondary channels;
6. Hydraulic constrictions of flow at bridge crossings, causing back watering and loss of sediment transport capacity.

Unfortunately, although each of these mechanisms is physically plausible and contributes to varying degrees, there is no professional consensus among the various people who have studied physical processes in the Skokomish River as to which of these hypothesized mechanisms are more important than others (Bountry et al., 2009). This is unfortunate because without clear understanding of the mechanisms for aggradation, we are less likely to be able to come to a consensus on which management solutions will be the most effective. What is indisputable, however, is that the river is aggrading (Stover and Montgomery, 2001), and at rates higher than those which could have existed for any extended period of time in the past. For example, at the U.S. Geological Survey (USGS) gaging station at the HWY 101 Bridge, Stover and Montgomery documented an aggradation rate of 1.3 meters over the 32 year period from 1965 to 1997, a rate of 0.4 meters per decade. The six mechanisms discussed above that may potentially be influencing this aggradation are discussed below.

Rapid deforestation in the form of clearcut logging is perhaps the most often cited mechanism for causing the observed changes in the lower Skokomish River. Logging activities in the upper South Fork Skokomish Basin and in Vance Creek have been documented to increase the rate of mass wasting events in the portion of the watershed that has been harvested by a factor of 3.1 (ME2 Environmental Services, 1997), from 1.1 to 3.4 events per km^2, during the 50 year period from 1946 to 1995. Mass wasting volumes contributed to the river during this time period by landslides associated with forest practices were estimated to be about 229,000 m^3, not including the large amounts of sediment input associated with the edges of fluvio-glacial terraces in middle portions of the watershed which were not mapped, but which could have been destabilized as a result of increased sediment input from harvest-related mass wasting, from logging of riparian trees, or removal of logjams.

This documented increase in the rate of mass wasting in the watershed, considered together with the rapid pace of forest harvest that occurred when much of the watershed was managed under the Shelton Cooperative Sustained Yield Unit, and the accelerated harvest that occurred in the early 1950s when the area was proposed to become inundated by a third hydropower dam reservoir, has led several previous researchers to conclude that extensive logging and its associated road building, mainly in upper portions of the South Fork Skokomish (SF) and Vance Creek sub-basins, is the main cause of increased sediment loads to the river channel (Canning et al. 1998; KCM 1993, 1997; Stover and Montgomery 2001). Indeed, approximately 60 to 80% of the South Fork Skokomish drainage basin has been harvested and thousands of miles of roads and railroad lines have been built (Canning et al. 1988; KCM 1993). As a whole, the Skokomish watershed has experienced over 600 mass wasting events over the

last 50 years. Sixty-five percent (65%) of these events were associated with the road network, and presumably would not have occurred in the absence of forest management (ME2 Environmental Services 1997). Generally speaking, road densities are higher in the lower watershed, but these are found on lower gradient slopes and at least a portion of them are paved, reducing the potential for them to release sediment into the river channel. Upper watershed tributaries have an average of about 2.8 km of road per km^2 (km/km^2) of watershed (4.5 mi/mi^2) while the middle and upper South Fork Skokomish have about 1.55 km of road km^2 of watershed (2.5 mi/mi^2) (Correa 2003). These are much higher values than observed in the nearby Duckabush and Hamma Hamma watersheds with road densities of 0.37 and 0.87 km/km^2, respectively (WDFW and PNPTT 2000).

Although significant amounts of additional sediment has entered stream channels as a result of the exacerbated mass wasting and logging activities in this system, it is unclear how much this has contributed to aggradation in the lower river. ME2 Environmental Services (1997) used aerial photos to estimate changes to the surface area of active channel and unvegetated terraces in five alluvial reaches over the period from 1929 to 1997, and detected and increasing trend in the three reaches located in the middle and upper South Fork Skokomish. They then went on to assume that these changes in unvegetated surface represent increases in active channel sediment storage, from which they could compute the storage volume change and compare it to the sediment input rate from mass wasting processes as well as an estimate of sediment transport derived from extrapolation of the bedload model (Simons and Associates, 1994). With these assumptions, they concluded that the sediment volume inputs from mass wasting represented only a small proportion (about 10 percent) of the change in active channel storage, the rest presumably coming from unmapped erosion and mass wasting associated with the glacio-fluvial terraces bounding the river. They further concluded that the estimated residence time for sediment stored in these depositional reaches was relatively long, on the order of 40 to 160 years for the two upper South Fork Skokomish reaches, which was too long for it to have influenced the current aggradation processes in the lower mainstem.

However, their methodology provides no means to check their assumptions. In particular, the assumed relationship between unvegetated area and sediment storage, and the relationship between presumed changes in storage and volume of sediment transported are highly uncertain, since no systematic measurements of streambed elevation were taken for comparison. Nor are there sediment transport measurements for the reaches in question to calibrate or confirm the transport model, which is in dispute (Watson, 1996). These considerations lead to an alternative interpretation of this analysis, which is that the increase in unvegetated area may better represent erosion than sediment in storage (deposition), in which case, two conclusions follow (Skokomish Indian Tribe and WDFW, 2010):

- that the increased mass wasting sediment input during the mid to late twentieth century, which is directly attributable to forest harvest and associated road building, was sufficient to massively destabilize the channel in these alluvial reaches along the South Fork Skokomish, releasing volumes of sediment from floodplain storage in quantities much larger than the volume which originally triggered the destabilization (a "knock-on" or cascading effect, in geomorphic terms); and,
- that significant portions of this *eroded* sediment volume may have been transmitted downstream.

In other words, the mass wasting triggered a threshold response, causing channel destabilization, which produced positive feedback in the form of additional sediment input, and was transmitted on downstream as a "knock-on" effect or cascading response. Whether this is the major cause of aggradation in the lower South Fork Skokomish and mainstem, however, remains undetermined.

This leads naturally to consideration of the next possible mechanism for aggradation, which is that removal of large wood pieces and logjams, and clearing of riparian zone old-growth forest, resulted in conversion of an island-braided system to a less-stable braided system, triggering release of stored floodplain sediments.

Large wood input and retention as logjams can influence channel form as significantly as both sediment and hydraulic inputs (Montgomery et al. 2003). The island-braided channel type, in which main and secondary channels are separated by stable, vegetated islands observed in some river systems is thought to evolve in sediment-rich systems in the presence of logjams (i.e., Collins and Montgomery 2002; Abbe and Montgomery 2003). In addition, logjams can be important in the development of floodplains (Abbe and Montgomery 2003) and in limiting bank erosion (Abbe and Montgomery 2003; O'Connor et al. 2003). Changes in the amount and the size of wood in a river can have similar impacts to changing sediment inputs or discharge patterns (Montgomery et al. 2003). Removal of large logjams has resulted in significant channel widening in other systems (Triska 1984; Brooks and Brierley 2000). Although removal of logjams initially increases the sediment transport capacity (Harvey et al. 1988; Brooks and Brierley 2000), if the ensuing bank erosion leads to a wider channel, and the concurrent drop in surface water elevation leads to reduced side channel activation, the end result is a system with lower sediment transport capacity (Huang and Nanson, 2007), setting the stage for aggradation.

There is evidence from early descriptions and early aerial photos that the South Fork Skokomish River flowed through a dense old-growth coniferous forest, that its channel was relatively narrow compared to current conditions, and that large logjams were a significant feature (Skokomish Indian Tribe and WDFW, 2010). The Skokomish Indian Tribe and WDFW (2010) hypothesize that the watershed and its associated channels were in a relatively stable condition prior to Euro-American settlement. The upper South Fork Skokomish alluvial valley above the South Fork Skokomish canyon, Vance Creek floodplain below the Vance Creek canyon, lower South Fork Skokomish below the South Fork Skokomish canyon and the lower mainstem are hypothesized to have consisted of stable river channels, side channels, and relic channels. These channels were thought to be separated by islands vegetated with mature forests and to contain numerous logjams, some of which were very large. This hypothesis is supported by early land surveys (Figure 2). The Skokomish River system, like most Olympic Peninsula rivers, is sediment rich, and had adjusted itself into an equilibrium morphology that accommodated the presence of large wood while efficiently transporting its sediment load. This morphology was likely an island-braided or anabranching system (Huang and Nanson, 2007), perhaps functionally similar to that described by Collins et al. (2003) for other Puget Sound rivers such as the lower Nisqually.

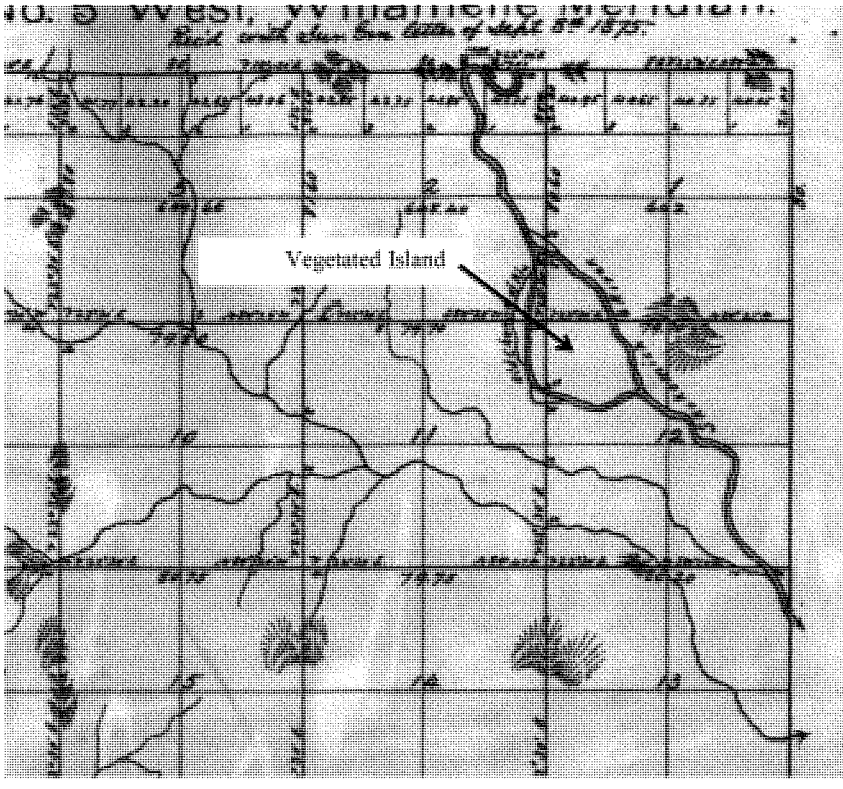

Figure 2. Example of the stable vegetated islands hypothesized to exist in the upper South Fork Skokomish, lower South Fork Skokomish below the Canyon, lower Vance Creek below the Canyon, and lower mainstem just below the North Fork Skokomish confluence. This map shows a vegetated island approximately one mile downstream of the canyon on South Fork Skokomish River (General Land Office) GLO Surveyor map from July 1875). The canyon is located at the top of the map with Vance Creek shown at the bottom of the map (Modified from Skokomish Indian Tribe and WDFW 2010).

These island-braided river systems are capable of storing large volumes of sediment in their islands and floodplains, and depend on an intact riparian forest and large, somewhat stable log jams for their overall channel stability. Removal of the logjams alters the partitioning of hydraulic energy in such a way as to cause increased bank erosion and channel instability, which can lead to export of stored sediment from the reach. Removal of riparian trees hastens the process of destabilization, such that the net effect of land clearing and channel cleaning can be a massive release of stored sediment, as described by Ballantyne (2002). As the channel widens through bank erosion, its capacity to transport sediment becomes reduced over what it was with multiple channels with lower width to depth ratios (Huang and Nanson, 2007), and it begins to aggrade. Several investigators have concluded that this phenomenon may be responsible for the current condition of the lower South Fork Skokomish and mainstem Skokomish Rivers.

This island braided morphology may have been common in sediment-rich areas such as the Skokomish Valley where stream gradient is decreasing in a downstream direction, with resulting decrease in stream power and sediment transport capacity. The steady decrease in gradient as you move from the mountains toward the marine environment is common to most western Washington Rivers. However, these systems apparently transported sediments efficiently with stable morphology prior to human manipulation. Downstream decreasing gradient is associated with transitions in morphology, which include changes in channel type (i.e., from a plane-bed or forced pool-riffle to island-braided morphology, Collins et al. 003), cross-sectional shape or area, substrate type, and bedload composition. The island braided morphology seems to be a transitional type that occurs where the sediment load is dominated by coarse bedload, and sediment storage as relatively stable islands and bars is occurring over long time scales (decades to centuries). Downstream from island braided reaches, it would be expected to encounter a meandering pool-riffle channel type with finer-textured bedload and with suspended load dominating the sediment yield (Beechie et al., 2006). However, in the Skokomish, as in some other Western Washington rivers, that latter transition never occurs, but rather the coarse-bedded morphology extends all the way to where the river transitions into a deltaic setting (Bountry et al., 2009).

Reduction in flow from the North Fork Skokomish due to the operation of Cushman dam, resulting in reduced sediment transport capacity in the lower mainstem is another factor often cited as cause for aggradation (Orsborn 1991a; Jay and Simenstad 1996; Stover and Montgomery 2000). For periods of time following the construction of the dams in 1930, the entire flow of the North Fork Skokomish was diverted directly into Hood Canal (Wampler 1980) through the penstocks of the Potlatch Power plant. More recently, Orsborn (1991a) reported that average monthly flows in October to March were reduced by 78 to 83%, while monthly average flows in the April to September period were reduced by 90 to 96%. More importantly, from a sediment transport standpoint, 2 and 50 year flood peak discharges have been reduced by 80% and 74%, respectively.

Channelization (straightening) of the river channel using riprap, crib structures, cabled logs, and removal of large wood, resulting in temporary improved hydraulic capacity, but reduced sediment transport efficiency is the next mechanism of interest. When a channel is straightened to increase flood conveyance, it is usually widened as well. This tends to improve hydraulic capacity, but actually reduces the sediment transport capacity over that of a more sinuous channel with a deep thalweg, a lower width to depth ratio, and the presence of secondary currents along the bed and banks that keep sediment mobilized. Channelization of the

Skokomish Basin began in the 1930s. At least four locations are thought to have been straightened, including the lower South Fork Skokomish just downstream of the canyon, just downstream of the Vance Creek confluence, the mainstem just below the old North Fork Skokomish confluence and the Church levee, and between HWY 101 and State Route (SR) 106. Due to the lack of information about the level of channelization it is impossible to quantify the impacts of this activity. However, sediment transport would likely have been reduced and edge habitat for juvenile salmon was certainly reduced.

Confinement of the channel by levees, resulting in backwatering of some areas, translation of depositional zones in a downstream direction, in-channel deposition of suspended sediments in low gradient areas, and loss of storage for coarse sediments in secondary channels is the next most commonly referenced cause of aggradation in the mainstem Skokomish River (Bountry et al. 2009). Levees that cause river channel or flood plain constrictions can cause a backwater pool to form upstream of the constriction (Bureau of Reclamation (BOR) 2002), which would result in slower velocities and subsequent sediment deposition in the backwater zone (i.e., local aggradation). This local aggradation would reduce channel gradients upstream, further impacting sediment transport. By contrast, the initial constriction caused by the levee may actually increase local sediment transport capacity. However, this increased capacity will also be relatively local in nature and may result in the relocation of sediment deposits. For example, if the levee acts as a constricting "conduit" between an area of relatively higher gradient and a reach downstream where the gradient is less, the levee can cause translation of a depositional area in a downstream direction, where coarse sediment that would have been deposited upstream may then be transferred and deposited further downstream than it otherwise would have been. Levees isolate the river from its floodplain, which removes some potential deposition zones for coarse sediment, such as side channels, from the system. As the river approaches its estuary, suspended sediment may begin to deposit on the channel bed instead of spreading out over the floodplain as would happen without levee confinement. Levee construction can increase stage height during floods due to the complex interaction between channel roughness, deposition, and reduction in floodplain connectivity (Pinter et al. 2000; BOR 2002; Remo and Pinter 2007).

In the Skokomish Basin, levees have been constructed from the confluence of the South Fork Skokomish with Vance Creek all the way down to Hood Canal (Figure 3). The construction of these levees on the mainstem Skokomish River coincides with the beginning of main channel aggradation documented by Stover and Montgomery (2001). Reviewing this information suggests that the greatest impacts of levee constricting the channel and/or floodplain occur at four locations including, Nalley Island, near the old North Fork Skokomish confluence, just downstream of the Church dike, and the HWY 101 roadway across the Skokomish floodplain. Figure 3 shows the location of current levees and levees/dikes that have been removed;

Hydraulic constrictions of flow at bridge crossings, causing back watering and loss of sediment transport capacity, is the final mechanism of interest. Narrow bridges or those with fill used for the bridge approaches, can have impacts similar to those described above for levees. These bridge features can constrict the channel, isolating the river from its floodplain and side channels, and resulting in backwatering upstream of the bridge and the subsequent deposition of sediments (BOR 2002). There are currently four channels in the lower Skokomish River valley with bridge crossings, including from north to south, the Skokomish River overflow channel,

mainstem Skokomish River, Weaver Creek and Purdy Creek (West Consultants, Inc. 2006). Two other bridges occur, one on Vance Creek, upstream of the HWY 101 bridges and one downstream on the Skokomish River serving SR 106. These bridges appear to have been first built in the 1930s (Table 1). Several of these bridges were rebuilt in the 1970s and 1980s. LiDAR clearly show that floodplain fill has been used to provide approaches for these four bridge (Figure 4). Many of these bridges are narrow openings relative to the channel width of the channels they cross and have resulted in at least some backwatering in the Skokomish Valley during flooding. For example, water has backed up behind the Highway 101 Bridge and SR 106 Bridge during floods (Bountry et al. 2009). In 2009, the 110 ft. span over Purdy Creek was replaced in 2009 with a 350 ft. span. Increasing the size of this single span is expected to generally decrease backwatering upstream of all four HWY 101 bridges (West Consultants, Inc. 2006).

Each of the factors discussed above could potentially be impacted by climate change. Climate change has been a continuous occurrence throughout the history of the world. However, current climate change appears to have been accelerated by human activities (Climate Impacts Group 2009). Climate change can influence the intensity and timing of precipitation, alter contribution ratio of rain and snow, alter vegetation cover, increase sea level (Goudie 2006) and alter disturbance regimes (Climate Impacts Group 2009). These factors can in turn alter sediment transport capabilities of the river and material input (i.e., sediment, LWD). These changes could be significant enough to further destabilize the channel. Sea level rise would impact the Skokomish delta by increasing base level elevation, resulting in potentially greater reductions in sediment transport capabilities in the lower river. In contrast to other natural disturbances (i.e., fires, extreme floods), which occur over short periods (usually less than weeks), climate change occurs over long time periods and is more similar to long-duration anthropogenic disturbances (i.e., logging) (Bakke 2009). Although change occurs over a longer timeframe, sudden changes in the associated physical processes may occur as some threshold is reached (i.e. hydrologic inputs sufficient to cause mass wasting), thereby having an immediate impact to aquatic habitat. In addition, these long-term changes can result in long term instability relative to more sudden impacts. Although climate change has influenced peak flows in other basins, it's unclear if these same changes have occurred in the Skokomish River (England 2007). As discussed above under the 'hydrology' sub-section, there are some indications that peak discharges and trends in peak discharges have increased in some parts of the watershed but not others. Although summer low flows are reduced relative to historic values, these could be the result of sediment aggradation in the lower South Fork Skokomish, lower Vance Creek, and mainstem as well as flow reductions resulting from diversion of flows from the North Fork Skokomish. Based on this information, it appears that climate change has had a minimal impact on sediment inputs and hydrology of the Skokomish Basin.

In conclusion, the combination of the physical nature of the Skokomish Basin as a sediment rich system; increased sediment inputs resulting from land clearing and logjam removal; and reduced hydraulic capabilities resulting from water diversion, river and floodplain constrictions (i.e., levees and bridges) has resulted in too much sediment entering the river channel and has reduced the rivers hydraulic energy to remove the sediment, thereby resulting in channel aggradation. Whether the resulting aggradation is primarily the result of increased sediment input or reduced inability of the river to transport this sediment is unclear. Changes in either sediment inputs or sediment transport capabilities would result in aggradation and thereby

influence the other factor through positive feedback. Regardless of the cause, this increased sediment deposition in the river channel increases the frequency of flooding, which negatively influences humans and fish habitat. In addition, increases in flooding frequency results in a host of natural and anthropogenic responses which generally adversely affect juvenile salmon rearing habitat. It is also quite clear that both increased sediment inputs and decreased hydraulic capabilities of the system need to be addressed to reduce flooding in the Skokomish Basin and improve fish habitat.

Table 1provides a summary of the timeline of natural and human induced events that may have influenced the processes leading the hypotheses regarding channel aggradation and habitat in the Skokomish Basin. This table was modified from Skokomish Indian Tribe and WDFW (2010). These events can generally be classified as climate change, land clearing, logjam removal, floodplain constriction, channelization, water withdrawal, and restoration. Each of the disturbances listed have the potential to re-activate paraglacial processes (Ballantyne 2002), which would result in channel instability.

Table 1. Timeline of natural and human induced events that have influenced factors affecting channel stability and fish habitat in the Skokomish Basin. The decade when the event occurred, a summary of the event, the factor influenced (i.e., sediment input, hydrology), and the likely impact of the alteration are listed. Modified from a similar table (Table 4.38) in Skokomish Indian Tribe and WDFW (2010).

Decade	Event	Factor Influenced	Likely Impact
~14,000 BP	Glacial recession in the Skokomish Basin		
<1850	Only minor alterations of watershed by humans exist; homeland of Twana people	None	None
1850	Euro-Americans begin settling lower Skokomish floodplain	Sediment and Large Wood (LWD) input	Minimal reduction in bank stability and LWD input
1860	Land clearing and agriculture development of lower Skokomish floodplain	Sediment and LWD input	Minimal reduction in bank stability and LWD input
1870	Land clearing and agriculture development of lower Skokomish floodplain	Sediment and LWD input	Minimal reduction in bank stability and LWD input
1880	Continued agricultural development of lower Skokomish floodplain	Sediment and LWD input	Increased sediment input due to erosion in the lower river, reduced LWD inputs in the lower river
1880	Beginning of industrial logging in lower valley	Sediment and LWD input	Increased sediment input due to erosion in the lower river, reduced LWD inputs in the lower river
1890	Logging of lower valleys, logjam clearing, log driving; farm development continued	Sediment and LWD input	Impacts sediment and LWD inputs. These events likely resulted in substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion, but logs not allowed to accumulate
1900	Logging of lower valleys	Sediment and LWD input	Likely substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion, but logs being actively removed

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1900	Logjam clearing	Sediment input, sediment transport, channel stability	Likely substantial increases in sediment input due to erosion in the lower river, LWD retention and bank stability reduced, channel evolution from island braided to braided underway
1900	Log driving	Sediment input, sediment transport, channel stability	Likely substantial increases in sediment input due to erosion in the lower river, LWD retention and bank stability reduced, channel evolution from island braided to braided underway
1900	Farm development continued	Sediment input and LWD input	Likely substantial increases in sediment inputs due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion but logs actively removed
1910	Extensive logging of lower North Fork Skokomish (NF) on Pope and Talbot lands	Sediment input and LWD input	Likely substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion but logs actively removed
1910	SR 106 (old State Road 21 and 14)	Hydrology	Reduced floodplain conveyance of flood flows due to hypothesized fill for bridge abutments. This likely reduced sediment transport above the bridge resulting in increased sediment deposition.
1920	Construction of Cushman dams; diversion of NF flow out of the Skokomish Basin at Cushman Dam No. 2 in 1930	Hydrology	Sediment transport capabilities of the North Fork Skokomish and mainstem river are reduced resulting in aggradation in the mainstem Skokomish which further limits sediment transport capabilities
1930	Clearcut logging begins on USFS lands in the SF	Sediment input and LWD input	Likely substantial increases in sediment input due to erosion in the lower river, LWD inputs perhaps similar to historic level due to increased erosion in the upper South Fork Skokomish

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1930	Extensive diking within river delta for farm development	Hydrology	Reduced floodplain conveyance for floodwaters, resulting in backwatering upstream of dikes likely causing sediment deposition upstream. Reduced sediment storage on delta islands, increased sediment storage on the delta prism
1930	Channel channelization/straightening	Hydrology	Reduced sediment transport capabilities
1930	River channel gravel mining	Sediment inputs	Reduced channel sediments. Likely resulted in local head cutting along with potential bed and bank scour, channel destabilization
1930	HWY 101 bridges built at Purdy Cr., Weaver Cr., north Skokomish overflow channel	Hydrology	Reduced conveyance for floodwaters, backwatering and sediment deposition upstream of the bridge
1930	Evidence of aggradation	Sediment input	Likely increase in bank erosion
1940	Creation of Shelton Cooperative Sustained Yield Unit (CSYU) Agreement on Simpson Timber and USFS lands in the South Fork (SF) Skokomish (1946); logging accelerates	Sediment and LWD input, hydrology	Increased mass wasting in upper reaches, triggering channel instability and sediment inputs in alluvial reaches along South Fork Skokomish and Vance Creek, as well as increased frequency of moderate flood peaks in the South Fork Skokomish
1940	Lower mainstem aggrades 1.5 ft (0.46 m)	Hydrology	Likely increase in bank erosion and decreased channel habitat diversity
1950	Clearcutting in SF anticipating hydroelectric project	Sediment and LWD input, hydrology	Reduced slope and bank stability results in increased mass wasting and sediment inputs, reduced wood recruitment, increased flood peaks in the South Fork Skokomish
1950	Logjam removal in SF and other streams in anticipation of an additional hydroelectric project	Sediment input	Reduced bank stability, release of sediments from protected islands and from upstream accumulations

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1950	Diking in Vance Creek and lower river	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwatering, reduced floodplain and side channel storage of sediment and increased retention of sediments in the channel
1950	Variable aggradation in lower river	Hydrology	Likely increase in bank erosion and decreased channel habitat diversity due to ongoing aggradation
1960	Extensive development of dikes	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwater effects, reduced floodplain and secondary storage of sediment and increased retention of sediments in the channel
1960	Accelerating road building and logging in the CSYU	Sediment and LWD input, hydrology	Increased mass wasting and sediment inputs, triggering channel instability and mobilization of floodplain sediments; reduced wood recruitment due to riparian zone logging, , increased frequency of flood peaks in the South Fork Skokomish
1960	Evidence for increased aggradation in lower river.	Hydrology	Likely increase in bank erosion and reduced channel habitat diversity
1970	Dike and revetment system lengthened and repaired	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwater effect , reduced floodplain and secondary channel storage of sediment and increased retention of sediments in the channel
1970	Road building and logging in CSYU occurring at high rates	Sediment and LWD input, hydrology	Increased mass wasting and sediment inputs, triggering channel instability and mobilization of floodplain sediments; reduced wood recruitment due to riparian zone logging; increased frequency of flood peaks in the South Fork Skokomish

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1970	HWY 101 bridge at Weaver Creek re-built	Hydrology	Unknown. It's unclear if this resulted in increased or decreased conveyance (i.e., additional, wider bridge, or new additional smaller bridge?)
1980	Rapid logging of CSYU continues to early 1980s, then declines later in the decade	Sediment and LWD input, hydrology	Increased mass wasting and sediment inputs, triggering channel instability and mobilization of floodplain sediments; reduced wood recruitment due to riparian zone logging; increased frequency of flood peaks in the South Fork Skokomish
1980	Dike structural repairs and additions to various structures made	Hydrology	Reduced sediment transport capabilities upstream of the artificial constrictions due to backwater effects; reduced floodplain and secondary channel storage of sediment and increased retention of sediments in the channel
1980	Timber-Fish-and-Wildlife (TFW) agreement signed	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
1980	3.2 ft (0.98 m) of aggradation since 1969 measured at HWY 101	Hydrology	Likely increase in bank erosion and reduced channel habitat diversity
1980	HWY 101 bridges over the Skokomish and SR 106 bridge rebuilt	Hydrology	Unknown. It's unclear if the bridge is wider and if additional floodplain filling occurred.
1990	Logging on USFS lands in SF reduced significantly then essentially stopped (mid 1990's)	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
1990	Watershed restoration activities begin on USFS lands.	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
1990	Extensive logging of second growth on Simpson lands	Sediment input and Hydrology	Impacts to sediment inputs and hydrology likely reduced compared to historic impacts

Table 1. Continued

Decade	Event	Factor Influenced	Likely Impact
1990	Forest and Fish Law enacted (1999)	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
2000	Logging of second growth timber on Simpson lands	Sediment input and Hydrology	Impacts to sediment inputs and hydrology likely reduced compared to historic impacts
2000	Continued evidence for aggradation	Hydrology	Likely increase in bank erosion and reduced channel habitat diversity
2000	Restoration work in upper SF to close roads	Sediment input and Hydrology	Streambank and hill slope stability likely begin to improve, peak flow impacts likely begin to reduce as well
2000	GI initiated	No effect	No effect
2000	Cushman Settlement reached (2009)	Hydrology	Minimal impact to this point
2010	Cushman Settlement agreement implemented	Hydrology	Improved sediment transport capabilities in the North Fork Skokomish below the two dams and in the lower mainstem
2010	Floodplain restoration in SF by USFS	Sediment input	Increased bank stability and floodplain sediment storage, and potential for improved sediment transport
2010	Dikes removed and borrow ditches filled on Nalley Island	Hydrology	Increased conveyance of floodwater, reduced backwater effect, increased sediment storage capability on delta islands and reduced sediment storage in the channel
2010	Purdy Creek Bridge improved (2009)	Hydrology	Increased conveyance of floodwater, reduced backwater effect, improved local sediment transport
2010	Air temperatures increased by 0.8°C (1.5°F) since 1920 in the Pacific Northwest	Sediment input and Hydrology	Likely increase in peak flow magnitudes and shift from spring peak flows to winter peak flows, reduced summer baseflows; potential increase in mass wasting due to wetter winters.

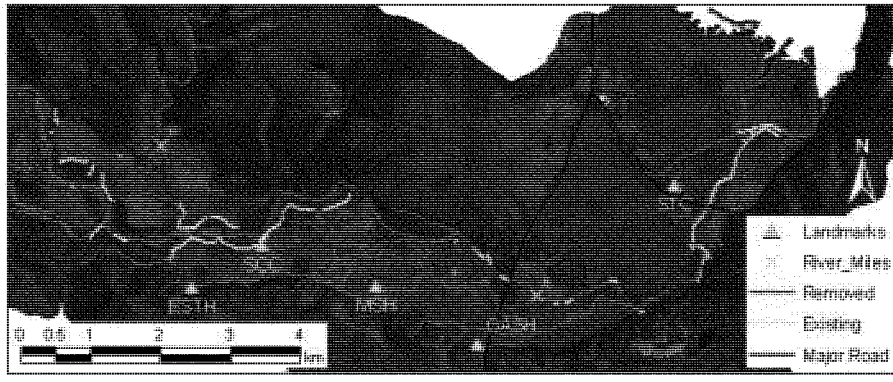

Figure 3. Locations of current levees and levees/dikes that have been removed in the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH).

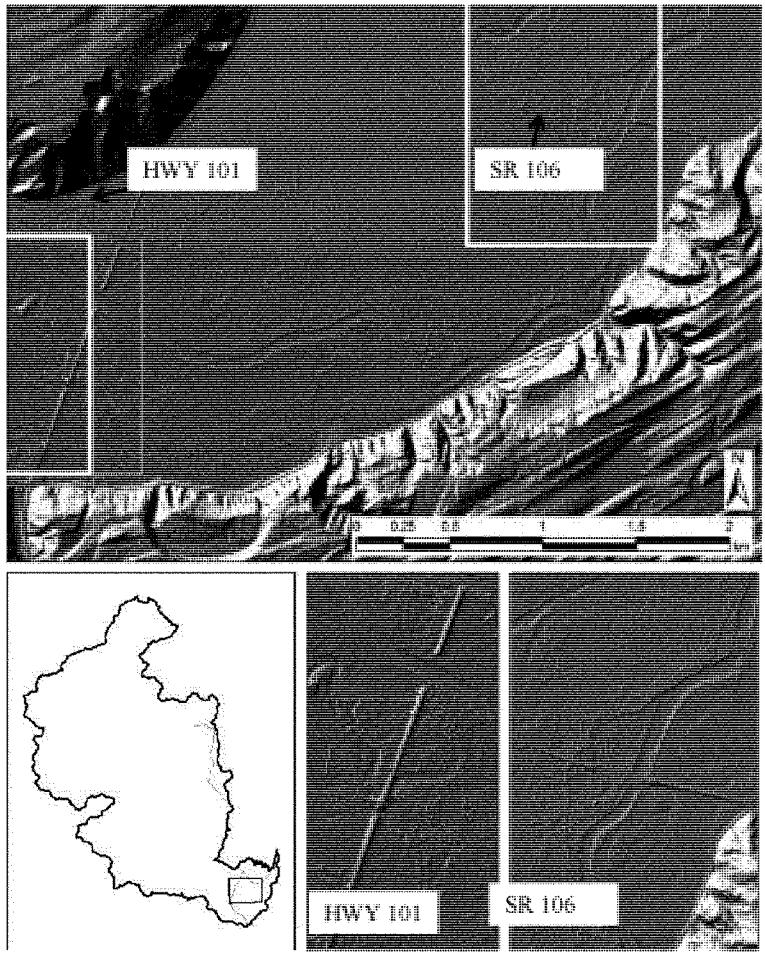

Figure 4. LiDAR images depicting the floodplain fill that has been used to provide approaches for four HWY 101 bridges and one SR 106 bridge in the lower Skokomish Basin.

Current Habitat Conditions for All Species: Stream Habitat

The natural and anthropogenic processes described above combine to form the current fish habitat existing in the Skokomish Basin. The focus of the current study is on habitat for juvenile anadromous salmonids and the following section describes the current state of juvenile salmonid habitat. However, reference will also be made to impacts on adult salmonids as well, since the distribution and abundance of adults can influence the distribution and abundance of

juveniles. Information from data collected as part of the Skokomish GI, as well as past habitat data collections, are summarized in this section.

Sample Sites

New data collected for the Skokomish GI was conducted in numerous study reaches and off-channel ponds throughout the Skokomish Basin (see Appendix A for details). Study reaches within the Skokomish Basin were stratified by channel confinement and stream gradient, for a total of 8 strata (Table 2). We then sampled a total of 21 study reaches during the summer of 2008 and 24 study reaches during the winter of 2009 (Figure 5). Of the reaches sampled during the summer, 16 were randomly selected and 5 were selected by the USACE. Of the winter sample reaches, 19 sites were randomly selected and 5 were selected by the USACE (See Appendix B for details of habitat sampling methods). A total of 22,618 m in stream length was sampled during the summer, 15,100 m from randomly selected reaches and 7,518 m from the USACE reaches. A total of 22,963 m was sampled during the winter, with 17,808 m from randomly selected reaches and 5,154 m from the USACE reaches.

Two of the USACE selected reaches, the Old North Fork Skokomish, South Fork Skokomish confluence reach (ONFSF) and the New North Fork Skokomish, South Fork Skokomish confluence (NNFSF) reaches, intersected one of the randomly selected reaches (2-27) and, therefore were shortened so that the reaches did not overlap. This resulted in these two USACE reaches being shorter than they would have been otherwise based on their bankfull width. In addition, the reaches 2-30 and 2-38, which were only sampled during the summer, also overlapped, and were shortened to prevent the overlap resulting in these reaches being shorter than they would have been otherwise based on their bankfull width. The downstream end of the snorkeled reach for 2-30 was at the same point as the upstream end of the snorkeled reach for 2-38.

General habitat availability for anadromous salmonids was determined by reviewing segment reach length data from the Northwest Indian Fisheries Commission (NWIFC) Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) (NWIFC 2004), barrier information from WDFW (Williams et al. 1975), and discussions with fisheries biologists familiar with the system (L. Ogg, USFS – retired; Marty Ereth, Skokomish Indian Tribe – now with Pierce County; personal communication). Based on this assessment, we determined that there is approximately 132 km (82 mi) of anadromous fish habitat in the Skokomish Basin (Figure 6). There is slightly more mainstem (55.4%) habitat than tributary (44.6%) habitat within the anadromous zone of the Skokomish Basin. A majority of this habitat is low gradient (<2%) unconfined channels (floodplain width $\geq$ 4 channel widths), which makes up nearly 80% of the anadromous zone within the Skokomish Basin (Table 2; Figure 5). Very little of the anadromous habitat (<8%) has a gradient greater than 4%. In addition, there are about 4.1 km of the mainstem and 1.6 km of side channel classified as being in the stream estuary ecotone (Figure 7). The classification of the stream-estuary ecotone was based on observations of tidal influence during our sampling (observed at site 2.23 but not site 2.28 – see Figure 5) and the present of estuarine dependent species such as flounder.

Table 2. Stream segment strata used to stratify tributary and mainstem river habitat in the Skokomish Basin based on stream gradient and channel confinement.

Strata	Stream Gradient	Channel Confinement	Total Stream Length (km)	Percent of Total Length	Number of Sites Sampled
S1U	<1%	Unconfined	79.40	60.1	20
S1C	<1%	Confined	16.39	12.4	5
S1-2U	1-2%	Unconfined	13.11	9.9	5
S2-4U	2-4%	Unconfined	7.60	5.8	2
S2-4C	2-4%	Confined	7.95	5.4	2
S4-8C	4-8%	Confined	5.71	4.3	2
S8C	>8%	Confined	1.97	1.5	2

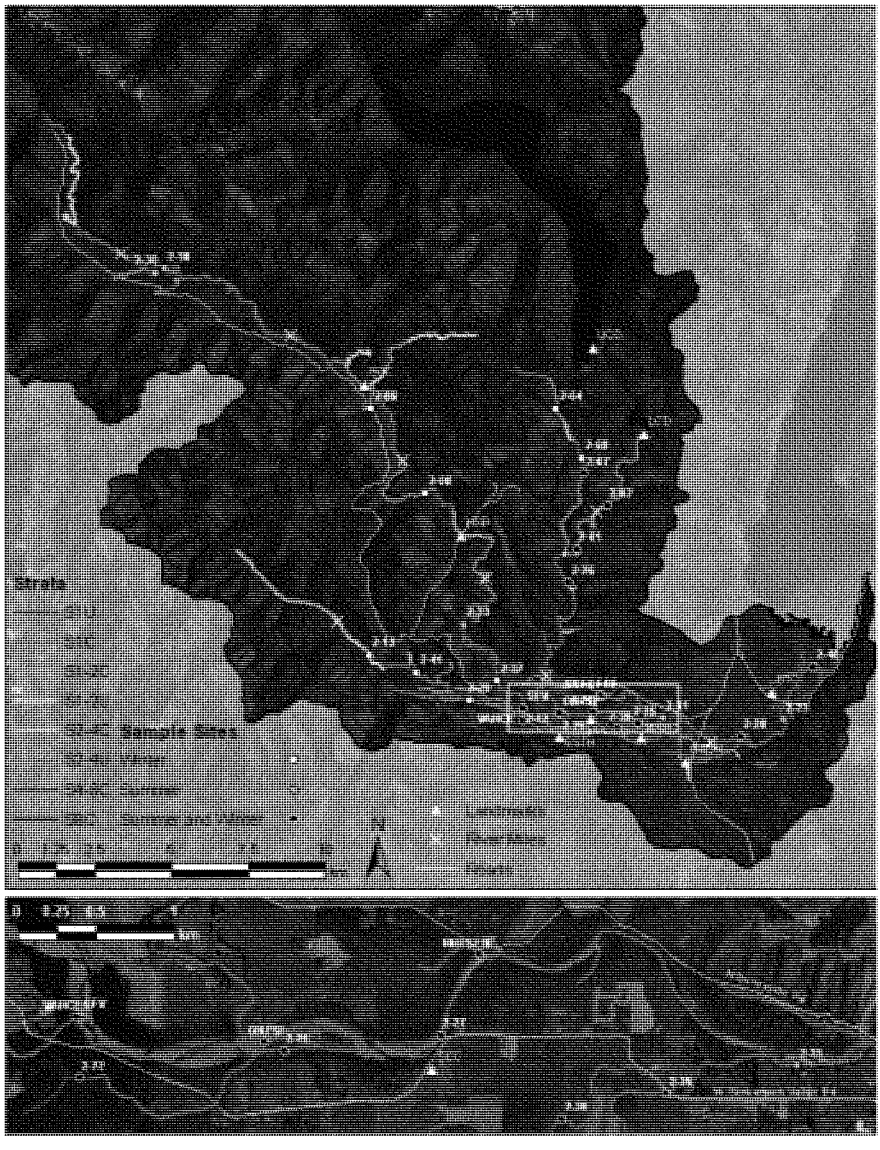

Figure 5. Locations where habitat was measured during the summer and winter of 2008 and 2009, respectively. Strata codes represent gradient at <1% (1), 1-2% (1-2), 2-4% (2-4), 4-8% (4-8) and >8% (8), while confinement codes are confined (C) and unconfined (U). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

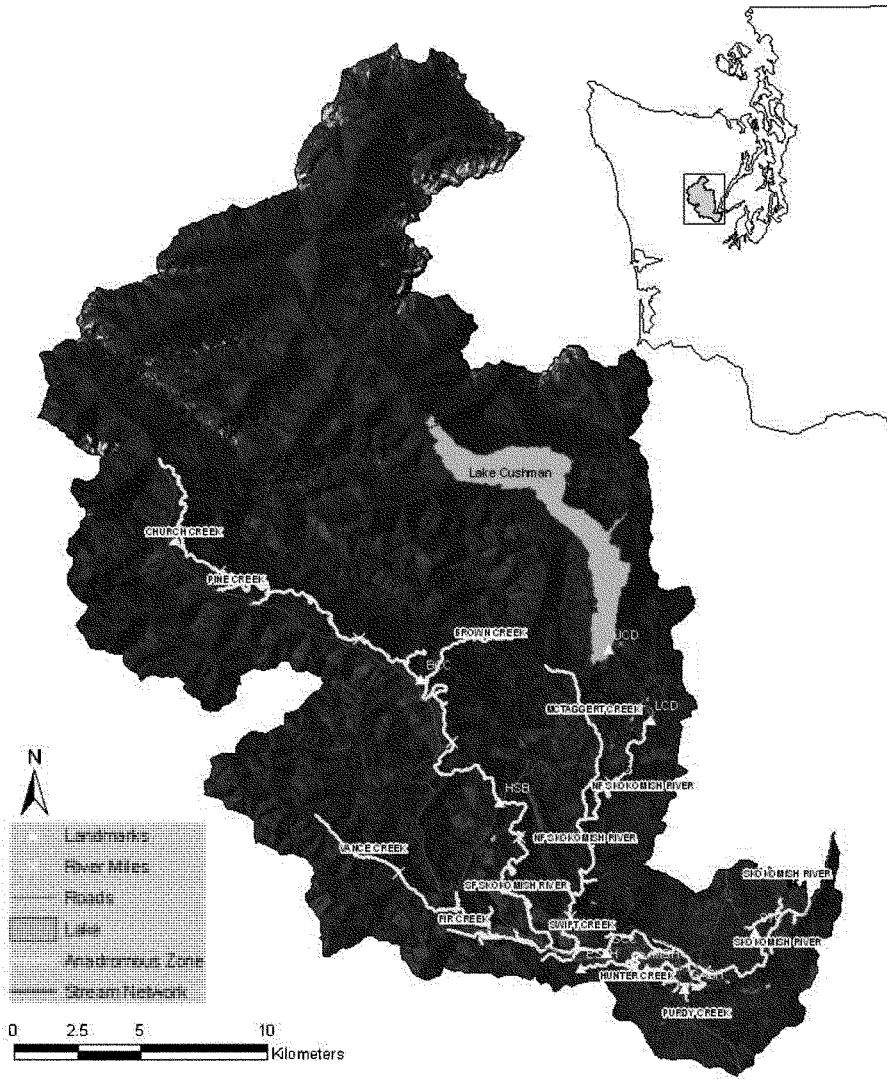

Figure 6. Anadromous fish zone within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

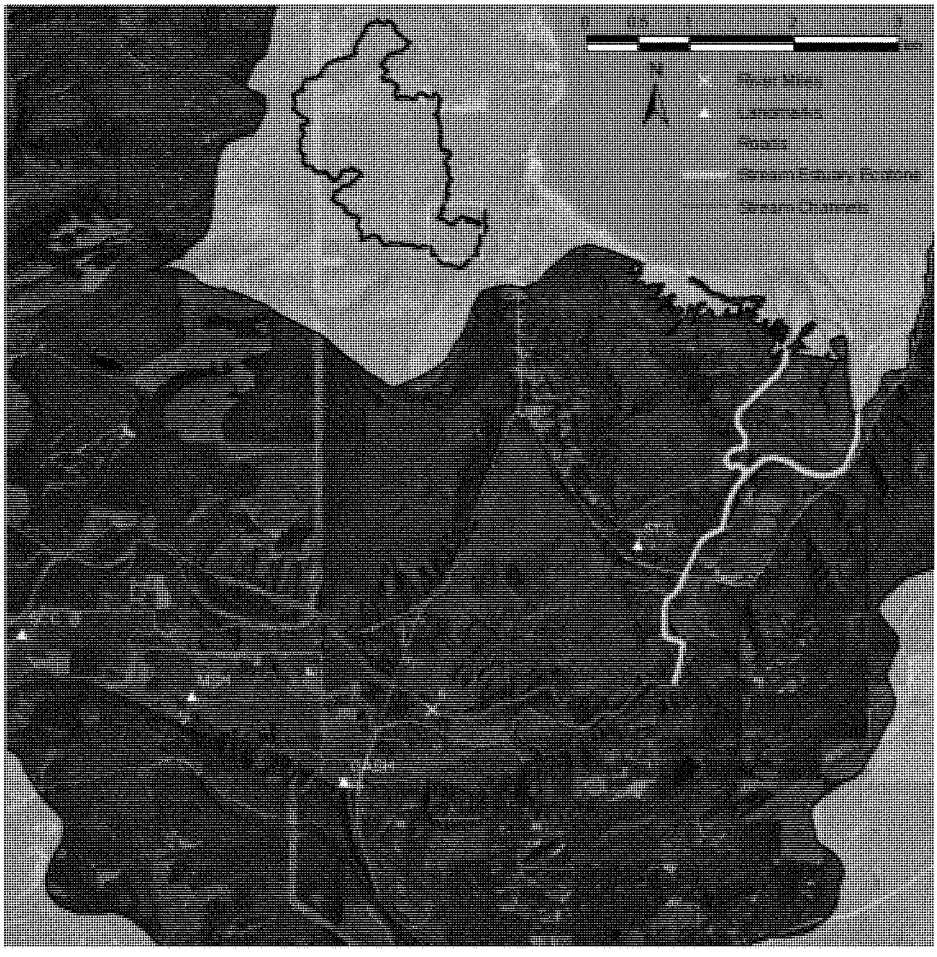

Figure 7. Extent of the stream estuary ecotone in the lower Skokomish River. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC).

The fact that a majority of the available habitat is in the mainstem rather than tributaries is somewhat unique and may somewhat limit salmon productivity in the system. In general, a significant proportion of habitat available to juvenile salmonids in river basins is usually located in tributaries (i.e., ~33% in the Skagit Basin (Beechie et al. 1994), and tributaries are thought to produce significant proportions of juvenile salmonids, particularly coho salmon (i.e., Beechie et al. 1994). However, this limitation may be overcome by the fact that so much of the Skokomish Basin is made up of low gradient unconfined reaches, which are generally the most productive

salmon habitats (Burnett et al. 2007). Unfortunately, much of this habitat in the Skokomish Basin is also the most degraded.

Salmonid Habitat Degradation

Threats to juvenile salmon habitat in the Skokomish watershed are the result of the cascading effects of the disturbances to physical process occurring throughout the watershed as described above. The resulting sediment aggradation and general impact to the general processes has four main effects on juvenile fish habitat including reduced 1) habitat availability, 2) habitat connectivity, 3) habitat stability, and 4) habitat quality. Each of these effects and the factors responsible for them are discussed below.

Reduced Habitat Availability

Habitat availability in the Skokomish Basin has been reduced as a result of dams, loss of side channel habitat, and channelization. Construction of the two Cushman dams blocked migration to approximately 26 km (16 mi) of mainstem habitat, based on assessment of stream segment lengths in the Seg-16a Geographic Information System (GIS) layer provide by SSHIAP (NWIFC 2004). This assumes that prior to the construction of the dams; salmon were able to ascend to RKM 53 (RVM 33), as asserted by the Skokomish Indian Tribe and WDFW (2010). We estimated that an additional 13 km (8 mi) of tributary habitat would have been available, based on this same data source. We assumed that migratory barriers were present in tributary reaches with more than a 4% gradient; a relatively conservative measure. A majority of the isolated tributary habitat was from Big Creek and Dow Creek. However, it's unclear what the gradient of these streams was, as they currently lie below Lake Cushman, which is not depicted on our GIS layers. Based on this assessment, the Cushman projects block access to approximately 25% of the mainstem habitat and 18% of the tributary habitat available to anadromous salmon in the Skokomish Basin. In addition, the Cushman projects block access to approximately 320 ha (965 acre) of lake habitat that would have been provided by the pre-dam Lake Cushman. This loss of habitat may be even more important than the actual amount of habitat loss implies, since the area inundated and blocked by Cushman Dam has been stated to potentially have been some of the most productive salmon habitat in the Skokomish Basin (Skokomish Indian Tribe and WDFW 2010). The impact of the two Cushman dams will be partially mitigated through the new FERC licensing agreement that requires upstream passage of adults and downstream passage of juveniles through these projects.

The loss of vegetated islands and their associated side channels, as a result of clearing riparian zone old-growth forests and removal of logjams, represents a significant loss of habitat for salmonids. Based on the assessment above, several locations within the Skokomish Basin historically had well established vegetated islands within the valley floodplain, which were surrounded and intersected by numerous river channels (see Figure 2). Although some of these channels were likely relic channels, which may have contained water only during high flows, many likely had flowing water during non-base flow periods (Skokomish Indian Tribe and WDFW 2010). Currently, there are very few vegetated islands in the valleys of the Skokomish Basin. We examined aerial photographs from 2007 at a 1:2,500 scale using GIS to determine the number of side channels in the system. For the purpose of this exercise we defined main channel, side channel, and braided channel habitat as follows:

- Main channel: Primary channel containing a majority of the stream discharge

- Braided channel: Secondary channel separated from the main channel by a grave bar lacking vegetation or having only sparse and young (<2 yrs) vegetation, such as immature trees and/or brush.
- Side channel: Secondary channel separated from the main channel by an island with mature vegetation.

Examination of aerial photos show eight vegetated islands in the lower Skokomish Basin below the canyons, seven in the lower mainstem, and one in lower Vance Creek. Total side channel stream length was estimated at 4.6 km in the lower mainstem and 360 m in lower Vance Creek. However, more than a third of this total was associated with the distributary channel around Nalley Island, located in the Skokomish estuary. Although it's possible we missed some side channels during this analysis, it is still quite likely that channel diversity has been reduced throughout the Skokomish Basin, especially in the upper and lower South Fork Skokomish. For example, the Skokomish Indian Tribe and WDFW (2010) state that an island described by the GLO surveyor Ross Shoecraft, which was located just downstream of the South Fork Skokomish canyon was approximately 1 mile (1.6 km) long and a half mile wide. Thus, the side channel around this lost island would have represented a third of current estimated side channel habitat. It's likely that this channel was significantly longer than 1.6 km (the length of the island) and that several other side channels may have traversed the island as well.

In addition to assessing aerial photos for channel complexity, we obtained data on all channel types within our study reaches. We observed side channels in only 6 of our study reaches during both summer and winter surveys (Table 3; Table 4; Figure 8). Side channel habitat, when present, also generally made up less than 20% of the total channel length surveyed at the site. This limited availability of side channels occurred despite the fact that we surveyed a nearly continuous stretch of stream from just above the old North Fork Skokomish confluence to just above HWY 101; an area that historically likely had numerous side channels. The apparent reduction in side channel habitat represents a significant loss of habitat for salmon. Adult salmon are known to spawn in side channels (Eiler et al. 1992; Hiss 1995). In addition, loss of channel diversity reduces available habitat for juvenile salmonids. Juvenile salmon use side channel habitat extensively (Murphy et al. 1989; Hirschi and Reed 1998; Jeanes and Hilgert 2000; Peters, FWS, unpublished data). Juvenile Chinook salmon densities in reaches of the Cedar River were positively related to the amount of edge habitat and the proportion of side channel habitat within the reach (R. Peters, FWS, unpublished data). This is likely due to the fact that newly emerged juveniles are dependent on edge habitat associated with the river bank and velocities in the mainstem may be too fast (Rosenfeld et al. 2008). Juvenile Chinook salmon in the Cedar River were rarely more than a couple of meters away from the river edge (R. Peters, FWS, unpublished data). Thus, the loss of side channel habitat represents a significant loss of edge habitat for juvenile salmonids.

Although the number of side channels in the Skokomish Basin has been reduced, the number of braided channels has likely increased (Table 3 and Table 4). Our GIS assessment counted eight braided channels totaling 1.6 km in the lower mainstem, 13 braided channels totaling 2.4 km in the lower South Fork Skokomish, 15 braided channels totaling 1.2 km in lower Vance Creek, and 35 braided channels totaling 4.6 km in the upper South Fork Skokomish. We observed braided channels in all but 3 of the summer study reaches and 6 of the winter study reaches. Braided channels were three times and four times more abundant than side channels during summer and winter, respectively. In addition, braided channels made up a majority of the

habitat within one reach in the summer and winter surveys. Thus, it appears that there may have been a transition from side channel dominated lateral habitats to braided channel lateral habitats throughout much of the Skokomish Basin. Although braided channels also provide edge habitat, the quality of this edge habitat for juvenile salmon is likely reduced relative to side channels. Juvenile Chinook salmon densities in the Cedar River, Washington were positively related to overhead cover provided by adjacent riparian vegetation (R. Peters, FWS, unpublished data), likely due to the added protection from predators (Helfman 1981). This may explain why juvenile Chinook salmon in the Cedar River showed a marked preference for side channels relative to the mainstem river and associated braided channel (R. Peters, FWS, unpublished data; Murphy et al. 1989).

Table 3. Percent (based on length) of the habitat in reaches surveyed dnring this study composed of braided channels (BC), backwaters (BW), main channel (MC), overflow channel (OC), and side channels (SC), along with the ratio of total channel length to main channel length per reach (Tot:MC Ratio) in the different study reaches during the summer of 2008. Site names of reaches correspond to those in Figure 5. The range, mean, and Standard Error (SE) conditions observed over all the sites are also provided.

	Bankfull	Channel Type					Tot:MC
Site Name	Width (m)	BC	BW	MC	OC	SC	Ratio
2-01	15.7	10.2	11.3	78.6	0	0	1.3
2-02	17.8	12.2	9.1	78.6	0	0	1.3
2-23	32.8	1.8	7.5	90.7	0	0	1.1
2-25	11.4	10.0	0	79.5	0	10.5	1.3
2-26	14.6	9.2	4.1	79.5	0	7.2	1.3
2-27	29.7	16.8	4.1	67.8	0	11.4	1.5
2-28	33.6	1.7	2.7	95.6	0	0	1.0
2-30	40.8	7.0	7.9	85.1	0	0	1.2
2-31	43.3	4.4	3.6	72.8	0	19.1	1.4
2-33	56.5	17.5	11.8	70.7	0	0	1.4
2-35	9.9	0	0	100.0	0	0	1.0
2-38	49.0	61.1	3.3	35.2	0.4	0	2.8
2-39	12.3	7.4	0	92.6	0	0	1.1
2-40	41.7	0	0	93.2	0	6.8	1.1
2-67	8.2	16.2	0.5	83.2	0	0	1.2
2-72	5.3	9.2	5.9	84.9	0	0	1.2
NF	17.1	0	0	100.0	0	0	1.0
NNFSF	53.0	13.9	5.5	80.7	0	0	1.2
ONFSF	70.0	17.3	4.0	48.5	0	30.3	2.1
SFV	42.6	32.4	10.9	56.7	0	0	1.8
Vance	24.7	22.7	0	77.3	0	0	1.3
Mean	30.0	12.9	4.4	78.6	0.0	4.1	1.4
SE	4.0	3.0	0.9	3.6	0.0	1.7	0.1
Minimum	5.3	0.0	0.0	35.2	0.0	0.0	1.0
Maximum	70.0	61.1	11.8	100.0	0.4	30.3	2.8

Table 4. Percent (based on length) of the habitat in reaches surveyed during this study composed of braided channels (BC), backwaters (BW), main channel (MC), overflow channel (OC), and side channels (SC), along with the ratio of total channel length to main channel length per reach (Tot:MC Ratio) during the winter of 2009. Site names of reaches correspond to those in Figure 5. The range, mean, and Standard Error (SE) conditions observed over all the sites are also provided.

Site Name	Bankfull width (m)	Channel Type					Tot:MC Ratio
		BC	BW	MC	OC	SC	
2-01	15.7	3.2	8.5	88.3	0	0	1.1
2-02	18.0	9.3	15.0	75.7	0	0	1.3
2-06	35.0	27.1	0	72.9	0	0	1.4
2-08	30.0	17.3	3.7	79.0	0	0	1.3
2-13	17.0	0	0	100.0	0	0	1.0
2-25	14.3	0	6.3	75.1	0	18.5	1.3
2-26	14.6	2.7	21.3	63.6	0	12.4	1.6
2-27	43.0	9.4	12.2	76.3	0	2.2	1.3
2-28	35.0	0.8	9.2	90.1	0	0	1.1
2-29	31.0	18.5	9.8	68.4	0	3.3	1.5
2-35	12.3	0	0	100.0	0	0	1.0
2-37	40.0	15.0	22.0	63.0	0	0	1.6
2-39	9.9	5.4	0	94.6	0	0	1.1
2-40	42.0	15.6	0	84.4	0	0	1.2
2-41	30.0	55.8	5.0	39.2	0	0	2.6
2-64	3.0	10.2	4.5	85.3	0	0	1.2
2-67	12.3	15.0	0	85.0	0	0	1.2
2-69	5.0	19.7	0	80.3	0	0	1.2
2-72	5.0	24.3	17.9	57.7	0	0	1.7
NF	15.0	0	0	100.0	0	0	1.0
NNFSF	53.0	0	1.7	98.3	0	0	1.0
ONFSF	70.0	29.7	9.0	39.0	0	22.3	2.6
Vance	30.0	0	5.9	84.1	0	10.0	1.2
Mean	25.3	12.1	6.6	78.3	0	3.0	1.4
SE	3.5	2.8	1.5	3.6	0	1.3	0.1
Minimum	3.0	0	0	39.0	0	0	1.0
Maximum	70.0	55.8	22.0	100.0	0	22.3	2.6

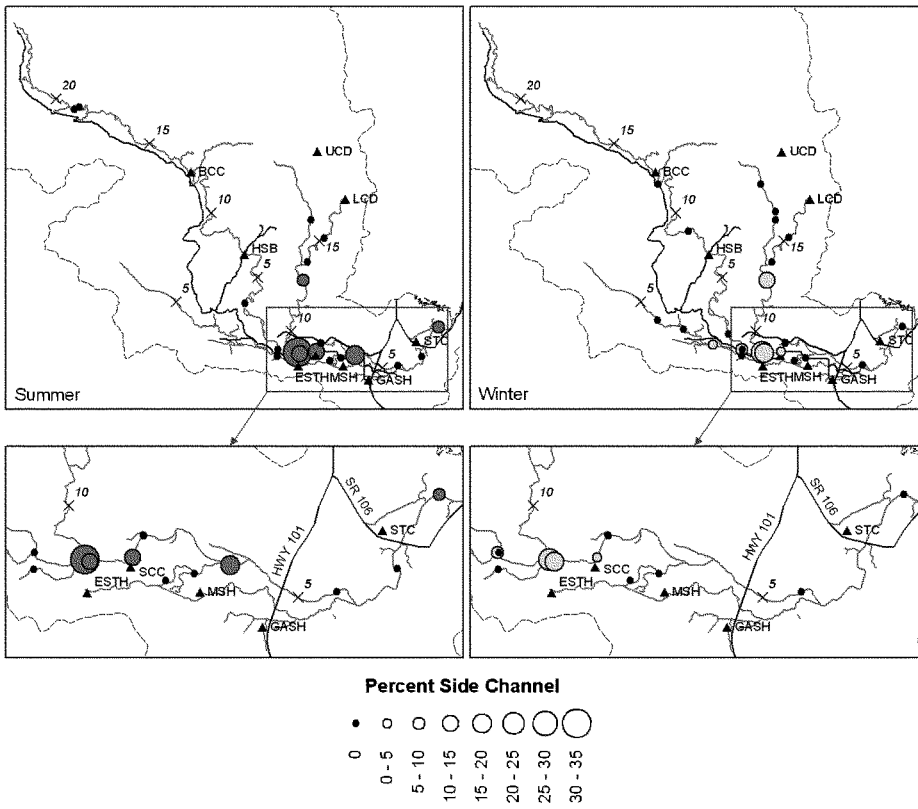

Figure 8. Percent (based on length) of habitats in the study reaches sampled during this study composed of side channels during the summer of 2008 and the winter of 2009 in the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

In addition to the creation of dams and the loss of side channels, channel straightening has caused a loss in stream habitat within Skokomish Basin. Although it is difficult to quantify the impacts of this activity, it is likely that overall loss is substantial. For example, Bountry et al. (2009) noted channel straightening below the HWY 101 Bridge (Figure 9). This single event reduced the channel from approximately 2.4 km (1.49 mi) to 1.4 km (0.86 mi), a 1 km (42%) reduction in total channel length in this area. Bountry et al. (2009) also state that channelization may have occurred in the vicinity of the Church Dike (near the Skokomish Community Church (SCC) on the maps), which is located downstream of the old North Fork Skokomish confluence.

Channelization also likely eliminated the rivers connection to side channel habitat, further reducing overall habitat availability as discussed previously.

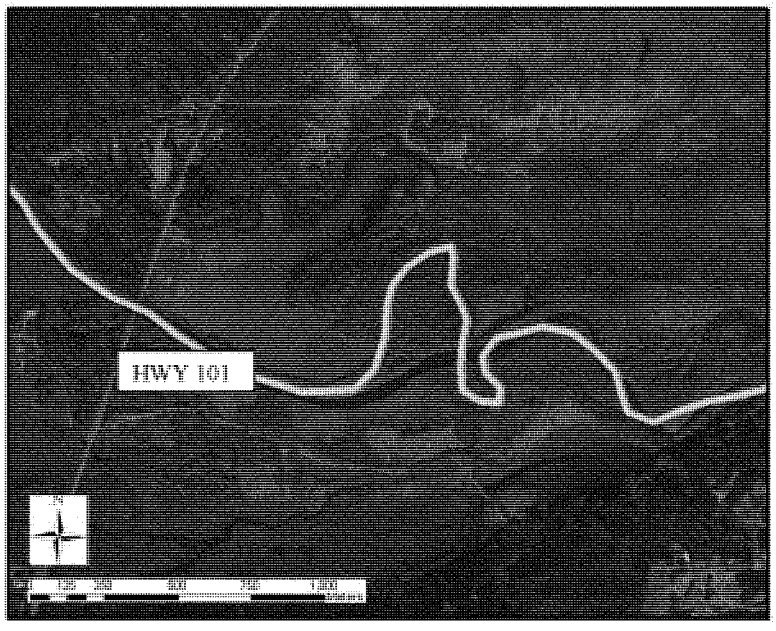

Figure 9. An example of channelization found within the Skokomish Basin. The 1938 channel (aqua line) is plotted over the 2007 channel shown in the base aerial photo of the river directly below Highway 101. This channelization represents a 42% reduction in channel length at this location (2.4 km). Figure is modified from Bountry et al. (2009).

Reduced Habitat Connectivity

Reduced habitat connectivity can result from numerous land management activities including dam construction, flow diversion, levee construction, road fill associated with bridge approaches, channelization, sediment aggradation, reduced base flow discharges, and road construction associated with logging activities. Cushman Dam completely blocks anadromous fish from the upper Skokomish Basin and was therefore discussed with habitat loss above. However, flow diversion from Cushman directly to Hood Canal can also impact habitat connectivity by reducing low flow discharge and isolating habitat. Much of the North Fork Skokomish was isolated from the rest of the river due to low flows resulting from historic water diversions from Lake Cushman (Skokomish Indian Tribe and WDFW 2010). However, the new

FERC agreement will provide additional flow during the low flow period, thereby improving habitat connectivity.

In an effort to control frequent high flow and overbank events, residents of the valley, along with various federal and state agencies, have historically undertaken an aggressive diking, channelization, and bank stabilization campaign (Canning et al. 1988). While this discontinuous network of dikes and associated structures may have mitigated low-level and site-specific flooding, they are of little use during large magnitude flood events (Rigby 2000). Diking has occurred quite extensively in the lower watershed, from approximately Vance Creek downstream. Some diking has also occurred on the north bank of the South Fork Skokomish, directly upstream of Vance creek. Levee construction, road fill associated with bridge approaches, and channelization can impact habitat connectivity by disconnecting the main channel from its floodplain and side channel habitats. In addition, adult and juvenile salmonids pushed into the floodplain during flood events that overtop the levees can become stranded there as flows recede, especially in areas where levees prevent floodwaters from moving from the floodplain back into the main channel.

Off-channel habitat is crucial to overwintering juveniles such as coho and steelhead, which use them to escape high winter flows. Off-channel habitats are also used as predator refugia by juvenile salmonids, and adult salmon utilize off channel habitat for spawning. The patchwork mosaic of diking can make it more difficult or impossible for juveniles that find their way onto the floodplain to return to the river proper when flows recede, particularly when the water is cold, when overbank flows are more likely (Bradford 1997). Sediment aggradation in this system has led to increase in overbank flow, even without an increase in overall discharge (Stover and Montgomery 2001). This has resulted in flooding occurring at successively reduced discharges and progressive increases in this potential impact.

Channel aggradation also impacts summer low flows by causing the complete dewatering of the lower portions of Vance Creek and the South Fork Skokomish (Skokomish Indian Tribe and WDFW 2010). This creates a complete barrier to upstream passage by adults and subsequently impacts the distribution of juveniles. For example, the barrier reduces the ability of juvenile salmon to redistribute within the system prior to winter freshets. In addition, the dewatering significantly reduces the amount of available rearing habitat and results in the stranding and potential mortality of juveniles. The dry channel conditions in the lower South Fork Skokomish result in approximately 12 km (7.5 mi) of the South Fork Skokomish being inaccessible to adult Chinook salmon.

Loss of floodplain connectivity appears to be worse in the lower watershed than the upper watershed. According to Correa (2003), habitat in the mainstem Skokomish, the South Fork Skokomish from RKM 14.5 to RKM 19.3 (RVM 9.0 to RVM 12.0) and Hunter, Weaver, and Vance Creeks are the most degraded, in terms of floodplain connectivity (Figure 10; detailed table in Appendix B). Although there are numerous data gaps in the data set used by Correa (2003), the fact that this is the portion of the watershed that has undergone the most anthropogenic influences suggests these results are likely representative of the Skokomish Basin as a whole.

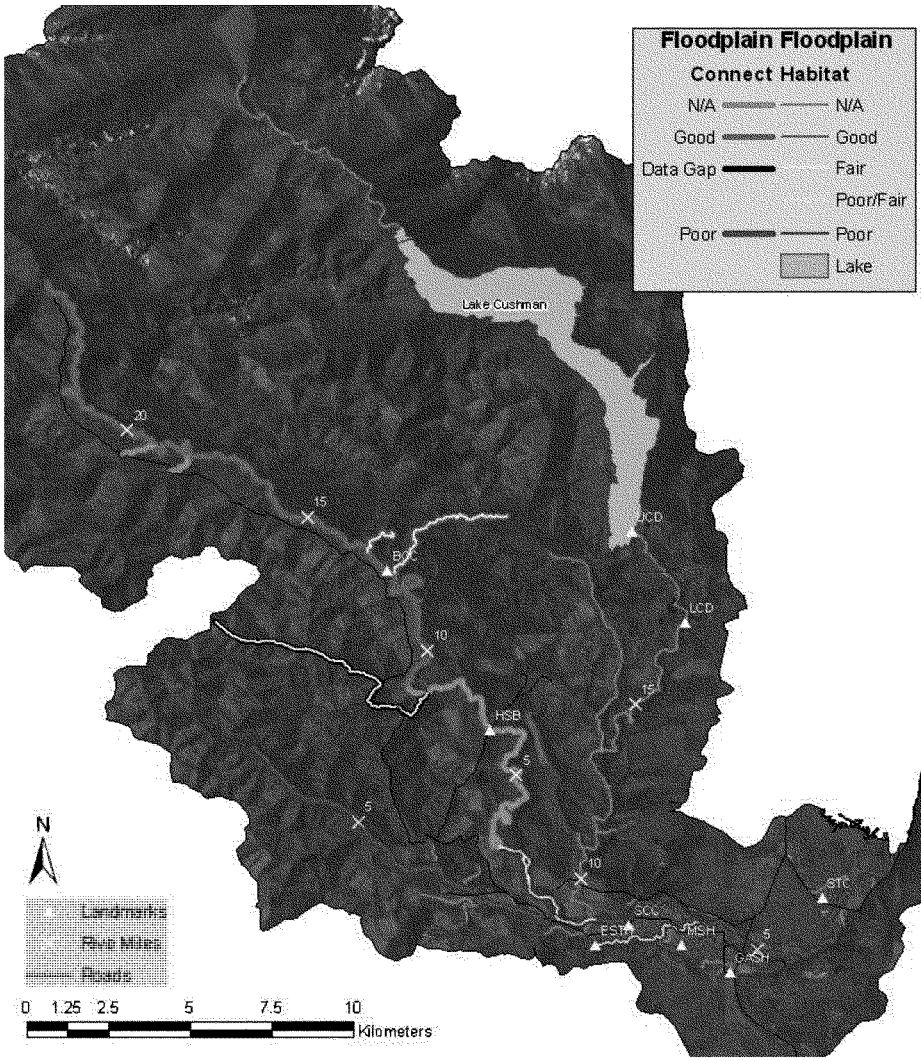

Figure 10. Floodplain connectivity ratings (bold lines) and floodplain habitat ratings (fine lines) for areas within the Skokomish Basin (based on Correa 2003), including areas where data gaps exist. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Reduced Channel Stability

Channel aggradation within the Skokomish Basin has been reported to total approximately 1.8 m in the Skokomish River from 1939 to 1997 (Stover and Montgomery 2001). The combination of Simons and Associates (1993 and 1995) and England (2007) data yields a similar estimate of total aggradation of 1.4 m. This channel aggradation causes several negative effects on juvenile salmon survival. The dramatic increase in sediment results in a largely unstable stream bed, where localized scour and fill can occur at lower discharges than those found in the original non-aggrading stream bed. This localized scour can physically removing redds during the process (Tripp and Poulin 1986; Schuett-Hames et al. 2000). In addition, localized fill can also bury salmon redds that would have otherwise escaped the effects of scour (Gottesfeld et al. 2004). In addition, fine sediment deposited in redds that weren't scoured can suffocate salmon redds by restricting water flow past developing embryos (Devries 2000).

Aggradation can also result in unstable channel conditions at larger spatial scales. This results from the channels inability to transport the excess sediment, resulting in frequent avulsions through unstable gravel bars or islands. This also result in the stranding of juvenile salmon as portions of the active channel become isolated from the mainstem as water levels recede (Sommer et al. 2005).

A dramatic example of the effects of aggradation on channel stability and migration were illustrated by the changes that occurred at the confluence of the North and South Fork Skokomish during the 2004 water year. The North Fork Skokomish became blocked by sediment and LWD from the South Fork Skokomish. The North Fork Skokomish eventually breached a levee, entered an abandoned stream channel, and now enters the mainstem approximately 2 km downstream from its original confluence (Geo Engineers 2006). This event resulted in the dewatering of redds and isolation of juveniles in the reach downstream of the avulsion. Ironically, this event increased the available habitat for salmonids by lengthening the North Fork Skokomish stream reach.

Reduced Habitat Quality

In addition to habitat loss, reduced connectivity, and reduced habitat stability, aggradation and the factors that have influenced aggradation have negatively influenced the quality of the habitat that remains. Aggradation can cause five main disturbances that affect juvenile salmon habitat, including 1) reduced riparian cover, 2) decreased summer instream flows, 3) increased summer temperatures, 4) decreased LWD, and 5) decreased pool habitat. Many of these factors are interrelated, with impacts to one factor subsequently impacting another. Channel aggradation has also precipitated a host of anthropogenic responses in the lower watershed, such as clearing woody debris jams, riverine gravel removal, diking, and bank stabilization (USACE 2010) that exacerbate the problems stated above or that are themselves detrimental to juvenile salmon habitat. Dunham and Chandler (2001), Correa (2003), and Merlin Biological (2005) report specific habitat details for the South Fork Skokomish mainstem and Church Creek, the entire Skokomish watershed, and the South Fork Skokomish sub-basin, respectively. In addition, ME2 Environmental Services (1997) (on behalf of The Simpson Timber Co.) and the USFS and the Skokomish Tribe (1995) both completed watershed analysis on the South Fork Skokomish and its tributaries. These past and current data collections and summaries suggest that some level of habitat degradation has occurred in the Skokomish Basin,

with less degraded habitat in the upper watershed and tributaries relative to the lower watershed and mainstem.

The Skokomish Indian Tribe and WDFW (2010) document increases in active channel widths throughout this region. This increase in active channel width will impact juvenile salmon habitat in several different ways. First, it reduces the availability of overhead cover, which protects juvenile salmon from predators (Helfman 1981). Second, the reduction in riparian vegetation adjacent to the wetted channel reduces shading, which can result in increased water temperatures (see below for more a further discussion of this topic). Third, it reduces the input of large wood to the river channel, thereby reducing instream cover, an important component of juvenile salmonid habitat (i.e., Shirvell 1994; Peters 1996a ; Roni and Quinn 2001; Beechie et al. 2005). Finally, channel widening is likely associated with reduced channel depths and loss of pool habitat. However, increased channel width and reduced riparian cover may actually increase primary productivity due to increased solar radiation reaching the stream channel (reviewed by Chamberlain et al. 1991).

Reduced Riparian Vegetation

Based on past studies and data collected during this study, riparian vegetation appears to be degraded within the Skokomish Basin, with the greatest degradation occurring in the lower Skokomish watershed and in mainstem channels relative to tributaries. Correa (2003) classified riparian conditions throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (Figure 11). The Skokomish mainstem, Weaver Creek, Hunter creek, and the lower South Fork Skokomish (RKM 0 – 4.8) were classified as having poor riparian conditions. Purdy Creek was classified as poor to good, while Richert Springs was classified as fair to good. The South Fork Skokomish was classified as fair from RKM 16.1 to 37.8, but good in the remaining sections. Tributaries to the upper South Fork Skokomish were classified as good (Rock Creek, Brown Creek, LeBar Creek, Cedar Creek, and Pine Creek), with the exception of Church Creek, which was classified as fair. No assessment was completed for the North Fork Skokomish or Vance Creek.

Based upon our data collection, riparian vegetation conditions appear to be severely degraded in some areas, but relatively healthy in others (Figure 12, Figure 13, Figure 14). Based on mature riparian vegetation cover, riparian conditions were most degraded in the upper South Fork Skokomish, the mainstem Skokomish from the Vance Creek confluence to HWY 101 and in Hunter Creek (Figure 12). Mature riparian cover varied from poor to relatively good (>70%) in the North Fork, Vance Creek, McTaggert Creek, and was generally good in Swift Creek and the lower mainstem below HWY 101. Riparian conditions based on riparian cover along the stream bank were similar, except that riparian cover was generally greater than 50% along the banks of the North Fork Skokomish and McTaggert Creek (Figure 13). Riparian condition ratings based on percent riparian cover in the middle of the channel varied from those stated above for the lower mainstem Skokomish (Figure 14). Riparian cover in the middle of the channel at these locations was generally less than 30%. The riparian conditions at the remaining sites were similar to those observed for mature riparian canopy and riparian cover along the bank. The varied riparian conditions observed are likely the result of the interacting influences of historic land clearing and logging practices that allowed for harvest to occur adjacent to the channel, recovery at these locations, and changes in overall channel width.

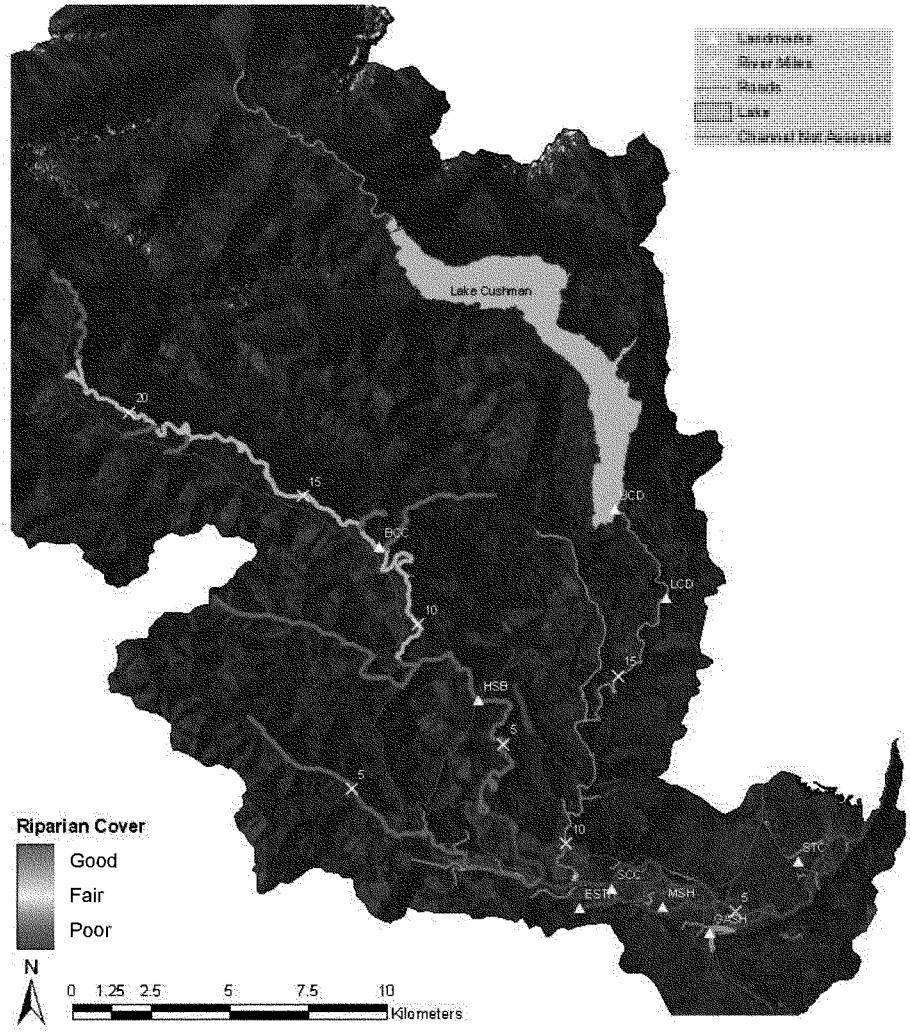

Figure 11. Riparian conditions throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

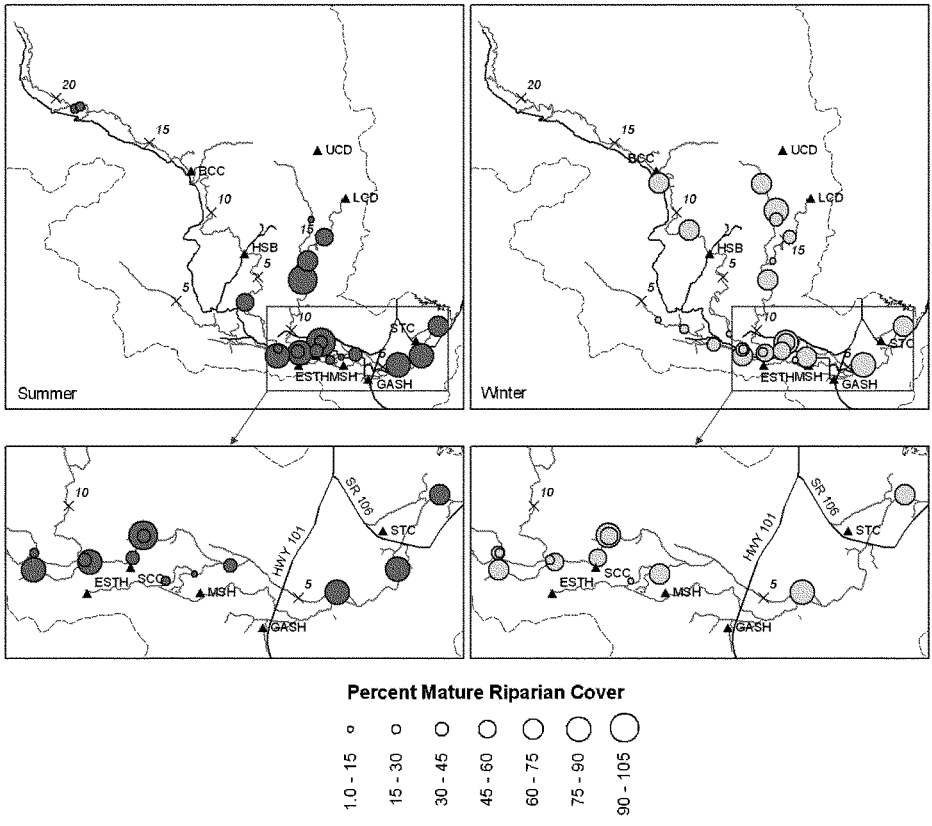

Figure 12. Percent mature riparian cover of the total bank at each site sampled in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

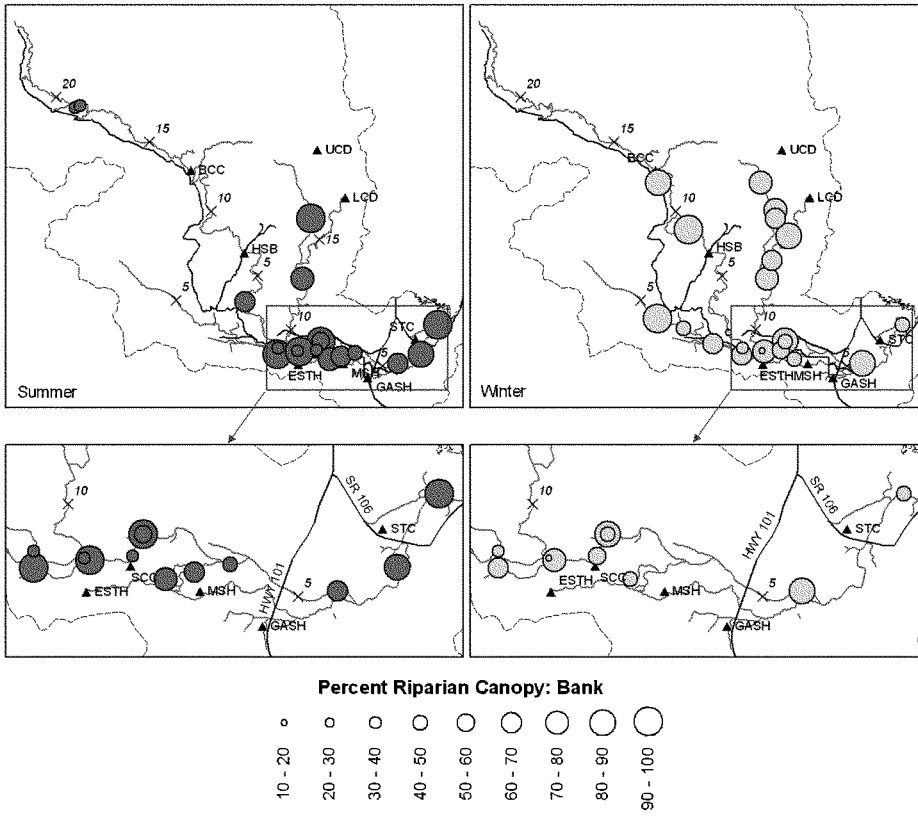

Figure 13. Percent of bank with riparian canopy at each site sampled during the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

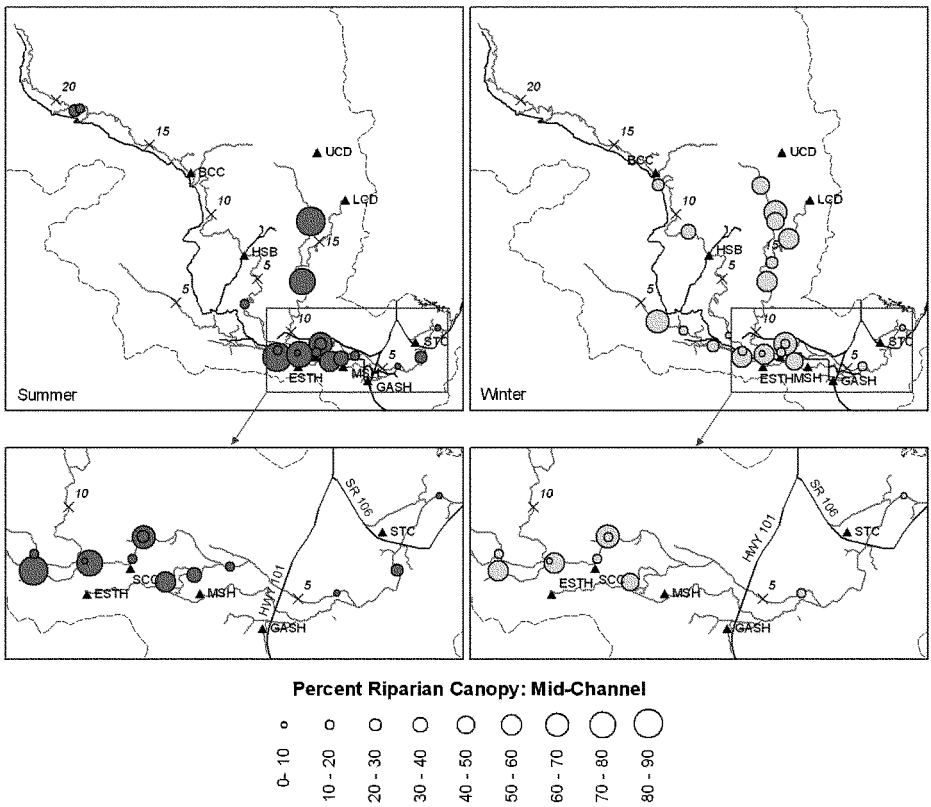

Figure 14. Percent riparian canopy cover in the mid-channel at each site sampled in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Decreased Instream Flows

Summer low flows in the Skokomish Basin are reduced relative to historic values (Skokomish Tribe and WDFW 2010). This could be the result of the river going sub-surface as a result of aggradation in the lower South Fork Skokomish, lower Vance Creek, and mainstem, as well as flow reductions resulting from diversion of flows from the North Fork Skokomish. As described above, channel aggradation can impact summer low flows by causing flows to go subsurface. Complete dewatering of the lower portions of Vance Creek and the South Fork Skokomish has been observed recently (Skokomish Indian Tribe and WDFW 2010). This

creates a complete barrier to upstream passage by adults and subsequently impacts the distribution of juveniles. The South Fork Skokomish was dry for several hundred meters above the confluence of the North Fork Skokomish during the summer of 2009, but not the summer of 2008.

Increased Summer Temperatures

Increased water temperatures appear to be a sporadic problem in the Skokomish Basin, with some past studies identifying water quality issues, while others have not. Water temperature problems appear to be a greater concern in the lower Skokomish Bain than the upper Skokomish Basin. Skokomish Indian Tribe (2006) noted severe water quality impairment for warm water temperature and low dissolved oxygen (DO) during summer low flows at the HWY 101 Bridge. Interestingly enough, they found that these two metrics were not violated further downstream at the SR 106 Bridge. However, State standards for fecal coliform levels were violated at the SR 106 Bridge site. Mid Skobob Creek and the mouth of Purdy Creek were listed as severely impaired for fecal coliforms, temperature, and DO. The upper section of Purdy Creek, the Weaver Creek sampling sites, and Hunter Creek were not impaired for temperature but were impaired for DO and fecal coliform. In addition, data collected by the Washington Department of Ecology (WDOE) indicates that concentrations of fecal coliform bacteria in the lower river valley exceeded State water quality standards in Ten Acre Creek, in addition to Weaver, and Purdy Creeks, and at the SR 106 Bridge.

Correa (2003) classified water temperature conditions throughout portions of the Skokomish Basin based on qualitative criteria of good, fair, and poor (Figure 15). Data for main channels existed only for the upper South Fork Skokomish (above RVM 23.5), which was classified as having good water temperatures. Hunter, Weaver, and Purdy Creeks, which are tributaries to the mainstem, were classified as having good water temperatures. Water temperatures at all but one of the South Fork Skokomish tributaries assessed had water temperatures classified as good, including Church, Pine, Cedar and Brown Creeks. Lebar Creek was classified as having fair water temperatures.

Dunham and Chandler (2001) assessed several sites within the South Fork Skokomish Basin (Figure 16). With the exception of one site, which had temperatures that exceeded 18°C for 36 days, temperature was not identified to be a major issue in the South Fork Skokomish. Although this one site had temperatures much greater than the other sites evaluated, the observed temperatures were still less than those expected be a barrier to adult Chinook salmon (i.e., 21°C, Richter and Kolmes 2005; Strange 2010). In addition, temperatures at this site were less than lethal limits for juvenile salmon (i.e., Becker and Genoway 1979; Geist et al. 2010) and less than temperatures expected to impact growth (i.e., Brett et al. 1982; Marine and Cech 2004; Geist et al. 2010).

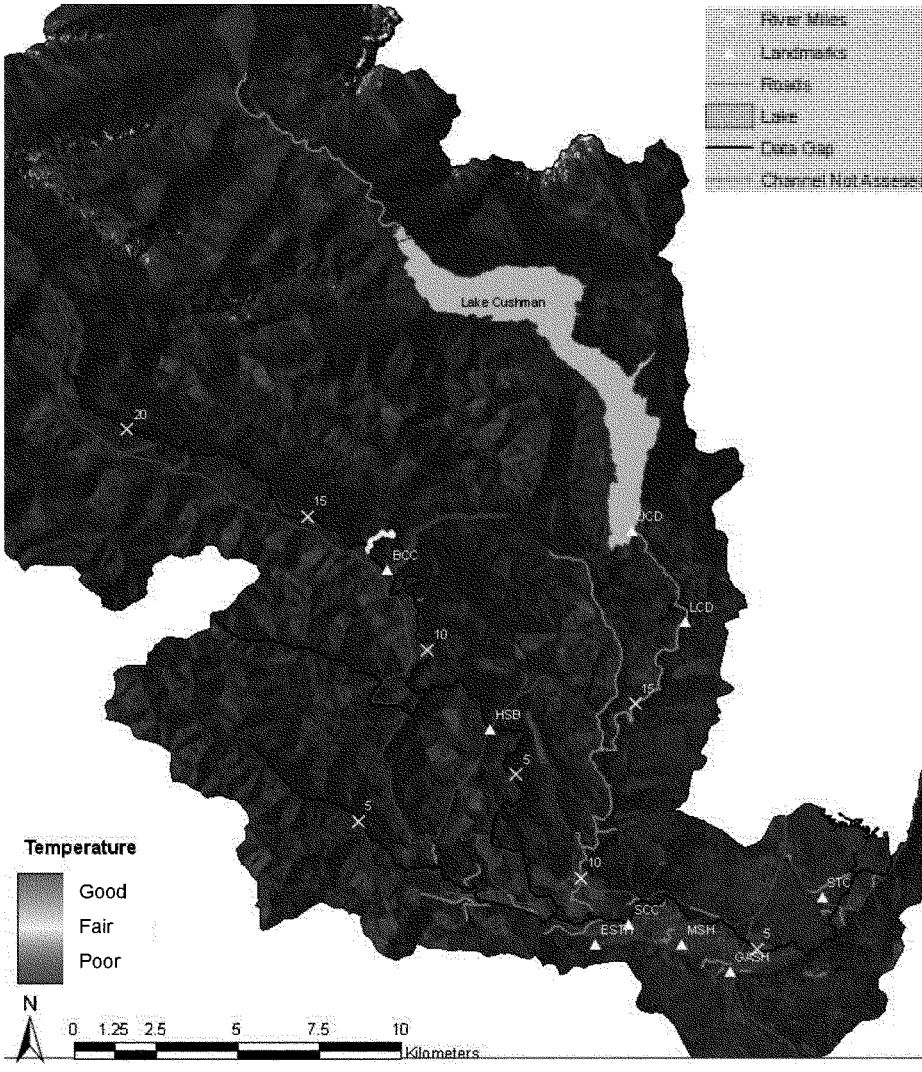

Figure 15. Water temperature conditions throughout sections of the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 5. Summer mean and maximum temperature data collected during a 48 day period in 2000 and the number of days temperatures exceeded temperature thresholds of 12-20°C (from Dunham and Chandler 2001, sites are displayed in Figure 16).

		Summer		Number of days temperatures exceeded:				
Stream	Site	Mean	Max	12C	14C	16C	18C	20C
Church Cr.	1	10.67	13.58	23	0	0	0	0
S.F. Skokomish	1	15.22	19.27	48	48	44	13	0
S.F. Skokomish	10	13.71	18.36	48	45	28	5	0
S.F. Skokomish	11	13.29	17.54	48	44	20	0	0
S.F. Skokomish	12	13.38	17.52	48	45	20	0	0
S.F. Skokomish	13	12.81	16.72	47	41	11	0	0
S.F. Skokomish	14	12.44	16.02	47	37	1	0	0
S.F. Skokomish	15	11.84	15.50	46	23	0	0	0
S.F. Skokomish	16	11.14	14.97	43	19	0	0	0
S.F. Skokomish	17	10.26	14.51	36	8	0	0	0
S.F. Skokomish	18	10.35	14.32	37	8	0	0	0
S.F. Skokomish	19	9.68	13.46	26	0	0	0	0
S.F. Skokomish	2	15.39	19.39	48	48	42	13	0
S.F. Skokomish	20	8.82	10.82	0	0	0	0	0
S.F. Skokomish	21	8.00	9.43	0	0	0	0	0
S.F. Skokomish	22	8.47	10.23	0	0	0	0	0
S.F. Skokomish	23	10.92	13.18	12	0	0	0	0

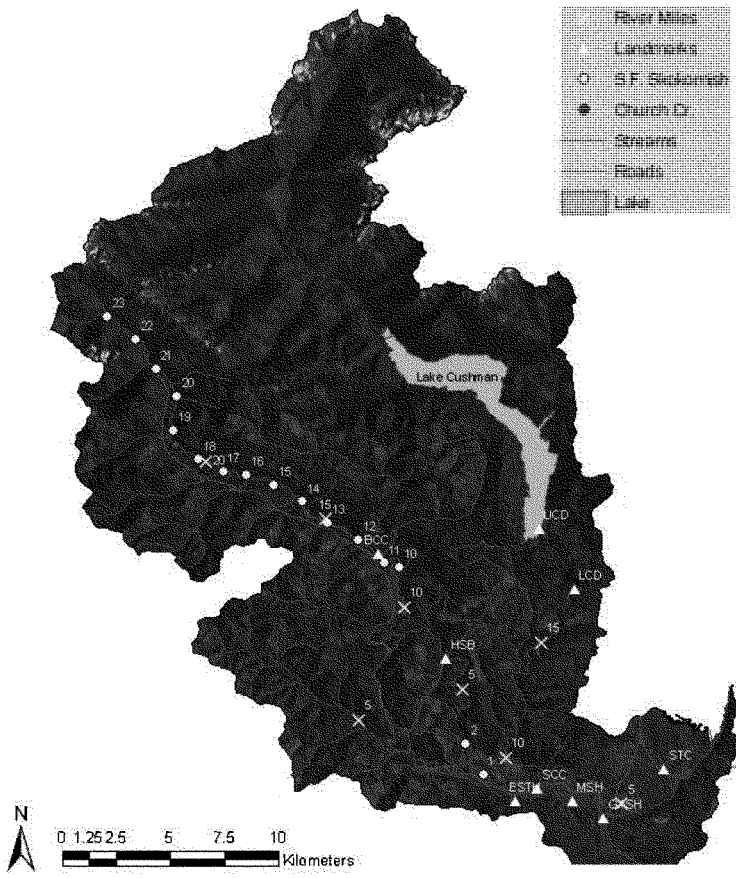

Figure 16. Study sites where habitat and fish data were collected by Dunham and Chandler (2001). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Reduced LWD

As discussed above, reductions in large wood input to the river channel occurs as the active channel width increases. LWD has several beneficial effects for juvenile salmon, including increasing habitat complexity and number of pools, providing instream cover and predation refugia, and increasing primary productivity (Quinn 2005). A number of past studies have assessed large wood levels within the Skokomish Basin and have identified reaches where wood levels are below a desired standard. According to Correa (2003), habitat in the mainstem Skokomish, the South Fork Skokomish from RVM 0 to RVM 10 and Hunter, Weaver, Vance, LeBar, and Pine creeks are the most degraded, in terms of LWD presence (Figure 17).

Data from Merlin Biological (2005) indicates that LWD and pool frequency generally increase as you move upstream on the South Fork Skokomish, with habitat greatly improving upstream of RKM 25.1 (RVM 15.6) (Table 6). In addition, their report found that most of the major tributaries had significant old growth buffers and that LWD loading was in good condition overall. Although LWD and pool frequency increases as you move upstream in the South Fork, data from Dunham and Chandler (2001) indicate relatively poor LWD quality in the South Fork Skokomish and Church Creek (Table 7). Only about one-third of the sites they sampled were classified as having wood present that provided good quality cover (i.e. wood class ratings of 3 or 4). The observation of increased wood in the upper watershed likely is the result of increased wood delivery as a result of landslides (Benda et al. 2003) in the area.

Fox et al. (2003) developed recommended large wood quantities and volumes for western Washington river's (Table 8). Although we collected different wood metrics, we attempted to compare observed quantities and volumes of large wood from the current study with their recommendations. We determined that large wood was limited in many sites of lower Vance Creek, the South Fork Skokomish, and the mainstem (Figure 18). The number of Large Debris Piles (LDP) per bankfull width was very low for all sites sampled. In particular, the USACE Vance Creek site did not have any LDP during either summer or winter surveys. The number of single LWD in the South Fork Skokomish was also very low and translated to 0 to 0.07 LWD per m with an average of 0.02. This indicates poor LWD quality within the reach.

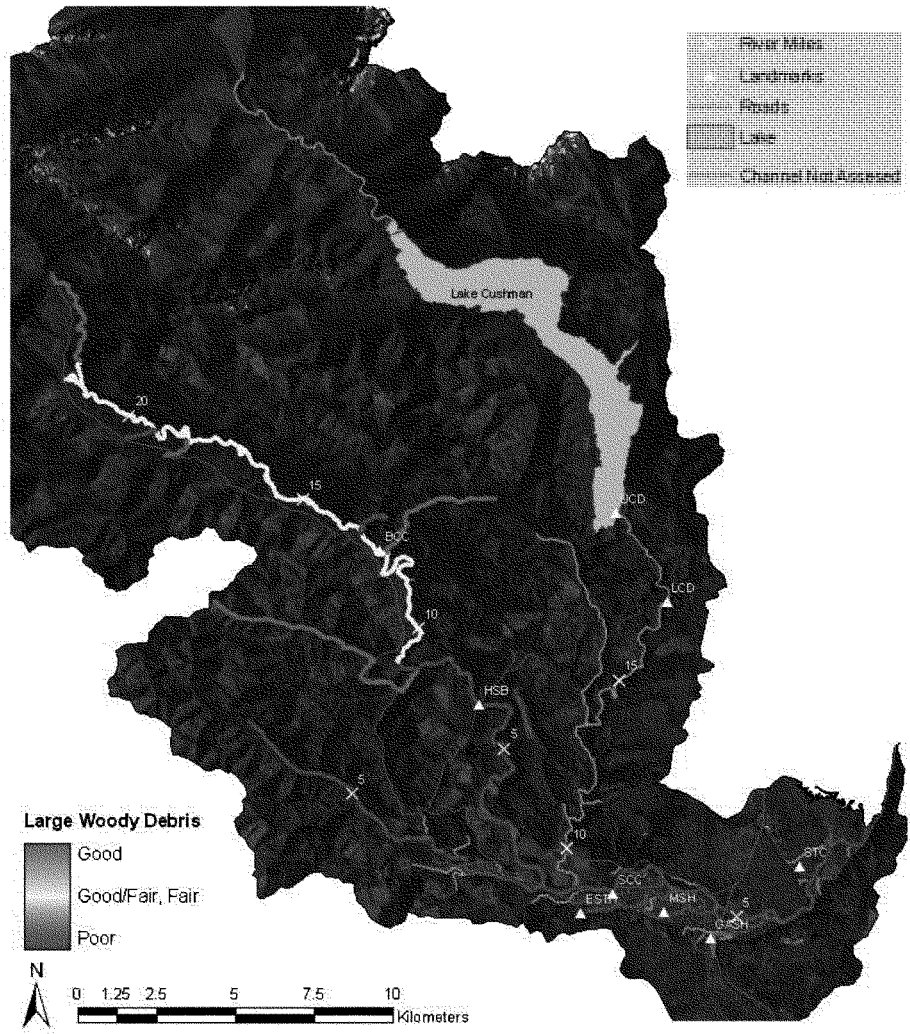

Figure 17. Classification of levels of large woody debris (LWD) throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003 Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 6. Juvenile salmon relevant habitat in the South Fork Skokomish of the Skokomish River watershed. Modified from Merlin Biological (2005).

Reach	Pools/km (mi)	Pools > 0.91 m deep/km (mi)	No. of LWD/km (mi)	Dominant/Subdominant Substrate
RKM 17.7-22.9 (RVM 11-14.2)	14.5 (9)	12.4 (7.7)	138.1 (85.8)	Gravel/cobble
RKM 22.9-25.1 (RVM 14.2-15.6)	13.8 (8.6)	13.8 (8.6)	42.5 (26.4)	Gravel/cobble
RKM 25.1-34.4 (RVM 15.6-21.4)	16.9 (10.5)	15.8 (9.8)	273.1 (169.7)	Gravel/cobble
RKM 34.4-37.8 (RVM 21.4-23.5)	20.9 (11.3)	17.4 (10.8)	203.3 (126.3)	Gravel/cobble
RKM 37.8-41.8 (RVM 23.5-26.0)	23.2 (14.4)	19.6 (12.2)	221.5 (137.6)	Cobble/gravel

Table 7. Summary of habitat data metrics for Church Creek and the South Fork Skokomish River (from Dunham and Chandler 2001, sites are shown on Figure 16).

Stream	Site	Length (m)	Mean Width (m)	Max Depth (m)	Gradient	Conductivity	No. of Large Woody Debris (per meter)				Wood class	% fines
							Single	Rootwads	Aggregates	Total		
Church Creek	1	100	6.96	1.01	2.16	34.7	0.12	0.06	0.01	0.19	2	12.0
S.F. Skokomish	1	100	15.71	1.40	0.31	62.9	0.07	0.03	0.01	0.11	3	31.5
S.F. Skokomish	10	108	14.89	1.35	0.18	56.5	0.08	0.02	0.00	0.10	2	25.9
S.F. Skokomish	11	100	37.65	0.65	0.99	60.6	0.15	0.04	0.03	0.22	2	9.0
S.F. Skokomish	12	97	10.07	1.65	0.00	37.3	0.09	0.02	0.01	0.12	2	32.0
S.F. Skokomish	13	102	13.16	1.35	0.95	35.1	1.47	0.49	0.17	2.13	4	25.0
S.F. Skokomish	14	100	14.24	0.73	0.19	33.7	0.10	0.01	0.01	0.12	3	4.6
S.F. Skokomish	15	100	19.59	0.83	0.24	31.6	0.02	0.00	0.00	0.02	1	15.5
S.F. Skokomish	16	115.5	10.87	1.43	0.24	63.1	0.02	0.00	0.00	0.02	1	18.8
S.F. Skokomish	17	80	10.59	1.80	1.54	59.3	0.01	0.00	0.01	0.03	1	3.8
S.F. Skokomish	18	110	10.80	0.73	0.79	54.8	0.08	0.01	0.00	0.09	1	10.0
S.F. Skokomish	19	100	11.80	1.12	1.74	59.8	0.03	0.01	0.01	0.05	1	2.5
S.F. Skokomish	2	100	19.91	1.10	0.45	64.0	0.05	0.00	0.01	0.06	4	7.0
S.F. Skokomish	20	103.2	13.98	3.00	0.52	35.4	0.04	0.01	0.01	0.06	2	24.7
S.F. Skokomish	21	80	7.16	1.36	1.75	55.4	0.15	0.00	0.01	0.16	2	10.7
S.F. Skokomish	22	155	7.28	0.55	1.46	31.2	0.14	0.01	0.07	0.21	2	4.5
S.F. Skokomish	23	100	5.85	0.73	8.11	42.7	0.06	0.01	0.03	0.10	4	2.8

Table 8. Recommended ranges of instream wood quantity and volumes for western Washington streams by bankfull width class (BFW Class) (From Fox et al. 2003).

LWD Piece Quantity: Number of Pieces Per 100 m of Channel Length				
Region	BFW Class	Good	Fair	Poor
Western WA	0-6 m	>38	26-38	<26
	>6-30 m	>63	29-63	<29
	>30-100 m	>208	57-208	<57

LWD Volume: Cubic Meters Per 100 m of Channel Length				
Region	BFW Class	Good	Fair	Poor
Western WA	0-30 m	>99	28-99	<28
	>30-100 m	>317	44-317	<44

Key Piece Quantity: Number of Pieces Per 100 m of Channel Length				
Region	BFW Class	Good	Fair	Poor
	0-10 m	>11	4-11	<4
	>10-100 m	>4	1-4	<1

Minimum Piece Volume to Define Key Pieces	
Bankfull width Class	Minimum Piece Volume (m^3)
0-5 m	1*
>5-10	2.5*
>10-15	6*
>15-20	9*
>20-30 m	9.75
>30-50 m	10.5**
>50-100 m	10.75**

* Existing Washington Forest Practices Board (WFPB) (1997 definitions)

** Rootwads must be attached

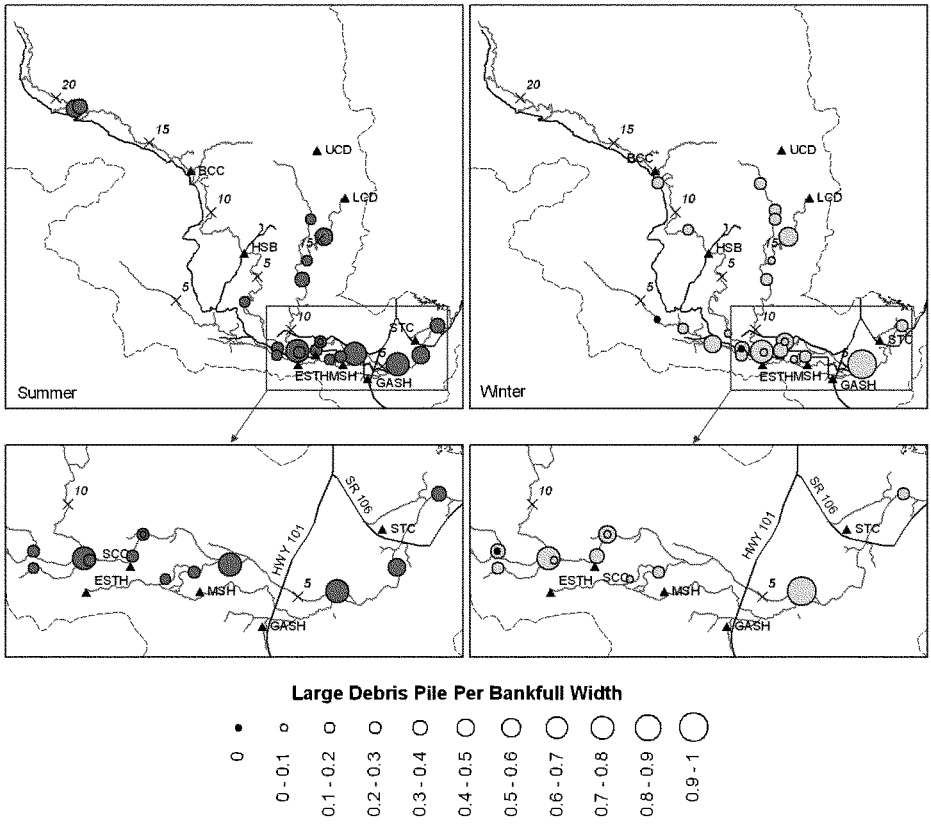

Figure 18. Number of large debris piles per bankfull width at each site sampled in the summer of 2008 and winter 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cusluman Dam (UCD).

Reduced Pool Habitat

Data from Merlin Biological (2005) indicates that pool frequency and depth increases as you move upstream on the South Fork Skokomish, with habitat greatly improving upstream of RKM 25.1 (RVM 15.6) (Table 6). The USFS and Skokomish Tribe (1995) rated the entire South Fork Skokomish as having poor pool frequency. In contrast, all the tributaries, except Church Creek, were rated as good or fair for pool frequency. Correa (2003) classified reaches of the South Fork Skokomish and several tributaries and found that percent pool habitat was poor in the from RKM 0 (RVM 0) to RKM 4.8 (RVM 3) and RKM 16.1 (RVM 10) to RKM 37.8 (RVM 23.5), but good from RKM 4.8 (RVM 3) to RKM 16.1 (RVM 10) and above RKM 37.8 (RVM 23.5). The percent of pool habitat was also poor in Weaver, Hunter, Vance, LeBar and Pine Creeks. The percent pool habitat was rated as good in Richert Springs and Cedar Creek (Figure 19). Classification of pool quality in these reaches varied from that of percent pool habitat, indicating that the quality of the few pools that were present was generally good in the South Fork Skokomish, but poor in the tributaries (Figure 20). Pool quality throughout the entire South Fork Skokomish was rated as good, while pool quality in tributaries was rated as good in only Brown Creek.

ME2 Environmental Services (1997) provides similar information to Correa (2003) and Merlin Biological (2005) in their watershed analysis of the South Fork Skokomish, but separated the data into summer and winter rearing habitats, and also highlighted four "areas of special concern". In general, ME2 Environmental Services (1997), reports that the pool depth was good across all fish bearing reaches, although they used their own subjective determination of what depth was required for juvenile salmon rearing. For summer rearing habitats, they state that percent pool habitat was good in the alluvial terrace tributaries of the South Fork Skokomish (tributaries to Vance Creek), fair in the upland tributaries (Fir Creek), and poor in tributaries above the South Fork Skokomish canyon (Brown, Pine, and LeBar Creeks). Data for Vance Creek was difficult to obtain because of its dry channel. In terms of winter rearing habitat, their most significant finding is the virtual non-existence of off channel habitat in the South Fork Skokomish watershed, although similar habitat can be found in the lower reaches of the alluvial terrace tributaries and in side channels of the upper watershed.

Data collected during the current study generally support the previous findings with regard to pool availability. The mean percent of summer sample sites that consisted of deep water (DW) was 44.8% in the summer and 25.8% in the winter (Table 9). Shallow water (SW) habitats comprised 29% in the summer and 40.6 % in the winter. The percentage of deep water habitats decreased in 12 of 15 between the summer to winter surveys from an average of 47% to 30% in the sites we sampled both summer and winter (n = 15). Based on Washington Department of Natural Resources (WDNR) watershed analysis indices (WDNR 1997), the habitat quality rating for percent pool (using percent deepwater as percent pools) would be poor for 9 of 21 summer sites, fair for 6 sites, and good for the other six sites. For winter sites, 20 of 23 sites would be rated as poor, two sites would be rated as fair, and one site would be good. Overall, the percent of the habitat that consists of pools to provide summer and winter rearing habitat for juvenile salmonids is rated as poor in most areas of the Skokomish River (Table 9). Percent DW habitats tended to be greater in the stream estuary ecotone, tributaries and the North Fork Skokomish than the South Fork Skokomish during the summer, and greatest in tributaries and the North Fork during the winter (Figure 21).

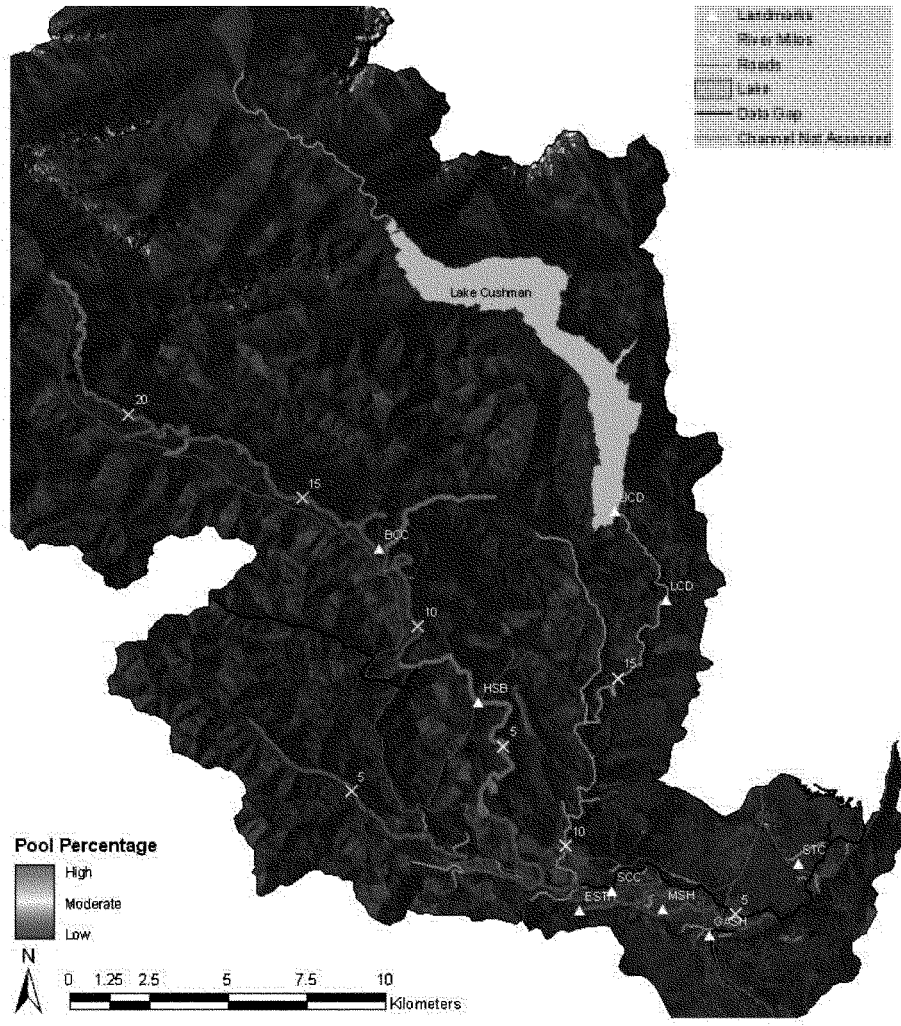

Figure 19. Classification of percent pool habitat throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

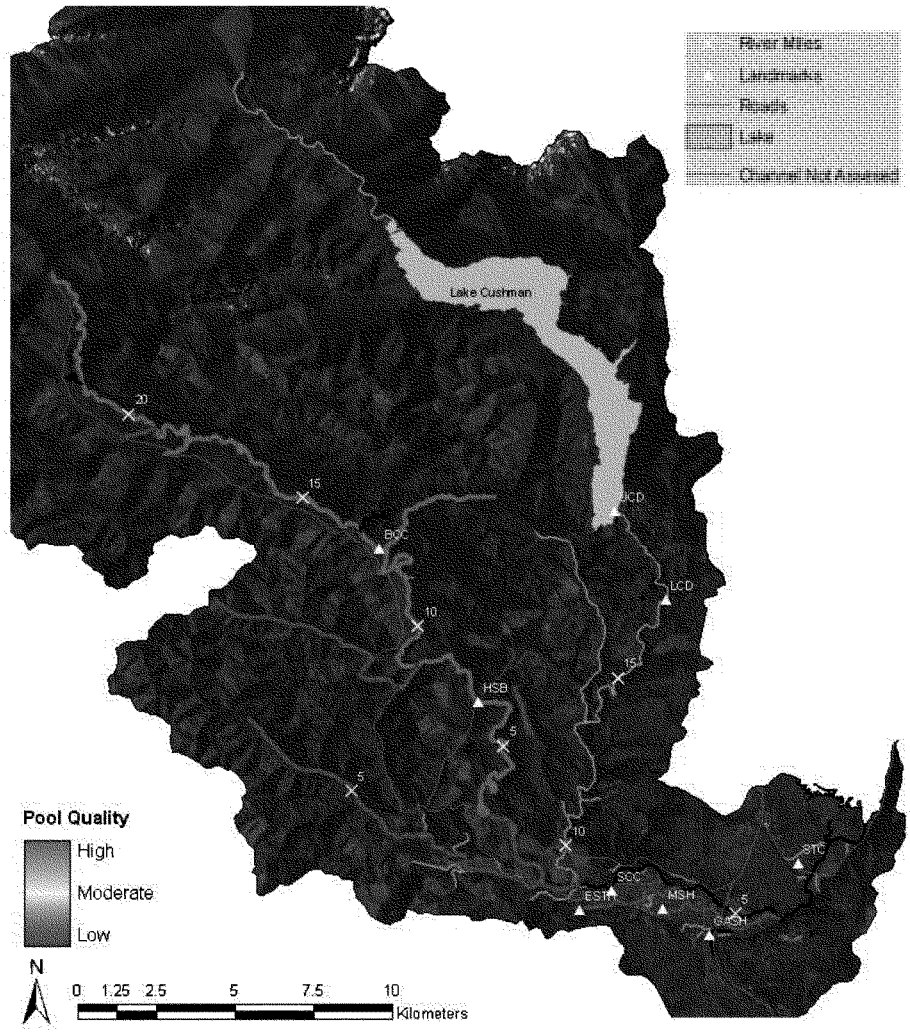

Figure 20. Classification of pool habitat quality throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of good, fair, and poor (modified from Correa 2003). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 9. Percent of average depth water (AW), deep water (DW), and shallow water (SW) present in study reaches sampled during summer 2008 and winter 2009, along with the mean, standard error (SE), minimum, and maximum values observed for all of the reaches. AW habitats are typically glides, runs, and rapids. DW habitats are generally pools, while SW habitats are generally shallow glides and riffles.

Summer				Winter			
Site Name	AW	DW	SW	Site Name	AW	DW	SW
2-01	0.4	76.1	23.5	2-01	41.4	49.3	9.3
2-02	18.5	59.5	22.0	2-02	51.9	25.7	22.4
				2-06	47.6	6.8	45.6
				2-08	53.1	18.8	28.1
				2-13	87.6	12.4	0
2-23	20.2	47.6	32.2				
2-25	0	45.3	54.7	2-25	0	34.0	66.0
2-26	50.1	35.7	14.2	2-26	34.6	31.5	33.9
2-27	28.3	34.7	37.0	2-27	50.8	27.9	21.3
2-28	16.1	25.5	58.4	2-28	9.5	14.6	76.0
				2-29	38.1	15.2	46.7
2-30	4.4	23.9	71.7				
2-31	30.1	44.0	26.0				
2-33	0	44.6	55.4				
2-35	100	0	0	2-35	0	0	100
				2-37	26.9	22.7	50.4
2-38	0	46.4	53.6				
2-39	28.2	68.4	3.4	2-39	40.9	53.7	5.4
2-40	42.0	58.0	0	2-40	0	28.8	71.2
				2-41	43.3	26.6	30.1
				2-64	9.3	29.5	61.2
2-67	52.6	41.4	6.0	2-67	56.8	16.5	26.7
				2-69	7.3	9.2	83.4
2-72	0	99.8	0.2	2-72	5.7	87.4	6.9
NF	0	100	0	NF	39.6	0	60.4
NNFSF	51.7	30.6	17.7	NNFSF	57.2	34.7	8.1
ONFSF	64.4	14.3	21.3	ONFSF	54.3	28.1	17.6
SFV	25.2	22.1	52.7				
VANCE	19.0	22.2	58.8	VANCE	17.1	20.1	62.8
Mean	26.2	44.8	29.0	Mean	33.6	25.8	40.6
SE	5.8	5.6	5.2	SE	4.9	4.0	5.9
Minimum	0	0	0	Minimum	0	0	0
Maximum	100	100	71.7	Maximum	87.6	87.4	100

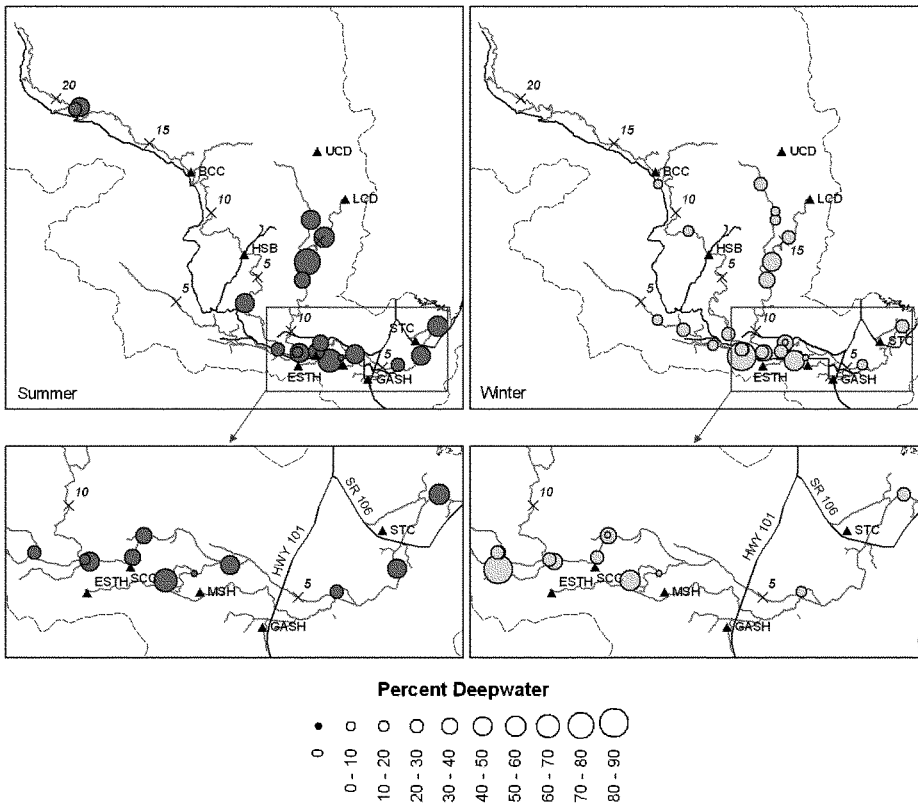

Figure 21. Percent of the habitat surveyed classified as deep water at sites assessed in the summer of 2008 and winter of 2009 within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

We measured four metrics to evaluate pool quality, including average thalweg depth, maximum thalweg depth, average residual pool depth, and maximum residual pool depth. These four metrics allow for comparisons of pool depths to be compared to overall reach depths. Residual pool depths, defined as the maximum pool depth minus the pool tail (crest) depth (Lisle 1987), are sensitive to management activities (Kershner et al. 2004) and have been correlated to fish densities (Mossop and Bradford 2006).

Pool quality, based on depth, in the reaches we sampled was variable based on the data we collected during this study and varied somewhat from that reported by others (Merlin

Biological 2005, Correa 2003). However, since neither Merlin Biological (2005), nor Correa 2003 clearly defined their criteria for classifying pool quality, comparisons are very difficult.

Average thalweg depths varied from approximately 0.25 m to nearly 2.25 m (Figure 22), while maximum thalweg depths varied from 0.25 m to nearly 5 m (Figure 23). Average and maximum thalweg depths were generally greatest in the mainstem, Hunter Creek and the South Fork Skokomish and shallowest in Vance Creek, Swift Creek, the North Fork Skokomish and McTaggert Creek. Average residual pool depths ranged from approximately 0.2 m to 1.6 m (Figure 24), while maximum residual pool depth ranged from 0.4 m to nearly 4 m (Figure 25). As expected, average and maximum residual pool depths were shallowest in tributaries relative to the mainstem, with the exception of Hunter Creek, which had relatively deep water and the upper South Fork Skokomish which had very shallow residual pools compared to other mainstem habitats. Both average and maximum residual pool depths appeared to be shallower during the winter than during the summer within the South Fork Skokomish and upper mainstem Skokomish (above HWY 101), but not in tributaries or the North Fork Skokomish. This suggests that pools may have filled during fall freshets after we completed the summer surveys and before we completed the winter surveys. The observation of shallow residual pool depths in the upper South Fork Skokomish contrasts observations by Correa (2003). The cause for this discrepancy is unclear, but may be due to sediment deliveries from historic or active landslides.

Judging pool quality is across different stream sizes is difficult. Residual pool depth observations from our surveys and those from Merlin Biological (2005) were similar. Pleus et al. (1999) provided the criteria to determine what habitats are considered pools (Table 10). Our mean residual pool depths greatly exceeded these values throughout the Skokomish Basin, suggesting that pool depths within the somewhat limited pools available is in relatively good condition. Mossop and Bradford (2006) found that mean maximum residual pool depths ranging from 0.1 to 0.5 m was correlated with juvenile Chinook salmon densities in small tributaries of the Yukon River with bankfull widths of approximately 5 m. These streams would be similar in size to Swift Creek and McTaggert Creek, where mean residual pool depths were 0.2-0.4 m and 0.1-0.2 m, respectively. This suggests that pool quality in Mctaggert Creek may be in somewhat poor condition (Figure 24). Mean residual pool depths in the upper South Fork Skokomish, which has a bankfull width substantially wider than 5 m, were generally less than 0.6 m. Thus, pool quality in the upper South Fork appears to be degraded (Figure 24).

Table 10. Minimum residual depth criteria for habitat units within streams of different bankfull width to be classified as pools (from Pleus et al. 1999).

Bankfull Width (m)	Residual Pool Depth (m)
0 – 2.49	0.1
2.5-4.9	0.2
5-9.9	0.25
10-14.9	0.3
15-19.9	0.35
>20	0.4

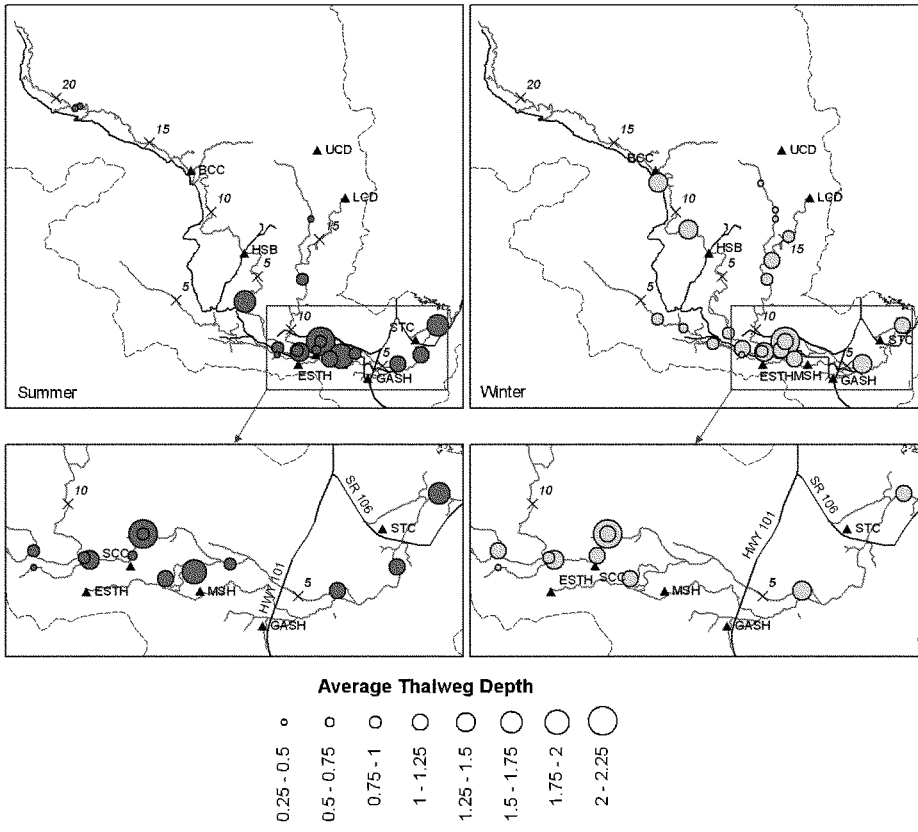

Figure 22. Average thalweg depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

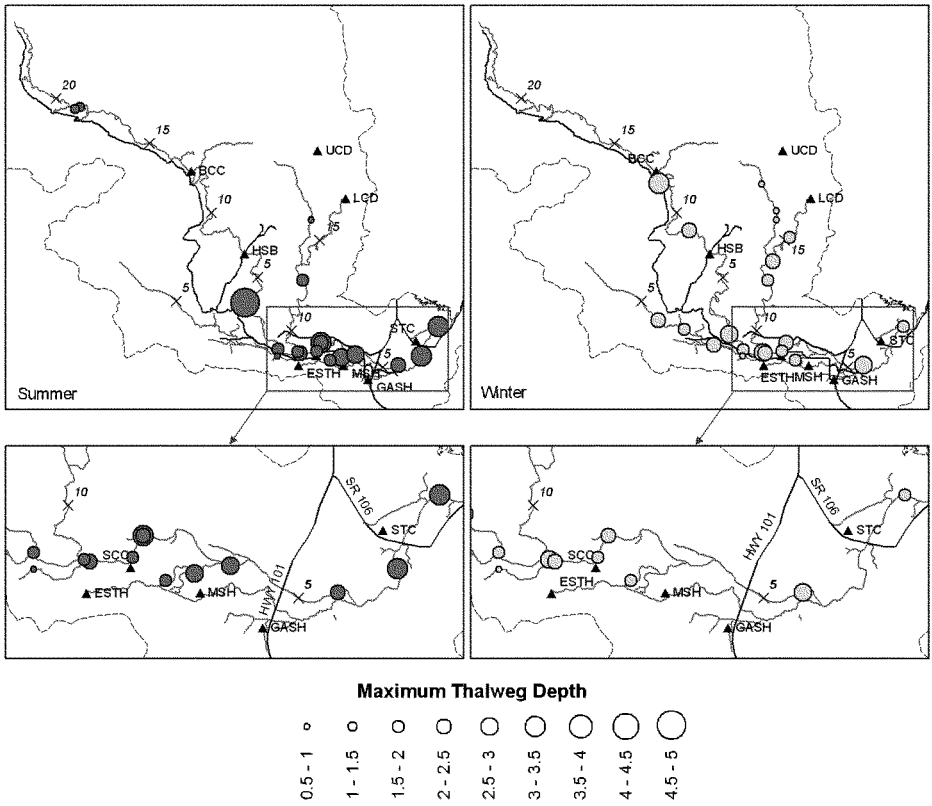

Figure 23. Average maximum thalweg depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

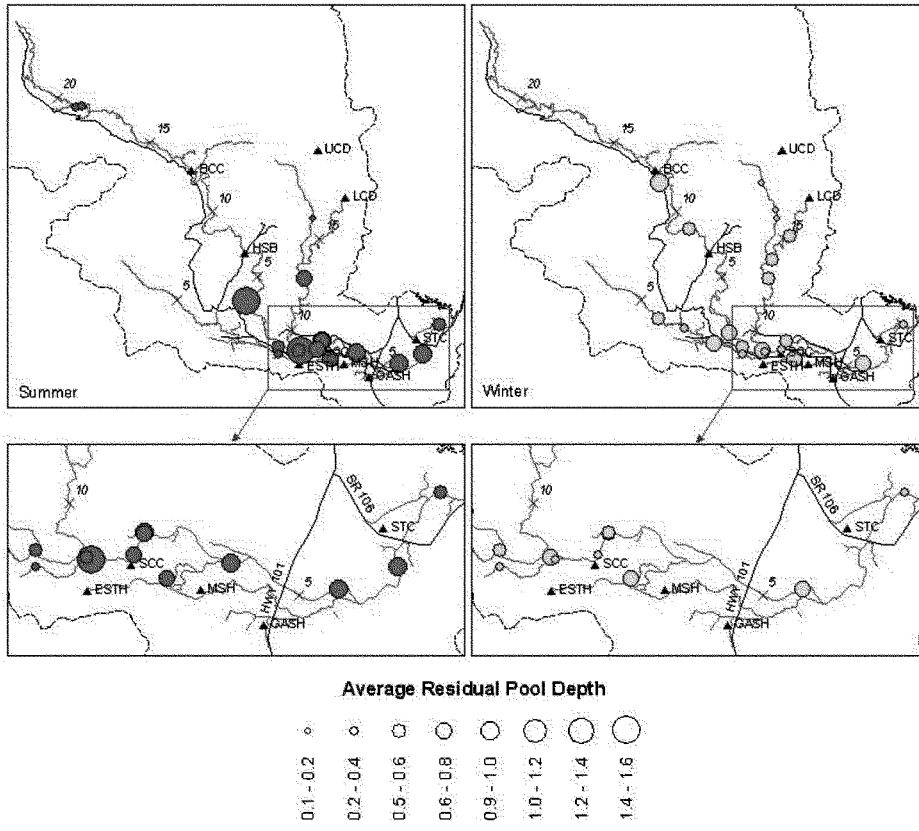

Figure 24. Average residual pool depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009.within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

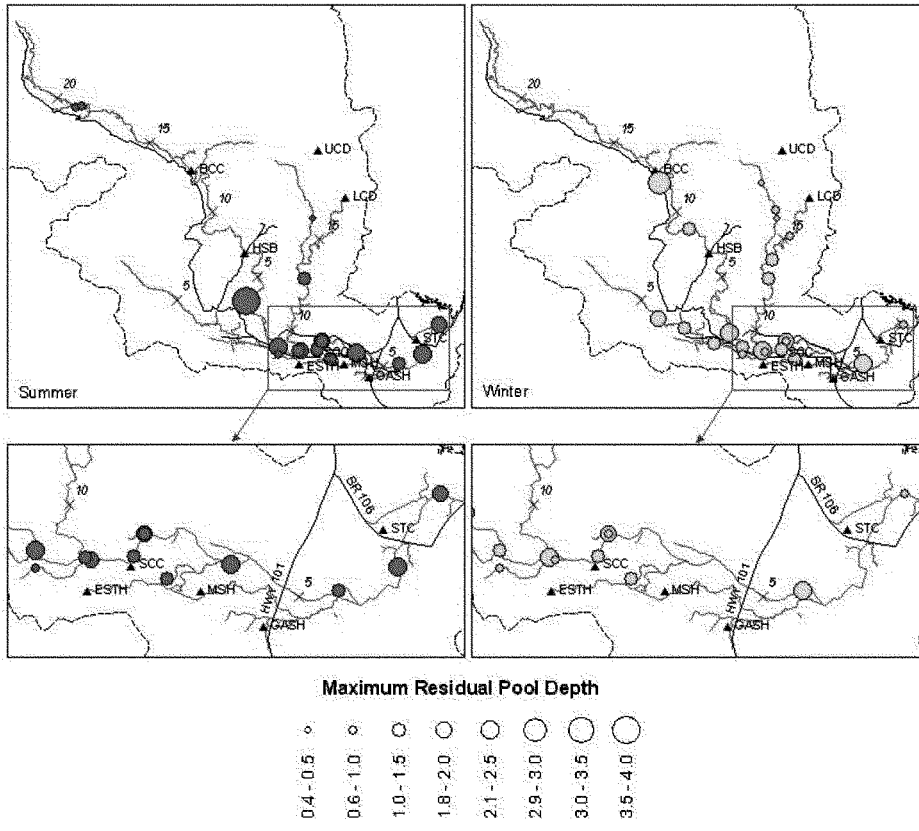

Figure 25. Maximum residual pool depth (m) of stream reaches assessed in the summer of 2008 and winter of 2009 within the Skokomish Basin. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Based on the discussion in this section, it is apparent that impact to large scale habitat conditions have been impacted in the Skokomish Basin to a greater degree than finer spatial scale habitat conditions. The Skokomish Basin is somewhat unique for western Washington Basins, in that a majority of the habitat available to anadromous salmonids is mainstem habitat rather than tributaries (i.e. 55.4% mainstem). The relative scarcity of tributary habitat may be compensated for by the high proportion of mainstem and tributary habitat that are productive low gradient, unconfined systems. However, these systems also appear to be the most highly degraded.

Of the four main habitat issues discussed above, habitat loss appears to be the most significant. The Cushman Dams block anadromous salmonids access to approximately 25% and 18% of the available mainstem and tributary habitat in the basin, respectively. Significant habitat has also been lost by the apparent loss of vegetated islands and their associated side channel habitats, which are productive to both adult (Eiler et al. 1992; Hiss 1995) and juvenile salmonids (Murphy et al. 1989; Hirschi and Reed 1998; Jeanes and Hilgert 2000; Peters, FWS, unpublished data). Much of this side channel habitat has apparently been transformed into less productive braided channel habitat. Channel straightening also appears to have resulted in significant losses of channel length available for salmonids. This along with channel aggradation that has reduced tidal influence in the lower mainstem also appears to have substantially reduced the stream-estuary ecotone, an important rearing and transition area for salmonids.

Reductions in habitat connectivity also appear to be significant. The extensive network of levees that run from approximately Vance Creek downstream to the estuary reduces access to lateral and off-channel habitats. In addition, these levees may also result if fish that have been washed into the floodplain during overbank flows being trapped and isolated from mainstem habitats. Finally, dry channels during summer low flow block adult migration to significant proportions of the watershed.

Although there is no quantitative data available to evaluate channel and bed stability in the Skokomish River, the literature suggests that the aggrading conditions of this system would result in unstable habitat that would be detrimental to salmon. Local scour and fill, sufficient to scour salmon redds, would be expected to occur at relatively low discharges relative to a system where sediment inputs and transport capabilities are in equilibrium (Tripp and Poulin 1986). In addition, frequent (i.e., yearly) avulsions and abandonment would be expected in the braided system, which would isolate salmon redds and juvenile salmonids rearing in those channels. The potential significant impacts of channel and bed instability and the lack of information in the Skokomish Basin would make this an important data gap to address in the future.

Although finer scale habitat issues such as reduced riparian cover, decreased summer flows, increased summer temperatures, decreased LWD, and decreased pool habitat exist, they likely don't impact salmon in the Skokomish Basin to the same degree as the larger scale habitat issues discussed above. Riparian conditions in the basin are somewhat degraded, but conditions also vary considerably. Decreased summer flows are a significant issue in the basin; however, the new Cushman FERC agreement will address one of the primary concerns. However, subsurface flows in Vance Creek and the South Fork Skokomish need to be addressed. Summer temperatures appear to be only a sporadic issue in the basin, occurring primarily in the lower basin. LWD and pool habitat abundance is degraded in the system and is perhaps the greatest

concern of these fine scale issues. Although pool habitat appears to be reduced in the system, the quality of the existing pools, based on depth, seems to be adequate for juvenile salmonids.

Current Habitat Conditions for All Species: Off-Channel Pond Habitat

Off-channel ponds provide critical habitat to juvenile salmonids, especially during winter storm events (i.e., Peterson 1982a, Peterson and Reid 1984; Cederholm and Scarlett 1991). However, the physical characteristics of these ponds can influence fish growth and survival (Peterson 1982b). For example, fish growth generally decreases, while survival generally increases in deeper ponds relative to shallow ponds (Peterson 1982b). In addition, the availability of cover and open spaces lacking cover can influence fish use in ponds and lakes (Tabor et al. 2006). For this reason, we evaluated the availability and conditions of off-channel ponds in the Skokomish Basin. Habitat availability was completed using a GIS assessment to determine the spatial distribution and extent of off-channel ponds in the system, while site specific physical conditions within the ponds was assessed by visiting randomly selected site within off-channel pond habitat (see Appendices B and C for details).

Our GIS habitat assessment identified 28 different off-channel ponds that could potentially be accessible to anadromous salmonids (Table 11, Figure 26). The total surface area and perimeter of these ponds was 20.3 ha and 29,499 m, respectively. The ponds ranged in size from 0.08 to 4.96 ha, and averaged 0.7 ha. Since the ponds were smaller than 8 ha, they were all classified as palustrine systems. Two ponds were classified as being outside the anadromous zone. Pond #21 was located on a terrace and lacked an obvious egress channel to the N.F. Skokomish or McTaggart Creek and pond #20 was dry during the summer and had no outlet to the mainstem Skokomish River during the winter. All the remaining ponds were determined to be within the trout, coho, or bull trout zone. Ponds #26, #27, and #28 were outside the Chinook and chum zone. In addition, pond #25 was outside the chum zone.

We selected 14 sites within these ponds for summer sampling. These sites were located within six of the 26 different off-channel ponds. Four of these sites (two each in two ponds) were dry during the summer and therefore were not sampled. We selected 20 pond sampling sites for winter sampling. These sites were located in seven different ponds. Two sites were located in a pond (# 14) that was completely chocked with aquatic vegetation (i.e., no open water) and therefore were not sampled. Two additional sites in another pond (#20) were not sampled because the pond lacked a connection to the river channel (located in the middle of an agricultural pasture).

Cover was relatively abundant in the ponds we sampled during both summer and winter (Table 12). Terrestrial and aquatic vegetation provided the most cover area in both the nearshore and offshore transect at most sites during both summer and winter. Many of the transects were completely covered by these cover types. For example, many of the transects had bottoms that were covered entirely by aquatic vegetation. Small and large woody debris piles were the next most common cover types. Some large woody debris was occasionally present, while rock and undercut bank cover was rare. These results are reflected in the proportion of the transect area covered by the different cover elements (Table 11, Table 12). The lack of open space with no cover, observed during the summer, could reduce the quality of pond habitats for juvenile

salmon, since juvenile salmon appear to move away from complex habitats at night to rest near the bottom in open areas lacking cover (Tabor et al. 2002).

Pond depths were relatively consistent among the sites we sampled (Table 14). In general, nearshore depths were around 1 m, ranging from 0.46 to 1.9 m. Offshore depths averaged just less than 2 m, ranging from 0.96 to 2.61. Depths were consistent between summer and winter sampling events. These depths suggest that only the shoreline would have provided rearing habitat for newly emerged juvenile salmonids, but the rest of the pond habitat would be used after about 4 months of rearing. Tabor et al. (2006) found that most juvenile Chinook salmon in Lake Washington were found in water less than 0.5 m deep through April and that it wasn't until May that a majority of the fish used depths up to 2 m. However, the dense aquatic vegetation covering the pond bottoms we sampled may influence fish distribution within the ponds, since it may serve as a 'false bottom' resulting if fish perceiving the depth as shallower than that we measured (Tabor et al. 2006). The depths of the ponds we surveyed would suggest that they would be relatively productive habitats, but may have reduced overwinter survival relative to deeper ponds (Peterson 1982b).

The bank slope at the sites we surveyed was relatively gradual and became flatter the further you moved from shore (Table 15). There were no major differences at the sites between summer and winter surveys. The bank angles of the first 1.5 m of the pond averaged between 25 and 30° during the summer and winter; ranging from approximately 19 to 37° during the summer and 15 to 51° during the winter. The bank angle from 1.5 to 3 m offshore averaged approximately 12° during summer and winter and ranged from approximately 3 to 33° during the summer and 1.5 to 25° during the winter. These slopes are within the range found to be preferred by juvenile Chinook salmon in riverine habitat (Cedar River, R. Peters, FWS, unpublished data) and thus would likely provide quality habitat for early rearing juvenile salmonids.

The substrate at the pond sites sampled was not very diverse, with only fine substrate (<2mm), substrate from 2-16 mm in size, or aquatic vegetation observed at our transects (Table 16). Aquatic vegetation and fine substrate were the primary dominant substrates during the summer, with aquatic vegetation the most common dominant substrate type (both nearshore and offshore). In contrast to summer observations, fine substrate was the dominant substrate at most sites during the winter. Aquatic vegetation was the subdominant substrate at all but one of the remaining sites (nearshore transect at S-09), where substrate 2-16 mm in size was the subdominant substrate. As discussed above, the presence of dense aquatic vegetation covering the bottom may limit juvenile salmonid use of the ponds at during the summer. This is due to juvenile salmonids preference for open areas away from cover at night (Tabor et al. 2002, R. Peters, FWS, unpublished data).

Table 11. Surface area (ha), perimeter length (m), potential fish use, and the number of sites sampled within off-channel pond habitat identified during the current assessment of the Skokomish Basin (GIS based assessment 1:1,000). Fish zones (i.e., trout zone, chum zone) represent areas that are assumed to be accessible to these fish species. Trout zone includes areas where either cutthroat trout or steelhead were present. See Figure 26 for their location in the Skokomish Basin.

Pond #	Area (ha)	Perimeter (m)	Trout Zone	Coho Zone	Chum Zone	Chinook Zone	Bull Trout Zone	Number of sample sites	
								Summer	Winter
1	0.3	924.6	Yes	Yes	Yes	Yes	Yes	1	1
2	0.4	529.6	Yes	Yes	Yes	Yes	Yes	0	0
3	0.2	753.7	Yes	Yes	Yes	Yes	Yes	0	0
4	0.5	540.0	Yes	Yes	Yes	Yes	Yes	0	0
5	0.2	266.4	Yes	Yes	Yes	Yes	Yes	0	0
6	1.6	2143.8	Yes	Yes	Yes	Yes	Yes	0	2
7	0.2	519.2	Yes	Yes	Yes	Yes	Yes	0	0
8	0.1	236.1	Yes	Yes	Yes	Yes	Yes	0	0
9	0.1	187.0	Yes	Yes	Yes	Yes	Yes	0	0
10	0.1	216.5	Yes	Yes	Yes	Yes	Yes	0	0
11	0.2	522.2	Yes	Yes	Yes	Yes	Yes	0	0
12	3.0	3316.1	Yes	Yes	Yes	Yes	Yes	4	4
13	0.1	397.1	Yes	Yes	Yes	Yes	Yes	0	0
14	1.5	1599.8	Yes	Yes	Yes	Yes	Yes	0	0
15	5.0	6324.4	Yes	Yes	Yes	Yes	Yes	4	8
16	0.4	1429.8	Yes	Yes	Yes	Yes	Yes	0	0
17	0.3	1215.5	Yes	Yes	Yes	Yes	Yes	0	0
18	0.5	702.8	Yes	Yes	Yes	Yes	Yes	0	0
19	0.6	845.4	Yes	Yes	Yes	Yes	Yes	0	0
20	1.4	1756.2	No	No	No	No	No	0	0
21	1.1	624.8	No	No	No	No	No	0	0
22	0.2	422.7	Yes	Yes	Yes	Yes	Yes	0	0
23	0.3	617.0	Yes	Yes	Yes	Yes	Yes	0	0
24	0.4	720.3	Yes	Yes	Yes	Yes	Yes	0	0
25	0.4	265.6	Yes	Yes	No	Yes	Yes	0	0
26	0.5	922.8	Yes	Yes	No	No	Yes	1	1
27	0.4	988.3	Yes	Yes	No	No	Yes	0	0
28	0.2	511.8	Yes	Yes	No	No	Yes	0	0

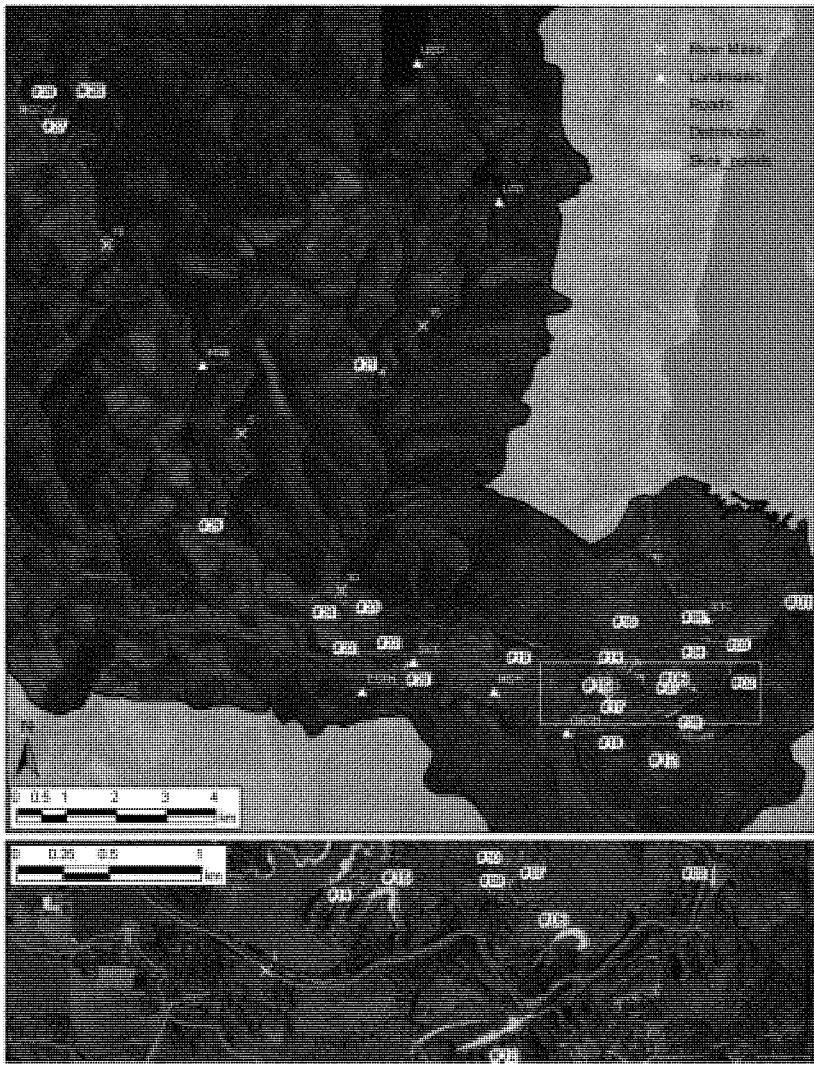

Figure 26. Location of ponds in the Skokomish Basin. Labels in yellow indicate ponds that were sampled for fish abundance and habitat conditions. Ponds labeled with yellow backgrounds contained sites sampled during this study, those with a white background were not. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 12. Proportion of each nearshore transect surface area (450 m^2) comprised of various coarse cover types in the Skokomish Basin ponds during the summer of 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

Season	Pond #	Site	Aquatic vegetation	Terrestrial vegetation	Small woody debris and brush	Small debris piles	Large debris piles	Large woody debris
Summer	1	S-05	0.33	0.03	0.08	0	0	0
	12	S-09	0.67	1.00	0.14	0.39	0.23	0.01
		S-21	0.17	0.50	0.02	0.77	0.27	0
		S-25	0	1.00	0.21	1.00	0	0.22
		S-29	0.20	1.00	0.21	1.00	0	0.02
	15	S-10	0.67	0.11	0.16	0.01	0	0
		S-14	1.00	0	0.01	0.03	0	0.01
		S-19	1.00	0.67	0.02	0.02	0	0
		S-22	1.00	0.67	0	0.09	0	0.01
	26	S-16	0	0	0	0.12	0	0.05
Winter	1	S-05	0	0.33	0.05	0	0	0.02
	6	S-15	0	0.33	0.04	0.07	0.18	0
		S-31	1.00	0	0	0.05	0.17	0.02
	12	S-09	0	0.26	0.17	0.33	0.09	0.03
		S-21	0.16	0.33	1.00	0	1.00	0
		S-25	0.33	1.00	1.00	0.67	0.07	0.01
		S-29	1.00	1.00	0.49	0.40	0	0
	15	S-03	1.00	0	0.07	0.02	0.11	0.00
		S-10	0.33	1.00	0.12	0.05	0.10	0.01
		S-14	0.20	1.00	0	0.01	0	0.01
		S-19	0.33	1.00	0	1.00	0	0
		S-22	0.33	1.00	0	1.00	0.07	0.01
		S-23	1.00	0	0.04	0	0.18	0.03
		S-34	0.50	1.00	0.03	0.07	0.30	1.00
		S-35	0.67	1.00	0.01	0.20	0.00	0.03
	26	S-16	0	1.00	0	0	1.00	0

Table 13. Proportion of offshore transect surface area (450 m^2) comprised of various coarse cover types in Skokomish Basin ponds during the summer 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

Season	Pond #	Site	Aquatic vegetation	Terrestrial vegetation	Small debris piles	Large debris piles	Large woody debris
Summer	1	S-05	0	0	0	0	0
	12	S-09	0.13	1.00	0.63	0	0
		S-21	0	1.00	0.55	0.10	0.02
		S-25	0	1.00	0	0	0
		S-29	0	1.00	0	0	0
	15	S-10	0.67	0	0	0	0
		S-14	1.00	0	0	0	0
		S-19	1.00	0	0	0	0
		S-22	1.00	0	0	0	0
	26	S-16	0	0	0.05	0	0.04
Winter	1	S-05	0	0.50	0	0	0
	6	S-15	0	0	0	0	0.01
		S-31	0	0	0.01	0.03	0.03
	12	S-09	0	0	1.00	0	0
		S-21	1.00	0.04	0.02	0.02	0.01
		S-25	1.00	0	1.00	0.02	0
		S-29	1.00	0	1.00	0	0
	15	S-3	0	0	0	0	0
		S-10	0	1.00	0	0.03	0
		S-14	0	1.00	0	0.03	0
		S-19	0	1.00	1.00	0	0
		S-22	0	1.00	1.00	0	0.01
		S-23	0	0	0	0	0
		S-34	0	1.00	0.01	0.07	0.01
		S-35	0	1.00	0.01	0.04	0.01
	26	S-16	0	1.00	0	1.00	0

Table 14. Mean and standard error (SE) for the depth at nearshore and offshore transects of each sampled Skokomish River pond during summer of 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

		Nearshore		Offshore	
Pond #	Site	Mean (m)	SE	Mean (m)	SE
			Summer		
1	S-05	1.39	0.23	2.33	0.25
12	S-09	0.63	0.06	2.11	0.27
	S-21	0.62	0.05	1.22	0.19
	S-25	1.19	0.11	1.88	0.14
	S-29	1.19	0.16	1.98	0.19
15	S-10	1.02	0.12	1.3	0.15
	S-14	1.12	0.21	1.42	0.17
	S-19	1.06	0.13	1.94	0.14
	S-22	1.42	0.10	2.08	0.15
26	S-16	1.01	0.13	1.26	0.17
Mean	all	1.07	0.086	1.75	0.130
			Winter		
1	S-05	1.90	0.05	1.55	0.15
6	S-15	1.15	0.17	1.65	0.58
	S-31	0.82	0.21	1.97	0.52
12	S-09	0.76	0.10	2.55	0.12
	S-21	0.77	0.07	1.56	0.23
	S-25	1.22	0.19	2.28	0.16
	S-29	1.16	0.19	2.56	0.18
15	S-03	0.76	0.12	0.96	0.28
	S-10	0.81	0.06	2.14	0.23
	S-14	0.64	0.12	1.38	0.42
	S-19	0.71	0.08	2.34	0.27
	S-22	0.99	0.07	2.2	0.09
	S-23	1.06	0.18	1.6	0.30
	S-34	1.23	0.11	2.61	0.20
	S-35	0.98	0.12	2.07	0.12
26	S-16	0.46	0.06	1.02	0.18
Mean	all	0.96	0.084	1.90	0.132

Table 15. Mean slope angle (degree) at 1.5 m and 3 m from shore of nearshore transects in Skokomish Basin ponds during summer of 2008 (8/20-9/24) and winter of 2009 (2/23-4/8).

		1.5 m		3 m	
Pond #	Site	Mean	SE	Mean	SE
			Summer		
1	S-05	28.63	5.23	33.32	7.55
12	S-09	19.59	2.90	6.79	2.16
	S-21	19.67	2.14	5.60	3.69
	S-25	34.14	4.69	9.55	4.30
	S-29	32.44	6.45	12.48	4.15
15	S-10	31.15	3.22	6.97	3.34
	S-14	29.55	5.72	15.75	6.51
	S-19	28.58	4.05	15.77	3.53
	S-22	37.72	2.94	17.14	3.44
26	S-16	31.58	5.19	3.53	8.56
Mean	all	29.31	5.78	12.69	8.67
			Winter		
1	S-05	51.36	1.16	1.52	2.75
6	S-15	31.35	2.37	13.37	9.16
	S-31	18.99	4.82	18.32	7.80
12	S-09	21.49	3.05	11.88	3.57
	S-21	22.97	2.24	9.81	1.47
	S-25	28.04	6.31	25.47	2.31
	S-29	29.82	5.97	16.93	6.34
15	S-03	24.59	5.35	3.57	1.81
	S-10	24.79	2.59	7.93	1.89
	S-14	17.50	3.63	11.79	3.77
	S-19	23.33	4.09	3.81	1.20
	S-22	29.29	2.54	10.12	2.56
	S-23	25.47	6.82	20.95	2.67
	S-34	35.17	4.17	10.49	2.51
	S-35	27.04	3.30	14.39	3.10
26	S-16	15.51	3.31	2.78	3.66
Mean	all	26.69	8.38	11.45	6.78

Table 16. Dominant and subdominant substrate types along nearshore and offshore transects of Skokomish Basin ponds. 1=less than 2mm particle size; 2=2-16mm particle size; 7=plants.

			Nearshore		Offshore	
Season	Pond #	Site	Dominant	Subdominant	Dominant	Subdominant
Summer	1	S-05	1	-	1	-
	12	S-09	7	1	1	7
		S-21	1	7	1	7
		S-25	7	1	7	1
		S-29	7	1	7	1
	15	S-10	7	-	7	-
		S-14	7	-	7	-
		S-19	7	-	7	-
		S-22	7	-	7	-
	26	S-16	7	-	7	-
Winter	1	S-05	1	-	1	-
	6	S-15	1	-	1	-
		S-31	1	-	1	-
	12	S-09	1	2	1	7
		S-21	1	7	7	1
		S-25	1	7	7	1
		S-29	1	7	7	1
	15	S-03	1	1	1	1
		S-10	1	7	1	7
		S-14	1	7	1	7
		S-19	1	7	1	7
		S-22	1	7	1	7
		S-23	1	1	1	1
		S-34	1	7	1	7
		S-35	1	7	1	7
	26	S-16	1	-	1	-

Water temperatures at the pond sites we sampled were within appropriate ranges (Bjornn and Reiser 1991; Richter and Kolmes 2005) for juvenile salmonids (Table 17). Summer temperatures averaged approximately 15°C, which is well below lethal limits. These temperatures exceeded the optimum temperature (8-11°C) for growth efficiency listed by Brett et al. (1969), but not those reported (14-17°C) by Richter and Kolmes (2005). The differences observed in the temperature ranges providing for the most efficient growth between Brett et al. (1969) and Richter and Kolmes (2005) are likely due to differences in procedures and/or acclimation temperatures used prior to the experiments. Thus, based on these different results, it's likely that the temperatures we observed are at the upper end of the temperatures providing

for optimum growth of juvenile salmonids. Four sites had temperatures greater than 19°C, which is still below lethal levels (Bjornn and Reiser 1991, Marine and Cech 2004). As expected, temperatures were much cooler in the winter than during the summer. The observed temperatures were within the optimum range for growth efficiency listed by Brett et al. (1969), but below those listed by Richter and Kolmes (2005). Thus, winter temperatures appear to be on lower end of the temperature range providing for optimal growth efficiency.

DO was relatively consistent between nearshore and offshore transects during both summer and winter (Table 17). Dissolved oxygen (DO) was slightly greater at the nearshore transect than the offshore transect, possibly due to wave and/or photosynthesis activity. However, four summer nearshore sites had DO values less than 5 mg/l, which is generally considered detrimental to salmonids. At two nearshore sites and four offshore sites, summer DO levels were less than 3 mg/l. Additionally, DO levels often fluctuate diurnally and even lower levels may have occurred early in the morning before aquatic macrophytes began actively photosynthesizing. As expected, DO values were also much greater during the winter surveys than they were during the summer surveys, and were also a bit greater in nearshore areas than offshore areas. DO levels during the summer were less than 8 mg/l, where food conversion efficiency in salmonids is inhibited (Davis 1975; Alabaster et al. 1979). The DO levels measured in the Skokomish River pond habitats was less than that observed in off-channel ponds in other systems. For example, Peterson (1982a) measured DO levels in off-channel ponds of the Clearwater River during the winter and found DO levels were greater than 7 mg/l in all cases and generally greater than 10 mg/l. Given this, further and more detailed evaluations of DO in these off channel ponds are warranted.

Water turbidity was relatively low among nearshore and offshore transects during summer and winter (Table 17). Water turbidity levels of less than 3 Nephelemetric Units (NTUs), as generally observed in this study, are generally not considered to impact juvenile salmonids foraging (i.e., Bash et al. 2001) or growth (Sigler et al. 1984). In fact, juvenile coho salmon don't avoid turbid waters until turbidity levels reach about 70 NTU (Bisson and Bilby 1982). Although, the turbidity levels we observed during our sampling were low, this could be somewhat biased by the fact that we didn't sample during high flow events, since we wouldn't have been able to complete our snorkel surveys to assess fish abundance. Thus, our results may be biased towards lower turbidity levels since turbidity may have increased in the ponds during high flow events, especially if the ponds were inundated. Although, this may have occurred, our sampling suggests that potential turbidity issues would likely be short in duration, thereby limiting their impacts.

Water pH was lower in offshore transects relative to nearshore transects during both summer and winter, and was also reduced during the winter relative to summer (Table 17). The differences in pH values we observed between summer and winter are possibly due to differences in density and photosynthesis activity of aquatic vegetation. Water pH measurements were taken shortly after dusk and pH levels may have been somewhat lower at dawn during the winter due to reduced photosynthesis activity. Regardless, all pH levels appear to be within a normal range for juvenile salmonids. The acidic conditions observed at the offshore transects during the winter is concerning, since the levels observed (i.e. pH ~ 5.1) would potentially impact survival and impair smolt development (McCormick et al. 2009).

Salinity was extremely low (< 0.05 ppt) at the pond sites we sampled (Table 17), suggesting that saltwater intrusion rarely occurs. In fact, nearly all values were zero and those that weren't, were close to zero.

Based on the water quality data we collected, there does not appear to be any major water quality issue during the winter in pond habitats of the Skokomish watershed. However, summer water quality measurements indicated DO levels could be low enough to impact salmonids. Two sites, S-9 and S-21, had DO levels less than 3 mg/l, yet abundance of coho salmon fry was relatively high. DO levels were only taken at one spot in the water column and coho salmon fry may be using other areas in the water column with greater DO levels. To get a more complete picture of DO levels, measurements need to be taken diurnally throughout the summer and throughout the water column. Additionally, summer DO levels may fluctuate from year to year based on weather conditions and thus, DO levels need to be measured over several years.

Off-channel habitat in the Skokomish Basin appears to be abundant and in relatively good condition relative to providing habitat for juvenile salmonids. Twenty-six ponds were determined to lie within the anadromous zone, with 23 of these likely accessible to Chinook salmon. Water depths and bank angles associated with the pond margins were within the preferred range for juvenile salmonids. The water depths (<3 m) would be expected to provide productive habitats that would provide ample food for juvenile salmonids; however, overwinter survival may be somewhat reduced at these depths (Peterson 1982b). The dense mats of aquatic vegetation covering the bottom could reduce habitat quality for fish since open spaces preferred at night (Tabor et al. 2006) would be lacking. However, this would need to be evaluated further before any management recommendations could be proposed. With the exception of DO, water quality within the ponds is within the appropriate range for juvenile salmonids. Thus, off-channel pond habitat appears to be abundant and of sufficient quality to provide substantial rearing for juvenile salmonids.

Table 17. Mean and SE values for Dissolved Oxygen (DO) (mg/l), temperature, turbidity (NTU), pH, and salinity (parts per thousand (ppt) across all sampled Skokomish River pond sites in both nearshore and offshore transects during summer and winter.

	Nearshore				Offshore			
	Summer		Winter		Summer		Winter	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
DO (mg/l)	6.27*	0.82	8.09	0.30	5.41*	0.79	7.10	0.73
Temperature (°C)	15.62	1.46	8.69	0.29	15.41	1.46	7.58	0.77
Turbidity (NTU)	2.78	0.67	2.17	0.20	2.81	0.76	1.08	0.32
pH	8.97	0.05	6.79	0.88	8.50	0.51	5.09	0.76
Salinity (ppt)	0.03	0.02	0.01	0.01	0.02	0.01	0.04	0.04

* Four data points each were less than 5mg/l

Combined, 9,000 fish were observed along 52 transects (nearshore/offshore and summer/winter combined (Table 18). The total area surveyed of nearshore transects was only 50% larger than offshore transects; however, 7.4 times as many fish were observed along the nearshore transects as the offshore transects. The number of fish per transect was generally higher during the summer than the winter (summer, 376 fish/transect; winter 261 fish/transect). This was due in large part to the large number of small juvenile coho salmon observed during the summer along some transects. There also appeared to be large differences in fish species composition and abundance between ponds. For example, only a few brook trout (n = 35; 8.8 fish/transect) were observed in Pond #26; whereas, in Pond #15 5,598 fish were observed (233 fish/transect) representing 10 fish species. Sixty-four percent of all fish were threespine stickleback, which were commonly observed in both summer and winter. Juvenile salmonids consisted primarily of coho salmon (90.7% of all juvenile salmonids). Other juvenile salmonids included Chinook salmon, cutthroat trout, and chum salmon. Large trout were frequently encountered in ponds. Based on other sampling, the vast majority of trout in ponds appear to be cutthroat trout. Sculpin, which are a common inhabitant of lowland systems of the Puget Sound, were occasionally observed; however, their abundance was lower than expected. Dense vegetation and woody debris as well as their coloration patterns (well-camouflaged) may have limited our ability to observe them. The number of non-native fishes included 35 brook trout in Pond #26 and 20 largemouth bass, one unidentified ictalurid, and one common carp in Pond #15.combined;

Table 18. Number of fish observed along 150-m transects in Skokomish River ponds, summer 2008 (8/20-9/24) and winter of 2009 (2/23-4/8). Trout includes cutthroat trout and steelhead. Other fish includes lamprey, chum salmon, brook trout, common carp, catfish, largemouth bass, and flounder.

Location	Season	Pond #	Number of transects	Chinook	Coho	Trout	Stickleback	Sculpin	Other
Nearshore	Summer	1	1	0	787	1	77	13	2
		12	4	22	728	26	565	14	0
		15	4	0	27	0	1,470	1	14
		26	1	0	0	0	0	0	14
		total	10	22	1,542	27	2,112	28	30
	Winter	1	1	0	8	0	1	1	1
		6	2	10	134	1	34	2	1
		12	4	17	156	74	258	69	2
		15	8	138	318	61	2,805	12	10
		26	1	0	0	0	0	0	3
		total	16	165	616	136	3,158	84	17
Offshore	Summer	1	1	0	130	2	0	3	0
		12	4	21	5	1	7	0	0
		15	4	0	90	1	384	0	3
		26	1	0	0	3	0	0	15
		total	10	21	225	7	391	3	18
	Winter	1	1	0	9	5	5	60	4
		6	2	3	40	3	48	11	1
		12	4	0	0	6	0	3	0
		15	8	23	89	3	71	4	7
		26	1	0	0	0	0	0	3
		total	16	26	138	20	127	78	12

A series of univariate regression analyses were conducted to examine the relationship between pond habitat variables and fish abundance. Habitat variables examined included percent cover (aquatic and terrestrial vegetation, woody debris piles, and large woody debris), complexity score (combined score of cover types), depth, slope, and predator abundance (density of large predatory fishes). Densities of each major fish category (threespine stickleback, sculpins, trout, juvenile coho salmon, and juvenile Chinook salmon) were analyzed separately. Because few fish were observed in the offshore transects, analyses were limited to the nearshore transects. In general, few habitat variables were closely related to nearshore fish abundance. The strongest relationship was between winter trout density and total coarse cover area as well as complexity score (Figure 27). This relationship was substantially reduced if each of the cover types was examined separately with trout density.

Regression analyses were also conducted just for Pond #15 transects (number of transects: summer, $n = 4$; winter, $n = 8$) to determine if using one pond would reduce the

variability between transects. Other ponds could not be used due to a small sample sizes. In general, there was little improvement in the regression analyses by just using Pond #15. However, the density of juvenile Chinook salmon was slightly negatively related to mean depth and slope (Figure 28). These results are consistent with research of juvenile Chinook salmon in lentic waters (Sergeant and Beauchamp 2006; Tabor et al. 2006). Additionally, trout density was slightly positively related to slope ($r^2 = 0.33$).

We also compared substrate type with fish densities. Because there were only two categories (with and without plants), we used the Mann-Whitney *U* test to make comparisons. For winter samples, the only significant comparison was with trout density (Figure 29). Transects where the dominant substrate was plants had a significantly higher density of trout than transects with sand/silt as the dominant substrate. Summer sample sizes were too small to make any comparisons. However, the two sites with the highest number of juvenile coho salmon in the summer were also the only two sites where plants (aquatic macrophytes) were not the dominant substrate type. This result may be an artifact of our surveys being only conducted at night. Juvenile coho salmon appear to move away from complex habitats at night to rest near the bottom in more open areas (Tabor et al. 2002).

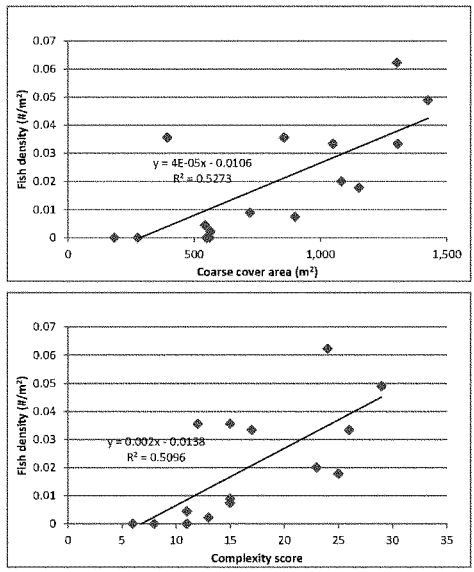

Figure 27. Relation between cover (total cover area and a complexity score) and winter trout density (#/m^2) in Skokomish Basin ponds. Cover area and the complexity score incorporate aquatic and terrestrial vegetation, small and large woody debris piles, and large woody debris. Based on other sampling, the vast majority of trout in ponds appear to be cutthroat trout.

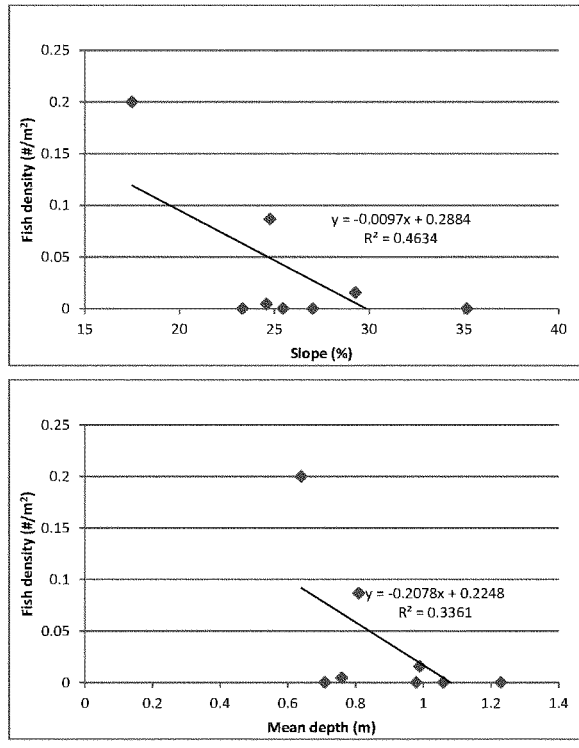

Figure 28. Relation between slope (%) and mean depth (m) with juvenile Chinook salmon density (#/m^2) in Pond #15, winter 2009 (2/24-3/26).

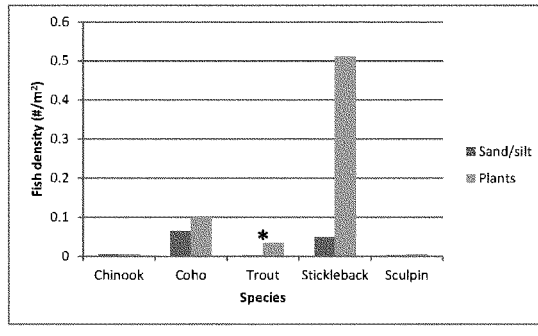

Figure 29. Winter median fish density (#/m^2) of transects with two different dominant substrate types. Asterisk indicates a significant difference between the two substrate types (Mann-Whitney U test; $P < 0.05$).

Results of our pond surveys indicated off-channel ponds are routinely used by salmonids and other fishes. Ponds can provide valuable habitat during both winter and summer. However, ponds are generally considered more important for winter habitat by providing refuge from high discharge events (Peterson 1982a) and providing ideal foraging conditions (Peterson 1982b). In some systems, winter habitat limits salmonid smolt production and off-channel ponds can be an integral element of winter habitat. For example, enhanced off-channel ponds on Fish Creek in Oregon represented less than 1% of the Fish Creek Basin habitat but contributed 50% of the coho salmon smolt production (Reeves et al. 1991). In the Skokomish Basin, off-channel ponds appear to provide valuable winter habitat for coho salmon, Chinook salmon, and cutthroat trout. The only salmonid species to use the ponds extensively in the summer was coho salmon. The importance of off-channel ponds as summer habitat is unclear. Ponds likely provide good foraging conditions; however, low DO levels, possible increased predation risk (e.g., from largemouth bass), and reduced connectivity to the mainstem may limit their value as summer habitat.

Construction and rehabilitation of off-channel ponds is considered a valuable tool in habitat restoration efforts (Frissell and Ralph 1998). We identified 28 different off-channel ponds with a total area over 20 ha. Therefore, a fair amount of pond habitat already exists but habitat conditions and connectivity to the mainstem are not well known. A closer examination of each pond is needed to ensure that they are adequately connected to the mainstem. If they are not well connected, rehabilitation efforts are needed. Managers should also look for new opportunities where a pond could be constructed. Shallow ponds (maximum depth < 2 m) are more productive than deeper lakes (maximum depth > 3 m) but juvenile salmonids may have lower survival rates in shallow ponds (Peterson 1982b). An ideal pond may be a shallow pond that has numerous cover aspects (e.g., woody debris) to reduce predation risk. Shallow ponds may be less expensive to construct but may require more maintenance once sediments and vegetation limit the amount of open water.

Rehabilitation efforts could also consider the removal of non-native predatory fishes. Of the five ponds we examined, two had non-native predatory species that could impact survival of juvenile salmonids and other fishes. An inventory of all ponds is needed to determine the overall distribution of non-native fishes. Largemouth bass were present in Pond#15. Largemouth bass are native to eastern North America and have been widely introduced in North America including the Pacific Northwest. They typically inhabit ponds, lakes, and slow-moving rivers. Their greatest impact on salmonid populations appears to be in rearing lakes of juvenile coho salmon (Reimers 1989; Bonar et al. 2005). Adult brook trout were present in Pond#26. Brook trout are also native to eastern North America and have been widely introduced. In lakes where they occur, they appear to an important predator of juvenile salmonids inhabiting the littoral zone (Biro et al. 2008).

Current Habitat Conditions for All Species: Estuarine and Nearshore Habitat

The Skokomish estuary is the largest and most complex river estuary in Hood Canal, historically covering 799 ha (1,974 acres) at the Skokomish River mouth and Hood Canal interface (Todd et al. 2006). However, direct (diking) and indirect (sediment inputs, water withdrawal) effects have altered the estuary significantly. Habitats have been altered leading to the Skokomish stream-delta complex being rated as severely impaired (Todd et al. 2006).

The Skokomish estuary likely to consist of diverse array of habitats including, old-growth riparian forests, emergent freshwater marshes, salt marshes, tidal channels, and mud flats historically (Skokomish Tribe and WDFW 2010). However, the current estuary has been significantly changed from historic conditions due to human alterations. Human induced changes to the Skokomish estuary began prior to 1885, when the Bureau of Indian Affairs facilitated land clearing for agricultural and residential uses (Todd et al. 2006). In addition, the land management activities in the upper watershed would have influenced the physical characteristics near this time by increasing bank erosion and sediment delivery to the system. Extensive diking in the estuary began in the late 1930s, which would have isolated habitats and influenced hydraulic (both riverine and tidal) and sediment transport characteristics in the estuary.

Direct changes to the estuary have eliminated the old-growth riparian forests and isolated tidal channels. Bortleson et al. (1980) classified historic and current riverine nearshore wetlands in the Skokomish Basin as intertidal (5 km^2 vs. 4.5 km^2) and subaerial (2.1 km^2 vs. 1.4 km^2) and determined that they have been reduced by 10 and 33 percent, respectively. Collins and Sheikh (2005) classified these same historic habitats as estuarine (2.6 km^2), riverine tidal (0.3 km^2) and palustrine (4.0 km^2). Of this habitat a majority was composed of emergent estuarine wetlands (~70%) with the remaining wetlands divided nearly equally among scrub-shrub estuarine and riverine-tidal wetlands (Collins and Sheikh 2005). In contrast, the current Skokomish estuary lacks riverine-tidal wetlands, while emergent estuarine wetlands are similar to their historic values and scrub-shrub estuarine wetlands have nearly doubled in their availability (Collins and Sheikh 2005).

Recent restoration of the Skokomish estuary has been reversing the loss of estuarine habitat. Restoration began naturally in the mid-1990s when the outer dike of Nalley Island was breached during a storm. Additional estuarine restoration occurred recently with extensive dike removal and borrow ditch filling at Nalley Slough (2007) and Nalley Island (2010). These restoration projects reclaimed approximately 324 acres of estuarine habitat in the Skokomish estuary (ESRP 2010).

Indirect changes to the estuary have also occurred and have substantially influenced current habitat conditions. Increased sediment inputs and the diversion of water out of the basin in the upper basin have resulted in physical changes in the estuary. Deposition has occurred on the inner delta, while erosion has occurred on the outer delta, resulting in the steepening of the delta surface (Jay and Simenstad 1996). The total area of unvegetated tidal flats has decreased by about 2%, while highly productive low intertidal surface area (15-19%) and eelgrass (*Zostera marina*) habitat (17%) have decreased substantially more. Aggradation in the estuary has also resulted in the development of salt marsh islands and general extension of salt marshes within the estuary. In addition, sediments have become finer within the inner delta (Jay and Simenstad 1996).

We found little information regarding eelgrass habitat specific to the Skokomish estuary. Jay and Simenstad(1996) state that eelgrass habitat in the estuary has been reduced by 17% due to increased sediment deposition and delta steepening resulting from increased sediment inputs upstream and out of basin water diversion. Thom and Hallum (1990) report that between 32.5 and 35.2 percent of Hood Canal shoreline is occupied by eelgrass based on surveys completed by WDF between 1975 and 1989 and the coastal zone atlas (1977). Thus, it appears that the loss of

eelgrass habitat throughout the greater Hood Canal area has not been as great as that in the Skokomish estuary.

Riverine and estuarine aggradation has also impacted tidal influence in the stream-estuary ecotone, which appears to be shifting downstream (Skokomish Tribe and WDFW 2010). It was reported to extend to approximately 14.5 km (9 mi) upstream of the river mouth to the an area near the confluence of the North Fork and South Fork Skokomish Rivers (Jay and Simenstad 1996). Skokomish Indian Tribe and WDFW (2010, citing Marty Ereth, former Skokomish tribal biologist, personal communication) place the extent at approximately 5.6 to 6.4 km upstream of the mouth (3.5-4 mi). Our fish collection data, suggests that tidal influence may actually have shifted even further downstream to approximately 4 km (2.5 mi) upstream of the mouth.

Although the authors realize that the nearshore habitat adjacent to the Skokomish estuary provide important habitat for juvenile salmonids and other fish species found in Hood Canal, these nearshore areas are outside the scope of this GI. Thus, they are not covered in this report. In addition, Puget Sound nearshore habitats have been described in detail in the Puget Sound Nearshore Ecosystem Restoration Project, which is a cost-shared GI by the USACE and WDFW.

Skokomish Basin Conditions: Biological Characteristics

Dating back to the early 1900s, biologists have used various metrics describing aquatic biological communities to elucidate the status and trends of water bodies, especially lakes and rivers (Cairns and Pratt 1993). In particular, benthic macroinvertebrates and algae have been commonly used as indicators of fresh water quality. Benthic macroinvertebrates are a group of organisms (insects, worms, and crustaceans) that reside in the benthos (bottom substrates) of freshwaters (e.g., rivers and lakes) for at least part of their life cycle. Those organisms that are retained in sampling nets of mesh sizes > 200-500 μm are termed "macro", which distinguishes them from other more microscopic animals and multicellular organisms. Periphyton is a term that describes a community of autotrophs and detritivors growing on surfaces of the benthos. The largest component of periphyton is algae, particularly diatoms that use sunlight to fix carbon dioxide (CO_2) in the biochemical process of photosynthesis. Periphyton forms the base of the aquatic food web and is grazed upon by many different macroinvertebrate taxa (as well as some vertebrates, such as larval frogs), which in turn provide food for stream dwelling fish, birds, and herepetofauna.

Biological monitoring, or biomonitoring, is the practice of using biological responses to evaluate changes in the environment. Although changes can be natural, most biomonitoring programs have been established to detect changes due to anthropogenic impacts. Aside from changing in predictable ways to the impacts of pollution and habitat degradation, macroinvertebrates and periphyton have qualities that make them good candidates as bioindicators. They are ubiquitous, have a large number of species and a diverse array of life history requirements, spend long periods of time (or their entire life) in the effected habitat, and are relatively sedentary compared with the spatial grain and extent used in most biomonitoring studies. Benthic macroinvertebrate communities, in particular, integrate the effects of multiple stressors across multiple spatial and temporal scales and, in effect, continuously monitor the conditions of the water they inhabit (Rosenberg and Resh 1993).

We collected periphyton and macroinvertebrates samples from the same 29 locations in the Skokomish River watershed from 25 August - 14 October, 2009 in riffle habitats. Details of the methods used to collect the samples can be found in Appendix C.

Primary and Secondary Prodncers

Primary Producers: Periphyton

We collected periphyton from the same 29 locations in the Skokomish River watershed, including sites in the mainstem, South Fork Skokomish, North Fork Skokomish, and 5 different tributaries. Periphyton are a group of organisms typically used in bioassessments worldwide (e.g., Lange-Bertalot 1979, Van Dam et al. 1994, Patrick 1973). We analyzed the standing crop, or amount of biomass present at the time of sampling as well as the diatom community structure based on taxa richness and relative abundance. Taxa richness, the total number of unique diatom taxa found at a given site, averaged 32 species (range 13 – 56; Table 19) Although taxa richness was higher in mainstem sites (35) than in tributary sites (27), this difference was not statistically

significant (Kruskall-Wallis test = 3.0, $P = 0.08$). Shannon diversity ($base_2$) averaged 3.31, ranged from 0.60 to 4.56. The amount of chlorophyll-a, an estimate of the algal component of periphyton standing crop, averaged 26.5 mg/cm^2 (range 2.3 – 207.9, Table 19).

We used periphyton as bioindicators by calculating numeric biocriteria for each site based on the taxa present and their abundances. These biocriteria are based on the concept that certain taxa will increase or decrease in abundance in the presence of a particular disturbance (see appendix C for more details). Scores for the three biocriteria metrics generally scored well across all mainstem and tributary sites (Table 19). Taxa derived scores for the siltation index, pollution index, and metals index showed 90%, 100%, and 59% of the streams scoring at the "excellent" level, respectively. The majority of the sites not scoring in the excellent category for metals scored in the "good" category, suggesting that overall metal impairment is not widespread in the Skokomish River watershed. The only site scoring a "poor" ranking for any metric was Pine Creek, which showed possible impairment from metals (Table 19). This site had the lowest diatom richness (13) and Shannon diversity (0.60) of all the sites sampled. The scores for the Montana bioindex, a multimetric index similar to Index of Biotic Integrity (IBI) and based on Montana streams, revealed that the 89% and 64% of the mainstem and tributary sites were in good or excellent condition, respectively.

Figure 30. Locations where periphyton and invertebrate samples were collected during the summer of 2009. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 19. Summaries of diatom assemblage metrics and bioindicator scores for 29 study sites where periphyton was sampled in the Skokomish River watershed. Bioindicator scores for siltation, pollution, and metals impacts, as well as a B-IBI based on diatom assemblages, were derived from work in Montana (Bahls 1993, Teply and Bahls 2005) which represents one of the most comprehensive regional stndies available. Full summary statistics are provided in Appendix JJD_2.

Site	Site Code	Taxa Richness	Shannon Diversity*	Chl-a (mg/cm^2)	Siltation Biocriteria	Pollution Biocriteria	Metals Biocriteria	Montana Bioindex
MS Skok	2-23	45	4.31	33.42	Excellent	Excellent	Excellent	Good
MS Skok	2-31	41	3.92	18.48	Excellent	Excellent	Good	Good
MS Skok	2-28	50	4.56	33.31	Excellent	Excellent	Excellent	Excellent
MS-ONP Index	ONP Index	26	2.62	15.44	Excellent	Excellent	Excellent	Good
NF Skok	2-01	30	2.61	207.92	Excellent	Excellent	Good	Good
NF Skok	2-26	56	3.87	7.46	Excellent	Excellent	Excellent	Good
SF Skok	2-06	42	3.99	17.77	Excellent	Excellent	Excellent	Excellent
SF Skok	2-12	20	2.24	6.74	Excellent	Excellent	Fair	Fair
SF Skok	2-30	26	2.94	10.75	Excellent	Excellent	Good	Good
SF Skok below Canyon	2-33	47	4.21	25.92	Excellent	Excellent	Excellent	Excellent
SF Skok	2-37	38	3.82	7.40	Excellent	Excellent	Excellent	Good
SF Skok	2-38	22	3.22	4.34	Excellent	Excellent	Good	Good
SF Skok	2-42	19	2.77	42.52	Excellent	Excellent	Good	Fair
SF @ Vance	SF Vance	28	2.87	8.87	Excellent	Excellent	Excellent	Good
SF Skok Old NF/SF CF	SFONF	24	3.05	53.66	Excellent	Excellent	Excellent	Good
MS Skok below new CF	SFNNF	41	3.57	2.33	Excellent	Excellent	Good	Good
SF Skok	2-08	42	4.24	70.10	Good	Excellent	Excellent	Good
SF Skok	2-10	35	3.71	17.72	Excellent	Excellent	Excellent	Good
Browns Cr.	2-14	29	3.50	13.14	Excellent	Excellent	Excellent	Good
Browns Cr.	2-17	28	3.37	14.08	Good	Excellent	Excellent	Good
Church Cr.	2-15	18	2.15	24.80	Excellent	Excellent	Good	Fair
McTaggert Cr.	2-18	25	2.81	3.12	Excellent	Excellent	Excellent	Fair
McTaggert Cr.	2-64	28	3.16	26.42	Excellent	Excellent	Good	Good
McTaggert Cr.	2-67	30	3.47	7.85	Excellent	Excellent	Excellent	Good
McTaggert Cr.	2-69	26	2.82	16.46	Excellent	Excellent	Good	Good
Vance Cr.	2-13	34	3.74	10.07	Fair	Excellent	Good	Fair
Vance Cr.	2-29	31	3.93	20.16	Excellent	Excellent	Excellent	Good
Vance Cr CF	Vance	31	3.95	16.07	Excellent	Excellent	Excellent	Excellent
Pine Cr.	2-63	13	0.60	31.61	Excellent	Excellent	Poor	Poor

* Shannon diversity based on Log(base2)

Secondary Producers: Macroinvertebrates

We also collected benthic macroinvertebrate samples using a slack sampler, a net with 500 μm mesh used for sampling benthic organisms that captures dislodged individuals from a 1.25 m^2 portion of the river bottom. We conducted this sampling concurrent with the 29 locations where we collected periphyton (Table 20; Figure 30; see appendix C for additional details on sampling and processing methods). Across all sites, invertebrate abundance averaged 6835 individuals per sample (range 1578 – 18,648), high values that are generally indicative of waters in good condition with high primary and secondary productivity. Differences between mainstem Skokomish River sites (mean 7232, Standard Deviation (SD) = 3380) and tributary sites (mean 6187, SD – 5238) were not statistically different ($t = 0.66$, $P = 0.52$). Taxa richness, or the total number of unique taxa at each site, averaged 48 (range 37-66) and was moderate to high across sites. There were no sites with relatively few taxa, a common effect on macroinvertebrate communities inhabiting degraded waters. Differences between mainstem (mean 46.4, SD = 6.5) and tributary (mean 51.4, SD = 6.1) were statistically different (t = -2.1, P = 0.05). The relatively high taxa richness and abundance was reflected in Shannon diversity values that averaged 2.86 and ranged from 1.92 – 3.40. Differences in Shannon diversity were not different between mainstem and tributary sites ($t = -0.88$, $P = 0.39$).

Similar to the approach taken with periphyton, we calculated two multimetric indices for each location and estimated the biological condition based on comparisons with other data that spanned conditions from severely degraded to relatively pristine reference conditions. The B-IBI scores based on Karr's (1998) index showed that none of the sites sampled were degraded to a level for B-IBI classification of low biological integrity (Table 20). Of the 18 Skokomish River sites, 15 were scored as having moderate biological integrity and 3 were scored as having high biological integrity. This was in contrast to the tributary sites, which had a much higher proportion of sites scoring in the highest integrity category. Of the 11 tributary sites, nine were rated as having high biological integrity. The four sites in McTaggert Creek were scored as 48, 48, 50, and 50, sites in Brown's and Church Creeks scored > 46, and Pine Creek scored 48 (Table 20), with the highest possible index score being 50. The only two tributary sites that scored moderate condition were in Vance Creek. Specific details of the 10 metric scores used to calculate Karr's B-IBI, as well as other biocriteria for each site are provided in an appendix (Appendix C).

When Celedonia's (2004) large river B-IBI was used, the Skokomish River sites had higher scores than the scores based on Karr's B-IBI, which was developed for smaller, wadeable streams. The large river B-IBI had 14 sites scored as being in excellent condition and 4 sites in good condition. Although there were qualitative differences between the two multimetric approaches, this should be expected because the criteria that they use to make comparisons are based on different metrics and a different suite of reference streams and rivers. Also, Celedonia's B-IBI site ranking has 4 categories (excellent, good, fair, poor) whereas Karr's index has three categories, which may also lead to differences in the results between the two indices. Nevertheless, the two B-IBI indexes were in general agreement that none of the 18 Skokomish River sites were of low/poor biological integrity.

Both of the B-IBIs used for assessment of Skokomish watershed condition, one for streams and smaller rivers and the other for larger rivers, strive to balance structural and

functional community attributes (Karr and Chu 1999, Celedonia 2004). These multimetric indices are expected to discriminate among differentially impacted sites based on independently derived criteria that likewise discriminates, but is often more expensive to conduct, among gradients of disturbance. As pointed out by Caledonia (2004), the metrics selected are but a small subset of available attributes and should balance structural and functional categories, respond to gradients of human disturbance in a predictable fashion, and can effectively separate minimally disturbed from severely impacted sites.

We also created a graphical representation of a suite of metrics for each site, inclusive of the 10 metrics used for Karr's index as well as a suite of other informative metrics (Figure 31). This approach shows a matrix of columns (sites) and rows (biocriteria metrics) with each cell in the matrix being colored according to the Karr's B-IBI score for that metric at a particular site. The color scheme used is that of a heat map, where red indicates low biological condition, yellow indicates moderate biological condition, and green indicates high biological condition. The columns are arranged into groups of mainstem, north Fork Skokomish, south Fork Skokomish, and tributary sites. Reading the heat map allows for visual interpretation of how each metric score varies across different study sites (reading across a row), as well as indicating the biological condition of a particular site is across a suite of different macroinvertebrate metrics that are generally indicative of impairment (reading down a column).

The heat map (Figure 31) reveals some interesting trends in metric scores useful for interpreting differences in biological condition, especially between mainstem and tributary sites. Particularly notable is that long-lived taxa in the mainstem Skokomish River watershed are depauperate, with 75% of mainstem, 50% of North Fork Skokomish, 75% of the South Fork Skokomish, and 45% of tributary sites having low numbers of long-lived macroinvertebrate taxa. This could be due to a lack of channel roughness caused by high embeddedness (see habitat results below) decreasing the quantity of interstitial spaces in the stream bed, the lack of habitat complexity, scour effects of a highly mobile river bottom, or the lack of wood boles or other habitat features that long-lived species use as spatial refugia during high flows. A shift in the proportion of long-lived to shorter-lived taxa following disturbance has been shown for multiple trophic levels and taxonomic groups, including stream macroinvertebrates (e.g., Davies and Jackson 2006). Another functional taxonomic attribute, the percent of shredder macroinvertebrates, was also low. This invertebrate group contains a wide range of taxa that feed upon allochthonous organic material provided by surrounding riparian forests and represents an important nutrient source for stream communities (reviewed by Cummins et al. 1989). The course particulate organic matter processed by shredders into fine particulate matter is utilized by other invertebrate species along the river continuum (Vannote et al. 1980). The paucity of shredders present could be due to the fact that most of the sites occurred in stream and river reaches with low vegetation and riparian canopy cover. Also, lack of channel and habitat complexity, especially log jams and other features that would help retain allochthonous material, could be playing a role in the paucity of shredders present.

Table 20. Summaries of macroinvertebrate assemblage metrics and B-IBI scores for 29 study sites where invertebrates were collected from riffle habitats in the Skokomish River watershed. The B-IBI was based on Karr (1998) and calculated using 10 metrics whereas the Large River B-IBI of Celedonia (2004) was based on 9 metrics (see text). A more comprehensive set of macroinvertebrate assemblage statistics are available in Appendix JD_1.

Site	Site Code	Total Abundance	Taxa Richness	Shannon Diversity	Karr's B-IBI*	Lg. River B-IBI**
MS Skok	2-23	2388	42	2.30	30-M	8.3-E
MS Skok	2-31	5078	53	3.11	40-H	9.4-E
MS Skok	2-28	3992	49	2.96	36-M	8.3-E
MS Skok ONP Index	ONPindex	5986	47	3.19	40-H	9.4-E
NF Skok	2-01	9543	46	3.10	38-M	10.0-E
NF Skok	2-26	9792	41	2.39	38-M	8.3-E
SF Skok	2-06	1832	46	2.82	44-H	7.2-G
SF Skok	2-12	12,864	40	2.77	36-M	8.9-E
SF Skok	2-30	12,288	48	3.09	40-M	8.9-E
SF Skok below Canyon	2-33	3681	66	3.34	38-M	9.4-E
SF Skok	2-37	5356	46	3.01	38-M	9.4-E
SF Skok	2-38	11,232	40	2.70	36-M	7.8-G
SF Skok	2-42	6276	52	2.95	42-M	9.4-E
SF @ Vance	SF Vance	7349	49	3.14	38-M	8.9-E
SF Old NF/SF CF	SFONF	8144	47	2.58	32-M	8.3-E
MS Skok below new CF	SFNNF	5032	44	2.68	36-M	8.3-E
SF Skok	2-08	11,271	42	2.65	36-M	6.1-G
SF Skok	2-10	8064	37	1.92	30-M	6.7-G
Brown's Cr.	2-14	3294	46	2.44	40-H	n/a
Brown's Cr.	2-17	4592	50	3.02	42-H	n/a
Church Cr	2-15	2796	46	3.00	40-H	n/a
McTaggert Cr.	2-18	5324	60	3.40	50-H	n/a
McTaggert Cr.	2-69	5078	60	3.24	48-H	n/a
McTaggert Cr.	2-67	5151	60	2.89	48-H	n/a
McTaggert Cr.	2-64	2957	47	2.79	50-H	n/a
Vance Cr.	2-13	4723	46	2.96	46-H	n/a
Vance Cr.	2-29	13,920	47	2.73	36-M	n/a
Vance Cr. CF	Vance	18,648	49	2.59	34-M	n/a
Pine Cr.	2-63	1578	55	3.16	48-H	n/a

*10 metric B-IBI modified from Karr (1998) Top B-IBI score = 50; H = High biological integrity (BIBI Scores > 40), M = Moderate biological integrity (BIBI Scores between 25-39), L = Low biological integrity (BIBI Scores between 0-24) based on comparisons with a Pacific Northwest montane stream with high biological integrity (Bob Wissman, ABA, personal communication).

**Lg River IBI – 9 metric B-IBI based on M.T. Celedonia (2004) and intended for larger river systems in western Washington. See text for details.

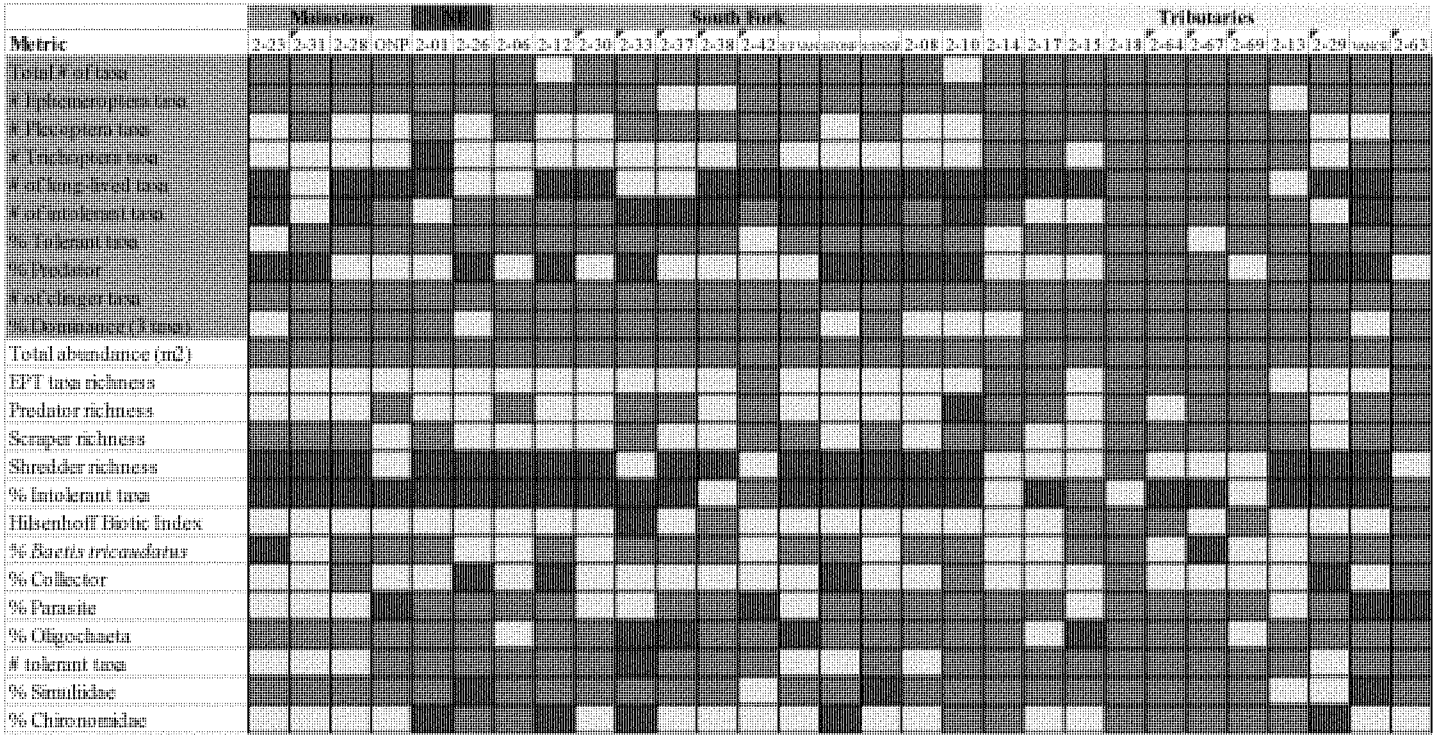

Figure 31. Heat map showing scores for several macroinvertebrate bioindicator metrics for study sites sampled in the Skokomish River watershed. The first 10 metrics (shaded gray) were used to create B-IBI scores (Karr 1998) based on comparisons with a Pacific Northwest montane stream with high biological integrity, whereas the others were scored by Bob Wissman (personal communication), a regional expert in macroinvertebrate taxonomy Cells were coded green (high biological integrity), yellow (moderate biological integrity) and red (low biological integrity) and columns were ordered by channel type and ecology.

Linking Primary and Secondary Species Assemblages to Environmental Data

In addition to the multimetric and reference condition methods discussed above, we also examined the macroinvertebrate and periphyton data using a suite of multivariate statistics (See appendix C for detailed methods). We discuss the results for each test separately for macroinvertebrate and diatom data.

The multi-dimensional scaling (MDS) plot for macroinvertebates (Figure 32) revealed that community structure differed among tributary, mainstem, and South Fork Skokomish sites, with clear separation occurring in the plot among these three site groups. On average, tributary sites were grouped together in the MDS plot (i.e., thus, by definition, more similar to each other in assemblage structure) than they were to South Fork Skokomish or mainstem sites. The South Fork Skokomish and mainstem sites also shared more within group similarity than among different groups, but the differences were not as strong as found in the tributary sites. The stress value of the macroinvertebrate ordination was 0.20, at the upper limit for interpretable results in MDS (Clarke and Ainsworth 1993).

The two-way Analysis of Similarities (ANOSIM) procedure in Primer, which was used to examine the variability in species composition among groups of sites, confirmed the visual interpretation of the MDS plots for macroinvertebrates that there were differences in assemblage structure among groups. We looked at two different ways to group the data. R values were significant for both type of channel (Mainstem, South Fork Skokomish, and Tributary; R = 0.46) and confinement (R = 0.65) (Table 21). Pair-wise comparisons for channel type suggested that tributary sites were significantly more different from South Fork Skokomish (R = 0.51) sites than they were from mainstem sites (not significantly different). Mainstem sites were also significantly different from South Fork Skokomish sites, based on pair-wise comparisons.

The MDS plot for diatoms also revealed separation among stream channel types, although there appeared to be much more overlap among groups than seen in the macroinvertebates. The stress value of the ordination was 0.17, within the level of interpretable structure recommended by Clarke and Ainsworth (1993). This assessment was confirmed by the lower ANOSIM scores (Table 21) seen among sites (R = 0.3). Unlike the macroinvertebrate results comparing confined versus unconfined reaches, there was not a significant difference due to confinement in the diatom assemblage structure (Figure 32, Table 21). The trend in pair-wise comparisons between different sites mirrored the results seen for macroinvertebrates; significant differences in assemblage structure occurred between mainstem/tributary sites and South Fork Skokomish sites, with mainstem and tributary sites not being significantly different.

To further explore the possible causes for differences in assemblage structure, we looked at univariate and multivariate approaches that linked environmental variables to the MDS plots of assemblage structure. We began with an ordination of the 14 environmental variables, which produced a Principal Component Analysis (PCA) that showed some separation among the different channel types (Figure 33). The first axis separated tributary from mainstem and South Fork Skokomish sites and was largely correlated with bank full width, water temperature, wetted width, and velocity. The second axis separated mainstem sites from tributary sites, and was correlated with increased cobble and embeddedness and decreasing levels of gravel. While the results were statistically significant, the two PCA axes explained only 35% of the variability in the data.

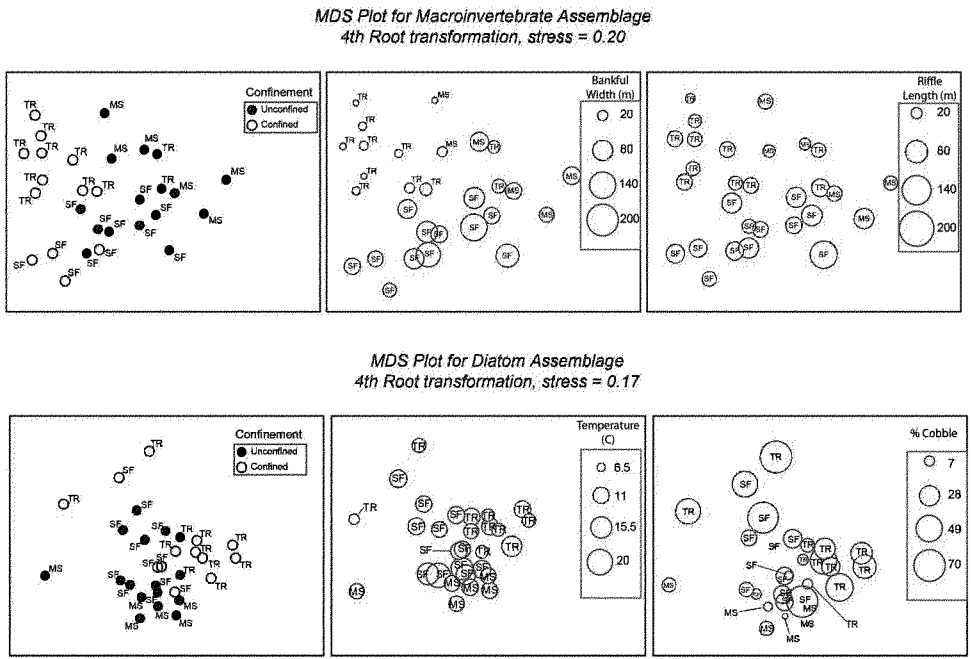

Figure 32. Non-metric multidimensional scaling plots of macroinvertebrate and diatom community composition data (both 4th-root transformed) collected from maiustem, tributary, and South Fork Skokomish study sites. The upper row of panels represent 3 views of the same ordination of macroinverebrate data, whereas the lower row shows the diatom ordination. Far left panels have points labeled according to whether a site was confined (open circle) or unconfined (shaded circle). Center panels are labeled with bubble plots that are proportional to the site scores for bankfull width (macroinvertebates) or embeddedness (diatoms). Far right panels are labeled with bubble plots that are proportional to the site score for riffle length (macroinvertebates) or % cobble (diatoms).

Table 21. Results of two-way crossed ANOSIM (Analysis of Similarities) with river type (mainstem (MS), South Fork Skokomish (SF), tributary (TR)) and confinement (confined, unconfined) as factors. The significance of global R values and pair-wise comparison R values were computed with 999 permutations and exact statistics are given in parentheses. Pair-wise comparisons were computed only when the global test was significant.

			Pair-wise Comparisons		
Dataset	**Factor**	**Global R**	MS-SF	MS-TR	TR-SF
Macroinvertebrate	Type	**0.46** (0.001)	**0.32**(0.02)	0.21(0.18)	**0.51**(0.001)
	Confinement	**0.65** (0.001)			
Diatoms	Type	**0.3** (0.005)	**0.46** (0.003)	0.25(0.25)	**0.24** (0.04)
	Confinement	0.1 (0.27)			

Next, as explained in the methods section in detail, we used the Bio-Env routine in Primer to match triangular similarity matrices of biological (macroinvertebrate or diatom) and environmental data. The idea is to search multiple subsets of environmental data for those that maximize the correlation between biological and environmental ordinations. We performed a step-wise searching routine using Primer's BVSTEP and found a moderate level of rank correlation between the biological and environmental resemblance matrices. For the macroinvertebrate assemblage data, the top 10 combinations of environmental data produced rank correlation coefficients ranging between 0.369 and 0.343 (Table 22). The variables appearing in the most sub-sets included bank full width (6 of 10 models), wetted width (10 of 10), and water depth (6 of 10).

The Bio-Env results for diatoms also showed a moderate level of rank-correlation among the 10 top subsets of data (Table 23). The top models had a rank correlation of 0.450 and were composed of either 5 (bank full width, water temperature, conductivity, % boulder, and % cobble) or 4 (water temperature, conductivity, % boulder, and % cobble) variables. Water temperature (7 of 10), % cobbles (10 of 10) and conductivity (10 of 10) appeared in the top 10 subsets of environmental data. Interestingly, a different suite of variables were significant for the two different Bio-Env procedures run for diatoms and macroinvertebrates. This suggests that different environmental factors may be responsible for the distribution, abundance, and assemblage structure in these two communities. However, much more study would be required, as we examined only a small number of possible explanatory variables.

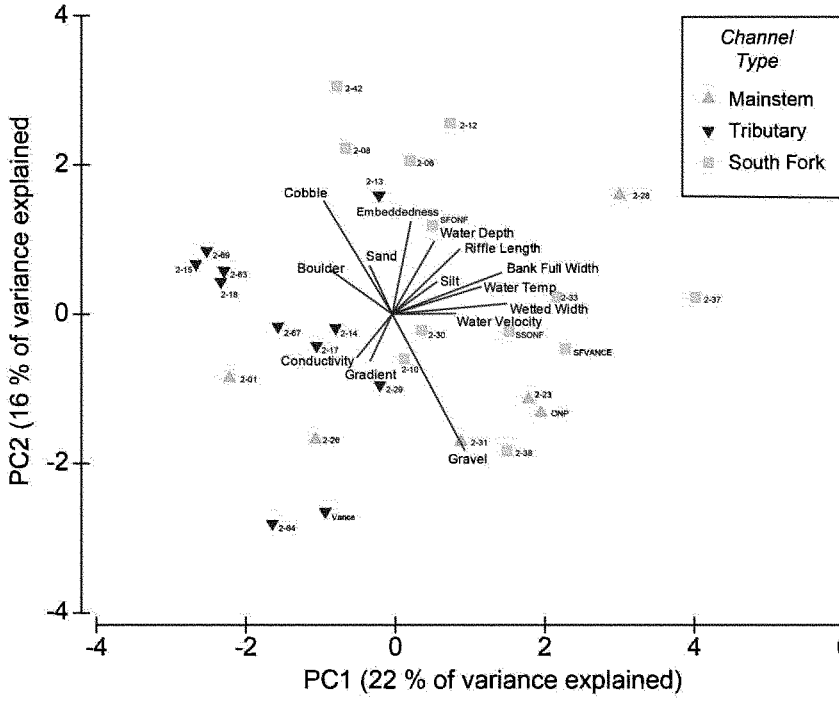

Figure 33. Results from correlation-based principal components analysis (PCA) of 14 environmental variables collected at macroinvertebrate and diatom collection sites. The PCA explained 38% of the variance within the first two principal components. Sites are denoted by channel type (mainstem, tributary, and South Fork Skokomish) and labeled with study codes. Eigen vectors reflect variable loadings (direction and magnitude) on each axis.

Finally, we plotted the a few of the variables that showed up in the majority of subset models from the Bio-Env routine as bubble plots in the original MDS ordinations. This univariate approach is another way to visualize gradients that may play a meaningful role in separating groups of sites from one another in the species assemblage space visualized in the MDS plots. The size of the bubbles is proportional to the variable score at each site. When superimposing bank full width as bubbles on the MDS plot, the smaller size of tributary sites compared with South Fork Skokomish sites becomes apparent (Figure 32). The mainstem sites have, on average, smaller bank full widths than the South Fork Skokomish sites. A gradient among South Fork Skokomish bank full widths also exists and it appears that the within this group the macroinvertebrate assemblages of wider South Fork Skokomish sites are more similar

to each other than to other South Fork Skokomish sites with smaller bank full widths. Riffle length also was smaller in riffles than mainstem or South Fork Skokomish sites, although the gradients are not as large as those seen for bank full widths. The bubble plots for diatoms exposed a large gradient in % cobble, but not as large of a difference in embeddedness (Figure 32). For % cobble, the distribution of bubble sizes was not related to channel type, as sites from mainstem, South Fork Skokomish, and tributary sites had some sites with large and small % cobble values. Nevertheless, there was a tendency for sites with larger % cobble to group together in the diatom MDS plot, suggesting that the diatom communities were being influenced by substrate size, in addition to channel type.

A final observation about the macroinvertebrate communities observed in the Skokomish River watershed was the lack of snails, pea clams, and crustaceans in the samples. These taxa are fairly common in mid- to low-elevation streams in western Washington (Bob Wissman, Aquatic Biology Associates, personal communication). The skeletons of mollusks and crustaceans are composed of calcium carbonate and thus sufficient levels of calcium must be in the environment for these animals to occur or survive (Greenway 1985). Lack of these invertebrates may be indicative of low calcium levels, which may be a natural occurrence due to the underlying geology. Additional studies are required to explain this preliminary finding of limited mollusk and crustacean populations throughout the Skokomish Basin.

Table 22. Best subsets of environmental variables whose triangular similarity matrix had the highest Spearman's correlation coefficient with the macroinvertebrate similarity matrix using the BVSTEP routine of Primer. Subsets of possible variables were Bankfull width (BFW), gradient, Riffle Length, Wetted width, Water Depth, Water Velocity, Water Temperature, Conductivity, % boulder, %cobble, %gravel, %saud, %silt, and embeddedness.

No. Variables	Correlation Coefficient	Selected Variables
5	0.369	BFW, Wetted Width, Depth, %Cobble, % Sand
5	0.358	BFW, Wetted Width, Depth, % Gravel, % Sand
4	0.356	BFW, Wetted Width, %Cobble, % Sand
4	0.351	BFW, Wetted Width, Depth, % Gravel, % Sand
5	0.349	Length, Wetted Width, Depth, %Cobble, % Sand
5	0.349	BFW, Wetted Width, % Gravel, % Sand, %Silt
5	0.348	Wetted Width, Depth, %Cobble, % Sand, embeddedness
5	0.347	BFW, Wetted Width, %Cobble, % gravel, % Sand
1	0.346	Wetted Width
5	0.343	Wetted Width, Depth, %Cobble, % Sand

Table 23. Best subsets of environmental variables whose triangular similarity matrix had the highest Spearman's correlation coefficient with the diatom similarity matrix using the BVSTEP routine of Primer. Subsets of possible variables were Bankfull width (BFW), gradient, Riffle Length, Wetted width, Water Depth, Water Velocity, Water Temperature, Conductivity, % boulder, %cobble, %gravel, %sand, %silt, and embeddedness.

No. Variables	Correlation Coefficient	Selected Variables
5	0.450	BFW, Temperature, Conductivity, %boulder, %Cobble
4	0.450	Temperature, Conductivity, %boulder, %Cobble
4	0.441	BFW, Temperature, Conductivity, %Cobble
3	0.438	Conductivity, %boulder, %Cobble
5	0.432	Temperature, Conductivity, %boulder, %Cobble, % gravel
2	0.432	Conductivity, %Cobble
3	0.431	BFW, Conductivity, %Cobble
5	0.427	BFW, Temperature, Conductivity, %Cobble, % gravel
4	0.424	BFW, Temperature, Conductivity, %Cobble
5	0.418	BFW, Temperature, Conductivity, %Cobble, % gravel

Habitat Conditions at Primary and Secondary Sampling Locations

There was a great deal of similarity between mainstem and tributary sites in both macroinvertebrate and periphyton biocriteria scores, yet these two river types usually differ in habitat features important to biological communities. Thus, we collected a suite of habitat measurements relevant to macroinvertebrate and periphyton communities at two spatial scales and then tested for differences between mainstem and tributary sites. The first scale characterized microhabitat within the 1.25 m^2 slack sample location where macroinvertebrates and periphyton were collected. At this scale, differences in habitat features such as particle size (e.g., boulder vs. sand), water velocity (slow vs. fast) and depth can drive differences in community structure in two otherwise similar river reaches. The second spatial scale measured the riffle from where slack samples were collected. Again, differences in important features such as particle size, water depth, vegetative cover (shading), and velocity at this scale can drive differences in biological communities living in riffles.

Aside from the size of the riffles and the wetted width of the channel (which are generally larger in mainstem rivers compared to tributaries), mainstem and tributary sites were similar in many of the measured habitat characteristics (Table 24). The average length of sampled riffles was longer in mainstem sites (50 m, range 22 m – 121 m) than in tributary sites (34 m, range 14 m – 50 m) (Kruskall-Wallis test = 4.6, $P = 0.03$). Mainstem sites also had higher wetted widths (24 m, range 6 m – 49 m) than tributary sites (6 m, range 2 m – 11 m) (Kruskall-Wallis test = 17.1, $P < 0.001$). Gradient for both mainstem and tributary sites was similar (0.56 % vs. 0.55%, $t = -0.093$, $P = 0.93$), as was average embeddedness (2.1 for both, $t = 0.26$, $P = 0.80$), depth of slack sample (which was constrained by the study design to be less than 30 cm), and water velocity (0.37 vs. 0.32 m s^{-1} $t = 0.80$, $P = 0.43$).

We also estimated the particle size of substrate at the microhabitat and riffle scale (Table 25). Both methods revealed that most of the riffles sampled were dominated by gravel. We averaged the 5 visual substrate scores (percentage of the river bed composed of fines, sand, pebble, gravel, cobble, boulder) collected at each riffle and found that gravel was the dominant substrate at 73% of the sites, with cobbles being the highest percentage at the remaining sites.

Average embeddedness scores, which rated the proportion and extent of substrate covered in sand or silt on a scale of 1 to 5 (1 = < 5%, 2 = 6-25%, 3 = 25-50%, 4 = 51-75% and 5 = >76%), was generally less than 3 for most sites, suggesting that less than 50% of the substrate within the slack frame was embedded by fines and sand. At the riffle level, the median D_{50} particle size across all sites was 49 mm (6.5 mm – 109.5 mm), with mainstem sites having significantly larger D_{50} than tributary sites (60 mm vs. 31 mm, respectively, Kruskall-Wallis test = 5.8, P = 0.02). The unit less ratio of D85:D15, measure of substrate variability was also significantly different between mainstem (13.2) and tributary (24.1) counts (Kruskall-Wallis test = 5.8, P = 0.02).

Table 24. Location and habitat characteristics of 29 mainstem and tributary sites where macroinvertebrate and periphyton samples were collected from 25 August – 14 October, 2009 in the Skokomish Basin, Washington (see **Figure 30** for locations within the Skokomish Basin). (UTM = Universal Transverse Mercator coordinate system)

Site	Site Code	UTM Northing	UTM Easting	Wetted Width (m)	Gradient (%)	Riffle Length (m)	Depth (m)	Velocity (ms^{-1})	Conductivity (µS)
MS Skok	2-23	4-89-395	52-40-052	37	0.23	32	0.24	0.38	67.9
MS Skok	2-31	4-85-256	52-40-217	34	0.18	38	0.18	0.48	80.2
MS Skok	2-28	4-87-855	52-39-506	34	0.80	66	0.24	0.38	26.9
MS-ONP Index	ONP Index	4-75-209	52-62-294	29	0.56	52	0.21	0.24	92.0
NF Skok	2-01	4-82-593	52-45-677	14	0.41	24	0.23	0.12	159.6
NF Skok	2-26	4-82-340	52-44-533	6	0.58	36	0.19	0.25	68.5
SF Skok	2-06	4-75-876	52-50-263	15	1.0	55	0.21	0.54	67.6
SF Skok	2-12	4-66-135	52-56-684	18	0.78	65	0.15	0.22	27.9
SF Skok	2-30	4-68-814	52-54-613	11	0.50	31	0.17	0.37	64.9
SF Skok below Canyon	2-33	4-79-242	52-42-482	33	0.42	121	0.10	0.07	61.3
SF Skok	2-37	4-80-000	52-41-501	49	0.87	43	0.16	0.64	68.1
SF Skok	2-38	4-69-147	52-54-773	18	0.75	40	0.15	0.65	58.3
SF Skok	2-42	4-66-530	52-55-897	12	0.24	64	0.22	0.45	65.5
SF @ Vance	SF Vance	4-80-965	52-40-471	20	0.27	69	0.21	0.38	66.7
SF Skok Old NF/SF CF	SFONF	4-81-689	52-40-272	11	0.18	64	0.18	0.37	58.7
MS Skok below new CF	SFNNF	4-83-02	52-40-650	44	0.72	22	0.14	0.57	49.6
SF Skok	2-08	4-78-067	52-47-320	26	0.59	34	0.18	0.34	72.4
SF Skok	2-10	4-75-399	52-51-194	22	0.88	51	0.10	0.20	66.2
Browns Cr.	2-14	4-77-025	52-52-393	6	0.98	39	0.19	0.43	66.2
Browns Cr.	2-17	4-76-360	52-51-418	9	0.48	30	0.12	0.30	68.8
Church Cr.	2-15	4-66-043	52-56-442	3	0.67	30	0.12	0.21	42.0
McTaggert Cr.	2-18	4-82-429	52-49-220	4	0.48	40	0.15	0.17	60.5
McTaggert Cr.	2-64	4-81-961	52-50-200	2	0.18	14	0.06	0.26	67.9
McTaggert Cr.	2-67	4-82-830	52-48-083	6	0.62	27	0.16	0.40	64.5
McTaggert Cr.	2-69	4-82-798	52-48-610	5	0.53	33	0.14	0.39	65.6
Vance Cr.	2-13	4-76-028	52-41-941	11	0.96	39	0.21	0.53	74.4
Vance Cr.	2-29	4-79-116	52-40-702	8	0.61	50	0.12	0.31	56.7
Vance Cr CF	Vance	4-80-570	52-40-186	7	0.53	32	0.08	0.33	85.3
Pine Cr.	2-63	4-68-257	52-54-648	9	0.15	40	0.12	0.24	46.6

Table 25. Summary statistics from Wolman (1954) pebble count data of study riffles and average values of dominant substrate size and embeddedness from five 1.25 m^2 samples of the stream bed where macroinvertebrates were sampled. D_{50} is the median particle size and D_{85}:D_{15} is a unit less ratio that provides an estimate of particle size variability based on 100 randomly selected substrate particles (see **Figure 30** for locations within the Skokomish Basin).

Site	Site Code	D_{50} (mm)	D_{85}:D_{15}	Slack Dominant-%	Embedded
MS Skok	2-23	6.5	32.3	GR-95	2.2
MS Skok	2-31	77.5	1.6	GR-81	1.6
MS Skok	2-28	24.5	51.7	GR-67	3.0
MS-ONP Index	ONP Index	109.5	4.5	GR-56	2.8
NF Skok	2-01	109.5	17.4	GR-55	1.6
NF Skok	2-26	48.5	3.2	GR-75	1.0
SF Skok	2-06	48.5	23.8	GR-41	2.4
SF Skok	2-12	77.5	3.2	CO-46	2.6
SF Skok	2-30	77.5	6.3	GR-68	2.2
SF Skok below Canyon	2-33	48.5	8.8	GR-69	1.6
SF Skok	2-37	77.5	2.2	GR-78	2.2
SF Skok	2-38	77.5	4.5	GR-100	2.0
SF Skok	2-42	77.5	8.9	CO-66	2.6
SF @ Vance	SF Vance	24.5	25.8	GR-86	2.0
SF Skok Old NF/SF CF	SFONF	48.5	6.2	GR-75	2.0
MS Skok below new CF	SFNNF	24.5	11.9	GR-86	1.8
SF Skok	2-08	77.5	17.4	CO-68	2.8
SF Skok	2-10	48.5	8.8	GR-72	2.0
Browns Cr.	2-14	77.5	33.5	GR-67	2.2
Browns Cr.	2-17	12.5	25.8	GR-71	3.3
Church Cr.	2-15	77.5	3.2	CO-44	2.2
McTaggert Cr.	2-18	77.5	33.5	GR-47	2.4
McTaggert Cr.	2-64	24.5	16.2	GR-86	2.0
McTaggert Cr.	2-67	11	59.1	CO-50	1.2
McTaggert Cr.	2-69	12	30.7	GR-35	2.0
Vance Cr.	2-13	11	12.4	CO-53	2.2
Vance Cr.	2-29	11	8.8	GR-73	1.6
Vance Cr CF		11	8.8	GR-90	1.8
Pine Cr.	2-63	12	33.5	CO-70	2.0

Conclusion: Primary and Secondary Producers

Our assessment of both macroinvertebrate and periphyton communities, based on indices proven to respond in a predictable way to aquatic ecosystem impairment, showed that most sites sampled in the Skokomish Basin were of moderate to high biological integrity. We did document differences among mainstem and tributary sites for some metrics, but as of yet unanalyzed differences in the size of the streams, their hydrological regime, and the surrounding land-use undoubtedly interact to explain some of these patterns. Our assessment of the Skokomish River watershed did not find any sites that indicated severe impairment to biological condition. Additional analyses coupling environmental factors with biological assemblage structure for both periphyton and macroinvertebrates are warranted and should be pursued.

We also note that our sampling occurred during a single season with a single sampling event occurring at each site. Although this level of effort is typical of watershed and regional scale studies, additional effort could find more detailed explanations for the patterns that we briefly described above and would be useful and necessary to make comparisons following any restoration actions that follow in the watershed. Morley et al. (2008), for example, studied macroinvertebrate and periphyton assemblage structure in the Elwha River for three years prior to dam removal. Although the patterns they describe for the current pre-dam removal conditions in the river above, between, and below the dams were generally consistent among years, there was some inter-annual variability which is expected for such dynamic ecological systems and should be accounted for when trying to determine the effects of restoration actions.

Fish Assemblage

Twenty-three species of fish have been identified in the Skokomish and South Fork Skokomish rivers (Watershed Management Team 1995); however, verification that Dolly Varden (*S. malma*) is present in the system has not been accomplished (Jeff Chan, FWS, personal communication). Most of the identified fish are salmonids, including: Chinook salmon, coho salmon, chum salmon, rainbow trout/steelhead, cutthroat trout (*O. clarki*), bull trout, and mountain whitefish (*Prosopium williamsoni*), all of which are common in the Skokomish Basin. Sockeye salmon (*O. nerka*) and pink salmon (*O. gorburscha*) were historically found in the Skokomish River. Five species of sculpin (*Cottus sp.*) are found in the Skokomish River, including prickly sculpin (*C. asper*), coast range sculpin (*C. alecticus*), riffle sculpin (*C gulosus*), Reticulate sculpin (*C. perplexus*), and shorthead sculpin (*C. confusus*). River lamprey (*Lampetra ayrsi*), western Brook lamprey (*L. richardsoni*),), and Pacific lamprey (*L. tridentate*) have also been observed in the Skokomish Basin.

Two WDFW hatcheries, George Adams and McKernan, currently release hatchery Chinook, coho, and chum salmon, and steelhead into the Skokomish Basin as on-station smolt releases, released at the hatchery. However, these facilities have historically out-planted fry into other locations in the Skokomish Basin in addition to the on-station releases. These two facilities release approximately 3.8 million Chinook; 300,000 coho; 8.5 million chum; and 34,000 steelhead. A third hatchery, Eels Springs raises cutthroat trout, rainbow trout, and kokanee for put-and-take fisheries in local lakes.

Juvenile Salmon Habitat Requirements and Status

General Requirements for all Juvenile Salmonid Species

All juvenile salmon spend at least a portion of their life in fresh water and have certain physical and biological requirements during these life history stages. While the length of time an individual spends in fresh water varies significantly among species, all Pacific salmon, at a minimum, must incubate in the gravel as eggs and alevins, emerge as fry, and then migrate to sea after some length of time residing in the stream or other freshwater habitats (i.e., ponds). Some species such as chum migrate to sea quickly and rely little on the resources and characteristics of the fresh water environment into which they hatch. Others, such as steelhead, spend months or even years in fresh water and therefore require different and/or additional physical characteristics. It is important to note that species which rely heavily on freshwater habitats to rear and grow generally do not spend much time in the estuary on their way to sea (e.g. coho and steelhead), while species that quickly migrate to sea (e.g. fall Chinook and chum) use the estuary for up to several weeks in preparation for their entry into salt water. Therefore, while an individual species may not require all habitats that they encounter as juveniles to be intact, as an aggregate, salmon stocks in the Skokomish Basin require a continuum of intact habitats from incubation through their eventual migration to salt water.

Incubation

All juvenile salmon begin their lives as eggs deposited in the gravel by an adult salmon. At a basic level, the more water there is in a stream, the more spawning habitat is available, up to a point when high velocity flows begin to reduce available habitat and stream characteristics can be used to estimate this relationship (Stalnker and Arnette 1976; Bovee 1978, 1982, 1986, Bovee and Milhous 1978). Once deposited into the substrate, DO, temperature, and channel stability are the three main factors that determine embryo survival and eventual emergence. In general, embryos may survive if DO levels are less then saturation, but their development may deviate from normal (Doudoroff and Warren 1965). Phillips and Campbell (1962) conclude that an average DO of 8.0 mg/L is sufficient for proper survival. In a review, Bjornn and Reiser (1991) advise that levels should remain near saturation with no more than temporary drops below 5.0 mg/L. Temperature directly affects the saturation level of DO, but is also the main determinant of the hatch time of embryos. There is some measure of species specificity which is discussed below, but generally salmon eggs need between 87 and 120 days to hatch at 5°C and 139 to 173 days to emerge at the same temperature. Although salmon eggs have the ability to hatch in a wide range of temperatures, the optimal temperature is between 5 and 11 °C (Murray and McPhail 1988). Salmon eggs and alevins require a stable environment for incubation and early rearing. Several studies have shown a negative relationship between egg-to-fry or smolt production with increased peak flow during incubation (e.g., Thorne and Ames 1987; Scrivener and Brownlee 1989; Seiler 1999). This mortality may be related to physical scour of redds (Schuett-Hames et al. 2000), scour-related fine sediment intrusion into the redd (Devries 2000), or through burial as a result of gravel deposition and channel migration.

The physical characteristics of the substrate which allow it to transmit water and the actual volume of water transferred per unit of time, are two commonly used variables to assess the suitability of a redd for incubation (Wickett 1954; Vaux 1968). These two factors combine to determine the DO concentrations delivered to incubating eggs. Sheridan (1962) showed that

surface water was responsible for delivering DO, as opposed to groundwater, and that DO levels decreased with redd depth. Embryo survival for several species of salmon have been directly linked to the apparent velocity of water through the redd (Cooper 1965; Coble 1961).

The main effect on embryo survival and their eventual ability to emerge up through the gravel is the size and amount of fine sediment in the gravel. The size of "fine sediment" particles varies from 0.84 mm up to 6.4 mm, with most studies agreeing on a category of less than 1 mm in diameter (McCuddin 1977; Stowell et al. 1983). Several studies have documented a negative trend between the percentage of fine sediment and embryo survival and emergence. Chapman (1988) reported that survival is not inhibited if less than 10% of the substrate is fine sediment, although at 15-20% fine sediment, dramatic reductions in survival have been documented (Holtby 1988). While the exact size and percentage of fine sediment that inhibits embryo survival varies by study, the conclusions remain the same, fine sediment in the redd is the single biggest threat to embryo survival and emergence as it directly affects the temperature and DO regime that the eggs experience.

Salmonid embryos are capable of surviving dewatering events for up to 5 weeks if temperatures remain in a suitable range, fine sediment does not impede air flow, and humidity stays at 100% (Reiser and White 1983). Possibly in an effort to combat the possibility of dewatering, chum and sockeye salmon have been observed spawning in areas of groundwater upwelling (Lister et al. 1980).

Salmon also require a stable incubation environment from the time of spawning through emergence. Excessive bed scour or channel migration can significantly impact incubation survival. Several studies have shown a negative relationship between egg-to-fry or smolt production with increased peak flow during incubation (e.g., Thorne and Ames 1987; Scrivener and Brownlee 1989; Seiler 1999). These authors inferred that direct scour of eggs or embryos was the mechanism resulting in mortality. However, no direct measurements of mortality were recorded. Recent studies have examined scour in and/or adjacent to salmonid redds and have identified potential factors resulting in increased scour. Salmonids have adapted to local scour conditions and bury eggs just below average scour depths (Montgomery et al. 1996). Therefore, very little change in scour depth would be required to result in significant mortality. Tripp and Poulin (1986) observed scour depths sufficient to destroy salmonid redds and this scouring was related to the frequency of landslides. Schuett-Hames et al. (2000) concluded that scour can be a significant source of mortality and is positively related to channel complexity.

Although scour related mortality has been inferred from several field studies, the actual mechanism of mortality remains unclear. DeVries (2000) determined that scour sufficient to result in direct displacement or crushing of embryos in low gradient streams with sediment transport equilibrium was unlikely regardless of flood magnitude and duration. He suggested that scour-related mortality was more likely in streams or stream reaches experiencing sediment transport imbalances. This would occur in streams or stream reaches experiencing increased sediment inputs as a result of landslides or increased bank erosion (e.g., the landslides observed by Tripp and Poulin 1986). He also suggested that scour-related fine sediment intrusion may be a more important mortality mechanism than direct redd scour. Thus, it seems that sediment transport regimes of rivers may be as important, or perhaps more important than increased peak flows with respect to scour- or peak flow-related mortality of salmonid embryos.

Rearing

After successfully hatching and emerging from the gravel, juvenile salmon enter the stream environment, where several factors affect their growth and survival: the physical environment, availability of food and competition for it, and predation. Similar to their requirements for incubation, temperature and the associated level of dissolved oxygen provide the physical basis for juvenile salmon development. In addition, suitable physical habitat characteristics such as water depth, current velocity, presence of wood, etc. are necessary for optimal growth to be attained. The amount of food available for consumption is determined by a combination of factors including general stream productivity and competition with other animals. Finally, some measure of protection from predators is required to ensure survival to seaward migration.

Physical Characteristics

For most free swimming juvenile salmonids, the upper limit of life threatening temperatures occurs between 23 and 25°C (reviewed by Bjornn and Reiser, 1991), with the lower limit being near freezing (Brett and Alderice 1958). Growth efficiency is determined by a combination of ration size and temperature, with higher temperatures being optimal if there is enough food available, with the peak lying at about 8-11°C for a fish fed at satiation (Brett et al. 1969). Most salmon rear in streams with DO levels near saturation, but DO levels could become a factor if temperatures are high, flows are low, and there a large amounts organic material (Hall and Lantz 1969). Minimal requirements for survival appear to lie near 5 mg/L, but food conversion efficiency is inhibited at levels below 8 mg/L (Davis 1975; Alabaster et al. 1979). Turbidity may also effect the growth and survival of juvenile salmon. The degree of disruption in growth seems to depend on fish size, with smaller fish experiencing more difficulty (Sigler et al. 1984). Bisson and Bilby (1982) reported that juvenile coho avoided areas with turbidities higher than 70 NTUs.

The habitat present in the stream is an important determinant of its ability to produce and grow juvenile salmonids. Although habitat requirements vary by species, general guidelines exist. The depth and velocity preferred by juvenile salmon varies by age and species, with larger fish generally preferring, or at least being capable of inhabiting, higher velocity flows. Lister and Genoe (1970) reported that coho and Chinook fry were found in the margins of a stream after emergence and moved to progressively faster and deeper areas as they grew. Results vary widely, but preferred depths of juvenile salmon less than 100 mm fork length range from <15 cm to approximately 60 cm and current velocities from 5 to 30 cm/s (see Bjornn and Reiser 1991 for a complete review, with a summary in the species specific section below). Juvenile salmon show a preference for additional habitat characteristics other than simply depth and current velocity, the most notable, being presence of LWD. LWD can have dramatic effects on channel hydrology, fundamentally changing other physical characteristics of a stream as well as effect primary productivity. Roni and Quinn (2001) found increased densities of coho salmon in stream reaches with artificially placed wood.

Productivity and Competition

The ability of a stream to produce and grow juvenile salmon is also determined by the streams inherent productivity and the level of competition present. Stream productivity is based on a complex combination of climate, water chemistry, and allocthonous and autochtonous

inputs (reviewed by Murphy and Meehan 1991). It is important to note that, generally speaking, Northwestern coastal streams and rivers are food limited for juvenile salmonids (Mason 1976; Slaney et al. 1986). On the other hand, Northwestern streams vary widely in the level of competition present, with some producing a few large fish and others producing many small ones. On a basic level, the number of successful adult spawners the previous fall will determine the raw number of competitors, while space and stream productivity will determine the amount of resources available to divide between them. Bjornn and Reiser (1991) provide a detailed review of factors affecting the carrying capacity of a stream for rearing juvenile salmonids.

Predation

Juvenile salmonids in streams experience predation primarily from fishes but also from birds and mammals (Quinn 2005). Larger salmonids and sculpin have been shown to be particularly vigorous predators (Patten 1975, Pearsons and Fritts 1999). Mergansers, kingfishers and herons can also be significant sources of mortality to juvenile salmon populations (Wood 1987). Cover, including LWD, riparian vegetation, undercut banks, aquatic vegetation, and large substrate can all provide refugia from predation for juvenile salmon. Several studies using various indices of cover have all concluded that increased cover results in higher densities of juvenile salmonids (Wesche 1974; Bisson et al. 1987; Holtby 1988; Peters 1996a).

Seaward migration

Juvenile salmon habitat requirements during their migration to sea are largely the same as those during their residence in fresh water residence, with the addition of one major habitat requirement, the coastal estuary. Before entering salt water, juvenile salmonids must at least pass through the estuary, while some spend several months rearing there. The estuary is a complex mosaic of habitats governed by the interaction of river outflow and tidal inflow, providing a broad range of micro habitats for the juvenile salmon. Estuaries are widely regarded as important habitat for juvenile salmon, not only for their ability to provide a transition zone for the physiological changes smolting salmon experience, but also as an additional rearing ground and migration corridor for seaward migration, they provide a refugia from predation (Simenstad et al. 1981). Different species of salmon depend on estuaries to varying degrees, which will be discussed below.

Chinook Salmon

Adult

Puget Sound Chinook: Fall/Summer Skokomish Chinook were classified as threatened as a component of Puget Sound Chinook ESA listing in 1999, and this status was reaffirmed in 2005. They were designated as their own stock in the 2002 SASSI based on geographic location, and have been rated as depressed. Allozyme analysis indicates that they are distinct from South Puget Sound Chinook stocks (Marshall 2000). However, this stock is likely a non-native stock arising from imported Green River lineage Chinook salmon in the 1960's (Skokomish Tribe and WDFW 2010). Spawning takes place between September and October with the historical peak being in mid-October, although currently spawning is generally finished by this time. It is generally accepted that Kokanee Dam is the first blockage to anadromous fish passage on the North Fork Skokomish (Skokomish Tribal Nation and WDFW 2007). Low flow events in August and September can result in all of the stream flow being sub-surface in the South Fork Skokomish in the vicinity of Vance Creek, thereby completely restricting upstream access on the South Fork Skokomish. Smolts are produced at the George Adams Hatchery at RKM 1.6 (RVM 1.0) on Purdy Creek which enters the main stem Skokomish at RKM 5.8 (RVM 3.6) (WDFW and PNPTT 2000).

Hatchery escapement data is based on the number of adults that return to this facility. Natural spawning occurs in the main stem Skokomish, the South Fork Skokomish (to RKM 8.0(RVM 5.0)) and North Fork Skokomish (to RKM 25.7 (RVM 16)), and Purdy, Hunter, and Vance Creeks. Data on natural spawners is based on counts from RKM 3.5 (RVM 2.2) to RKM 20.4 (RVM 12.7) on the main stem, Purdy Creek from RKM 0.0 (RVM 0.0) to the hatchery rack at George Adams, and RKM 0.0 (RVM 0.0) to RKM 8.9 (RVM 5.5) on the South Fork Skokomish (Figure 34). The escapement goal for this stock is approximately 3,650 fish, 1,650 natural spawners (i.e., river spawners) and 2,000 hatchery fish to George Adams Hatchery (Skokomish Indian Tribe and WDFW 2007). The overall goal has generally been met, largely due to large numbers of hatchery Chinook returning to the system. In contrast, the natural spawner escapement goal has only been met three times since 1990. Natural escapement, or the number of fish spawning in the river regardless of origin, was 531 in 2007 and 1,149 in 2008. In contrast, hatchery returns were 13,270 and 13,695 respectively. It is important to note that hatchery Chinook from George Adams stray in large numbers to the main stem and its tributaries and account for 20 to 80% (average approximately 60%) of the natural spawning fish in this system (WDFW 2007).

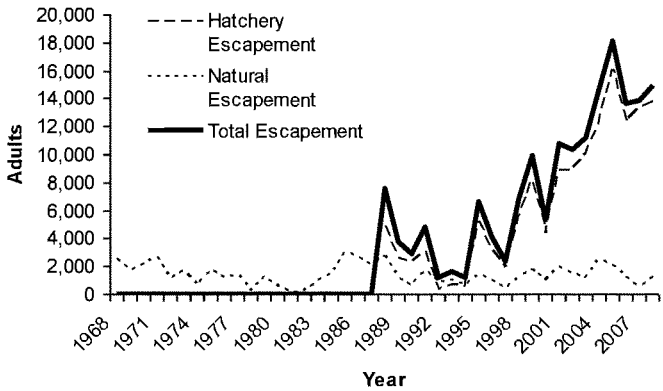

Figure 34. Hatchery escapement, natural escapement, and total escapement of adult fall Chinook in the Skokomish River from 1968 to 2007. Data for hatchery escapement is from the George Adams facility on Purdy Creek. Data on natural spawners is based on counts from RKM 3.5 (RVM 2.2) to RKM 20.4 (RVM 12.7) on the main stem, Purdy creek from RKM 0.0 (RVM 0.0) to the hatchery rack at George Adams, and RKM 0.0 (RVM 0.0) to RKM 8.9 (RVM 5.5) on the South Fork Skokomish. All data is from the WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm.

Puget Sound Chinook: Spring

The Skokomish River once supported a run of spring Chinook salmon. They were reported to have spawned in similar river locations as Fall Chinook (WDFW 1957). The stock was reported as in decline as early as 1950, but still used the lower 5 miles of the South Fork Skokomish and 13 miles of the North Fork Skokomish. However, in 1991, Nehlsen et al. (1991) reported the stock extinct. This extinction is likely due to overfishing (James 1980) and the construction of the Cushman Dams James (1980) which blocked access to a major component of their habitat and altered hydraulic patters in the system (Skokomish Tribe and WDFW 2010).

Puget Sound Chinook: Lake Cushman

Chinook salmon are also found in Lake Cushman, above Cushman Dam No. 1. The small self-sustaining population spawns upstream of the reservoir in RKM 45.4 (RVM 28.2) to RKM 48.1 (RVM 29.9) during the month of November (Skokomish Tribal Nation and WDFW 2007). Genetic analysis failed to reveal stock origin, but there is little individual differentiation, indicating that spawner numbers are low or the stock experienced a bottleneck in the past (Marshall 1995). A stock status has not been determined for Cushman Chinook, but the Northwest Fisheries Science Center considers them part of the Puget Sound Chinook salmon Evolutionary Significant Unit (ESU) (Meyers et al. 1998; NMFS 1999) which thereby confers protection under the ESA.

Juvenile

Of all the salmonid species in the Skokomish watershed, fall Chinook probably have the most extensive juvenile habitat requirements. They require both freshwater and estuarine habitats for growth and rearing. Because they rear in the lower watershed, they are affected by basically every habitat altering action that has occurred in the watershed. Summer low flows resulting from aggradation and flow reductions have the potential to limit habitat available to juveniles by blocking adult migration, dewater eggs or delivering lethal temperature and DO levels to incubating eggs. Scour from winter high flow events has the biggest impact on fall Chinook because their spawn timing occurs almost entirely before the initial high flows of fall, which can potentially scour their redds. Diking, channelization, and bank armoring result in the indirect effects of altering the habitat that is available to juvenile Chinook for rearing, namely, reducing pool depth and frequency and limiting off channel habitat. As mentioned previously, fall Chinook juveniles are the most reliant on estuarine habitat of all species in the Skokomish River, therefore the decreases in habitat that have been recorded in the Skokomish estuary, particularly the loss of eel grass, will impact them greatly. It is also important to note that limitations in any of the aforementioned habitats may not only limit overall stock production, but also impact life history diversity, i.e., the balance of age 0+ and 1+ smolts (Greene et al. 2010).

Natural spawned fall Chinook juveniles generally migrate out of the Skokomish River in the spring or early summer of their first year, so they spend at least a couple months feeding in freshwater before their seaward migration (Lestelle and Weller 1994). Spring or stream type Chinook typically spend a full year in the stream migrating out to sea in the spring of their second year (Taylor 1990). Fresh water habitat is important to the growth and survival to both types before their seaward migration. Chinook fry have been recorded in a wide range of depths and velocities, with average depths of approximately 40 cm and velocities of 15 cm/s (reviewed in Bjornn and Reiser 1991; Peters et al., unpublished data). They are generally found rearing in the lower reaches of a river system as compared to coho and steelhead. Both types make extensive use of the estuary as a rearing environment, transitional zone, and migratory corridor. Because of the diverse life history patterns exhibited by Chinook, they can be found in the estuarine environment in Hood Canal during all months of the year (Iwamoto and Salo 1977). Peak migration in Hood Canal begins in early March and peaks from late April through June, with fry from fall spawning adults generally preceding yearlings from the spring migrating adults (Seiler et al. 1981). Average estuarine residency times for individual juvenile Chinook could be as much as 189 days in larger systems but is more likely 20-40 days in a system such as the Skokomish, with smaller fish staying longer than larger ones (reviewed in Simenstad et al. 1981).

Available data on the population status of juvenile Chinook salmon in the Skokomish River is limited. We found no information on freshwater distribution and abundance of juvenile Chinook salmon in the Skokomish River. However, outmigration data was collected at several locations throughout the Skokomish Basin (WDFW 1957) and from a panel trap operated by the Skokomish Tribe in Skobob Creek between 18 April and 30 May 2003. Estuarine use and timing data for juvenile Chinook salmon was collected by the Skokomish Tribe between December 27, 2004 and July 5, 2005.

Juvenile Chinook salmon distribution was restricted to the lower Skokomish Basin generally below the first canyon on both the South Fork Skokomish (RKM 5) and Vance Creek

(RKM 6). However, they were estimated to be present all the way up to the lower dam on the North Fork Skokomish. Juvenile Chinook had a much greater distribution in the winter than in the summer, when they were present only below the confluence of the South Fork Skokomish and Vance Creek, and were absent from the North Fork Skokomish (Figure 35). However, this is likely an artifact of the timing of our summer sampling effort, which wasn't initiated until most juvenile Chinook salmon would have emigrated from the system.

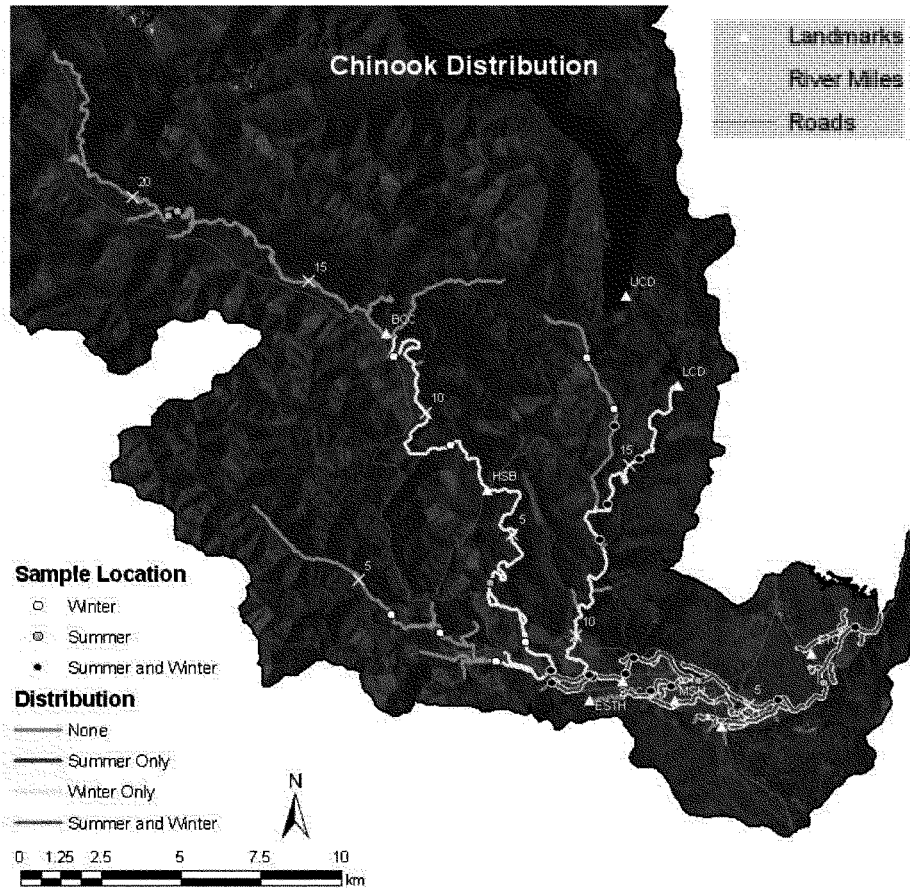

Figure 35. Expected juvenile Chinook salmon distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Our fish surveys results indicated juvenile Chinook salmon abundance varied by season and fish size class. We estimated that 3,157 and 17,963 juvenile Chinook salmon were present in the Skokomish Basin during the summer of 2008 and winter 2009, respectively. A majority of these fish were classified as greater than 50 mm fork length (large) in the summer (61%), while a

majority were classified as being less than 50 mm fork length (small) in the winter (82.5%). The variation in abundance and size between the two seasons is likely due to the timing of our surveys. Our summer surveys didn't begin until June after most juvenile Chinook salmon would have been expected to have left the system. Those that remained had likely been rearing for some time in freshwater and therefore would have been relatively large. In contrast, our winter surveys were completed from January through March, when many juvenile Chinook were emerging from the gravel.

We observed juvenile Chinook salmon in main stem, tributary and freshwater pond habitats. The importance of mainstem, tributary, and pond habitat for juvenile Chinook salmon differed by size class and season (Table 26). Small juvenile Chinook salmon were nearly equally distributed between mainstem and tributary habitat during the summer, while no small juvenile Chinook were observed in ponds. However, during the winter, over half of the small juvenile Chinook salmon were estimated to be rearing in mainstem habitats, with the remaining fish nearly equally distributed between tributaries and ponds. In contrast, a majority of large juvenile Chinook salmon were estimated to be rearing in ponds during the summer, with nearly equally small percentages rearing in mainstem and tributary habitats. During the winter, a majority of larger juvenile Chinook salmon were rearing in the mainstem, with about half as many rearing in tributaries and very few rearing in ponds.

In general, juvenile Chinook salmon are relatively uncommon in pond habitats. For example, Murphy et al. (1989) reported that juvenile Chinook salmon were relatively uncommon in beaver ponds or off-channel sloughs (similar to our backwaters). In addition, Morley et al. (2005) reported that juvenile Chinook salmon densities were low in about half the constructed groundwater-fed side channels they sampled. These sites were relatively deep and homogenous, in contrast to reference side-channels. Thus, they were likely similar to the pond habitats that we sampled in the Skokomish watershed. Thus, the large percentage of large juvenile Chinook salmon rearing in ponds during the summer is somewhat surprising. Although, juvenile Chinook salmon do rear in larger lakes when present in their watersheds (Tabor 2004, 2006).

Table 26. Proportion of the different sized juvenile Chinook salmon population estimated to be rearing in mainstem, tributary, and pond habitats during the summer (2008) and winter (2009).

fish	Season	Proportion Mainstem	Proportion Tributary	Proportion Pond
Chinook >50 mm	Summer	0.05	0.06	0.88
Chinook >50 mm	Winter	0.68	0.31	0.01
Chinook <50 mm	Summer	0.45	0.55	0.00
Chinook <50 mm	Winter	0.52	0.23	0.24

Reach densities of small juvenile Chinook were positively related to the percentage of the reach that was composed of backwater habitat during the winter; however, the relationship

explained very little of the overall variability ($r^2 = 0.18$). Reach densities of small juvenile Chinook salmon were negatively related to sediment score, although the relationship explained little of the variability ($r^2 = 0.26$). Thus, small juvenile Chinook salmon appear to prefer smaller substrate, which is consistent with observations from other systems (Hillman et al. 1989a; Hillman et al. 1989b; Garland et al. 2002; Peters, unpublished data), although large substrate preferences have also been reported (Lister et al. 1995).

Within pond habitats, the importance of nearshore and off-shore areas changed between seasons and size class for juvenile Chinook salmon. Densities of Chinook >50 mm were greater in the offshore (84 fish/ha) than the nearshore (44 fish/ha) during the summer; however, the 90% confidence intervals overlapped suggesting that this difference was not statistically different. In contrast, no Chinook salmon >50 mm were observed in the off-shore transect during the winter, while nearly 3 Chinook >50 mm were observed in the nearshore transect. Densities of small Chinook (<50 mm) were much greater in the nearshore (241 fish/ha) than the off-shore (80 fish/ha) during the winter. However, the 90% confidence intervals overlapped, suggesting the results were not statistically significant.

Although differences in densities were observed in some cases, these differences translated to differences in production for only small Chinook during the winter. The nearshore area of the ponds represented approximately 40% of the total pond surface area. Estimated abundance of large juvenile Chinook in the nearshore during the summer was approximately 26% of the total production from ponds in the summer. Although all of the large Chinook were observed in nearshore areas during the winter, the estimated production from all the ponds was only 19 fish. In contrast, small Chinook production in nearshore areas during the winter represented approximately 67% of the total production even though the nearshore represented only 40% of the total pond habitat. Thus, any restoration of existing pond habitat, or the development of new pond habitat should consider improving the ratio of nearshore to off-shore habitats.

As stated above, juvenile Chinook salmon densities were slightly negatively related to mean depth and slope in the near-shore area of the ponds (Figure 28). Thus, few juvenile Chinook salmon were observed in sampled areas as bank slope and mean depth increased, which is consistent with other reports in lentic habitats (Sergeant and Beauchamp 2006; Tabor et al. 2006).

Our estimates of distribution may be influenced by the timing of our summer sampling and the distribution of our winter sampling sites. Summer sampling was completed between May and early October. Thus, most ocean type Chinook salmon had likely left the system before our sampling occurred. In addition, the winter distribution of juvenile Chinook salmon may have been greater than reported; however, we were unable to access the upper watershed due to snow during the winter of 2009. Adult Chinook salmon transported to the upper watershed as part of an adult supplementation program implemented by the WDFW and the Skokomish Tribal Nation spawned in the upper watershed (Matt Kowalski, Skokomish Tribe, personal communication).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. WDF (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 miles above mouth), and the Skokomish mainstem (old

U.S. HWY 101 bridge). Juvenile Chinook salmon were caught in all five outmigration sampling locations. Outmigration occurred from February through September. Peak catches varied among the sampling locations. Outmigration peaked in late July in the upper South Fork Skokomish, with less prominent peaks observed in April, May, and June. The peak catches occurred in late April to mid-May in the lower South Fork Skokomish. Large catches were observed in mid-February and peaked in March in Vance Creek. A small peak occurred in catches in the North Fork Skokomish in late March, although catches were relatively low at this site. A bimodal pattern was observed at the lower mainstem site, with peaks in mid-March and mid-May. Based on relative abundance estimates, WDF (1957) determined that the lower South Fork Skokomish was the most important producer of fall Chinook, followed by Vance Creek and the North Fork Skokomish respectively.

The Skokomish tribe sampled outmigrating fish in Skobob Creek during 2003 using a panel trap. During this period, a total of 170 Chinook smolts were captured, with a relatively uniform distribution throughout the operating time of the trap. (Skokomish Indian Tribe, unpublished data). A screw trap has also been operated by NMFS on the South Fork Skokomish near the confluence with Vance Creek since 2007 to assess production and outmigration timing steelhead from April 1 to June 15.

New Chinook salmon outmigration data was collected during this project (see Appendix Outmigration for details on methods and general results). A total of 275 wild and 1,742 hatchery Chinook were captured from January 21 to July 19, 2009 (Figure 36). Chinook fry were caught primarily in January and February (77% of season fry total), but were also caught in low numbers (<10) from March through early July. Wild Chinook smolts were captured sporadically and generally in low numbers from late January through mid-July. One exception was the 51 fish captured on May 19, 2009; it is possible that a majority of these fish were unmarked hatchery fish released on either May 15 or May 18. Hatchery Chinook were caught from mid-May through mid-July. The peak catch occurred in mid-May, immediately after the hatchery releases.

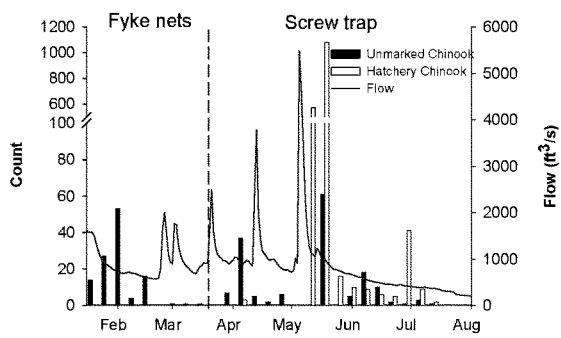

Figure 36. Weekly counts (first axis) of juvenile unmarked and hatchery Chinook captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

An estimated 239,511 Chinook migrated pass the screw trap between mid-March and late July (Table 27). About 93% (222,745) of the total Chinook estimate was hatchery parr and smolts, with unmarked (wild) Chinook comprising the remaining 7% (16,766). We feel that we likely underestimated outmigration numbers for naturally produced Chinook salmon. First, substantial numbers of Chinook salmon fry were caught in our fyke nets prior to operating the screw trap. However, we could not assess the efficiency of these traps because we never recaptured any marked individuals. Thus, our efficiency was likely very low. These early catches were not included in our outmigration estimate. In addition, our efficiency estimates for the screw trap appear to be flawed. The hatchery Chinook figure corresponded to about 6% of the 3,899,993 Chinook released by the Washington Department of Fish and Wildlife (WDFW) into the Purdy Creek between mid-May and mid-July 2009. The large difference in our estimate relative to the actual hatchery release may be due to poor survival of hatchery fish released at this location or due to underestimation at our trap. It's extremely unlikely that 94% of the hatchery Chinook release perish before reaching our trap. In addition, outmigration estimates for coho and chum salmon were also relatively low relative to the hatchery release. Thus, it is assumed that we underestimated production from the system.

Our underestimation was likely due to the release location being too close to the outmigration trap. Volkhardt et al. (2007) state that fish should be released at least two pool/riffle sequences upstream to allow fish to allow for a similar distribution pattern throughout the river to what is expected naturally. Our release site was located approximately 500 m upstream and was separated from our trap by one short riffle, a relatively large pool, and along run habitat. In addition, this site was located one complete meander bend upstream, providing at least two turns to distribute fish across the channel. This site was the last easily accessed site for approximately an additional 1,200 meters. We selected the closer site since we felt releasing the fish at the next access upstream might be too far upstream and could result in potentially significant predation losses.

Outmigration patters in the Skokomish River are similar to those from other Puget Sound systems. Chinook outmigration timing data from the Elwha River screw trap indicates that 0-age smolts begin to migrate downstream in late February and that the migration can continue all the way to the end of June in some years, but generally tapers off significantly by the beginning of June. The peak is generally the second half of March (National Oceanic and Atmospheric Administration (NOAA), unpublished data). On the Elwha, age 1+ smolts exhibit a very similar outmigration pattern to age 0+ smolts. Seiler (2003) reports a bimodal peak for juvenile Chinook salmon in the Cedar River. Large numbers of Chinook fry migrate to Lake Washington during January and March, with a second smaller peak migrating in mid-May to early-July. Kinsel et al. (2008) report that on average 50% of juvenile Chinook salmon migration occurs by the end of March in the Skagit system. In contrast, Griffith and Van Arman (2010) observed few juvenile Chinook outmigrants in February in the Stillaguamish River, where bi-modal peak outmigration occurred in April and early May to early June.

Table 27. Estimated migration of salmonid species during screw trap sampling on Skokomish River, March-July, 2009.

Species	Life Stage	Origin	Catch	Expanded Catch	Marked	Recaptured	Efficiency	Population Estimate	C. I. (95%) Lower	C. I. (95%) Upper
Chinook	Fry	Unmarked	33	39	2	0[1]	0.4%[2]	101	0	209
	Parr	Unmarked	27	28	16	0	0%	3472	-	-
		Hatchery	243	278	231	1	0.4%	34472	-	-
	Total		270	306	247	1	0.4%	37944	0	80848
	Smolt	Unmarked	98	108	70	0	0%	12936	-	-
		Hatchery	1499	1574	1007	8	0.8%	188530	-	-
	Total		1597	1682	1077	8	0.7%	201466	76786	326146
Chum	Fry		5347	5734	90	9	10.0%	52179	23062	81297
Coho	Fry	Unmarked	1630	1969	639	6	0.9%	180023	55737	304309
	Parr	Unmarked	187	261	65	0	0%	26274	-	-
		Hatchery	3	3	3	0	0%	302	-	-
	Total		190	264	68	1[3]	1.0%[4]	18872	0	23781
	Smolt	Unmarked	762	1014	396	6	1.5%	87639	-	-
		Hatchery	765	857	208	0	0%	74069	-	-
	Total		1527	1871	604	6	1.0%	161708	50092	273324

[1] Calculated from season trap efficiency rate of Chinook parr.
[2] Season trap efficiency rate of Chinook parr.
[3] Calculated from season trap efficiency rate of coho smolts.
[4] Season trap efficiency rate of coho smolts.

The size of juvenile Chinook salmon caught during our outmigration sampling was quite variable. The fork length of unmarked (wild) Chinook salmon ranged from 32 mm to 143 mm, averaging 56 mm. Weekly average fork lengths increased from around 40 mm in late January and February to above 75 mm in late May and early June (Figure 37), indicating that juvenile Chinook salmon were rearing in freshwater habitat. Weekly average fork lengths for hatchery Chinook ranged between 70 mm and 85 mm from May through early July. Comparison of length frequency distributions between unmarked and hatchery Chinook showed unmarked Chinook salmon were much smaller than their hatchery counterparts (Figure 38). The dominant size range for wild and hatchery Chinook were 31-40 mm and 81-90 mm, respectively. WDF (1957) stated that newly emerged Chinook averaged about 40 mm and the earliest yearlings averaged about 88 mm. Yearlings, which were more abundant in the lower South Fork Skokomish than the upper South Fork Skokomish averaged between 82 and 127 mm. Zero-aged Chinook ranged from about 40-42 mm at all the stations sampled. These size classes are similar to what we observed during our sampling efforts. Our data also suggests that a yearling life history strategy is still exhibited in the Skokomish River. Whether these yearlings are from naturally produced Chinook or residual or unmarked hatchery fish is unclear.

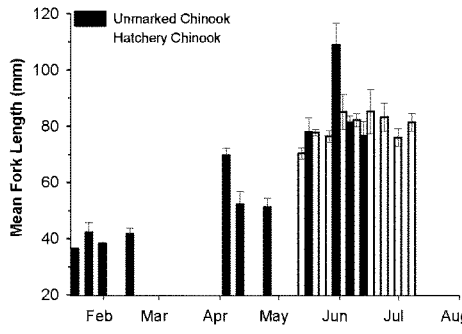

Figure 37. Weekly mean fork lengths and standard errors of juvenile unmarked and hatchery Chinook captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

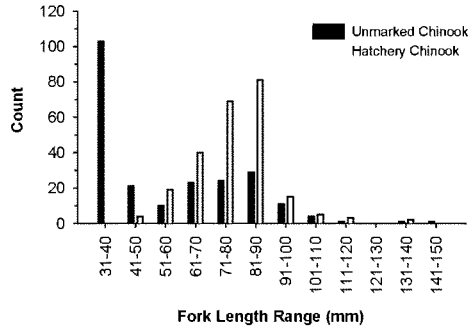

Figure 38. Length frequency of juvenile Chinook captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

Existing data for Chinook salmon estuary use and timing was collected by the Skokomish Tribal Nation between December 27, 2004 and July 5, 2005. The estuary sampling occurred in the vicinity of Nalley Island and West Slough. A total of 17 and 25 Chinook were captured at Nalley Island and West Slough, respectively. They were captured beginning from January through the end of April, with the peak occurring in late January through early February (Skokomish Indian Tribal, unpublished data). It's unclear why so few Chinook salmon were captured during their surveys or why the residence time was so short. This information contrasts sharply with the new data collected as part of the Skokomish GI.

New estuarine use data was collected from July 2008 through September 2009 during this project (See Appendix Estuary for details of methods). Sampling occurred exclusively on Nalley Island both at high and low tide (Figure 39). Juvenile Chinook were captured in the estuary from January through August, with peak abundance occurring in late May (Figure 40). A majority (75%) of the Chinook salmon observed in the estuary were of hatchery origin and the residence time of hatchery and unmarked Chinook salmon varied (Figure 41). In general, hatchery fish were observed later in the year and last observed earlier in the year than unmarked fish. Unmarked juvenile Chinook were first observed several months before their hatchery counterparts, but a single hatchery Chinook was captured four weeks after the last unmarked Chinook were captured.

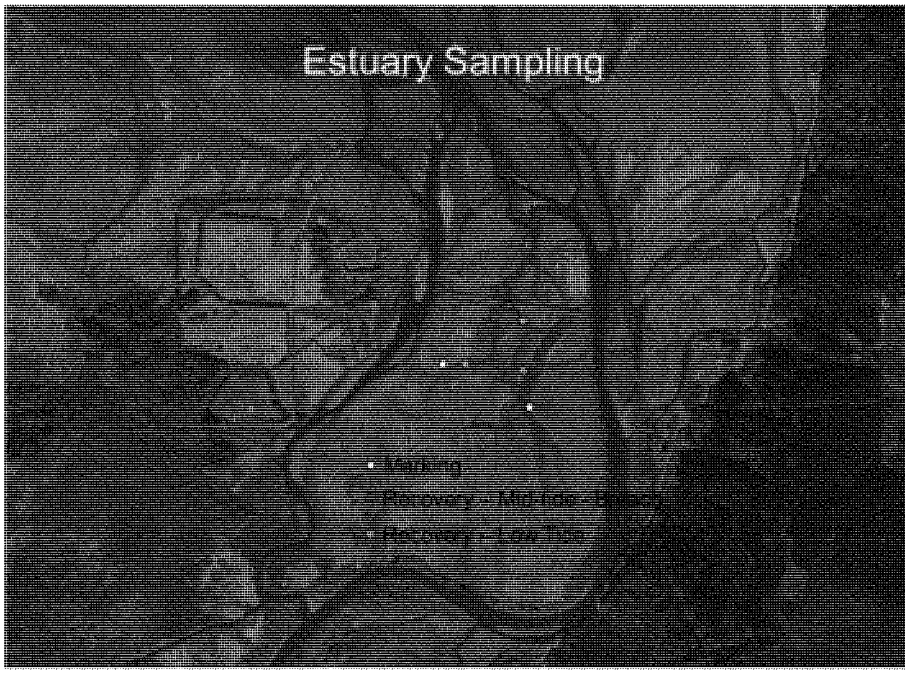

Figure 39. Primary sampling locations within the Skokomish River estuary. All the sampling was completed on Nalley Island. Fish were sampled at marking sites during high tide, marked and released back to those locations. Fish were sampled for marks at the Breach (red dot) from mid-tide to low tide and at the low tide sites during low tide.

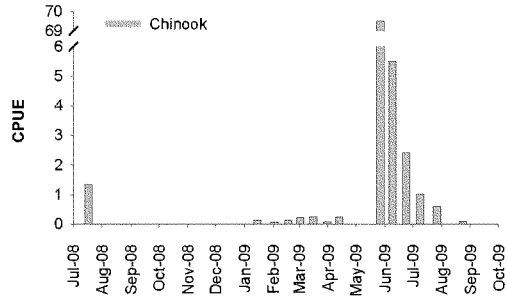

Figure 40. Catch-Per-Unit-Effort (CPUE) of Chinook salmon captured in the Nalley Island portion of the Skokomish River estuary between July 2008 and September 2009.

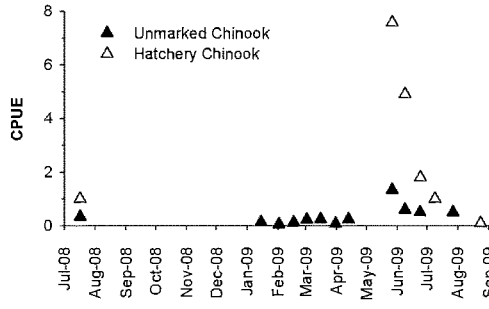

Figure 41. Comparison of residence timing of hatchery and unmarked juvenile Chinook salmon captured in the Nalley Island section of the Skokomish River estuary between July 2008 and September 2009.

Juvenile Chinook salmon in the estuary were differentially marked during each estuary survey to evaluate individual residence time and to calculate population estimates in the Nalley Island section of the estuary (see Appendix Estuary for details). Individual residence time for juvenile Chinook salmon could not be calculated since no juvenile Chinook salmon marked in the estuary was recaptured at a later date. However, juvenile Chinook marked at the screw trap between June 10 and June 18, 2009 for the outmigration study were captured in the estuary (Upper East 2 site) on June 24, 2009. Population estimates for juvenile Chinook could only be calculated on one day, May 27, 2009. The population estimate was 55,104 with 95% confidence intervals of 20,099 to 133,080. The 95% confidence intervals were quite large due to the low number of recaptures (2) in the relatively large number of marked fish released (335) and handled looking for recapture (491).

We summarized CPUE by location to examine the spatial distribution patterns within the estuary (Figure 42). CPUE for Chinook salmon was highest at the UW2 (low tide) location.

The size of juvenile Chinook salmon varied with survey (Figure 43). Juvenile Chinook salmon ranged from 71 to 90 mm in fork length. Mean fork lengths generally increased during the spring and summer months (Figure 43). Size differences among hatchery and unmarked fish varied among sample date (Figure 44), but in general mean lengths of hatchery juvenile Chinook salmon were 10 and 9 mm longer than their unmarked counterparts.

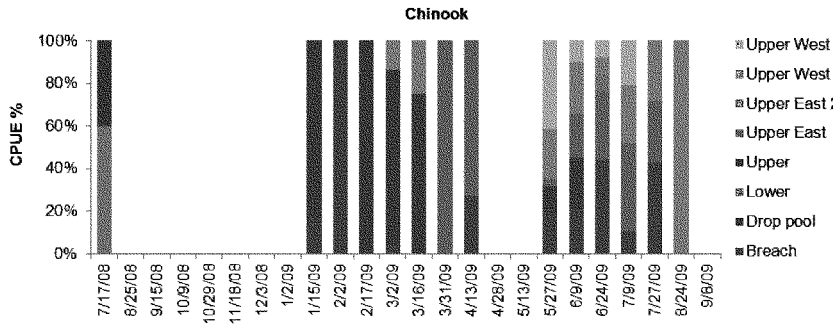

Figure 42. CPUE percentages of Chinook by sampling location, July 2008-September 2009.

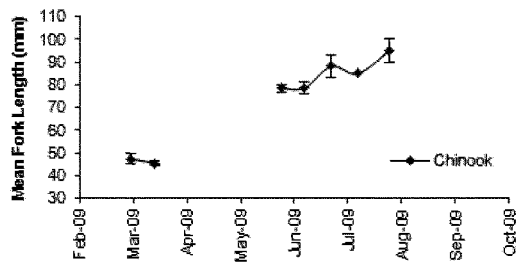

Figure 43. Mean fork lengths (+/- SE) of juvenile Chinook salmon caught in the Nalley Island section of the Skokomish River estuary between February and September 2009.

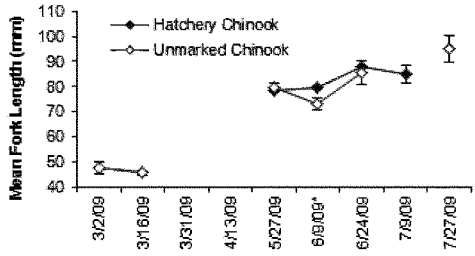

Figure 44. Mean fork length (+/- SE) of hatchery and unmarked juvenile Chinook salmon captured in Nalley Island section of the Skokomish River estuary between February and September 2009. The mean lengths are based on samples sizes of four or more. Asterisks next to the sampling dates, indicate the dates on which hatchery and unmarked fish are significantly different in length.

Limiting Factors: Chinook Salmon

The Skokomish Tribe and WDFW (2010) completed an extensive review of factors influencing Chinook salmon in the Skokomish Basin. Thus, it's unnecessary to completely restate their findings here. However, it is useful to discuss how the new data we collected may influence their conclusions. In addition, we do not entirely agree with all of the assertions made by those authors. We discuss these differences in the section below.

It is important to note that the current Skokomish Chinook salmon population likely has little resemblance to the historic population. This is due to the fact that the historic populations have either become extinct (Spring Chinook) or largely replaced by non-native stocks. The native population was driven to extinction and very low numbers as a result of hydro development, habitat degradation, and overharvest (Skokomish Tribe and WDFW 2010). Hydro development blocked access to very productive habitat for spring Chinook salmon and diverted substantial portions of the Skokomish Basin discharge out of the Skokomish Basin. This, along with land clearing activities, LWD removal, and floodplain isolation through levee and bridge construction, resulted in severe habitat loss and degradation. Overharvest, documented early in the 20th century, clearly impacted the population returning to this less productive habitat. This resulted in hatchery intervention that brought in the non-native Green River Chinook salmon stock. The large releases of these non-native hatchery fish into the system completely changed the population structure of Chinook salmon in the Skokomish River (Myers et al. 1998; Ruckelshaus et al. 2006). Thus, the habitat use and timing observed during the new data collection may not resemble that of the historic stock.

The life history patterns of juvenile Chinook salmon in the Skokomish Basin is similar to what might be expected for river-type Chinook salmon throughout Puget Sound. Their distribution was limited to the lower Skokomish Basin. This was apparently due to barriers to adult migration. WDFW (1957) noted that the cascades in the South Fork Skokomish canyon were barriers to adult fall/winter Chinook salmon. This still appears to be true, despite the

aggradation that has occurred just below the canyon and that has likely extended upstream into the canyon an unknown distance.

Abundance and production estimates in the Skokomish Basin suggest the population is severely depressed. Natural escapement, which includes both naturally, produced fish, as well as hatchery fish spawning in the river have been at relatively consistent and low numbers since the late 1960's. In addition, a majority of the spawners have been of hatchery origin (average of approximately 60% - WDFW 2007). These returns also appear to result in few juveniles. We estimated that just less than 18,000 juvenile Chinook salmon were present in the Skokomish Basin (not including the estuary) during the winter of 2009. This is relatively consistent with our outmigration estimate (i.e., 16,000 unmarked). Both estimates likely underestimate total production due to the fact that juvenile Chinook would be emigrating from the system during our snorkel surveys and thus would not have been counted. The smolt trapping estimates were likely low due to the release point being too close to the trap, which elevated our estimated trap efficiency. However, these values would still be low relative to those from other Washington State River Basins. For example, Seiler et al. (2003) estimated that 81,000 and 65,000 Chinook smolts were produced in the Cedar River in 1999 and 2000, respectively. In fact, their estimates of Chinook production from Issaquah Creek (30,000) exceeded our estimates for the Skokomish, despite the fact that Chinook migration had begun prior to their trap installation (Sieler et al. 2003).

As expected, juvenile Chinook salmon were observed throughout the system, including mainstem, tributary and off-channel pond habitats. Mainstem habitats appear to be more important during the winter, since a majority of the fish were observed in mainstem habitats relative to tributary and off-channel habitats at that time. However, pond habitats appear to become more important during the summer. Juvenile Chinook salmon were also common in the estuary and were relatively abundant compared (i.e., 55,000) to their observed abundance in freshwater habitats, despite the fact that we sampled a very small portion of the estuary. This suggests that a majority of juvenile Chinook salmon in the system may be migrating directly to the estuary without rearing in the freshwater environment for extended periods.

Based on our assessment, we feel Chinook salmon are limited in part by reduced availability, connectivity, stability, and quality of habitat, as well as impacts related to hatchery propagation in the system. However, habitat loss, channel stability, and hatchery influences are probably the most important factors impacting Chinook salmon in the Skokomish Basin. Significant spawning and rearing habitat has been lost as a result of dam construction in the North Fork Skokomish. Chinook salmon are isolated from additional spawning habitat for much of the early fall as a result of channel dewatering in the South Fork Skokomish and Vance Creek. Although habitat stability has not been sufficiently evaluated in this system, the level of aggradation suggest that scour of redds is likely a major issue. This would be exacerbated by the low flows associated with the timing of Chinook spawning in the system. These habitat factors would be exacerbated by the level of straying of non-local hatchery Chinook to the system (60% hatchery spawners – Green River lineage), since these fish would be expected to have reduced survival and reproductive capabilities relative to a natural locally adapted stock (i.e., HSRG 2004, Jonsson and Jonsson 2006; Araki et al. 2008).

Chum Salmon

Adult

Chum – Upper Skokomish Late Fall

Fall chum salmon in the upper Skokomish River are a wild, naturally reproducing stock. They were deemed an individual stock in the original 1992 SASSI based on their spatial and temporal spawning distribution and genetic analysis. They were originally listed as healthy in the 1992 SASSI and that status remains today. They spawn in most tributaries of the Skokomish system from December through January, with the heaviest concentration being the lower 7.6 km (4.7 mi) of the North Fork Skokomish. Natural spawner counts (Figure 45) are based on index reaches in the lower North Fork Skokomish, Reichert Springs, Swift Creek, and Vance Creek. They do not appear to be able to pass through the canyon on the South Fork Skokomish (ME2 Environmental Services, 1997). Allozyme analysis indicates that this stock contributes to the genetic heterogeneity of Hood Canal Chum but not all pairwise comparisons show significant differentiation (Phelps 1995).

Chum - Lower Skokomish Fall Chum

Lower Skokomish River Fall chum were identified as an individual stock in the 1992 SASSI based on their temporal and geographic differentiation with upper Late Fall chum. Spawning is concentrated between November and December and occurs in Purdy and Weaver Creeks along with the lower main stem Skokomish River. No quantitative data on adult escapement exists for the stock but many (probably strays) spawn in the river proper and its tributaries. Based on these qualitative observations, the stock has been listed as healthy. No genetic analysis has been done on this stock.

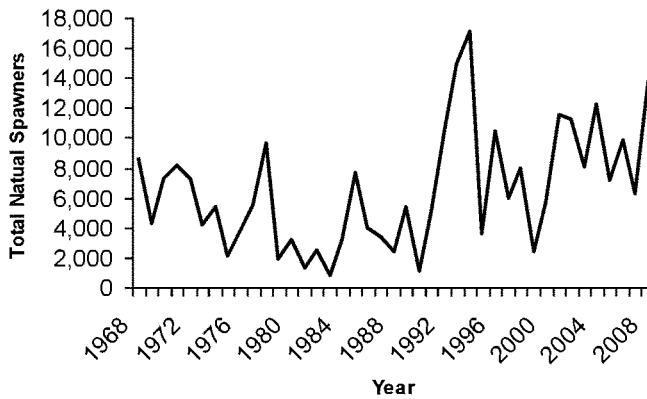

Figure 45. Total natural spawners of late fall upper chum in the Skokomish River from 1968 to 2008. Data are based on index reaches in the lower North Fork Skokomish, Reichert Springs, Swift Creek, and Vance Creek. All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm

Chum - Summer Chum

Skokomish River summer chum were identified as an individual stock in the Summer Chum Conservation Initiative (WDFW and PNPTT 2000) based on their early spawn timing, but have been labeled extinct in the Skokomish River as of the 2002 SASSI. A few summer chum are recorded in the main stem every year but not enough to characterize them as a self-sustaining population. Historically, they spawned from mid-September to mid-October in the lower portions of the watershed (WDFW and PNPTT 2000).

Juvenile

Fall chum in Hood Canal emerge from mid-April through May (Koski 1975). All juvenile chum salmon migrate directly to sea after emergence, and therefore rely little on freshwater habitat. However, some freshwater rearing has been inferred in other systems based on increasing size of individuals in freshwater (Peters 1996b). Regardless of how long they spend in freshwater, they do require the basic physical requirements of suitable temperature, flow, cover, etc. presented above for incubation and seaward migration. Migratory conditions are likely very important to juvenile chum salmon since they migrate at a small size, which increases their vulnerability to predation. In addition, factors such as discharge, turbidity, and light levels are important to fish during seaward migration (Tabor et al. 2004). Next to Chinook salmon, chum have been described as the most reliant on the estuary habitat, based on residence time (~25 days) (Simenstad et al. 1981). They use the estuary as a rearing location, refugia from predation, transition zone, and migration corridor. As with other species, eel grass beds provide important habitat for juvenile chum during their residency in the estuary (Wissmar and Simenstad 1988).

Chum salmon migrate directly to the estuary after emergence so their reliance on fresh water habitat is limited, although the effects of summer low flows and winter high flows and the associated sedimentation of redds can all affect spawning distribution and incubation success. The lack of surface water in lower Vance creek and the South Fork Skokomish during the summer months can limit the distribution of early chum salmon (i.e., summers) or dry up incubating eggs that were spawned prior to the channel going dry. In addition, because they spawn before (summer) or during the high winter flows (falls), main stem redds may be scoured or dewatered as a result of channel migration prior to emergence. Chum are the second most reliant salmonid species on the Skokomish estuary. In Puget Sound, during the first few weeks of estuarine residency, they occupy the top few centimeters of the water column and remain extremely close to shore (Ron Egan, WDFW, Olympia, WA, pers. comm., cited in WDFW and PNPTT 2000). Declines in estuary habitat, particularly the loss of near-shore areas and eelgrass beds, is the main limiting factor for juvenile chum salmon in the Skokomish watershed.

We found no published information on the freshwater distribution and abundance of juvenile chum salmon in the Skokomish River (Figure 46). During the field work conducted for this study, juvenile chum salmon were observed in main stem, tributary and freshwater pond habitats. Their distribution was restricted to the lower South Fork Skokomish, apparently by the first canyon in the South Fork Skokomish (RKM 5). In contrast to Chinook salmon, chum salmon were observed upstream of the first canyon in Vance Creek, suggesting that flows may limit adult Chinook salmon upstream migration in Vance Creek early in the fall. However, chum

salmon distribution was reduced in the North Fork Skokomish relative to Chinook salmon, extending only to RKM 9. This is likely due to the presence of small cascades in this region of the North Fork Skokomish.

Juvenile chum salmon had a greater distribution during the winter of 2009 than they did during the summer of 2008. Similar to Chinook salmon, this was likely due to the timing of our summer surveys, which were completed from late May through October. Thus, most juvenile chum salmon would have likely left the system by the time we initiated our surveys. The lack of sampling locations upstream of the canyons during the winter due to lack of access (deep snow) also may make our estimates of chum salmon distribution conservative. This possibility is supported by the observation of chum salmon above the first canyon in Vance Creek RKM 5, but is refuted by the more limited distribution of juvenile chum salmon in the North Fork Skokomish.

Juvenile chum were observed in mainstem, tributary, and pond habitats, although they were only present in pond habitats during the summer. In contrast, they were most common in mainstem habitat during the winter, with about half as many in tributaries and very few in pond habitats. We estimated a total chum fry population of 86 fish in the summer. In contrast, we estimated 25,577 fish during the winter (95% Confidence Interval: 8,810-50,599). All the juvenile chum salmon were rearing in ponds during the summer, while only 101 juvenile chum (of 25,577) were in the ponds during the winter.

Juvenile chum salmon densities in pond habitats were very low during both summer and winter. No juvenile chum salmon were observed in nearshore areas during the summer, while densities were approximately 6 fish/ha in the offshore transects. In contrast, juvenile chum salmon were observed in both the nearshore (8.9 fish/ha) and offshore (4.4 fish/ha) transects during the winter. Although these differences in density translated to large differences in the proportion of juvenile chum salmon produced from nearshore (0% summer, 58% winter) and offshore areas (100% during summer, 42% during winter), the limited production of chum salmon from the ponds does not warrant specific habitat restoration recommendations in ponds for chum salmon.

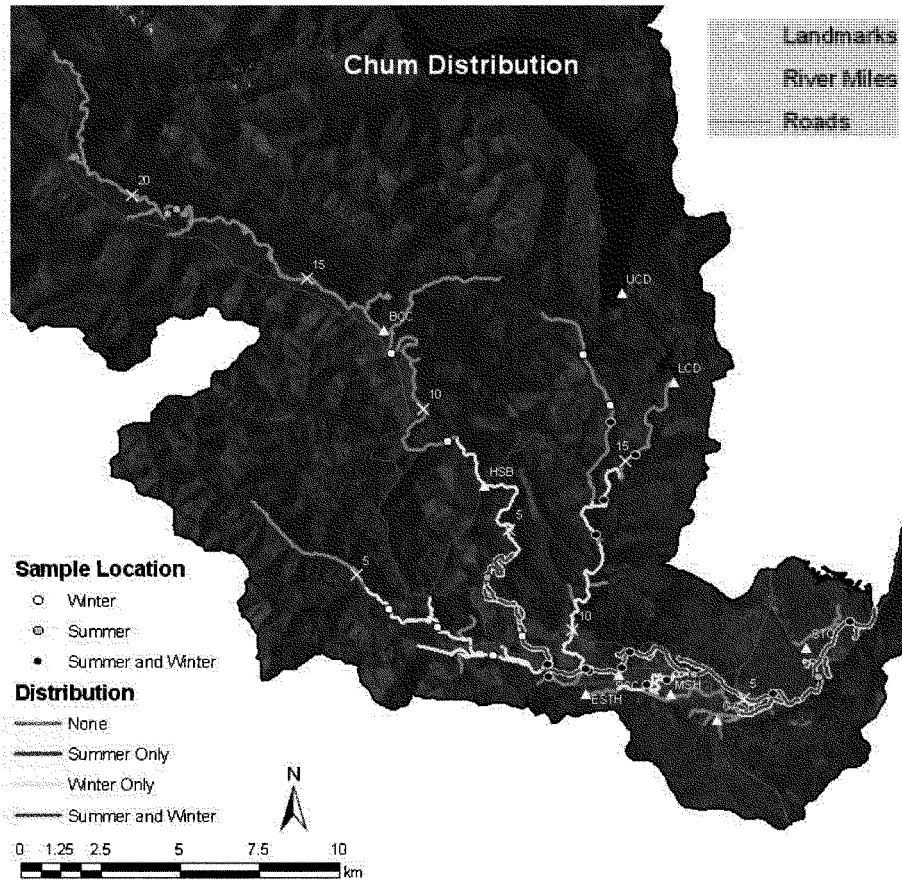

Figure 46. Expected juvenile chum salmon distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. WDF (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 mi above mouth), and the Skokomish mainstem (old U.S. HWY 101 bridge). Chum salmon were caught at all but the upper South Fork Skokomish sampling site. Outmigration started earlier at the mainstem site and was progressively later at upstream traps. Outmigrants were caught from mid-January through the June. Peak catches varied by location. Peak catches occurred in mid-May at the lower South Fork Skokomish site, April and early May in Vance Creek, and the end of March in the mainstem. A tri-model pattern occurred in the North Fork Skokomish with peaks occurring in March, April, and mid-May (the largest). Based on relative abundance estimates derived from this sampling effort, WDF (1957) concluded that the North Fork Skokomish was the largest chum producer followed by Vance Creek and then the lower South Fork Skokomish. However, they go on to state that the lower mainstem site could not be included in this assessment and that this area "is conclusively known" to be one of the largest production areas for chum salmon, especially early chum (i.e., summer chum).

Additional sampling was completed by the Skokomish Tribe using a panel trap to sample Skobob Creek between 18 April and 30 May, 2003. Because of the limited availability of information it is impossible to compare trends in abundance, but a discussion of relative abundance to other species and outmigration timing is possible. In 2003, a total of 26 chum fry were captured in the panel trap and they had a relatively uniform size distribution throughout the operating time of the trap. It is important to note, that while all species must eventually pass through the estuary, Skobob creek is not a major chum spawning tributary.

We caught a total of 8,054 chum salmon during our outmigration trapping efforts from January 21 to July 13, 2009 (Figure 47). Peak daily migration occurred on February 18, when 1,887 fish were counted. Prior to April in which two hatchery releases occurred (1st and 16th), 2,789 chum were captured. During the month of April, 5,105 chum were captured. From early May through mid-July, 160 chum were captured and daily catches were all fewer than 10 fish.

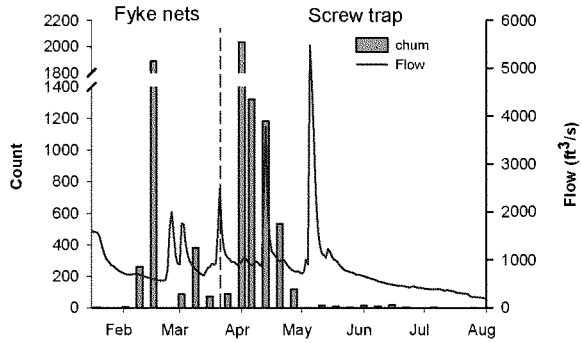

Figure 47. Weekly counts (first axis) of juvenile chum captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

We estimated that 52,179 chum migrated downstream during screw trap sampling (Table 27). The number was extremely low considering that 10 million chum released by WDFW in Weaver Creek, a tributary of Skokomish River, in 2009. This apparent large discrepancy between our estimate and the total hatchery release could be due to low survival of hatchery chum salmon released at this location or underestimation at the trap. Recapture rates of chum salmon (10% overall, 9 of 90), especially hatchery chum salmon (20%, 4 of 20) were much greater than those of other species which were generally between 0.5 and 1%. In addition, our estimates of hatchery coho salmon production represented only 25% of the hatchery coho smolt release from the same location. Thus, our production estimates are likely low. This is potentially due to the release location of marked individuals used to assess trap efficiency being located too close to the outmigration trap. If the release location was too close, the fish would not distribute equally across the river, resulting in an overestimate of trap efficiency. Although we followed the guidelines of Volkhardt et al. (2007), locating our release point two pool/riffle sequence (500 m) upstream of our trap, it was apparently too close in this system.

The fork lengths of chum fork caught during the outmigration sampling ranged from 30 mm to 84 mm and averaged 42 mm. Juvenile chum salmon are relatively small at outmigration, but freshwater rearing and growth also appear to occur. WDF (1957) noted that juvenile chum salmon outmigrants averaged 38 to 40 mm but showed definite growth in both Vance Creek and the mainstem in June. Juvenile chum salmon outmigrants in the current study had fork lengths that ranged from 30 to 84 mm and averaged 42 mm. Over the season, weekly mean fork lengths increased from below 40 mm in late January and early February to over 60 mm in early July (Figure 48). During the first three weeks of April when hatchery chum were released and presumably had a large presence, average lengths increased considerably into the 45-50mm range. Length frequency distribution indicated that the dominant size range was 36 to 40 mm (Figure 49).

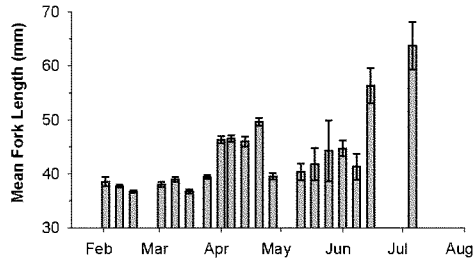

Figure 48. Weekly mean fork lengths and standard errors of juvenile chum captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

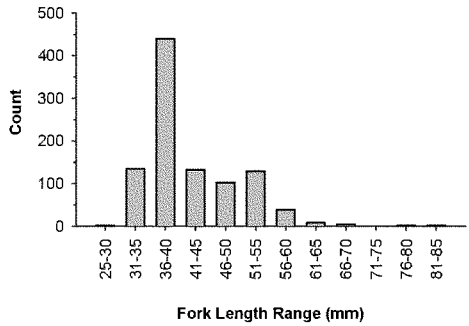

Figure 49. Length frequency distribution of juvenile chum captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on Skokomish River in 2009.

Estuary data was collected by the Skokomish Tribe between 27 December 2004 and 5 July, 2005. The estuary sampling occurred in the vicinity of Nalley Island and West Slough. A total of 1,232 and 120 chum fry were captured at Nalley Island and West Slough, respectively. They were captured throughout the sampling period, with the peak occurring from early February through April (Skokomish Tribe, unpublished data).

Juvenile chum salmon were the most numerous salmonid caught in the estuary during our sampling efforts, with a total of 2,261 being caught. Juvenile chum were captured from February through June, with abundance gradually increasing from March until the peak in mid-May (Figure 50). No juvenile salmon were observed during surveys from October through December. We could not calculate population estimates for juvenile chum salmon in the Nalley Island section of the Skokomish estuary since no marked fish were recaptured during our mark-recapture surveys. In addition, individual residence times could not be estimated for chum salmon since no marked fish were re-captured during subsequent surveys. However, juvenile

chum salmon was one of five species to dominate the catch in the Nalley Island section of the Skokomish River estuary during different part of the year, along with shiner perch, Pacific Staghorn sculpin, surf smelt, and starry flounder. Juvenile chum salmon made up the largest percentage of the catch from March through mid-May.

CPUE increased steadily from mid-February through mid-May and hen declined sharply, with low CPUE observed until early July (Figure 50). Juvenile chum salmon CPUE was greatest lower in the Nalley Island portion of the estuary near the breach. Juvenile chum salmon fork length varied from 30 to 70 mm; however, 45% of the fish were less than 40 mm. Average fork lengths increased during the spring and summer months (Figure 51).

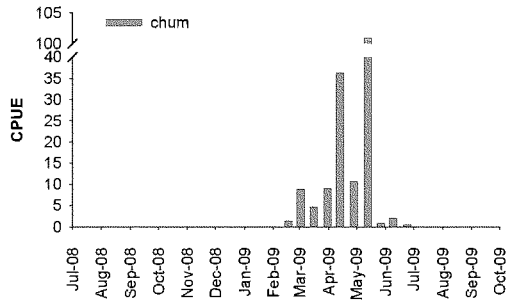

Figure 50. Catch-Per-Unit-Effort (CPUE) of juvenile chum salmon in the Nalley Island portion of the Skokomish River estuary between July 2008 and September 2009.

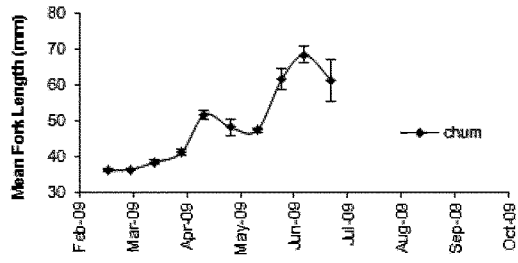

Figure 51. Mean fork lengths (+/- SE) of juvenile chum salmon caught in the Nalley Island section of the Skokomish River estuary between February and September 2009.

Limiting Factors: Chum Salmon

The general lack of information for chum salmon in the Skokomish Basin makes it difficult to assess limiting factors for this species. However, information can be inferred based on the status of the three stocks historically present in the Skokomish Basin, summer chum, lower fall chum, and upper late fall chum. Summer chum are apparently extinct in the system, while late upper fall chum are apparently healthy. Lower fall chum are listed as healthy; however, there is limited information regarding their actual abundance. The difference in stock status between summer chum and upper late fall chum suggest that habitat factors related to the difference is the timing of their major life history events. These major factors are river entry and spawning timing, and potentially outmigration timing and estuarine use.

Skokomish summer chum salmon spawn between mid-September and mid-October (WDFW and PNPTT 2000), which is much earlier than upper late fall chum in the Skokomish basin, which spawn from December through January. The primary habitat differences related to these spawning times is river discharge during spawning migration and egg incubation. Summer chum enter the river during summer low flow, when migratory barriers often exist in Vance Creek and the South Fork Skokomish. This would limit habitat available for summer chum salmon spawning. However, it's unclear if summer chum salmon spawned in these locations historically, since summer chum generally spawn within the lowest one to two miles of tributaries (WDFW and PNPTT 2000). In contrast, upper late fall chum salmon migration occurs during the time of year that discharge is adequate for upstream migration. The entry of summer chum salmon during low flow periods would also result in redds being closer to the middle of the channel potentially making them more susceptible to scour. In addition, they would spawn before the major fall freshets, meaning their redds would have to survive the high discharges associated with this time period. In contrast, upper late fall chum generally spawn after these major high flow periods, which would make them less susceptible to scour. Thus, the scour of redds is a potential factor influencing summer chum salmon stocks in the Skokomish Basin.

Differences in estuarine timing could also result in the differences observed in population status between summer chum and upper late fall chum. Summer chum fry generally emerge in late March to early April approximately one month earlier than Hood Canal fall chum (WDFW and PNPTT 2000). This early emergence could influence food availability for summer chum; however, this has not been documented for the Skokomish Basin. Thus, it's unclear how food availability may influence summer and upper late fall chum in the Skokomish Basin. This should be evaluated further in the future.

The loss of estuarine habitat likely limits chum salmon in the Skokomish Basin. The documented loss of the stream-estuarine ecotone and estuarine habitat as a result of diking described above would significantly reduce habitat available for chum salmon. As stated above, chum salmon are reliant upon estuarine and nearshore habitat for rearing. This limiting factor has recently been addressed by the removal of dikes at Nalley Slough and Nalley Island. Thus, it appears the most likely factor limiting chum salmon in the Skokomish Basin currently, is the stability of their spawning habitat. Given the lack of information regarding spawning habitat stability, this issue should be evaluated in the future.

Coho Salmon

Adult

Skokomish River coho were identified as an individual stock based on their distinct spawning distribution. They were labeled as healthy in the 1992 SASSI, which was upheld in 2002. It is a mixed stock with natural spawning occurring in most accessible tributaries to the Skokomish River with the most significant area being the lower North Fork Skokomish and Vance creek. The cascades within the South Fork canyon have been listed as a natural migratory barrier to coho salmon (WDF 1957); however, we observed juveniles well upstream of this location (see below for details). George Adams Hatchery has made substantial releases of fry from several out of basin locations. Nevertheless, allozyme analysis has identified the stock as distinct from all other Washington coho (David Teel, National Marine Fisheries Service (NMFS), cited on WDFW SASSI webpage). Spawner escapement estimates are based on: 1) cumulative fish day counts at a number of index reaches on small Skokomish River tributaries: Swift Creek (RKM 0.0 (RVM 0.0) to RKM 0.5 (RVM0.3)), Kirkland Creek (RKM 0.0 (RVM 0.0)) to (RKM 1.0 (RVM0.6)), Kirkland Cr. unnamed tributary (16.0015, RKM 0.0 (RVM 0.0) to RKM 1.4 (RVM0.9)), and Fir Creek (RKM 0.0 (RVM 0.0) to RKM 0.5 (RVM 0.3)); and 2) cumulative fish-days values for the North Fork Skokomish River index areas (RKM 19.3 (RVM 12.0) to RKM 25.1 (RVM 15.6)) which began in 1993 (Figure 52). A cumulative fish day count of 20,000 to 100,000 is roughly equal to a total escapement of 2,000 to 5,000 adult fish (All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm).

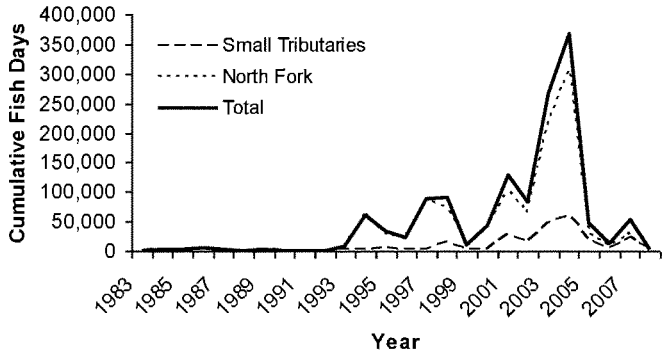

Figure 52. Cumulative fish days for coho spawners in small tributaries of the South Fork Skokomish and the North Fork Skokomish River

Juvenile

Coho salmon generally do not migrate to sea until the spring of their second year of life and therefore rely heavily on freshwater habitat as juveniles. Although they are typically

spawned in higher gradient streams, they generally rear in the middle reaches of a watershed and prefer slower velocities than most other juvenile salmonids (Quinn 2005). In a review, Bjornn and Reiser (1991), report coho juveniles being found in depths of 30 to 122 cm and velocities of approximately 5 to 20 cm/s. Coho juveniles generally prefer pools over riffles, and their densities are positively correlated with LWD presence (Roni and Quinn 2001). In addition, the importance of wood cover may increase with stream size (Peters 1996a). During high flow periods throughout the winter months, coho make extensive use of off channel habitat and migrate several kilometers down tributaries and main stem reaches to reach these habitats (Peterson 1982). Until recently, it was assumed that juvenile coho salmon do not make extensive use of estuaries, relying on them primarily as a transition zone and migration corridor during smolt outmigration. However, Miller and Sadro (2003) reported that coho fry may also use the stream-estuary ecotone to rear during the summer, migrating upstream to overwinter in side channel or off-channel habitat located in the lower watershed.

Coho salmon juveniles rear for at least one year in freshwater and then pass quickly through the estuary on their seaward migration. Therefore, deficiencies in their freshwater rearing requirements will be their main limiting factor. In the Skokomish River watershed, the disruption of LWD delivery, along with the reduction of off channel habitat are potentially two main habitats limiting factors effecting coho salmon. Juvenile coho growth in the middle reaches of the watershed are potentially effected by decreased quantities of LWD and the resultant lack of pool and slow water habitat that it creates. This potential is exacerbated by low flows which can isolate pools which result in increased densities, reduced food delivery and high temperatures. In the middle and lower reaches of the watershed, juvenile overwinter survival may be lowered due to the reduction in off channel habitat caused by channelization and diking as it reduces the amount of habitat available for predator and high flow refugia. Reduced pool frequency in the lower watershed due to aggradation, particularly in lower Vance creek, will also affect coho growth and survival as they prefer pool habitats. Lower flows and higher water temperatures in the lower watershed due to aggradation will also affect summer survival of juvenile coho. Coho smolts generally migrate through the estuary rapidly, so moderate declines in estuarine habitat should not greatly impact them; however, reductions in the mesohaline mixing zone could interfere with their physiological transition to salt water. However, as stated above coho fry may also use the stream-estuary ecotone to rear during the summer (Miller and Sadro 2003)

Next to trout, coho salmon had the widest distribution in the Skokomish Basin. They were observed in tributary, main stem, and pond freshwater habitats (Figure 53). Juvenile coho salmon were observed up to RKM 30 in the South Fork Skokomish, RKM 6 in Vance Creek, RKM 7 in McTaggart Creek, and up to the lower dam in the North Fork Skokomish River. As with the other species, distribution of coho salmon was somewhat greater in the winter. Historic accounts suggest that coho salmon cannot pass the cascades in the South Fork Skokomish canyon (WDF 1957). However, we observed juvenile coho salmon well upstream of this location. In reviewing our records, four different snorkelers observed coho salmon in two different sites (2-30 and 2-38) upstream of the cascades, including one snorkeler with over ten years of snorkeling experience. Thus, it is our opinion that coho can now access the upper reach in limited numbers (based on the few fish we observed). This may be due to aggradation occurring in the lower river, which may have made these cascades passable to coho salmon, or due to later return timing for coho salmon in the system. WDF (1957) stated that coho salmon

have been reported above the canyon, but they had not been recorded there by Washington Department of Fisheries personnel. They go on to conclude that these reports are likely spring Chinook and discount coho spawning upstream of the canyon. They report that coho spawn from October through February. However, Skokomish Tribal fisheries personnel have observed coho salmon spawning in mid- to late March during recent years (Matt Kowalski, Skokomish Tribe, Personal Communication). This somewhat later timing may result in hydraulic conditions in the cascades that allow some coho salmon to pass the cascades. The final option is that the cascades are passable intermittently and we just happened to sample during a year when they were able to pass this intermittent barrier.

The total number of juvenile coho salmon rearing in the Skokomish basin varied substantially between summer and winter. We estimated that just over 1 million and just over 108,000 juvenile coho salmon were rearing in riverine and pond habitats during the summer and winter, respectively. A majority of these fish were coho fry during the summer (98.2%), while the majority were classified coho parr (58.3%) during the winter. The remaining winter fish were nearly equally classified as coho smolts and coho fry. Survival estimate of coho fry from summer to winter, assuming all coho fry were classified as either coho parr or smolts during the winter was 8.6%. In contrast, Quinn and Peterson (1996) estimated coho salmon survival from October through smolt migration to be between 25.4% and 46.2% in Big Beef Creek, Hood Canal, Washington. Ebersole et al. (2006) observe overwinter survival rates of 10% in a coastal Oregon watershed, and our observations on the Skokomish were within the range they observed.

Although, a majority of juvenile coho salmon we observed were found in riverine habitat there was some seasonal and size class variation. During the summer, all coho parr and coho smolts were found in riverine habitat and 95% of coho fry were found in riverine habitat. However, during the winter, 16.5% of coho parr and 18.1% of coho smolts were found in pond habitats. Thus, off-channel pond habitat appears to be more important to these larger size classes during the winter than during the summer.

The relatively small proportion of fish using off-channel ponds is somewhat surprising. For example, we estimated that approximately 10,000 coho salmon used all off-channel ponds in the Skokomish basin during the winter of 2009. In contrast, Peterson (1982a) estimated that approximately 9,500 coho immigrated into two ponds with a total surface area just over 2 ha in the Clearwater River Basin. Cederholm et al. (1988) observed between 1,700 and 5,500 juvenile coho salmon immigrants into a 0.5 ha pond (after restoration). Thus, our estimate of approximately 10,000 coho in nearly 20 ha of off-channel pond habitat is surprising. It's possible that our estimates are biased since large portions of the ponds were covered in dense vegetation which we could not sample. However, our winter surveys were completed at night, when one would expect juvenile coho salmon to be laying in open water away from cover (i.e. Tabor et al. 2006, Peters, personal observation). The apparent low numbers of fish using off-channel ponds in this system is surprising especially since survival in these types of habitats is generally quite good. For example, Peterson (1982a) observed 28% percent and 78% survival, while Cederholm and Scarlett 1991 observed 43 and 70% survival in off-channel ponds in the Clearwater River. Thus, further examination of the numbers of coho using these systems is warranted to determine if physical habitat or water quality issues are preventing greater use of these habitats or if our estimates are accurate. Other than some low DO levels and the dense mats of aquatic vegetation covering the bottom, thereby reducing open areas for nighttime

rearing, the habitat conditions in the ponds we surveyed seemed to be appropriate. However, we did not assess the access to off-channel ponds.

The distribution of coho salmon within the ponds varied between summer and winter. Coho fry preferred nearshore (3,414 fish/ha) areas to offshore (1,155 fish/ha) areas during the summer. However, no coho fry were observed in nearshore areas during the winter, while densities of nearly 21 fish/ha were observed in the offshore areas. In contrast, yearling coho densities were greater in nearshore (639 fish/ha) areas than offshore areas (221 fish/ha) during the winter. No coho parr were observed during the summer. Coho smolt densities were also greater in nearshore areas (217 fish/ha) than offshore areas (121 fish/ha) during the winter. Although differences in point estimates were substantially different in some cases, the 90 percent confidence intervals overlapped, suggesting the differences are not statistically significant. This is likely due to the relatively small sample size and large variability in the data

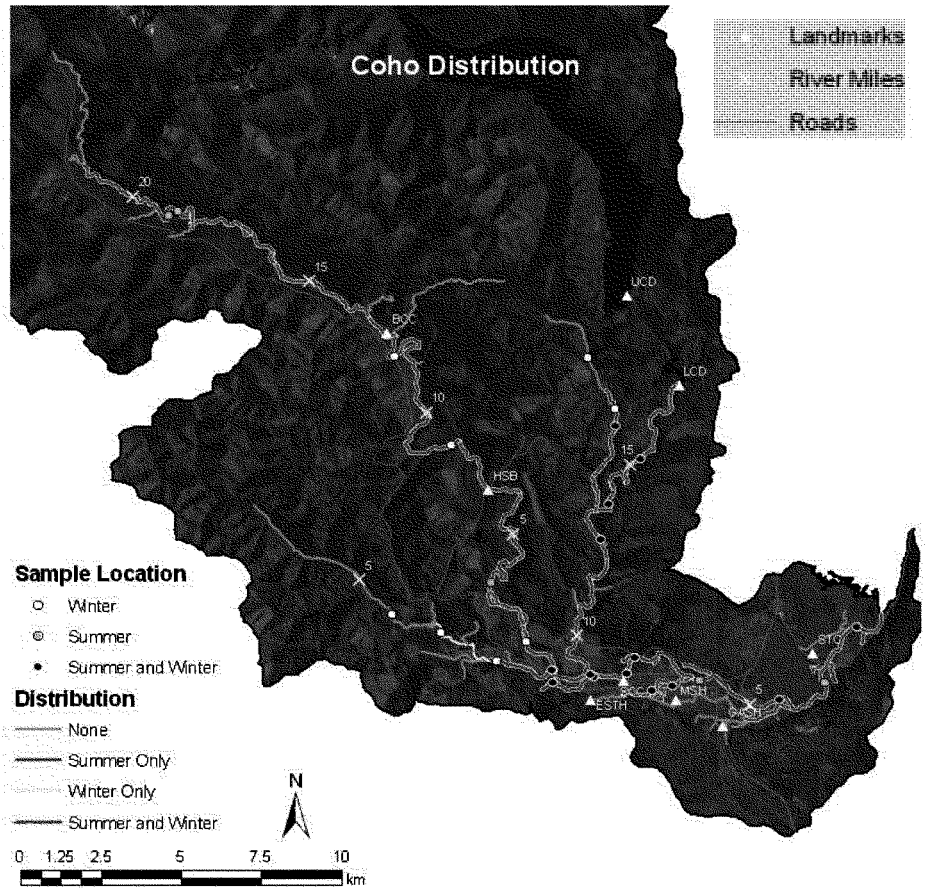

Figure 53. Expected juvenile coho salmon distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. WDF (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 mi above mouth), and the Skokomish mainstem (old U.S. HWY 101 bridge). They observed outmigration from January through September, with a peak in April through May. Catches were significantly reduced by late June with few fish caught through the rest of the sampling period. Additional data was collected by the Skokomish Indian Tribe in Skobob Creek where they operated a panel trap between 18 April and 30 May, 2003. In 2003, a total of 11,058 coho fry were captured in the panel trap, with a fairly uniform catch distribution throughout the trapping. However, two noticeable peaks occurred on 11 May and 26 May, where approximately 1,400 fish were captured.

A total of 2,633 unmarked and 771 hatchery coho were captured during our 2009 trapping season (Figure 54). Both fry and smolts were captured during the entire sampling period of January 21 to July 29, 2009. Coho fry outmigration peaked in late April through late May. Unmarked coho smolt outmigration peaked from mid-May through mid-June, while hatchery coho smolt outmigration peaked in mid-April, immediately after release (4/14-4/18/09).

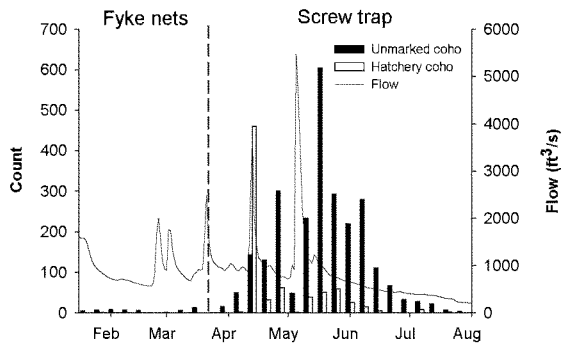

Figure 54. Weekly counts (first axis) of juvenile wild and hatchery coho captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

A total of 352,603 coho were estimated to have migrated downstream during screw trap sampling, with 80% unmarked and 20% of hatchery origin (Table 27). Coho fry was the most numerous size class, accounting for 51% of the coho population, while smolts were slightly less abundant and accounted for 46% of the population. Unmarked coho smolts were estimated at 87,639 and more abundant than their hatchery counterparts. The estimated number of hatchery smolts to migrate past the trap was approximately 25% of the 298,541 coho smolts released by WDFW into Purdy Creek in mid-April 2009. Thus, either survival of hatchery fish released into the system is very low, or our estimates are especially conservative. Based on apparent

underestimation of chum salmon from hatchery releases (discussed above), we assume that our estimates of coho salmon outmigration was also biased low.

WDF (1957) provide relative abundance estimates for coho salmon from their five sampling locations. No coho salmon were caught in the upper South Fork Skokomish trap. Vance Creek was listed as the most productive area followed by the North Fork Skokomish and then the lower South Fork Skokomish. However, they noted that the variation in production from the four areas was less than that observed for juvenile Chinook salmon. They estimated that 56,000, 35,000, and 21,000 coho salmon migrated past their Vance Creek, North Fork Skokomish, and lower South Fork Skokomish outmigration sampling locations, respectively. They could not make an overall estimate at the mainstem due to the size and non-uniform flow patterns at their lower mainstem sampling location. Summing the above estimates, which would seem reasonable since they cover different parts of the watershed, would provide an estimate of approximately 120,000 coho, substantially less than our estimate. However, their sampling locations miss several locations that likely produce significant numbers of coho salmon including Swift Creek, Hunter Creek, Purdy Creek, Weaver Creek, and lower mainstem lateral habitats and ponds.

The size of fish sampled during our outmigration sampling was quite variable. Unmarked coho sizes ranged from 25 to 159 mm and averaged 62 mm. Weekly mean fork lengths of wild coho showed considerable variation from late January to early April, ranging from 37 to 81 mm (Figure 55). During the following months, unmarked coho sizes were mostly between 50 and 75 mm. Weekly mean fork lengths of hatchery coho smolt were between 100 and 120 mm during most weeks the fish were present. Length frequency distributions also varied considerably between unmarked and marked coho (Figure 56). The most common size range was 31 to 40 mm for unmarked coho and 121 to130 mm for marked coho. The size distribution observed during our study was similar to that observed by WDF (1957). They observed 0-age coho throughout their outmigration sampling at all but the upper South Fork Skokomish outmigration station. These fish ranged in size from about 38 to just over 50 mm through about July, after which no 0-age size data is provided. Yearling fish averaged about 100 mm in the North Fork Skokomish during May, while the size of yearling fish increased from about 70 mm in February to about 100 mm in May.

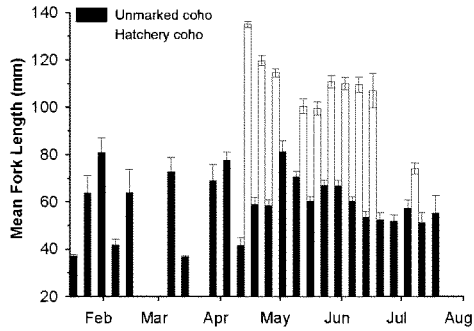

Figure 55. Weekly mean lengths and standard errors of juvenile wild and hatchery coho captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on the Skokomish River in 2009.

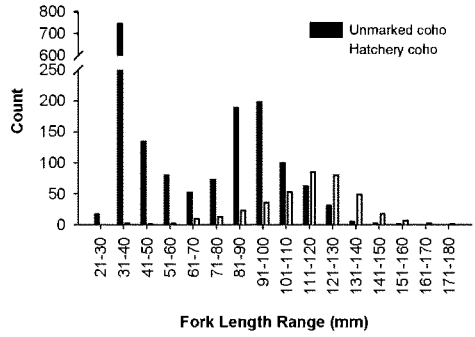

Figure 56. Length frequency distribution of juvenile coho captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on the Skokomish River in 2009.

Estuary data was collected by the Skokomish Indian Tribe between 27 December, 2004, and 5 July, 2005. The estuary sampling occurred in the vicinity of Nalley Island and West Slough. A total of 1,981 and 1,304 coho salmon were captured at Nalley Island and West Slough, respectively. However, these fish were not noted as fry or smolts, so we could not determine the relative numbers of fry and smolts in the samples. Very few fish were captured before mid-April and the peak occurred between mid-April and mid-May, although they were recorded until the last sampling event on 5 July (Skokomish Indian Tribe, unpublished data).

We caught 367 juvenile coho salmon during the estuary sampling. Juvenile coho salmon were captured from April through September, and were most abundant from mid-May through late June (Figure 56). Hatchery coho salmon represented 27% of all juvenile coho salmon captured in the estuary. Unmarked coho salmon were captured at least 15 days before their

hatchery counterparts were captured and nearly three months after hatchery coho salmon were last captured (Figure 57). Of the coho salmon captured, about 60% were smolts, 25% were parr, and 15% were fry.

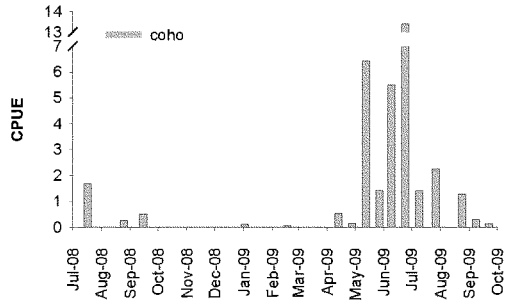

Figure 57. Catch-Per-Unit-Effort (CPUE) for juvenile coho salmon in the Nalley Island portion of the Skokomish River estuary between July 2008 and September 2009.

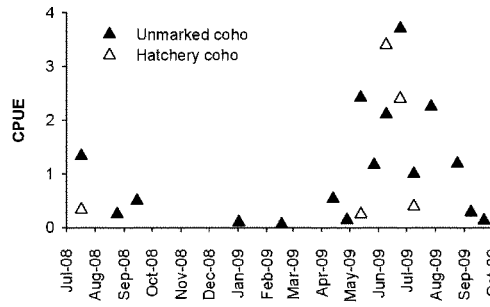

Figure 58. Comparison of residence timing of hatchery and unmarked juvenile coho salmon captured in the Nalley Island section of the Skokomish River estuary between July 2008 and September 2009.

Individual residence times and population estimates for juvenile coho salmon could not be estimated, since no marked fish were ever recaptured. Juvenile coho salmon in the estuary ranged from 71 to 90 mm in fork length and generally increased during the spring and summer months (Figure 59). Hatchery coho salmon were 9 mm longer than their unmarked counterparts (Figure 59).

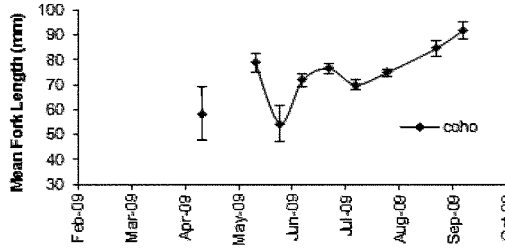

Figure 59. Mean fork lengths (+/- SE) of juvenile coho salmon caught in the Nalley Island section of the Skokomish River estuary between February and September 2009.

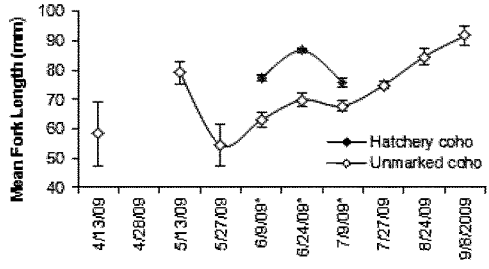

Figure 60. Mean for length (+/- SE) of hatchery and unmarked juvenile coho salmon captured in Nalley Island section of the Skokomish River estuary between February and September 2009. The mean lengths are based on samples sizes of four or more. Asterisks (*) next to the sampling dates, indicate the dates on which hatchery and unmarked fish are significantly different in length.

Limiting Factors: Coho Salmon

Although Skokomish River coho salmon have been listed as healthy by SASSI (2002), potentially significant habitat issues exist for this species. Juvenile coho salmon generally prefer pool habitats with slower velocities and densities have been found to be positively related to LWD presence (Roni and Quinn 2001). Pool habitat and LWD levels are somewhat reduced in the Skokomish Basin. In addition, pool habitats were reduced even more during the winter and the depths of existing pools were shallower than during the summer. Pool habitat is critical to juvenile coho salmon during the winter. This lack of pool habitat and LWD cover may be why the survival estimates we developed for the Skokomish Basin were substantially lower than those observed for coho salmon in Big Beef Creek (Quinn and Peterson 1996). Although our survival estimates were lower than those observe by (Quinn and Peterson 1996), they were within the range observed in an Oregon Coastal system (Ebersol et al. 2006).

Off-channel ponds, although abundant in the Skokomish Basin, may also limit coho salmon in this system due to their distribution. This statement is based on the relatively low numbers of coho salmon that we estimated to be using this habitat. It's unclear if the low number were due to migration barriers between the main channel and the off-channel ponds, the physical characteristics of the ponds, the locations of the ponds within the system, or just due to general low use of this habitat type in this system relative to other systems in western Washington. An assessment of migratory barriers to off-channel ponds would be relatively easy to complete and should be pursued in the future. With the exception of low DO at a couple of the sites we surveyed and the dense mat of aquatic vegetation, the physical characteristics of the ponds seemed adequate for juvenile coho salmon rearing. The fact that most of the off-channel ponds were low in the basin adjacent to the stream-estuary ecotone could result in less use than expected if juvenile coho salmon avoided this area due to tidal influence or saline water conditions. However, we observed juvenile coho salmon migrating through this area throughout our outmigration sampling and they were frequently observed in the estuary. In addition, salinities were very low in this area during our sampling. Thus, this does not appear to be an issue. Finally, juvenile coho salmon in the Skokomish Basin simply may not use off-channel ponds to the degree that they do in other western Washington Rivers. This seems unlikely given the wet maritime climate present in the basin, but is certainly a possibility.

Reduced habitat quality and connectivity in the estuary may also limit coho salmon in the system. As stated above, large numbers of juvenile coho salmon migrated through the stream-estuary ecotone during our sampling and coho fry were frequently observed in the Nalley Island portion of the estuary, despite the nearly complete enclosure of the island by dikes. In order to access Nalley Island, juvenile coho would have to migrate to the seaward side of the island and migrate through the dike breach. Once there, they would be required to make this same migration to move back upstream during the winter as observed in Oregon Coastal systems (Sadro and Miller 2003). Much of this potential limiting factor has been eliminated by the dike removal projects at Nalley Slough and Nalley Island. Given the small proportion of the watershed available for coho salmon, the extensive wetlands in the lower river, and the extensive estuary, this life history strategy could be very important for coho salmon production in this system. The level of expression of this life history pattern should be further evaluated in the future.

Steelhead

Adult

Summer

There is limited information on the status of summer steelhead in the Skokomish Basin. They were identified as an individual stock in the 1992 SASSI, but their status remains unknown. Historically, their spawning distribution was thought to be in the South Fork Skokomish canyon section (ME2 Environmental Services, 1997). Along with all other Puget Sound steelhead stocks, they were listed as threatened under the ESA on May 11, 2007. They are thought to spawn from February through April, but specific data on escapement is not collected.

Winter

Skokomish River winter steelhead were identified as an individual stock in the 2002 SASSI based on their distinct spawning distribution. Their depressed classification was retained in the 2006 SASSI based on chronically low escapement numbers and a continued negative trend. In addition, the stock was listed as threatened under the ESA on May 11, 2007. Most spawning takes place in main stem and South Fork Skokomish River from mid-February to mid-June. They are capable of accessing the entire watershed that is below anadromous barriers and initiate spawning in mid-April and continue through mid-June (ME2 Environmental Services 1997). Escapement data is based on redd counts from index reaches in the main stem Skokomish (RKM 0.0 (RVM 0.0) to RKM 14.5 (RVM 9.0)), in the North Fork Skokomish River (RKM 14.5 (RVM 9.0) to RKM 20.9 (RVM 13.0)) and in the South Fork Skokomish River (RKM 0.0 (RVM 0.0) to RKM 34.4 (21.4)) (Figure 61). Allozyme analysis seems to indicate that Skokomish winter steelhead are distinct from other Hood Canal stocks (Phelps 1997). In 2007, a winter steelhead supplementation program was started in the South Fork Skokomish to address the decline of the stock. Approximately 30,000 eggs are removed from redds in the river each year, and 20,000 to 30,000 two year old smolts are subsequently released into the system (Barry Berejikian, NOAA, personal communication).

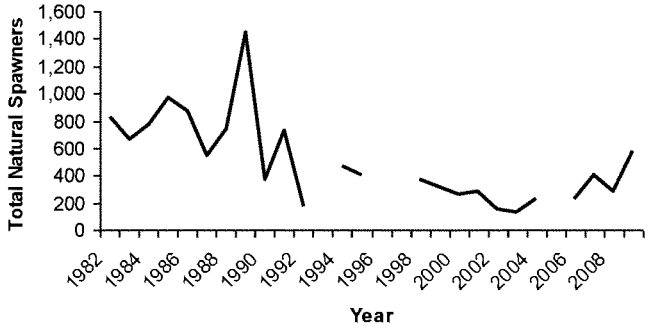

Figure 61. Total natural adult winter steelhead in the Skokomish River from 1982 to 2008. Escapement data is based on redd counts from index reaches in the main stem Skokomish (RKM 0.0 (RVM 0.0) to RKM 14.5 (RVM9.0)), in the North Fork Skokomish (RKM 14.5 (RVM 9.0) to RKM 20.9 (RVM 13.0)) and in the South Fork Skokomish (RKM 0.0 (RVM 0.0) to RKM 34.4 (RVM 21.4)). All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm

Juvenile

Steelhead rely heavily on freshwater habitats and exhibit a broad array of life history patterns that result in anywhere from 1 to 3 years of residency in freshwater before seaward migration. In general, they rear higher up in a watershed than either Chinook or coho, and therefore are found in higher gradient areas than other species. As reviewed by Bjornn and Resier (1991) juvenile steelhead have been recorded in a wide range of depths and velocities with approximate means being a depth of 40 cm and a velocity of 20 cm/s although velocities up to 40 cm/s have been recorded. This represents a range which is generally shallower and swifter than most other pacific salmon juveniles. Juvenile steelhead use riffles and fast flowing pool habitats during the summer (Bisson et al. 1988), but prefer pool habitats in the winter (Roni 2002). Similar to coho, juvenile steelhead make extensive use of off channel habitat during winter months and in some instances were found in higher densities then the main channel (Mundie and Traber 1983). Due to their lengthy residency in freshwater, steelhead generally do not reside in the estuary for extended periods on their way to sea (Quinn 2005).

Steelhead are the most dependent salmonid species on freshwater habitat of all anadromous species in the Skokomish River, spending up to three years in freshwater before migrating to sea. Therefore, they will be even more heavily dependent on intact freshwater habitats than juvenile coho salmon. Because they generally rear in the middle and upper reaches of the watershed, impacts from logging may impact them the most. This is especially true, since much of the sediment inputs from logging are presumed to still be in the upper watershed (Pentec 1997). Thus, spawning habitat may be unstable or redds may be susceptible to fine sediment intrusion. In addition, since steelhead are spring spawners, they will be most affected by reduced flows, and higher water temperatures during spring and summer. Loss of LWD inputs and

associated channel simplification is an issue in Brown, LeBar, and Church creeks (ME2 Environmental Services 1997). Increased sediment supply and higher stream temperatures could affect growth rates, which may ultimately influence life history patterns and age of smoltification. As they move through the lower reaches of the Skokomish Basin, the lack of off channel habitat due to reduced floodplain connectivity may reduce survival by limiting access to predator and high flow refugia.

There is little data for rearing densities of juvenile steelhead in the Skokomish Basin. Dunham and Chandler (2001) present data for combined rainbow and cutthroat trout densities at several sites in the South Fork Skokomish and one site in Church Creek (Table 28). Based on their data, trout appear to be distributed throughout the Skokomish Basin in relatively low densities. Data collected during this GI confirm these results of wide distribution (Figure 62). Juvenile trout were estimated to use the South Fork Skokomish up to RKM 30, the North Fork Skokomish upstream to the first dam, and up to RKM 8 on Vance Creek. Our predicted distribution suggests that trout did not use many of the tributaries in the upper Skokomish Basin. However, this is likely due to the lack of sampling locations in those tributaries. As with the other species, trout were estimated to have a greater distribution during the winter than the summer. However, this was may have been influenced by the distribution of our summer and winter sample sites.

Trout were observed in mainstem, tributary, and pond habitats. Although we did not separate trout into *O. mykiss* and cutthroat during our snorkel surveys, sampling for winter diet analysis suggest that *O. mykiss* were more common in mainstem and tributary habitats (188 in mainstem, 80 tributary, 1 pond). Others have also found that cutthroat trout tend to use pond habitats more than *O. mykiss,* especially if the bottom is composed of fine sediments. Thus, *O. mykiss* appear to prefer tributary and mainstem habitats to the pond habitats.

Table 28. Combined rainbow and cutthroat trout densities observed in Church Creek and several sites in the South Fork Skokomish River (from Dunham and Chandler (2001), sites are shown in Figure 62.

		Density (per m^2)	
Stream	Site	Juvenile	Adult
Church Cr	1	0.06	0
S.F. Skokomish	1	0.06	0
S.F. Skokomish	10	0.09	0
S.F. Skokomish	11	0	0
S.F. Skokomish	12	0.03	0
S.F. Skokomish	13	0.12	0
S.F. Skokomish	14	0.03	0
S.F. Skokomish	15	0.03	0
S.F. Skokomish	16	0.08	0
S.F. Skokomish	17	0.07	0
S.F. Skokomish	18	0.03	0
S.F. Skokomish	19	0.02	0
S.F. Skokomish	2	0.06	0
S.F. Skokomish	20	0.02	0
S.F. Skokomish	21	0	0
S.F. Skokomish	22	0.03	0
S.F. Skokomish	23	0	0

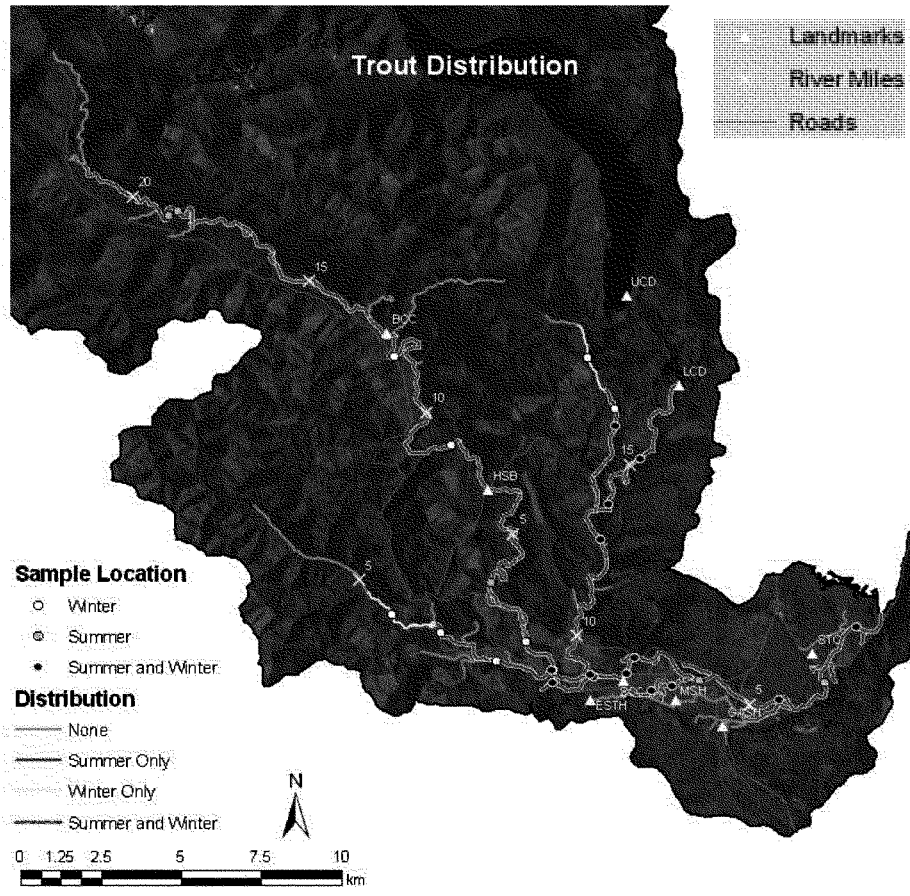

Figure 62. Expected juvenile trout (*O. mykiss* and *O. clarkii*) distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Outmigration data is limited for the Skokomish River. Three different outmigration sampling efforts have been completed. Washington Department of Fisheries (WDF) (1957) completed the most comprehensive outmigration sampling in the system to date. They sampled five location in the Skokomish River, just above and below the South Fork Skokomish canyon, Vance Creek (just below Valley Rd bridge), North Fork Skokomish (~1.5 mi above mouth), and the Skokomish mainstem (old U.S. HWY 101 bridge). Steelhead were caught at all five locations. Migration timing varied somewhat by location but generally occurred from February to September (the end of sampling). Peak outmigration occurred later in the South Fork Skokomish (late July) than it did in the other three stations, where the peak occurred in May. It's unclear if this timing is due to different aged fish, since no size class information is provided for the outmigration timing data. Although comparisons of relative abundance could not be made for all five locations, WDF (1957) determined that steelhead production in the upper South Fork Skokomish was greater than that of the canyon and lower South Fork Skokomish. The Skokomish tribe also sampled outmigration fish on Skobob Creek during 2003. No juvenile steelhead were captured during this effort (Skokomish Indian Tribe, unpublished data). Finally, a screw trap has been operated by NOAA fisheries on the South Fork Skokomish near the confluence with Vance Creek since 2007 to assess production and outmigration timing steelhead from April 1 to June 15. It appears that downstream migration may have occurred prior to the initiation of their sampling on April 1. Production estimates of 7,600 and 4,000 smolts were obtained for 2007 and 2008, respectively (Chris Tatara, NOAA Fisheries, personal communication). These estimates represent smolts greater than 125 cm and do not account for missed trap days or production from downstream habitat.

We collected additional outmigration data for the current study. We used fyke nets and a screw trap to monitor *O. mykiss* outmigration in the Skokomish River from June 2008 through July 2009 (See Appendix Outmigration for details). We caught a total of 51 *O. mykiss* during the January through July 2009 sampling period, with 50 unmarked and one marked hatchery fish. Our catches were likely low due to the fact that steelhead migrate near the bottom of the water column and the only appropriate location for our 5 foot screw trap to fish was in a relatively deep run. Although the fyke nets fished in a deeper location, they covered a very small portion of the overall surface area of the lower river, as did the screw trap.

O. mykiss were first caught in early February and last caught on the last day of trapping (July 2, 2009). Peak catches of unmarked *O. mykiss* occurred in early to mid-May (Figure 63). The lone hatchery *O. mykiss* caught during our sampling was caught on May 22, 2009. Unmarked *O. mykiss* caught in the outmigrant trap averaged 128 mm. These fish appeared to represent several year classes (Figure 64). Newly emerged fry were caught in early July. Apparent 1+ parr and 2+ parr were observed throughout the sampling. Washington Department of Fisheries (WDF 1957) reported that zero age *O. mykiss* averaged about 32 mm in fork length. They reference yearling *O. mykiss*; however, the figure they reference as showing lengths of yearling (their figure 18) is missing from the report. Thus, we could not determine the average length of these yearling fish.

No juvenile steelhead were captured in the sampling completed by the Skokomish Indian Tribe estuary sampling in 2005 (Skokomish Indian Tribe, unpublished data). We also did not capture any steelhead in our estuary sampling in 2008-2009. This is in agreement with the idea that juvenile steelhead move through the estuary quickly and is supported by the steelhead

telemetry data collected for this study (See Appendix Steelhead Outmigration, Estuary, Early Marine Survival for details).

Although juvenile steelhead generally migrate through the estuary rapidly, it is important to note that more extensive estuarine use has been documented in other systems. Bond et al. (2008) noted extensive use of the estuary by smaller (<150 mm) juveniles when compared with larger (>150 mm) individuals who moved almost directly to sea. More importantly, the smaller individuals that utilized the estuary exhibited relatively high growth rates during that period and had higher subsequent survival to adults.

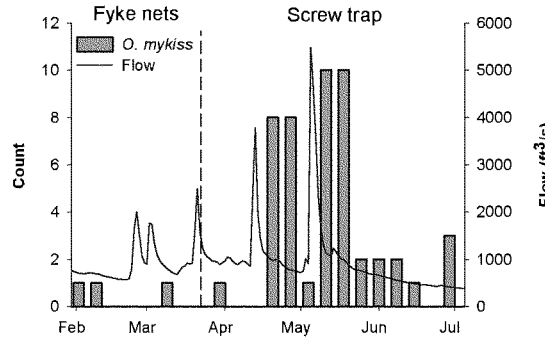

Figure 63. Weekly counts (first axis) of juvenile *O. mykiss* captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09), and daily average flow (second axis) on the Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

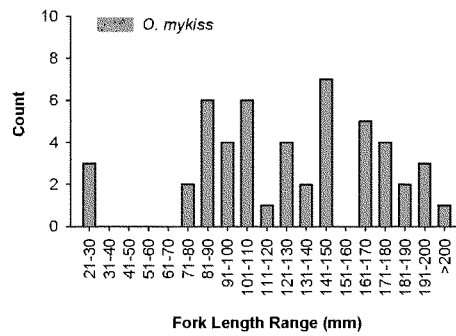

Figure 64. Length frequency distribution of *O. mykiss* captured in fyke nets (1/21-3/17/09) and screw trap (3/25-7/29/09) on the Skokomish River in 2009.

Smolt Size

Wild smolts tagged in 2006, as part of the early marine survival assessment, were significantly larger on average than wild and hatchery smolts tagged in 2007 and 2008, and wild smolts tagged in 2009 ($ANOVA_{length}$: $F_{5,212} = 23.57$, $p < 0.001$; $ANOVA_{weight}$: $F_{5,212} = 20.68$, $p<0.001$; Tukey's Multiple Comparison; Table 29). This difference is likely due to different capture methods employed in 2006 (some smolts were caught by hook-and-line). Age-1 hatchery smolt sizes in 2008 were comparable to those of wild smolts, though age-2 hatchery smolts in 2009 were both longer and heavier than all other groups (Table 29).

Table 29. Average length and weight of wild and hatchery reared steelhead tagged during this study. Only fish >155 mm were tagged, so smaller fish were excluded from these data.

Year	Number tagged	Rearing History	Mean Length (mm)	Mean Weight (g)
2006	27	Wild	195 ± 4	69.8 ± 6.0
2007	51	Wild	182 ± 3	56.0 ± 3.1
2008	41	Wild	180 ± 3	53.7 ± 2.5
	42	Hatchery	171 ± 1	49.0 ± 1.1
2009	23	Wild	175 ± 4	50.9 ± 3.3
	29	Hatchery	211 ± 3	93.5 ± 5.3

Smolt Survival

Wild steelhead smolt survival from the Point of Release (PR) to the River Mouth (RM) ranged from 82% to 99% (Figure 66). Survival estimates for hatchery smolt groups in freshwater were much lower (2008: 48%; 2009: 21%). All groups traveled from the PR to RM in less than 7 days and there were no significant differences in freshwater travel time between groups (Table 30).

Table 30 Travel and Residence Times between the point of release (PR) and the river mouth (RM), the RM to Hood Canal Bridge (HCB), HCB to the Strait of Juan de Fuca (JDF), and the RM to HCB). Numbers in parentheses indicate the sample size used to calculate the mean and SE.

Group	Travel Times (d ± SE)			Residence Time (d)
	PR-RM	RM-HCB	HCB-JDF	RM-HCB
2006 (Wild)	2.4 ± .07 (20)	15.6 ± 4.1 (15)	6.1 ± 0.9 (6)	17.4 ± 4.8 (15)
2007 (Wild)	4.7 ± 0.8 (31)	14.4 ± 2.9 (18)	7.3 ± 2.3 (4)	15.1 ± 2.8 (18)
2008 (Wild)	3.9 ± 1.4 (13)	11.1 ± 1.9 (11)	5.4 ± 0.3 (3)	19.9 ± 6.4 (11)
2008 (Hatchery)	6.42 ± 1.4 (10)	14.0 ± 3.8 (4)	3.29 (1)	14.1 ± 2.7 (4)
2009 (Hatchery)	2.4 ± 0.4 (17)	11.1 ± 1.8 (7)	5.3 ± 0.26 (2)	12.5 ± 1.6 (7)
2009 (Hatchery)	1.3 ± 0.2 (6)	10.3 ± 1.8 (4)	4.86 (1)	10.4 ± 1.7 (4)

River mouth to Hood Canal Bridge (HCB)

A very wide range of survival rates was observed for the smolts migrating from RM to HCB. The RM-HCB survival estimate was only 40% for hatchery smolts migrating in 2008, compared to a very high estimate of 100% survival for hatchery smolts in 2009 (Figure 66). Survival of wild smolts ranged from 62% in 2007 to 85% in 2008 and 2009 (Figure 66).

Mean RM-HCB travel times ranged from 10.3 days (2009 Hatchery) to 15.6 days (2006 Wild; Table 29). Wild and hatchery smolts from all years took similar amounts of time to travel from RM to HCB.

Mean Hood Canal residence time tended to be only slightly longer than RM-HCB travel times (Table 29), indicating that hatchery and wild smolts did not generally stay within Hood Canal once they reached the Hood Canal Bridge. Average residence times of each smolt group in Hood Canal were not different from each other.

Hood Canal Bridge to Admiralty Inlet (AI)

Survival estimates from the HCB to AI were generally lower than rates estimated through Hood Canal (Figure 2C), despite the HCB-AI distances being only 30% the distance of the RM-HCB segment (~25 km compared to 75 km). Overall, the lowest survival rate was experienced by wild smolts in 2008 (29%), while hatchery smolts had the highest survival rate in 2009 (65%) (Figure 66).

Hood Canal Bridge to the Strait of Juan de Fuca (JDF)

The 2006 HCB-JDF survival estimate was lower than the 2006 RM-HCB estimate (40% compared to 72.5%), though the distance from the RM to the HCB is over twice as long (~135 km compared to 75 km).

All smolt groups took less time on average to travel from the HCB to the JDF (135 km) than they took to travel the length of Hood Canal (75 km) (Table 29). Only one hatchery smolt was detected at JDF in 2008 and travelled from HCB to JDF in 3.3 days. The 2007 wild smolts (n=4) averaged 7.3 d to travel from the HCB to the JDF (Table 29).

Point of release to Strait of Juan de Fuca

In 2006, the minimum survival rate for Skokomish River wild smolts was estimated to be 28.6%. This estimate is a composite of the PR-RM, RM-HCB and HCB-JDF modeled survival rates. This was lower than survival estimates for two other Hood Canal steelhead populations tagged in the same year (Big Beef Creek: 41.7%; Dewatto River: 33.3%), but higher than the survival estimates for the Hamma Hamma River hatchery population (16.0%) (see Moore et al. 2010 for more details).

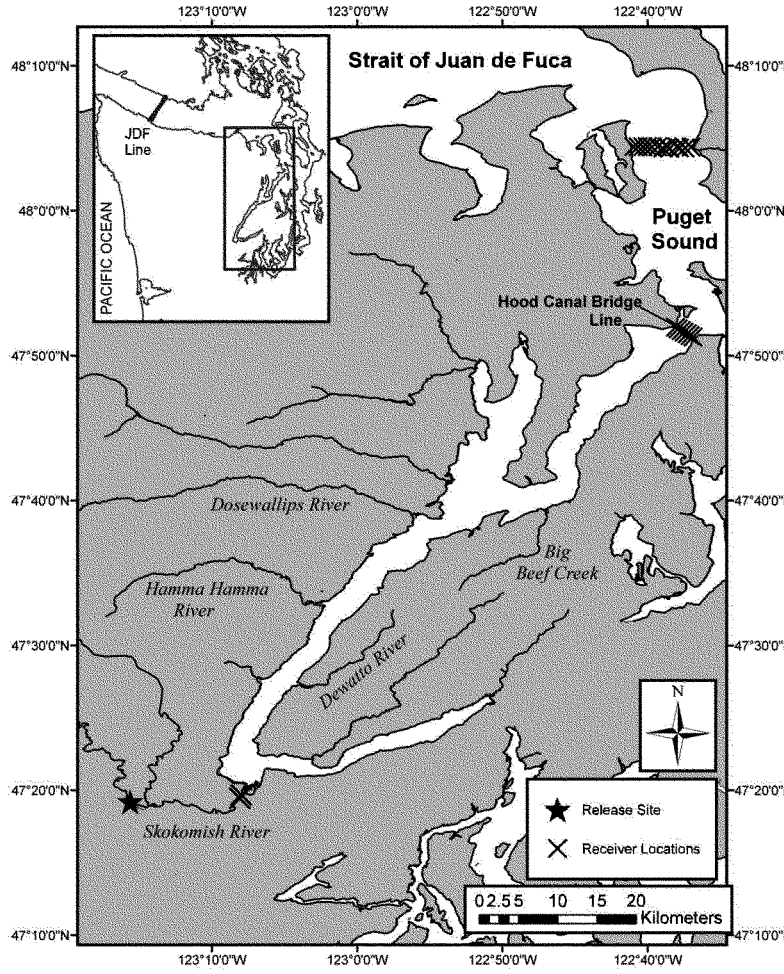

Figure 65. Locations of acoustic telemetry receivers in Hood Canal and Strait of Juan de Fuca. Two receivers were placed at each river mouth (RM) to detect outmigrating smolts. The Hood Canal Bridge Line was comprised of four receivers in 2006 and seven receivers in 2007, 2008, and 2009. The Admiral Inlet line (spanning the north entrance to Puget Sound) consisted of 13 receivers, and 30 receivers (31 in 2006) made up the Strait of Juan de Fuca line (JDF).

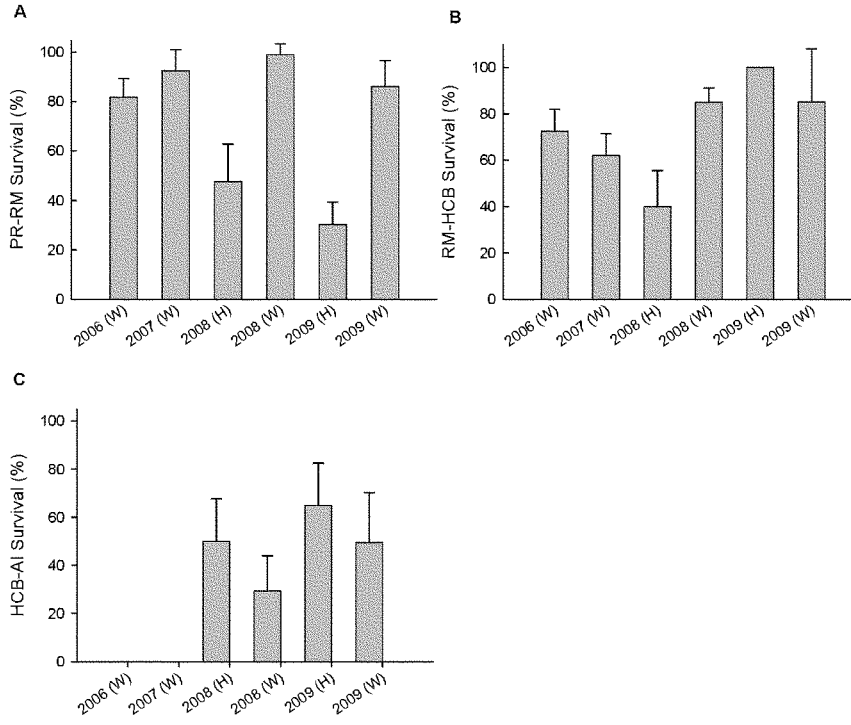

Figure 66. Bar chart showing survival rate estimates ± standard errors for three migration segments: (A) Point of release to river mouth (PR-RM), (B) River mouth to the Hood Canal Bridge (RM-HCB), and (C) Hood Canal Bridge to the Admiralty Inlet (AI) line (HCB-AI). The AI line was deployed in 2008, so no survival estimates to this point were made in 2006 or 2007.

Limiting Factors: Steelhead

Steelhead use freshwater habitats more extensively than any of the other anadromous salmonids found in the Skokomish Basin. In contrast, they appear to use estuarine habitat the least of the anadromous salmonids found in the Skokomish Basin. Based on their limited use of the estuary and the high survival through this habitat, freshwater habitats appear to be limiting steelhead in this basin.

The two habitat conditions that seem the most likely to limit steelhead production in the Skokomish Basin appear to be reduced lateral habitats such as side channels and the lack of pool habitat. Steelhead make extensive use of side channel habitat during the winter (Swales et al. 1986), which is lacking in the Skokomish system. In contrast to coho salmon, steelhead use off-channel ponds with fine substrate infrequently. Thus, although this type of habitat is abundant in the Skokomish Basin, it provides limited habitat for steelhead. The lack of side channel habitat would likely have the greatest impact on juvenile steelhead during fall and winter freshets.

The lack of pool habitat in the system would also impact juvenile steelhead during the winter. Juvenile steelhead prefer pool habitat during the winter, which provide refugia from high currents during the winter. However, pool habitat is lacking throughout the Skokomish Basin, especially in the critical fall and winter freshet season. Thus, one would expect winter survival to be impacted by this lack of preferred habitat.

Bull Trout

General Habitat Requirements

Although some stocks of bull trout are anadromous, they all make extensive if not exclusive use of fresh water habitats. In the Skokomish, they can be found in all reaches of the watershed below anadromous barriers (USFS, unpublished date, cited in Simpson 2000). On a micro habitat level, they generally prefer deeper water (33 cm) and slower velocities (9 cm/s) (Pratt 1984). Perhaps most important, compared to other salmonids, is their reliance on cold, well-oxygenated water (Goetz 1989). Bull trout generally occur in streams with temperatures less than 15°C (59°F), with spawning generally occurring in streams with temperatures below 9°C (48°F) (USFWS 2004). Dramatic increases in spawning migrations have been demonstrated above Lake Cushman on the North Fork Skokomish after fall water temperatures decline below 10°C (Brenkman et al. 2001.)

Bull trout in the Skokomish River watershed do not appear to be anadromous, based on otolith microchemistry (Larry Ogg, USFS, cited in Correa 2003) and therefore depend entirely on freshwater habitats throughout their life histories. However, it should be noted that some juveniles have been found in a screw trap in the lower river near the estuary, possibly indicating the existence of anadromy. Although apparently not a typical life history variation in the Skokomish at this point in time, it is important to note the extensive use of estuary, near shore, and open ocean habitats have been documented by Brenkman and Corbett (2005) and Brenkman et al. (2007) by bull trout of all sizes in other Olympic peninsula rivers. A healthy bull trout population would likely exhibit a broad continuum of migratory behaviors and thereby, habitat needs. In addition, bull trout are an apex predator, relying on healthy prey resources to support viable populations. Furthermore, juvenile salmon are generally their main prey source when

populations are sympatric (Beauchamp et al. 2001; Clarke et al. 2005). Therefore, recovering healthy salmon stocks could be an important step towards maintaining robust bull trout populations.

Bull trout generally require colder water than their salmon counterparts, and are found higher in the watershed. Populations above Lake Cushman have pristine habitat refugia available to them in Olympic National Park, and are not likely to experience any major factors limiting habitat in the foreseeable future, although the dams potentially act as barriers to migration of what could historically be anadromous or adfluvial populations. In addition, the population that spawns directly upstream of Lake Cushman may have fewer habitats available than they did historically due to the increased size of the lake as a result of the dam.

The South Fork Skokomish population is generally found upstream of a majority of the watershed's major disturbances. This area still has a high sediment load as a result of logging that may impact this population. Perhaps most importantly, logging may reduce the riparian cover near the stream channel thereby reducing LWD and pool frequency, and increasing stream temperatures. Also, bull trout redds are highly susceptible to scour as the smaller bodied individuals cannot bury their eggs as deep as salmon. Increased fine sediment supply from logging activities in the upper watershed can also effect egg-fry survival. Although the bulk of their population in the South Fork Skokomish lies upstream of the canyon section, they have been documented throughout the watershed and in a screw trap run by the Skokomish Tribe, and are therefore susceptible to previously mentioned factors affecting the lower watershed as well, such as low flows, high temperatures, and lack of pool habitat.

Adult

Three distinct stocks of bull trout exist in the Skokomish River watershed, a fluvial population in the South Fork Skokomish, a lacustrine-adfluvial population in Lake Cushman, and a fluvial population in the upper North Fork Skokomish. The two populations in the North Fork Skokomish are geographically isolated from the South Fork Skokomish stock by Cushman Dams #1 and 2 built by Tacoma Power (formerly City of Tacoma) in the 1920's and 1930's. All bull trout were listed as threatened under the ESA November 1, 1999. The SASSI report lists the status of both the South Fork Skokomish and upper North Fork Skokomish stocks as unknown, while the Lake Cushman stock is deemed to be healthy.

The Lake Cushman stock migrates into the North Fork Skokomish, below Staircase rapids (RKM 45.2 (RVM 28.1)), to spawn from late September through the end of December (Figure 67). Snorkel surveys conducted by WDFW (1971-1994) and the Park Service (1995-present) have occurred in different areas below and slightly above Staircase Rapids making different years difficult to compare, but both indicate stable populations (Figure 68). Snorkel surveys of the upper North Fork Skokomish (~RKM 49.09 (RVM 31)) in 1988 and 1995 both detected bull trout, but spawn timing or location remains unknown.

The USFS has monitored bull trout in the South Fork Skokomish and its tributaries since 1994 and indicates that they are present in the South Fork Skokomish proper and in Church, Pine, Cedar, LeBar, Brown, Rock, Flat and Vance Creeks. The highest concentrations of fish have been observed in the South Fork Skokomish from RKM 34.6 (RVM 21.5) to the falls at RKM 40.2 (RVM 25). Spawn timing is assumed to be mid-September through December but spawning locations are unknown. Bull trout have only been observed downstream of

anadromous barriers and therefore have access to this habitat throughout their life history. However, otolith microchemistry indicates that they are not anadromous (Larry Ogg, USFS, cited in Correa 2003), although more recently, emigrating smolts have been observed (SASSI 2006). Redd counts from RKM 29.8 (RVM 18.5) to RKM 38.2 (RVM 23.75) in South Fork Skokomish River and from RKM 0 (RVM 0) to RKM 1.6 (RVM 1.0) in Church Creek indicate a depressed, but stable population (Figure 69).

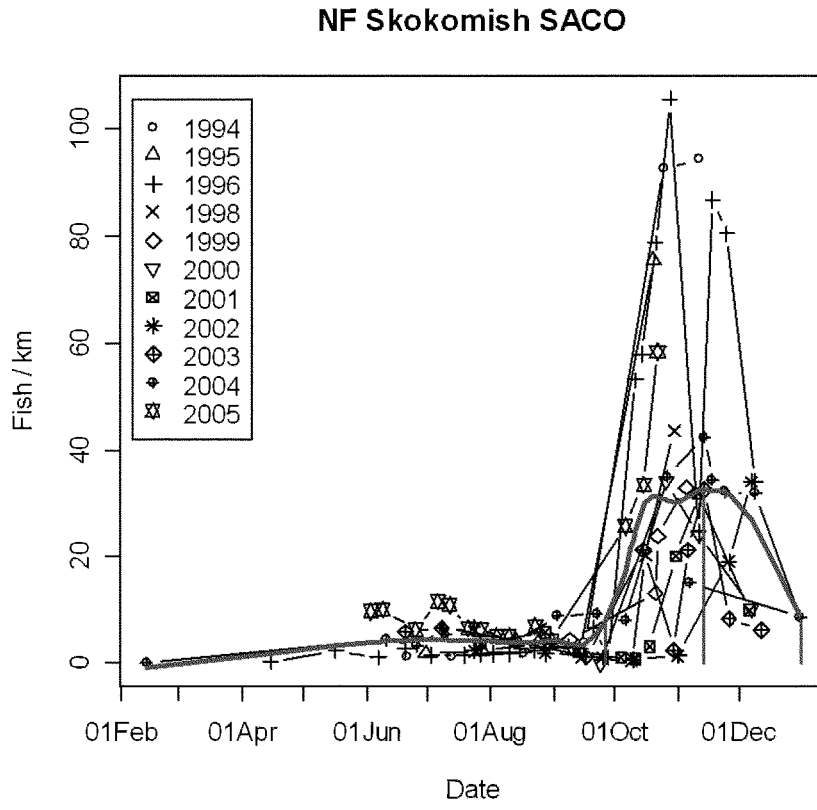

Figure 67. Onset, peak, and end of bull trout migration in the North Fork Skokomish River between Staircase and Lake Cushman (Sam Brenkman, Olympic National Park, unpublished data). The red line shows the mean onset (September 26), peak (November 14), and end (December 31) of bull trout migration.

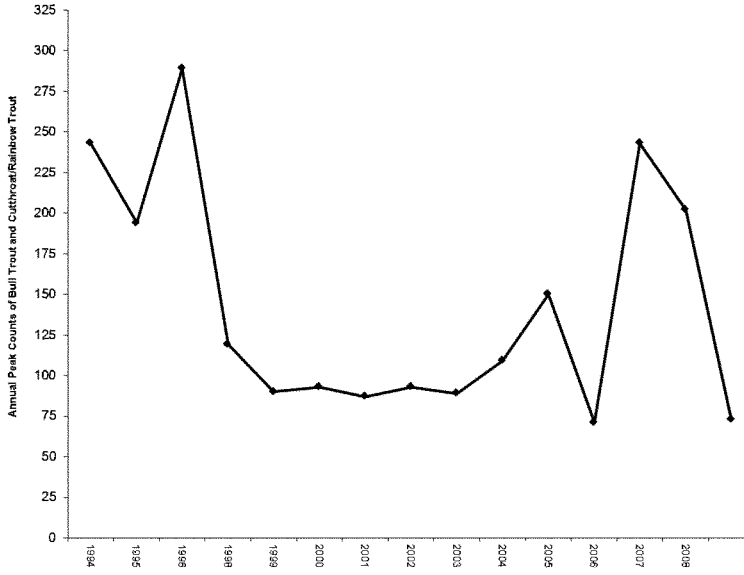

Figure 68. Annual peak snorkel counts in the North Fork Skokomish River, 1994-2009 (Sam Brenkman, Olympic National Park, unpublished data).

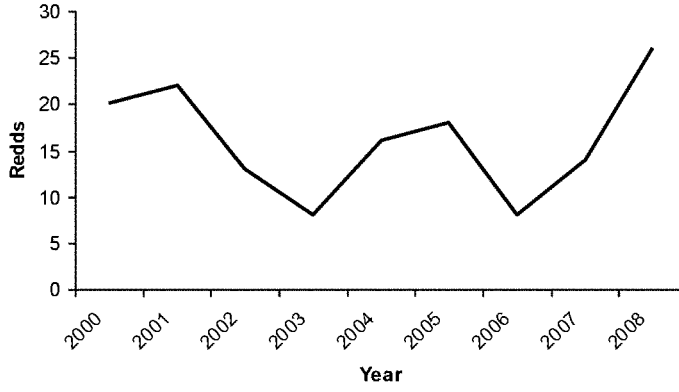

Figure 69. Adult bull trout redd counts from RKM 29.8 (RVM 18.5) to RKM 38.2 (RVM 23.75) in South Fork Skokomish and from RKM 0 (RVM 0) to RKM 1.6 (RVM1.0) in Church Creek. All data is from WDFW and publically available at http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm

There is limited data describing bull trout rearing densities in the Skokomish Basin. Brenkman (1998) assessed the distribution of bull trout in the North Fork Skokomish River using a combination of snorkeling and single pass electrofishing. Based on this information, bull trout appear to display only a lacustrine-adfluvial life history pattern in this area. They found no evidence of non-migratory bull trout in the Skokomish Basin. Bull trout are primarily observed from Staircase Rapids downstream to Lake Cushman and in the lower sections of Elk and Slate Creek. Based on these surveys, Brenkman (1998) suggest that bull trout are not present in the river or its tributaries above RKM 52. Dunham and Chandler (2001) present data for bull trout for 16 sites in the South Fork Skokomish and one site in Church Creek (Table 31). Bull trout were present in only 5 of 16 South Fork Skokomish sites and were not observed at the Church Creek site. Densities were less than 0.01 fish/m^2 at all sites where bull trout were observed.

We observed a total of 12 bull trout in 5 of the 21 riverine study reaches we sampled during the summer of 2008 and 2 bull trout in one of 23 riverine study reaches sampled during the winter. We did not observe bull trout in pond habitat during either survey. Based on the locations we observed bull trout, the channel type they were observed in, and the channel type of adjacent segments we estimated seasonal bull trout distribution (Figure 70). They were expected to be distributed throughout the Skokomish Basin during both the summer and winter based on our summer observations. We caught one bull trout during our winter survival survey at the USACE Vance Creek reach. This bull trout had a fork length of 132 mm.

Based on the numbers and distribution of bull trout observed during the summer, we estimated that a total of 115 bull trout (95% confidence interval: 42-207) bull trout were present in the anadromous portion of the Skokomish Basin. This represents a rearing density of 1.6 fish/km. No estimate was produced for the winter data due to the small number of fish and since we observed bull trout in only one reach. The summer estimate, when combined with the 2008 peak annual count for the North Fork Skokomish obtained by Olympic National Park personnel (202 fish, Sam Brenkman, Olympic National Park, unpublished data) provide a Skokomish Basin estimate for these two populations of 317 fish. This value is less than half the recovery goal for the Skokomish River (700 fish with an increasing trend) (USFWS 2004). Although snorkel estimates are known to underestimate population size, we took that into account and expanded our estimates by a factor of 1.5 based on bounded count expansion equations (See Appendix F for details of methods). Olympic National Park did not expand their estimates; suggesting that these estimates are low. Assuming a similar expansion factor would increase their estimates to 304 fish, resulting in a Skokomish Basin estimate of 419 fish, which is still substantially lower than the recovery goal.

We did not catch any bull trout during our outmigration or estuary sampling. Otolith microchemistry assessment of bull trout from the Skokomish Basin suggests that bull trout in this system do not display an anadromous life history pattern (Larry Ogg, USFS, Personal Communication, cited in Correa 2003). Although, the current evidence suggests that bull trout in the Skokomish River don't use the estuary. The apparent low abundance in the Skokomish Basin makes it unlikely that we would catch a bull trout during our sampling efforts even if they were present. In addition, extensive use of estuary, near shore, and open ocean habitats have been documented by Brenkman and Corbett (2005) and Brenkman et al. (2007) by bull trout in other Olympic peninsula rivers. Further assessment of bull trout in the system is warranted to fully address this issue.

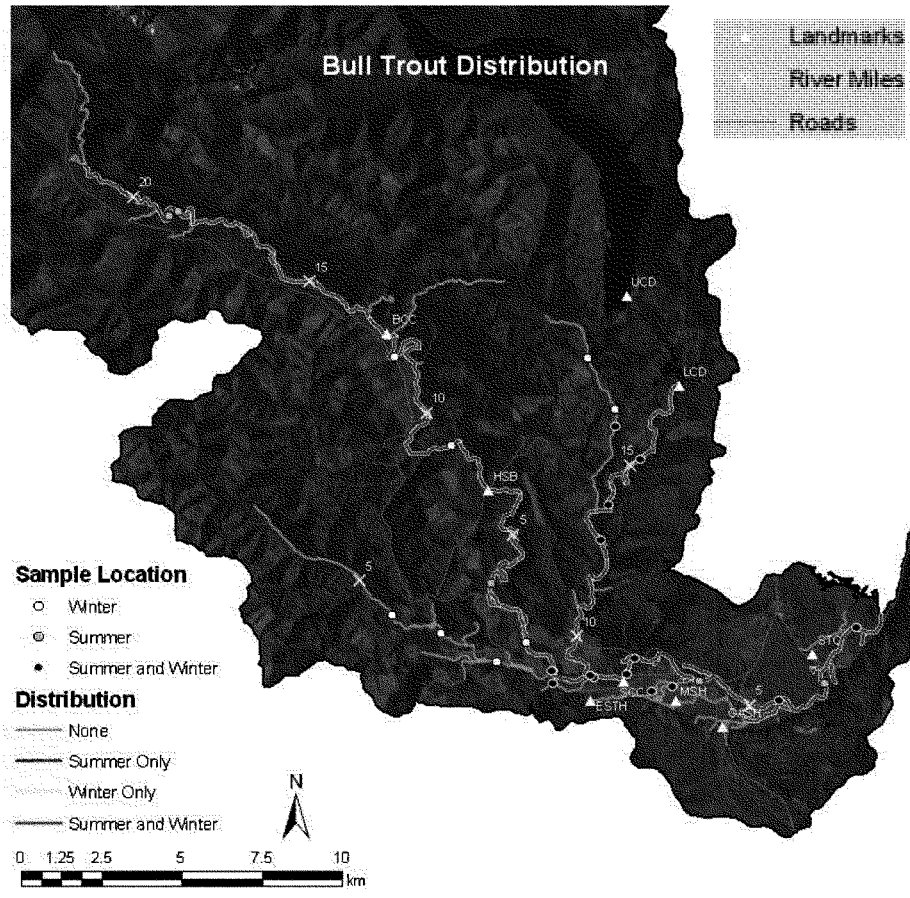

Figure 70. Expected bull trout distribution in the Skokomish Basin during the summer of 2008 and winter of 2009, based on observed distribution and reach characteristics (gradient and confinement). Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCD).

Table 31. Presence of all bull trout and densities of juvenile and adult bull trout observed in Church Creek and several sites in the South Fork Skokomish River (From Dunham and Chandler 2001), sites are shown in **Figure 62**.

			Density (per m^2)	
Stream	Site	Present	Juvenile	Adult
Church Cr	1	No	0	0
S.F. Skokomish	1	No	0	0
S.F. Skokomish	10	No	0	0
S.F. Skokomish	11	No	0	0
S.F. Skokomish	12	No	0	0
S.F. Skokomish	13	**Yes**	0	0
S.F. Skokomish	14	**Yes**	0	0
S.F. Skokomish	15	No	0	0
S.F. Skokomish	16	**Yes**	0	0
S.F. Skokomish	17	No	0	0
S.F. Skokomish	18	No	0	0
S.F. Skokomish	19	**Yes**	0	0
S.F. Skokomish	2	No	0	0
S.F. Skokomish	20	**Yes**	0	0
S.F. Skokomish	21	No	0	0
S.F. Skokomish	22	No	0	0
S.F. Skokomish	23	No	0	0

Cutthroat Trout

General habitat requirements

Coastal cutthroat trout exhibit a wide variety of migratory life history strategies including anadromous, potamodromous stream-dwelling and lake-dwelling (i.e., potamodromous fishes migrate entirely within freshwater, Myers 1949), and headwater stream-resident life history forms, all of which have age specific habitat requirements (Trotter 1989). Anadromous fish spawn in small tributaries from late winter through spring, with the peak in Washington being February (Hartman and Gill 1968; Trotter 1989). Spawning sites are generally not far from pools (Hunter 1973; Jones 1978). Juveniles remain in habitats along stream edges for the first few months after emergence and their densities may be affected by the availability of these lateral habitats (Moore and Gregory 1988). When they increase in size, they move to pools unless coho salmon are present, in which case they are driven to riffles (Glova and Mason 1976, 1977). They have also been shown to utilize floodplain pools and side channel habitat as winter refugia (Bustard and Narver 1975; Sedell et al. 1984; Hartman and Brown 1987). Several studies have reported mean depths and current velocities that cutthroat have been shown to occupy, with smaller fish utilizing depths of 32-54 cm and velocities of 10 – 14 cm/s, while

larger fish prefer deeper (54-62 cm) and faster (14-22 cm/s) areas, although all size classes have been shown to inhabit a wide range of depths and velocities (Thompson 1972, Hanson 1977, Pratt 1984). While feeding in-stream, cutthroat are drift feeders generally residing at the heads of pools (Wilzbach and Hall 1985). Age of seawater entry varies for anadromous cutthroat depending on the type of marine environment they enter. Juvenile cutthroat trout generally smolt after 2 years if they migrate to sheltered saltwater areas, but generally smolt after 3 or 4 if they migrate to the open ocean. However, juvenile cutthroat can smolt at any point from age 1 to 6 (Giger 1972; Lowery 1975; Trotter 1989; ; Johnson et al. 1999). Seaward migration peaks in May and the fish remain in shallow nearshore areas while in salt water. They generally spend only the summer at sea before returning to rivers in the next fall or winter after going to sea (Johnson et al. 1999). Headwater stream-resident cutthroat trout become sexually mature as early as age 2, but seldom live beyond age 4 or 5, rarely migrating more than 200 m from their birthplace (Trotter 1989).

Adults

We didn't find any information regarding adult cutthroat trout in the Skokomish system. We observed very few adult bull trout during our sampling and only in the off-channel ponds associated with the confluence of Purdy Creek with the mainstem Skokomish River.

Juveniles

Trout were observed in mainstem, tributary, and pond habitats. Although we did not separate trout into *O. mykiss* and cutthroat during our snorkel surveys, sampling for winter diet analysis suggest that cutthroat trout were more common in tributary and pond habitats (0 mainstem, 107 tributary, 17 pond). Others have also found that cutthroat trout tend to use pond habitats more than *O. mykiss*, especially if the bottom is composed of fine sediments. Based on this information, we assume that most of the trout observed in the ponds were cutthroat.

Cutthroat trout appear to prefer nearshore areas of off-channel pond habitats. Densities in the nearshore were greater than those in the offshore for zero-age trout during the winter, 1+ trout during summer and winter, 2+ trout during the winter, but not summer, and >3+ trout during summer and winter. Although the mean densities were differed, the confidence intervals generally overlapped, suggesting that the differences were not statistically different. This is likely due to the relatively small sample size and large variance estimates.

Other Historic Stocks (Pink and Sockeye)

While pink salmon and sockeye salmon are no longer found in the Skokomish Basin there potential for recolonization should be noted. Pink salmon are increasing exponentially in the North Pacific in general and Puget Sound specifically, providing a nearby source population for recolonization (Ruggerone 2010). In addition, a resident sockeye population persists behind Cushman dam as landlocked kokanee (Correa 2003). Although no plans to reintroduce them to the anadromous zone exist, they are likely genetic remnants of the original sockeye population in the Skokomish and thus could be a viable source stock if reintroductions were desired in the future.

Other Species

We observed 27 non-salmonid species in the Skokomish Basin and the Nalley Island portion of the estuary. The most abundant species included shiner perch, surf smelt, Pacific staghorn sculpin, three-spine stickleback, starry flounder, and Pacific sand lance (larvae). The most common species observed during our surveys are described below. For more detailed information on species and their abundance, please see Appendices G and H.

Lamprey

Western brook and Pacific lampreys were observed in our fish surveys. As Pacific, river, and western brook lamprey ammocoetes (larvae) are nearly indistinguishable from each other, we were unable to identify some juvenile lamprey captured in our surveys. Because river lamprey have been captured in other Puget Sound systems (Wydoski and Whitney 2003) and may exist in the Skokomish Basin, they are included in the summaries below.

Lampreys are a primitive group of fishes that are eel-like in form but lack jaws and paired fins (Moyle 2002). These species have a round sucker-like mouth (oral disc), no scales, and breathing holes instead of gills. Pacific lamprey is the largest of the three species, reaching lengths of 70 cm (McPhail 2007). Adult river lampreys vary in length from 16 to 30 cm, while Western brook are usually less than 16 cm long (McPhail 2007). Pacific and river lampreys are anadromous and parasitic, while the nonparasitic western brook lamprey normally spends it entire life in freshwater (Wydoski and Whitney 2003). Available information on the abundance, distribution, and stock status of lamprey species in western Washington is extremely limited and largely anecdotal. Data collected on juvenile lamprey is also often listed as "lamprey sp."

Western Brook Lamprey Life History

Information for western Brook Lamprey was pulled from Wydoski and Whitney (2003). Adult Western brook lampreys spawn in gravel bottomed streams in a riffle or at the tailout of a pool (McPhail 2007). Both sexes construct the nests, often moving stones with their mouths (Pletcher 1963). Spawning occurs from March to July and Western brook lampreys lay 1,100 to 5,500 eggs per adult female. After the eggs are deposited and fertilized, the adults typically die within 3 to 36 days. The newly hatched ammocoetes emerge about 10 days after spawning and drift into silty backwater areas (Pletcher 1963). They remain burrowed in the stream bottom, living as filter feeders on algae and detritus for 2 to 7 years. Metamorphosis to adult stage occurs from February through July, and at this time their gonads are not fully developed. They burrow into the stream substrate where they remain dormant through the winter months. In the spring, western brook lampreys emerge from their burrows sexually mature and remain in freshwater where they may migrate short distances to spawn (McPhail 2007). Western brook lampreys are nonparasitic and do not feed as adults.

River Lamprey Life History

The parasitic and anadromous river lamprey is genetically and morphologically similar to western brook lamprey, which overlaps in range. Except for the last 6 months to 1 year of life, the western brook lamprey and the river lamprey are indistinguishable from each other. Little information is available on river lamprey life history. According to Moyle (2002), their life span

is 6 to 7 years. Adult lampreys spawn in gravel bottomed streams, at the upstream end of riffle habitat. Both sexes construct the nests, often moving stones with their mouths. River lampreys lay 11,400 to 37,300 eggs per adult female. After the eggs are deposited and fertilized, the adults typically die within 3 to 36 days. After the eggs hatch, young ammocoetes drift downstream to areas of low velocity and silt or sand substrate. They remain burrowed in the stream bottom, living as filter feeders on algae and detritus for 2 to 7 years. Metamorphosis from the ammocoete to macropthalmia life stage occurs between July and April. At this time, macropthalmia are thought to live deep in the river channel, which may explain why they are rarely observed. As adults, their oral disc develops just before they enter the ocean between May and July. During the approximately 10 weeks they are at sea in the parasitic phase, they remain close to shore, feeding primarily on smelt, herring, and salmon near the surface (Beamish 1980). After the adult feeding phase, river lamprey return to freshwater, migrate to spawning areas, and cease feeding. Their degree of fidelity to their natal streams is unknown.

Pacific Lamprey Life History

Pacific lamprey is the most widely distributed lamprey species on the west coast of the United States. Historically, they are thought to be distributed wherever salmon and steelhead have occurred. Adult Pacific lampreys are parasitic and feed on a variety of fish. In the ocean, they have been caught in depths ranging from 300 to 2,600 feet, and as far off the west coast as 62 miles in the ocean. After spending 1 to 3 years in the marine environment, Pacific lampreys cease feeding and migrate to freshwater between February and June. Adults migrate upstream nocturnally (Potter 1980; Beamish and Levings 1991; Chase 2001) from late spring to fall (Luzier et al. 2006). They are thought to overwinter and remain in freshwater habitat for approximately one year before spawning, during which time they may shrink in size up to 20 percent (Fox and Graham 2008).

Pacific lampreys spawn in similar habitats to salmon; in gravel bottomed streams, at the upstream end of riffle habitat and at the tailouts of pools, typically above suitable young larvae (ammocoete) habitat (Mattson 1949; Pletcher 1963; Kan 1975). Spawning occurs between March and July depending upon location within their range (Wydoski and Whitney 2003). The degree of homing is unknown, but adult lampreys cue in on ammocoete areas. Ammocoetes release pheromones that are thought to aid adult migration and location of suitable spawning habitat. Both sexes construct the nests, often moving stones with their mouth (Pletcher 1963). Pacific lampreys lay 30,000 to 238,400 eggs per adult female (Kan 1975; Wydoski and Whitney 2003; Close et al. 2002). After depositing and fertilizing the eggs, the adults typically die within 3 to 36 days (Pletcher 1963; Kan 1975; Beamish 1980). Embryos hatch in approximately 20 days. Ammocoetes drift downstream to areas of low velocity and fine substrates (Stone and Barndt 2005) where they burrow, grow, and live as filter feeders for 2 to 7 years and feed primarily on microscopic plant and animal material (Wydoski and Whitney 2003; Beamish 1987). Several generations and age classes of ammocoetes congregate in high densities that form colonies. Downstream movement happens year round. Due to poor swimming ability, movement is probably driven by flow conditions and velocities (Moursund 2002). Movement is mostly nocturnal (Beamish and Levings 1991, White and Harvey 2003, Moursund et al. 2000) and correlated with discharge but not temperature (Hammond 1979; Potter 1980; Beamish and Levings 1991; Close et al. 1995). Metamorphosis to macropthalmia (juvenile phase) occurs gradually over several months as they develop eyes, teeth, and become free swimming.

Transformation from ammocoetes to macropthalmia typically begins in July to October (McGree et al. 2008). Juveniles emigrate to the ocean between late fall and spring where they mature into adults (Close et al. 1995; Kostow 2002).

Lamprey Habitats

Riffle and side channel habitats are important for lamprey spawning. Lamprey larvae are most abundant where the stream channel is relatively deep (0.4–0.5 m), gradient is low (<0.5%) and the riparian canopy is open (Torgerson and Close 2004). Ammocoetes rear in areas located near reaches where spawning occurred (Pletcher 1963). At finer scales, larval occurrence corresponds positively with low water velocity, pool habitats and the availability of suitable burrowing habitat (Roni 2002; Pirtle et al. 2003; Torgerson and Close 2004; Graham and Brun 2005). Ammocoetes are known to use slow depositional areas along streambanks and burrow into fine sediments during rearing periods (Pletcher 1963; Lee et al. 1980; Richards 1980; Potter 1980; Torgerson and Close 2004; Graham and Brun 2005; Cochnauer et al. 2006). Because lamprey ammocoetes colonize areas and are relatively immobile in the stream substrates, good water quality is essential for rearing. Potential threats to lampreys across their range include artificial barriers to migration, poor water quality, harvest, predation by nonnative species, stream and floodplain degradation, loss of estuarine habitat, decline in prey, ocean conditions, dredging, and dewatering (Jackson et al. 1996; Close et al. 1999; BioAnalysts, Inc. 2000; Close 2000; Nawa et al. 2003).

Summary of Lampreys Sampled

Most lampreys we captured or surveyed in the Skokomish Basin were identified as Western brook lamprey (Table 32). The majority of these lampreys were captured in outmigration surveys in 2008 and 2009 (Table 32 and Figure 71). Lamprey were also observed or captured during snorkel surveys and PIT tag surveys, while few numbers were captured at a lamprey weir operated on the main channel, in off-channel ponds, and while seining at a few snorkel sites (Table 32).

During the outmigration trapping period, a total of 204 Western brook lampreys were captured (Figure 71), ranging from 27 to 215 mm in total length. In 2009 when the entire outmigration period was sampled, catch peaked in late January and early February. The average fish size generally decreased during this trapping period, from around 130 mm in total length in late January, to around 85 mm during mid-July (Figure 72). Length frequency distribution of all fish captured in 2009 showed a wide of range of sizes; however, about half of all Western brook lampreys captured were between 110 and 150 mm in length (Figure 73).

We also observed Western brook lampreys during both summer and winter snorkel surveys. Between June and September 2008, an estimated 63 brook lampreys were observed in the mainstem, tributaries (Hunter and Vance Creeks), and the North Fork Skokomish (see Appendix F for details of sampling methods). Two unidentified lampreys were observed at the USACE SFV site, which were estimated to be 15 cm (6 in) and 45 cm (18 in) in length. Between February and April 2009, six brook lampreys were observed in the mainstem and the South Fork Skokomish.

During PIT tag surveys, a total of 25 lampreys were captured and measured. These fish were not identified to species. They ranged in size from 47 to 171 mm, and averaged 94 mm in

length. Additionally, we captured a total of 15 lampreys at a specially designed lamprey weir located near the screw trap from July 9 to July 29, 2009 (Table 32). Western brook lampreys caught at this site ranged in length from 80 to 153 mm, and averaged 135 mm. The Pacific lampreys ranged from 165 to 200 mm in length, and averaged 180 mm.

During summer pond surveys we observed four Western brook lampreys at site #14, three in the nearshore area and one in the offshore area, and one was also observed in the nearshore area at site #10. Two unidentified lampreys were observed at site #05 during winter surveys, one each in the nearshore and offshore areas. In addition, one brook lamprey (TL=130mm) was captured during seining at the North Fork Skokomish and South Fork Skokomish confluence in July 2008.

Based on our snorkel estimates, the efficiency of these estimates, and the percentage of habitat surveyed, we estimated Skokomish Basin population size for lamprey (see Appendix F for detailed methods). We estimated that 1,165 lampreys existed in the Skokomish Basin during the summer of 2008 and 30 lampreys were in the Skokomish Basin during the winter of 2009. The difference in estimates is likely due the life history patterns of brook lamprey. The summer estimates were completed from May through the summer and would have occurred when adult brook lamprey were spawning. We saw several pairs building nests during these surveys. However, brook lampreys burrow in the substrate during the winter (McPhail 2007) and thus would not have been visible during our surveys.

Table 32. Number of lampreys caught or observed during our sampling throughout the Skokomish River in 2008 and 2009.

			Length (mm)			
Surveys	Capture Date(s)	Number	Mean	Min.	Max.	Std. Dev.
Western brook lamprey						
Outmigration	6/11/2008 - 7/19/2009	204	123	27	215	32.9
Lamprey weir	7/17/2009 - 7/29/2009	9	135	80	153	23.1
Off-channel Ponds	8/21/2008	5	NA	NA	NA	NA
Seining	7/15/2008	1	130	NA	NA	NA
Pacific lamprey						
Outmigration	7/2/2008	4	157	136	175	20.4
Lamprey weir	7/9/2009 - 7/29/2009	5	180	165	200	14.6
Unidentified lamprey						
Outmigration	5/2/2009-7/17/2009	7	101	55	134	26.8
Lamprey weir	7/9/2009	1	120	NA	NA	NA
PIT Tag surveys	12/16/2008 - 3/3/2009	25	94	47	171	34.8
Off-channel Ponds	4/8/2009	2	NA	NA	NA	NA
Winter snorkel		30				
Summer snorkel	6/24/2008 - 9/18/2008	1,165 [a]				

[a] Estimated number based on expansion of snorkel estimates using bounded counts of observations. Most lampreys observed were identified as Western brook lamprey.

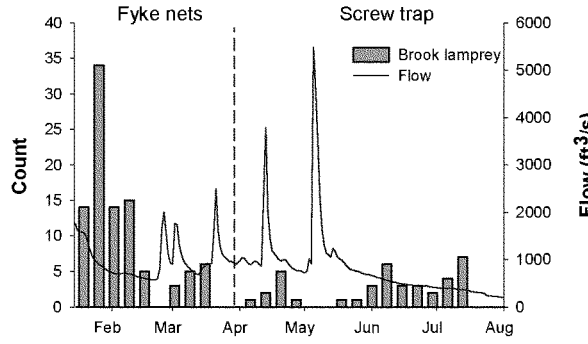

Figure 71. Weekly counts (first axis) of Western brook lampreys captured in fyke nets (6/11/08 - 3/17/09) and a screw trap (4/9-7/19/09), and daily average flow (second axis) of the Skokomish River in 2009. Flow data are from USGS gage 12061500 near Potlatch, WA.

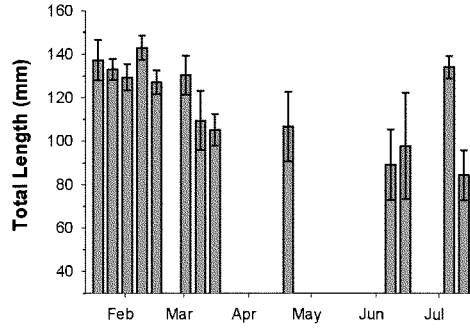

Figure 72. Weekly mean total lengths and standard errors of Western brook lampreys captured in fyke nets (1/21-3/17/09) and a screw trap (4/9-7/19/09) on the Skokomish River in 2009.

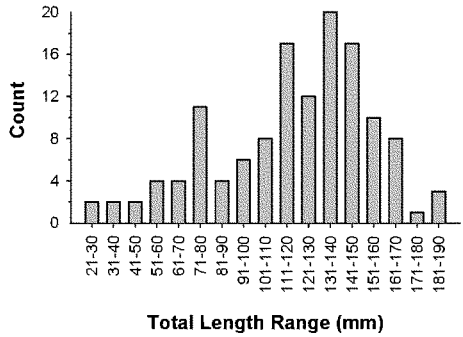

Figure 73. Length frequency distribution of Western brook lampreys captured in fyke nets (1/21-3/17/09) and a screw trap (4/9-7/19/09) on the Skokomish River in 2009.

Threespine stickleback (Gasterosteus aculeatus)

Threespine stickleback are small, relatively slow-moving fish that rely on spines and armoring to reduce predation risk. Across their native distribution, threespine stickleback inhabit a vast array of habitat types, from small streams to large lakes to the marine environment including the open ocean (McPhail 2007). Both resident and anadromous forms occur. Typically, they are found in slow waters in lower reaches of coastal streams and occur upstream to major fish barriers such as waterfalls. Often they are closely associated with aquatic vegetation. In the Skokomish Basin, they also inhabit a variety of habitat types from estuarine, riverine, and pond habitats. In both the estuarine and river samples, threespine stickleback were a minor component of the total number of fish observed (Table 33). However, 64% of all fish observed during pond snorkel surveys (winter and summer) were threespine stickleback. Five ponds were surveyed and they were observed in four ponds in the lower part of the Skokomish Basin but were absent from Pond #26 in the upper part of the Skokomish Basin. The upper extent of threespine stickleback in the Skokomish Basin is not well known.

Threespine stickleback commonly live for one year, spawn in May through August, and die shortly after spawning (Moyle 2002; Wydoski and Whitney 2003). However, a lifespan of 2-5 years is not uncommon (Baker 1994). Basic life-history information of threespine stickleback in the Skokomish Basin is not well known. We assume they successfully reproduce in the ponds and can complete their entire life-cycle in this habitat. Whether they spawn in riverine or estuarine habitats of the Skokomish Basin is unknown. Threespine stickleback in these habitats may just be fish that have been displaced downstream from the ponds. Length frequency data was only obtained from estuary seining and the screw trap. Screw trap caught fish were generally smaller than those caught in the estuary (Figure 74). Similar to other systems, threespine stickleback were usually less than 80 mm TL.

Table 33. Number of threespine stickleback and all other fishes surveyed during several types of sampling efforts, Skokomish Basin.

Location type	Sampling type	Number of stickleback	Number of other fishes
Estuary	Beach seining	281	58,396
River	Lamprey weir	2	237
River	Beach seine	0	189
River	Snorkeling	709	94,619
River	Fyke net	5	2,987
River	Screw trap	238	10,746
Pond	Snorkeling	5,788	3,212

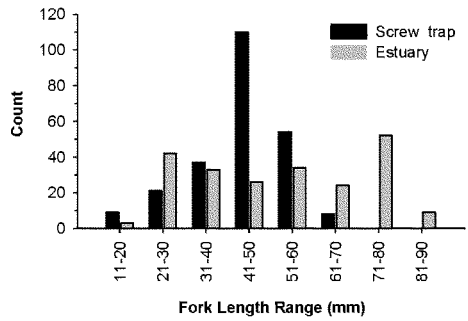

Figure 74. Length frequency of threespine stickleback collected in the estuary (n = 281) with beach seines and in the river (n = 238) with a screw trap, Skokomish Basin.

Freshwater sculpins Cottus spp.

Freshwater sculpins *Cottus* spp. are small benthic fishes that are an important component of freshwater ecosystems of the Pacific Northwest. In many habitats they are often the most abundant type of fish. A few different species often occur in the same watershed and are often spatially segregated (Tabor et al. 2007a). Within the Skokomish River, five species of freshwater sculpin have been documented which includes coastrange sculpin, prickly sculpin, riffle sculpin, reticulate sculpin, and shorthead sculpin (Mongillo and Hallock 1998). Prickly sculpin and coastrange sculpin typically inhabit the lower reaches with prickly sculpin inhabiting pools and other slow-water habitats while coastrange sculpin inhabit riffles and other fast-water habitats. Shorthead sculpin typically occur at higher elevations than the other four species. Riffle sculpin and reticulate sculpin usually occur in middle reaches in a variety of habitat types.

Riffle sculpin and reticulate sculpin are closely related and have not been clearly separated by existing morphometric characteristics (Wydoski and Whitney 2003). Therefore, whether they both occur in the Skokomish Basin is unclear. During our field collections, we referred to them collectively as one species, riffle sculpin. Kinziger et al. (2005) conducted genetic analyses of several sculpin species and found riffle sculpin and reticulate sculpin were unique species. However, the range and distribution of both species is in need of careful examination. For example, Wydoski and Whitney (2003) indicated the northern extent of reticulate sculpin is the Green River in Washington, while Moyle (2002) indicated that reticulate sculpin only extend north to the lower Columbia River. Reticulate sculpin appear to be widespread in many areas of western Oregon (Bond 1963) but their distribution in Washington is not well known. In contrast, riffle sculpin are known to be widespread in western Washington.

Freshwater sculpins were commonly encountered during fish surveys in the Skokomish Basin; however, most sampling efforts did not lend themselves for sampling and identifying freshwater sculpins. River and pond habitats were sampled primarily through snorkel surveys. Freshwater sculpins are small, cryptic, and often hidden in some type of cover and thus can be easily overlooked by snorkelers. Additionally, freshwater sculpins are difficult to identify while snorkeling and field crews just recorded them as unidentified sculpin. The only sampling technique that collected a relatively high percentage of sculpins was the lamprey weir, which collected several coastrange sculpin (Table 34). Freshwater sculpin are often abundant in complex habitats (e.g., riffles, woody debris, rip rap, undercut banks) that are best sampled with electrofishing equipment.

Table 34. Number of freshwater sculpins and all other fishes surveyed during several types of sampling efforts, Skokomish Basin.

		Number of fish				
Location type	Sampling type	Unidentified sculpin	Coastrange	Prickly	Riffle	Other fishes
Estuary	Beach seining	69	0	6	0	58,602
River	Lamprey weir	36	91	4	12	96
River	Beach seine	2	2	1	21	163
River	Snorkeling	3,672	0	0	0	91,206
River	Fyke net	2	1	10	1	2,978
River	Screw trap	10	5	34	3	10,932
Pond	Snorkeling	193	0	0	0	8,807

Coastrange sculpin (Cottus alecticus)

Coastrange sculpin occur in west coast streams of North America from California to Alaska (Wydoski and Whitney 2003). On the Olympic Peninsula, prickly sculpin are known to occur in most major drainages along the entire peninsula at an average elevation of 42 m (Mongillo and Hallock 1997). They are generally found in medium or large streams with a moderate to rapid current. Usually they inhabit areas with a cobble or gravel substrate. Coastrange sculpin also inhabit the shoreline and deeper benthic areas of lakes and occasionally are found in estuaries. In general, coastrange sculpin inhabit riffles, whereas, prickly sculpin inhabit pools and other slow-water habitat. However, in upstream reaches where no other sculpin exist, coastrange sculpin are found in both pools and riffles (Mason and Machodori 1976).

In most locations, the maximum size of coastrange sculpin is 115 mm TL (McPhail and Lindsay 1970) and few fish live past 5 years. In Oregon, coastrange sculpin spawn when they are three years old. However, in the Cedar River, Washington, coastrange sculpin < 60 mm TL have been observed with eggs, suggesting some fish may be sexually mature before age 3. Spawning takes place in the spring, sometime between February and June. Eggs are deposited under rocks and are adhesive, orange, and less than 1.5 mm in diameter. A male sculpin protects the nest and may spawn with several females. Fecundity ranges from 260 to 834, depending on the size of the fish. Larval coastrange sculpin are pelagic and do not become bottom-dwelling for 32-35 days after hatching (Scott and Crossman 1973).

Like other freshwater sculpins, coastrange sculpin appear to be opportunistic feeders. In streams and rivers, coastrange sculpin feed mostly on benthic invertebrates, particularly aquatic insects. During certain times of the year at some locations, fish eggs and small fish can make up a substantial portion of their diet (Roger 1971, Foote and Brown 1998).

Prickly sculpin (Cottus asper)

Prickly sculpin occur along the Pacific slope of North America from Seward, Alaska to Ventura River, California (Scott and Crossman 1979). Prickly sculpin typically only inhabit the lower reaches of most watersheds. On the Olympic Peninsula, prickly sculpin were collected at an average elevation of 23 m, the lowest average elevation of all cottid species (Mongillo and Hallock 1997). Prickly sculpin are commonly found in lakes, ponds, and quiet waters of rivers. In Lake Washington, prickly sculpin inhabit all depths, from the shoreline to depths > 60 m (Tabor et al. 2007a). Prickly sculpin can also be abundant in estuaries, they have been found in salinities as high as 24 ppt.

Prickly sculpin are the largest freshwater cottid in North America, attaining lengths above 220 mm TL (Tabor et al. 2007b). Some prickly sculpin become sexually mature at age 1 (12% in males, 50% in females) and by age 2 over 90% are sexually mature (Rickard 1980). Spawning takes place in the spring. In Washington, spawning usually occurs in April and May. Nests are usually under rocks or logs in areas with slow water velocities. A male sculpin protects the nest and may spawn with several females. Eggs are adhesive and slightly more than

1 mm in diameter. Fecundity ranges from 700 to 9,600, depending on the size of the fish (Rickard 1980). After hatching, the larvae remain pelagic for 30 to 35 days.

Prickly sculpin would best be described as opportunistic feeders. In most locations, they feed mostly on large benthic invertebrates. As prickly sculpin increase in size, they tend to select larger prey items. During certain times of the year at some locations, fish eggs and prey fish can make up a major portion of their diet (Tabor et al 2007b). Because there their size they can consume a variety of fish species. Because of their large size, they can consume a variety of fish species.

Riffle sculpin (Cottus gulosus)

Riffle sculpin occur in west coast streams of North America from California to Washington (Wydoski and Whitney 2003). On the Olympic Peninsula, riffle sculpin are known to occur in most major drainages along the south and west sides including the Sol Duc, Hoh, Queets, Quinault, Humptulips, Wynoochee, Satsop, and Skokomish at an average elevation of 108 m (range, 11-494 m; Mongillo and Hallock 1997). The riffle sculpin is commonly found in quiet waters and slow riffles of small streams and backwaters of large rivers (Tabor et al. 2007a). Riffle sculpin also inhabit ponds and small lakes. Riffle sculpin typically occupy the cool, upper reaches of streams, while prickly sculpin occupy the warm, lower reaches (Moyle 2002). It is found in areas having a variety of substrates, but generally in those with sand or gravel bottoms (Wydoski and Whitney 2003). The spectrum of stream habitats that riffle sculpin occupy is broadest when other sculpin species are absent (Moyle 2002).

Generally, the maximum size of riffle sculpin is 120 mm TL and few fish live past 5 years. Riffle sculpin in Conner Creek, Washington reached an age of 4 years, but most were less than 2 years old, with the average lengths about 35 mm TL for age 1 fish, and 66 cm TL for age 2 (Wydoski and Whitney 2003). It matures at two years of age and spawns in late February, March and April, with nests made in rotting logs and under rocks in swift riffles (Millikan 1968; Moyle 2002). A male sculpin usually protects the nest. Eggs are 2.5 mm in diameter, adhesive and pale yellow to deep orange. Fecundity ranges from 104 to 449, depending on the size of the fish (Bond 1963; Millikan 1976). Because their larvae are demersal and adults often have a restricted home range, riffle sculpin tend to disperse slowly. For example, Moyle (2002) noted that riffle sculpin in a small stream California took over 18 months to recolonize a riffle that went dry that was 500 m downstream of a large population.

Like other freshwater sculpin, riffle sculpin are opportunistic feeders. They feed on a variety of aquatic insects, isopods, amphipods and snails (Millikan 1968). Small fish and fish eggs are occasionally eaten.

Shorthead sculpin (Cottus confuses)

During our surveys, shorthead sculpin were never documented. However, this is largely because shorthead sculpin typically inhabit cool (< 16°C) headwater streams and we only conducted snorkel surveys in the upper Skokomish Basin and sculpins were not identified to species. We assume that many of the sculpins we observed in the upper part of the Skokomish

Basin were shorthead sculpin. In an earlier study, Mongillo and Hallock (1997) documented shorthead sculpin in the upper Skokomish Basin. They found shorthead sculpin inhabited higher elevations than any other non-game species on the Olympic Peninsula. When sympatric with other sculpins, shorthead sculpin appear to primarily inhabit riffles; however, they occupy a wide range of habitats (e.g., pools, ponds, lakes) when allopatric (Tabor et al. 2007a).

Shorthead sculpin occur in the Pacific drainage area of North America and are found in Puget Sound and Columbia River drainages in Washington. The northern range of shorthead sculpin in Puget Sound stops abruptly at the Snohomish River, which is probably due to historic glaciation patterns (McPhail 1967).

The maximize size of shorthead sculpin is about 130 mm TL. In general, shorthead sculpin will spawn during spring after maturing at age 2-3. Fecundity in shorthead sculpin (50-250 eggs) is considered low compared to other sculpin (Bond 1963). A few weeks after hatching, shorthead sculpin adapt a generally benthic lifestyle, which is maintained through the remainder of the fishes' life history. In most areas, the diet of shorthead sculpin consists almost entirely of aquatic insects.

Mountain whitefish (Prosopium williamsoni)

Mountain whitefish were never observed in any of our surveys of the Skokomish Basin anadromous zone. This result is surprising given that a population occurs in the North Fork Skokomish above Lake Cushman. Part of their distribution probably also includes Lake Cushman. Mountain whitefish are an abundant fish that are widely distributed along both slopes of the Rocky Mountains (McPhail 2007). Although primarily an inland species, they also occur in coastal rivers in western Washington along the west side of the Olympic Peninsula and east side of Puget Sound. The only location on the east side of the Olympic Peninsula that mountain whitefish occur is the upper North Fork Skokomish River. Why mountain whitefish do not occur in the anadromous zone of the Skokomish River is unclear. Possible explanations might fall into four categories: 1) poor forage conditions, 2) poor habitat conditions and frequent flood events, 3) a catastrophic event after which they were unable to recolonize, and 4) Skokomish River is not part of their historical distribution (i.e., they were introduced to the upper North Fork Skokomish).

1. Forage conditions – Mountain whitefish prey primarily on aquatic insects in rivers, while those in lakes prey on snails, zooplankton, and aquatic insects. Results of our benthic invertebrate surveys indicated that aquatic insects are abundant in the Skokomish River and there should not be any severe food limitation for mountain whitefish. Certainly, there should enough prey to support a small population of mountain whitefish.
2. Habitat conditions – Mountain whitefish display three basic life-history patterns: riverine, lacustrine, and adfluvial (McPhail 2007). Riverine populations typically occupy riffles during the summer and deep pools during the winter (Wydoski and Whitney 2003). The North Fork Skokomish population appears to be an adfluvial population that is in the river during the summer and overwinters in Lake Cushman (Figure 75). Having adequate overwintering habitat may a key element in the persistence of mountain whitefish

populations. Frequent flood events may severely reduce the quality of their overwintering habitat. Additionally, mountain whitefish spawn in the fall or early winter and frequent flood events could reduce spawning habitat. Mountain whitefish eggs are demersal and become lodged in between spaces of gravel and rubble (McPhail 2007). Therefore, mountain whitefish eggs may be more susceptible to scour events than other salmonids that dig deep redds.

3. Catastrophic event – Historically, a large spill of a toxic substance could have eliminated fish populations from a large portion of the Skokomish Basin. Other species could have easily recolonized because they are also found in other environments (i.e., small tributaries, upper reaches, marine environment). Mountain whitefish are found primarily in the mainstem and may have difficulty recolonizing. A catastrophic event would be most likely in a small, urbanized system. This would seem to be extremely unlikely in the Skokomish Basin because of its size and there are several major tributaries that would act a refuge for mountain whitefish. We are unaware of any major catastrophic event that could have eliminated the entire mountain whitefish population.
4. Historical distribution – On the Olympic Peninsula, mountain whitefish do not occur in the north and east watersheds, except for the North Fork Skokomish population. Perhaps this population is an introduced population. We are not aware of attempts to introduce mountain whitefish in Washington. Perhaps it was done accidentally as part of some other introduction in Lake Cushman.

Of the factors listed above, scour of eggs would seem the most likely mechanism that mountain whitefish could be eliminated from the anadromous zone of the Skokomish River. Also, it seems feasible that mountain whitefish are not native to the Skokomish River because they are not native to other areas of the east and north parts of the Olympic Peninsula.

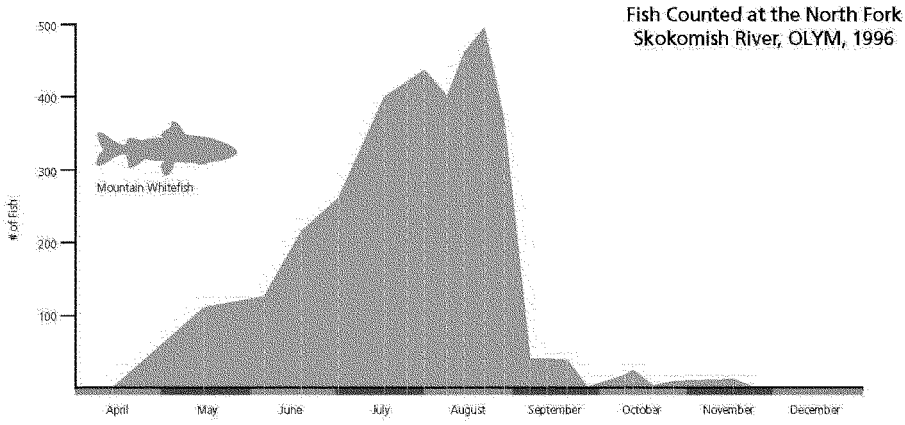

Figure 75. Number of mountain whitefish observed during snorkel surveys of the North Fork Skokomish River above Lake Cushman, 1996. Data and figure are from Sam Brenkman, National Park Service, unpublished data.

Shiner perch (Cymatogaster aggregate)

The shiner perch is a common species found in estuaries and bays of Puget Sound. It occurs primarily in nearshore shallow marine, bay, and estuarine habitats, both intertidally and subtidally (Emmett et al 1991). It also occurs in various coastal streams throughout Puget Sound (Wydoski and Whitney 2003). In our surveys, it was the most abundant species observed overall. Most fish were observed at the Nalley Island estuary, although two individuals were also observed during summer snorkel surveys at site 2-40, just upstream from the estuary and within the stream estuary ecotone. A total of 40,707 shiner perch (69% of total catch at the estuary) were captured by seine (Figure 76). From May through September 2009, it was the most dominant species at the estuary. Peak abundance occurred between late June and early July in 2009. The breach was the most productive location, where about 76% of the total was captured (Figure 77).

Shiner perch are live bearers. The young average 34 to 44 mm in total length at birth (Wilson and Millemann 1969) and adults can reach 200 mm in length (Wydoski and Whitney 2003). Among the subset of shiner perch we collected data from, fork lengths ranged from 27 to 134 mm (Figure 78), and mean fork lengths varied between 52 and 95 mm (Figure 79). Shiner perch less than 50 mm were observed only in June and July of both 2008 and 2009. Moreover, 75% of shiner perch captured during the occurrence of peak abundance in 2009 were in this size range. These figures suggest that June and July constitute the birthing season for shiner perch in the Nalley Island estuary.

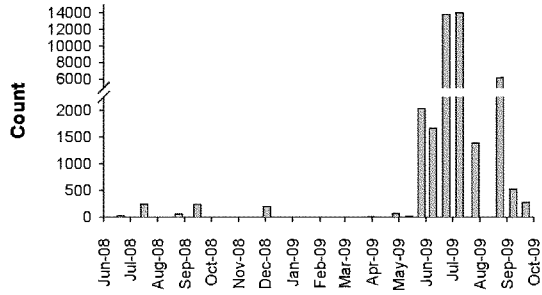

Figure 76. Timing of shiner perch captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

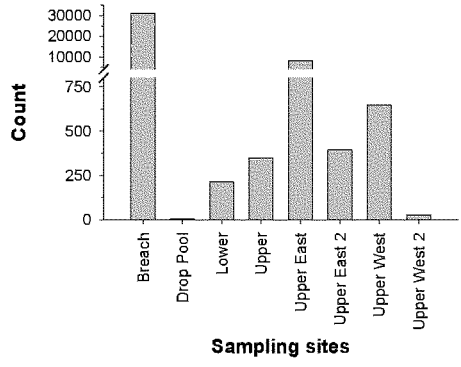

Figure 77. Shiner perch catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

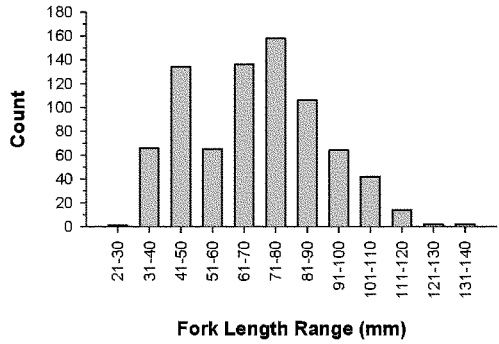

Figure 78. Length frequency distribution of shiner perch captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

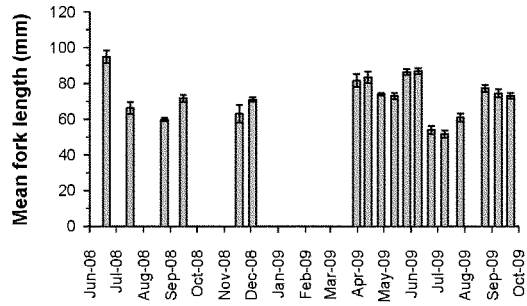

Figure 79. Mean fork length and SE of shiner perch captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Surf smelt (Hypomesus pretiosus)

The surf smelt is one of the most common forage fish species in the Puget Sound Basin. Larvae, juveniles, and adults can be found over a variety of substrates (Emmett et al. 1991), and adults use mixed sand and gravel beaches in many of the intertidal and shallow subtidal areas as spawning habitat (Penttila 2007). During our surveys, surf smelt were observed in the Nalley Island estuary and just upstream of the estuary. It was the second most abundant species observed at the Nalley Island estuary. A total of 9,552 surf smelt were captured by seine (Figure 80), mostly between October 2008 and March 2009, during which the species is also the most dominant species among all catches. Peak abundance occurred on January 2, 2009 when 6,854 (72%) surf smelt were caught. Population estimate based on mark-capture results indicated that over 200,000 surf smelt were present on that day. The Upper West 2 was the most productive site, where 61% of total was captured Figure 81). At site 2-40, we observed 287 surf smelt in July 2008 during summer snorkel surveys. Over the sampling period, fork lengths varied

between 40 and 169 mm (Figure 82), and mean fork lengths varied between 109 and 120 mm during the months from October 2008 through March 2009 (Figure 83).

In Puget Sound, surf smelt spawn throughout the year with heaviest spawning between June and September, and young-of-the-year surf smelt are virtually ubiquitous along shorelines (Penttila 2007). However, during our surveys, few fish (<20) were observed between June and September at the estuary, and over 94% of all surf smelt captured were adults (see size range in Emmett et al. 1991). It is unclear whether the Nalley Island estuary is used as spawning ground.

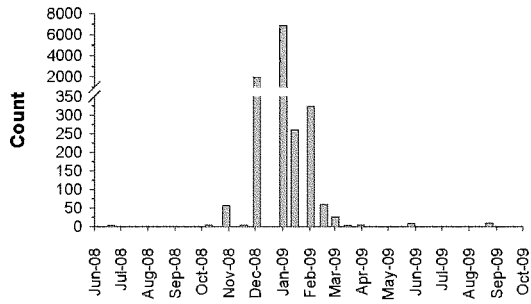

Figure 80. Timing of surf smelt captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

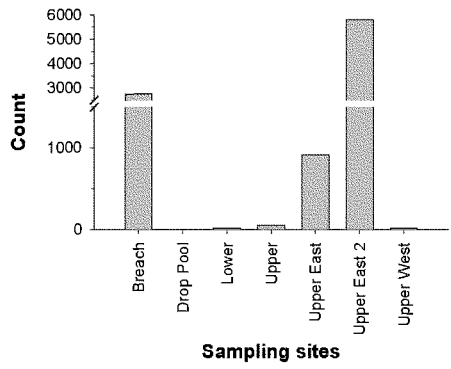

Figure 81. Surf smelt catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

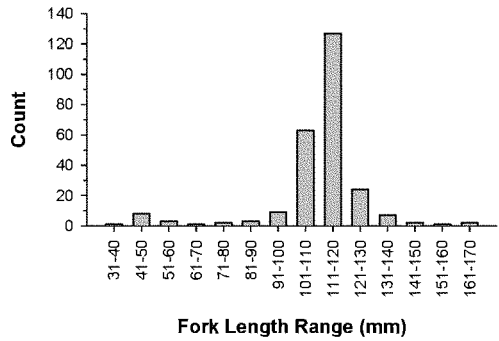

Figure 82. Length frequency distribution of surf smelt captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

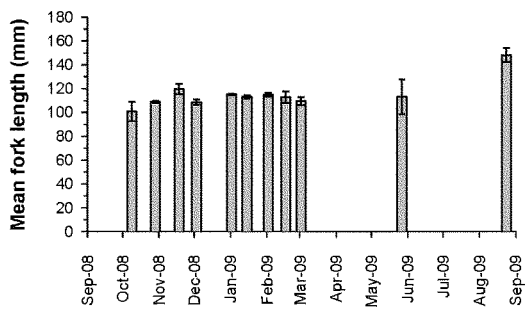

Figure 83. Mean fork length and SE of surf smelt captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Pacific staghorn sculpin Leptocottus armatus

The Pacific staghorn sculpin is a demersal species widely distributed in Pacific coast estuaries. Adults are usually found in the lower parts of estuaries, while juveniles are found in shallow water, riverine, estuarine, and marine habitats (Wydoski and Whitney 2003, Emmett et al. 1991). During our estuary surveys, it was the most frequently encountered species, present on all but one sampling date. Most staghorn sculpin (2,872) were observed in the estuary between June 2008 and September 2009 (Figure 84), while one fish was also captured in the screw trap on the mainstem in May 2009. Catches were low between August 2008 and March 2009, and substantially higher between April and July 2009. Peak abundance occurred in May and June 2009. The staghorn sculpin were captured at all eight seining sites, and about 40% were captured at the breach (Figure 85). Total lengths varied over a wide range, from 12 to 212 mm

(Figure 86). Mean total lengths increased gradually in 2009, from 24 mm in March to 134 mm in September (Figure 87). The lone staghorn sculpin captured in the screw trap measured 130 mm.

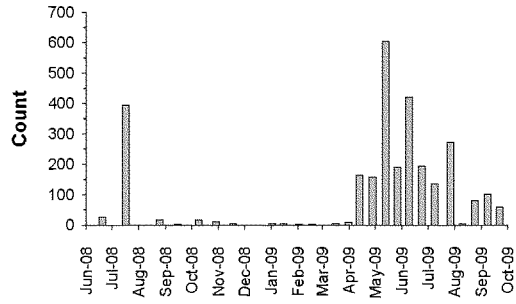

Figure 84. Timing of Pacific staghorn sculpin captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

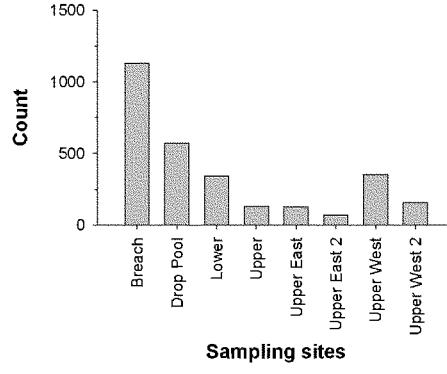

Figure 85. Pacific staghorn sculpin catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

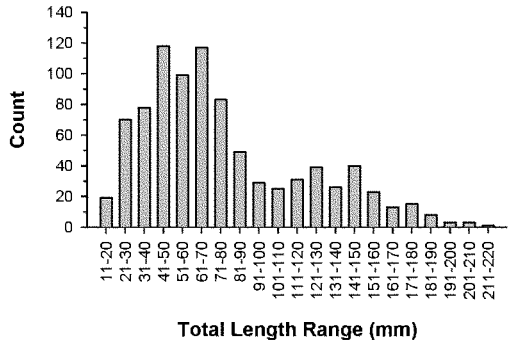

Figure 86. Length frequency distribution of Pacific staghorn sculpin captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

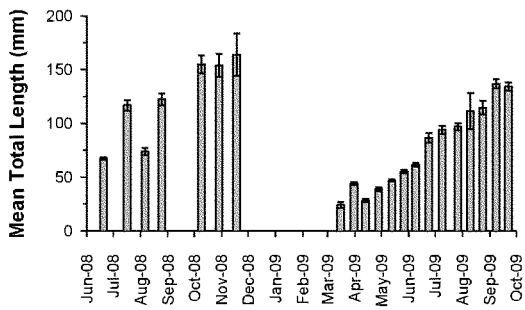

Figure 87. Mean total length and SE of Pacific staghorn sculpin captured in the Nalley Island portion of the Skokomish River estuary between Jnne 2008 and September 2009.

Starry flounder (Platichthys stellatus)

The starry flounder is the most abundant flatfishes in many Pacific coast estuaries north of San Francisco, California (Emmett et al. 1991). The species can tolerate a wide range of salinities, and is found in a variety of habitat types (Wydoski and Whitney 2003). During our surveys, we observed starry flounder in the Nalley Island estuary, the mainstem Skokomish River, and one downstream pond (Table 35). At the estuary, a total of 270 starry flounder were captured between June 2008 and September 2009 (Figure 88). The fish were present on most sampling dates, and were captured at all eight sampling sites (Figure 89). Overall, total lengths ranged from 19 to 226 mm, and the dominant size range appeared to be between 61 and 80 mm (Figure 90). Mean total length gradually increased from 48 in June 2008 to 130 mm in October

2008, and then decreased to 48 mm in June 2009 (Figure 91). The catch was dominated by juveniles and small adults (see size range in Emmett et al. 1991).

On the mainstem Skokomish River, 77 starry flounder were observed at two sites, 2-23 and 2-40, both just upstream of the Nalley Island estuary. Two starry flounder were also captured in the screw trap during outmigration trapping in 2009: one (FL=56 mm) in late June, and one (FL=60 mm) in mid-July. The location of the screw trap represented the upriver extent of the starry flounder observed in our surveys.

During pond surveys, two starry flounder were observed at site #05 in the nearshore transect in September 2008, while three more were observed at the same site in the offshore transect in April 2009.

Table 35. Abundance of starry flounder observed during surveys at Skokomish River in 2008 and 2009.

Location type	Sampling type	Starry flounder total
Estuary	Beach seine	270
Pond	Snorkel	5
River	Snorkel	77
River	Screw trap	2
		354

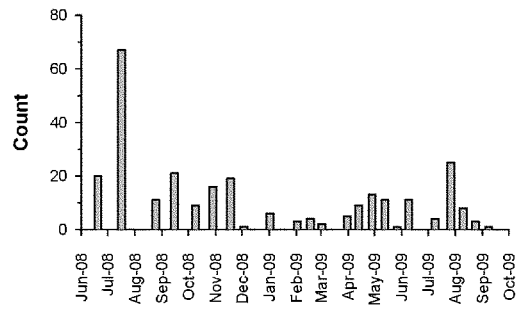

Figure 88. Timing of starry flounder captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

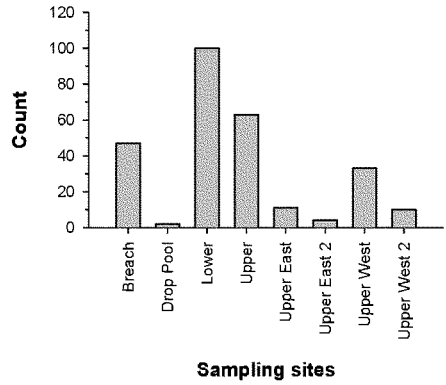

Figure 89. Starry flounder catches at different sampling sites on the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

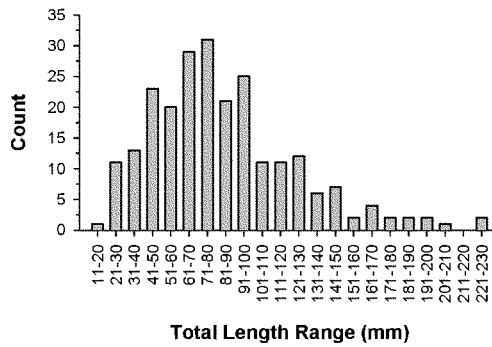

Figure 90. Length frequency distribution of starry flounder captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

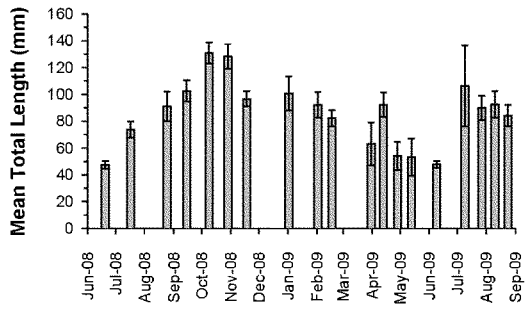

Figure 91. Mean total length and SE of starry flounder captured in the Nalley Island portion of the Skokomish River estuary between June 2008 and September 2009.

Hatcheries

In addition to the habitat limiting factors described above, it is important to acknowledge an anthropomorphically controlled biological factor which impacts native salmon in the Skokomish watershed, hatcheries. There are three hatcheries in the watershed, although only two produce anadromous salmon, George Adams (on Purdy Creek) and McKernan (on Weaver Creek). These facilities currently release hatchery Chinook, coho, and chum salmon into the Skokomish Basin as on-station fry and smolt releases. However, they historically out-planted fry into the Skokomish Basin in addition to the on-station releases. Significant out of basin stocks have been reared and released into the Skokomish watershed. The George Adams facility began production in 1961 and has used three out of basin Chinook stocks and eight out of basin coho stocks. In recent years, it releases approximately 3.8 million Fall Chinook each May, and 300,000 coho each April. The McKernan hatchery began producing chum fry in 1979 and currently releases 8.5 million chum fry each April and 35,000 steelhead. These large releases of juvenile salmon enter the system at the same time as naturally produced individuals and are a significant source of competition, especially the Chinook, coho, and steelhead as they will reside in the stream for at least several months and potentially a full year or more (reviewed by Einum and Fleming 2001; Weber and Fausch 2003; Jonsson and Jonsson 2006; Kostow 2009). In addition, large numbers of hatchery juveniles may increase predation on wild fish by artificially elevating predator populations (Steward and Bjornn 1990; Collis et al. 1995; Nickelson 2003). Large releases of hatchery fish from an overcrowded environment could potentially increase the rate of disease in wild populations (Hedrick 1998; Scramm and Piper 1995). Finally, hatchery fish that return as adults may not return to the hatchery and successfully spawn with wild fish, potentially reducing the fitness of wild offspring (reviewed by Hard et al. 1992; Naish et al. 2007). Hatchery fall Chinook, in particular, stray in large numbers to the lower South Fork Skokomish and Vance Creek (SASSI 2006).

Limiting Factors and Restoration Recommendations

As discussed above, salmon habitat issues in the Skokomish Basin can generally be categorized into four different types: habitat loss, and the reduced connectivity, stability, and quality of remaining habitat. The main factor resulting in habitat loss is the migratory barrier created by the Cushman hydro project. Additional habitat loss, and reduced habitat connectivity, stability, and quality of the remaining habitat are impacted by several factors. This includes the combination of the physical nature of the Skokomish Basin, increased sediment inputs resulting from land clearing and logjam removal, reduced hydraulic capabilities of the river resulting from water diversion, and river and floodplain constrictions (i.e., levees and bridges). These factors have resulted in too much sediment entering the river channel and reduced the rivers ability to transport that sediment, which has resulted in channel aggradation, altered channel morphology and degraded habitat conditions for both humans and fish in the Skokomish Basin.

The relative importance of these different habitat issues can be inferred based on the biological communities in the Skokomish Basin. Biological community structure has long been used to assess the health of ecological systems (Cairns and Pratt 1993). Periphyton and macroinvertebrate communities structure specifically were used to assess the health of the Skokomish Basin. However, there is additional information to be gleaned from the fish community structure as well. This section consolidates the information from the periphyton and macroinvertebrate assessment with an assessment of the fish communities in the Skokomish Basin to further assess the system and potential restoration measures.

Based on primary and secondary producers, the ecosystem health of the Skokomish Basin is relatively good. However, some metrics from these assessments could indicate habitat issues that would impact the fish community in the Skokomish Basin more than they would primary and secondary producers. Long-lived macroinvertebrate taxa were depauperate in a significant number of areas, especially in the South Fork Skokomish and lower mainstem. This may be due to lack of interstitial spaces caused by high embeddedness, lack of habitat complexity, bed scour, or lack of wood boles used as refugia by these taxa. Embeddedness was quite low at the sites we surveyed, suggesting that this factor likely was not responsible for the poor condition of long-lived taxa.

The percentage of the macroinvertebrate community composed of shredders was also relatively low. Shredders feed on allochthonous organic inputs derived from the riparian forest. There low abundance suggests that riparian cover is lacking or that habitat complexity and or logjams that would retain this material is lacking, which is supported by our habitat data collection. The loss of the vegetated islands and widening of the active channel described by the Skokomish Tribe and WDFW (2010) would result in reduced availability of allochthonous inputs. In addition, this would result in greater solar radiation reaching the channel which would generally benefit primary and secondary production (reviewed by Chamberlain et al. 1991). This could in part explain why the periphyton and macroinvertebrate metrics examined generally suggest the system is relatively healthy despite aggradation which would suggest otherwise.

The status and trends in the salmonid community offer some additional insight into the health of the system. Spring Chinook salmon are extinct in the Skokomish Basin due to the

combination of numerous habitat factors (i.e., dams, altered hydrology, etc.). Fall Chinook salmon escapement has been stable but low, a trend that may be partially due to hatchery fish spawning in the system. The production resulting from these spawners appears to be relatively low based on our assessment. This suggests that egg to fry survival may be low. This would result from eggs being smothered by fine sediment or scouring during winter storms (i.e., unstable channel). Scour is known to be a problem in rivers with excess sediment in the channel (Tripp and Poulin 1986, Devries 2000). Scour would be exacerbated by low flows during the fall Chinook spawning season that would result in fish spawning closer to the thalweg; increasing their susceptibility to scour.

Two of the three chum salmon stocks in the system are listed as healthy, while the other is extinct. Summer chum salmon are listed as extinct, while lower river fall and upper river late chum salmon are listed as healthy. The primary differences among these three stocks are adult run and spawn timing, emergence timing, and timing of estuarine residence. Summer chum enter the river during the late summer and early fall, compared to late fall and early winter for the fall chum salmon. This timing is similar to adult Chinook salmon, which could result in incidental harvest targeted at Chinook. In addition, they would be impacted by low flows and dewatered channels (i.e., South Fork Skokomish and Vance) during spawning in a manner similar to fall Chinook. This could isolate them from important spawning habitat and/or require them to spawn closer to the thalweg, thereby increasing their susceptibility to redd scour. Fall chum salmon would avoid this potential limiting factor, especially upper late fall chum, which has the highest spawning concentrations in the North Fork Skokomish. The North Fork Skokomish would be expected to have more stable spawning habitat as a result of reduced high flows which are metered by Cushman dam.

Since chum salmon rarely rear for extended periods in freshwater habitats, emergence timing is roughly synonymous with estuary entry. Summer chum would emerge earlier than fall chum and would therefore enter the estuary much earlier. Thus, differences in estuarine conditions could result in the observed differences in stock status. Since both stocks would be exposed to the same physical estuarine habitat conditions, some other factor such as food availability would have to be the cause of the differences observed in stock status. Since summer chum salmon historically thrived in this environment, one would expect that food availability was not an issue historically. It's unclear if the habitat alterations in the estuary would result in seasonal changes in food availability. Based on this, it appears that isolation from spawning habitat and channel stability resulting in increased scour of redds is the likely factor causing the differences in stock status of chum salmon in this system.

Coho salmon are listed as healthy in the Skokomish Basin. It's unclear if this is partially the result of hatchery strays as has been noted for Chinook salmon. Coho salmon spawn relatively late in the system which would help reduce the potential for their redds to scour. However, they rear for at least a year in the freshwater environment and thus would require high quality rearing habitat. We observed apparent significant reductions in the number of juvenile coho salmon in the system between the summer of 2008 and winter of 2009. This suggests that winter rearing habitat may limit coho salmon production in the system. This is surprising given the extensive wetlands in the lower river. We were surprised by the apparent low densities of juvenile coho salmon rearing in these off-channel ponds relative to densities observed in other systems. This may be due to the level and frequency of overbank flows in the system and the level to which they impact pond habitats. Although coho smolts use the estuary less than either

Chinook or chum salmon, coho fry may use the stream-estuary ecotone extensively (Miller and Sadro 2003). We observed significant numbers of coho salmon in the stream-estuary ecotone and the estuary of the Skokomish River. Estuary conditions do not appear to be limiting this species based on their overall status.

Skokomish River steelhead have been listed as depressed and are part of the greater Puget Sound steelhead that were listed as threatened under ESA. Steelhead generally spawn later in the spring and therefore would be less susceptible to scour than Chinook salmon or summer chum. However, their extended freshwater rearing requirements would make them very susceptible to reduced rearing habitat quality including low summer flows, reduced channel complexity, and disconnection from the floodplain and riparian zone. Steelhead could also be susceptible to scour while rearing. Juvenile steelhead hide in the substrate during the day in the winter when stream temperatures are cold and emerge at night. This behavior, if displayed during flooding, could lead to scouring impacts to juveniles hiding in interstitial spaces in the substrate. We observed relatively high reductions in successive age classes of trout during our surveys; however, these reductions were not as severe as those observe in juvenile coho salmon. Steelhead smolts are generally not as dependent on the estuary as Chinook and chum salmon. Steelhead smolts in the Skokomish passed through the lower river and through lower Hood Canal relatively quickly, suggesting they are not very dependent upon the estuary in this system. In addition, steelhead survival through the estuary was high, suggesting that estuarine conditions are not limiting this species.

Bull trout are listed as threatened under ESA throughout its range in Washington State, and their populations are depressed in the Skokomish Basin. Bull trout spawn in the fall and thus would be susceptible to redd scour. They also are the salmonid most dependent upon freshwater rearing habitat and thus would be susceptible to degraded habitat conditions. Bull trout, as an apex predator, would also be susceptible to factors impacting their food source, namely other fish in the Skokomish Basin. It's unclear how dependent bull trout are on estuarine habitat in the Skokomish Basin. No bull trout have been determined to display an anadromous life history pattern in the Skokomish River. However, the prevalence of this life history pattern in other bull trout populations on the Olympic Peninsula and Puget Sound suggest that bull trout in the Skokomish River likely display this life history pattern and we have simply failed to detect that strategy with our limited sampling.

Based on this evaluation it appears that channel stability, and habitat connectivity and quality are the main factors limiting salmon production in this system. The two stocks extirpated from the system, summer chum and spring Chinook were most susceptible to habitat loss (i.e., dams), reduced habitat connectivity, channel stability, and reduced habitat quality. In terms of stocks still present in the watershed, winter steelhead and fall Chinook are classified as depressed in SASSI, and along with bull trout are listed as threatened under ESA. Of these stocks, steelhead and bull trout would be most impacted by habitat loss associated with Cushman dam. Bull trout and Chinook salmon would be susceptible to reduced connectivity during the early fall and scouring of their redds. All three species rely on in-stream habitats, especially steelhead and bull trout and would therefore rely on habitat connectivity, especially during the winter. Fall Chinook would be the only species that was heavily reliant on the estuary.

Coho and fall chum are the only two stocks in the watershed listed as healthy. The main portion of the stock contributing to coho's status are the North Fork Skokomish populations,

which spawn in an area with relatively high channel stability as a result of flow management at Cushman dam. Fall chum basically forgo rearing in fresh water and spend extended periods of time in the estuary on their way to sea. Based on the status of various stocks, certain conclusions regarding habitat quality in the system can be drawn. First, species that rely heavily on both in-stream or estuary habitats (i.e., chum, Chinook), with the exception of fall chum, are depressed and/or extinct, indicating severe degradation of both habitats. Second, the spawning location and timing of the only fresh water reliant species listed as healthy, coho, is largely in the North Fork Skokomish. This indicates that this portion of the watershed probably has the most stable habitat, or conversely, the South Fork Skokomish is the most degraded of the two major forks of the Skokomish.

Finally, the healthiest stock in the Skokomish Basin, fall chum, does not use in-stream habitat extensively for rearing. Although the other estuary dependent species, fall Chinook, is classified as depressed, it also relies on in-stream habitat and spawns during a period that makes redd scour a significant threat. Therefore, it appears as though the estuary environment of the Skokomish is not as degraded, in terms of limiting salmon production, as the watershed's freshwater habitat

The healthiest stocks in the Skokomish Basin, coho and late fall chum, generally spawn after a significant risk of scour from fall floods has past. The depressed and extinct stocks in the Skokomish Basin; summer chum, spring and fall Chinook; all place their eggs in the gravel before the potentially catastrophic fall floods scour their redds. The scarcity of long-lived macroinvertebrate taxa also suggests that bed scouring is an issue. In addition, early fall migrating salmon, are exposed to high water temperatures, low dissolved oxygen, and potentially dewatered sections of river. Based on this phenomenon it can be inferred that aggradation in the lower river, which causes both an unstable channel and high winter flows is a major factor limiting salmonid production in the Skokomish river.

Based on our literature review, the biggest data gap related to characterizing salmonid populations remaining to be addressed in the Skokomish River and the factors that influence them is the lack of information on incubation and juvenile salmonids. Data is basically limited to information from a year of sampling outmigration by both a panel trap and netting in the estuary by the Skokomish tribe and two years of smolt trapping by NOAA, although that was focused only on juvenile steelhead. In addition, the extent to which hatchery origin fish are spawning in the wild is incompletely known and could be significant. The remainder of this report will focus on closing the data gap concerning juvenile production and outmigration timing in the Skokomish. Wild and hatchery fish interactions are beyond the scope of this study.

Information compiled in this report point to four major issues related to habitat productivity in the Skokomish Basin including habitat availability, channel stability, habitat quality/complexity, and connectivity. Habitat availability is significantly reduced relative to historic levels as a result of dam construction, loss of side channel habitat, and channel straightening. Channel stability (i.e., bed scour) was listed as a significant threat to several organisms that have low population levels in the system, including long-lived macroinvertebrate taxa, summer chum, fall Chinook, steelhead, and bull trout. Habitat quality/complexity was listed as a likely factor influencing every species evaluated in this report except Spring Chinook and summer chum. However, this was due simply to the weight given to other factors (i.e., dams, scour) impacting these two species. Habitat quality appears to be degraded in both

freshwater and estuarine environments; however, it appears to be worse in freshwater environments. Finally, habitat connectivity appears to increase the impacts of the habitat quality and scour, and impacts overall habitat availability.

Habitat and stock restoration recommendations for the Skokomish Basin need to consider the effects of future climate change. Relatively small changes in winter temperatures can shrink the transient snow zone appreciably; altering runoff patterns and the severity of peak flows (Cuo et al. 2008). Since the transient snow zone in the Skokomish Basin is relatively large, one would expect a relatively large change in precipitation from snow to rain to occur in the future (Knowles et al. 2006), resulting in a concurrent shift in runoff from spring and summer to mid-winter and associated increases in peak flow magnitude. This hydrologic change will subsequently influence sediment transport and channel stability which will influence what restoration activities are conducted and how they are designed. For example, restoration of spring Chinook in the South Fork as proposed by the Skokomish Tribe and WDFW (2010) may not be possible given the hydrologic changes which may not be appropriate for spring migrating salmon.

We recognize that several other authors and groups have made habitat restoration recommendations for the Skokomish Basin (i.e., Correa 2003, Skokomish Indian Tribe and WDFW 2010, HCCC 2010). The recommendations made in this report will be combined with those recommendations by the USACE and its partners to develop a final proposed list of habitat restoration projects. We also recognize that several restoration projects have already been completed in the Skokomish Basin. We point these out below as we describe and prioritize our recommendations.

Based on our assessment, we have concluded that factors influencing channel aggradation have the greatest impact on the fisheries resources of the Skokomish Basin. Channel aggradation has resulted in habitat loss, reduced channel stability and complexity have been identified as impacting biological communities in the system. Although habitat loss as a result of Cushman dam is significant, it influences only spring Chinook and steelhead. Flow alterations resulting from the Cushman Project have had a greater overall impact on the fisheries resource compared to loss of habitat as a result of the dam. In addition, the newly signed Cushman agreement provides for upstream and downstream passage of adult and juvenile salmon using trap-and-haul techniques. Thus, the highest priorities for restoration activities is given to projects that would reduce sediment input to stream channels, stabilize sediment already in the active channel, and providing sufficient hydraulic energy to route this sediment effectively.

This does not mean that other restoration projects are not valuable; they just weren't prioritized as highly as the projects described above. For example, the development of floodplain channel network in the vicinity of Hunter and/or Weaver Creeks could provide valuable fish habitat, provide for escape routes for fish pushed into the floodplain during overbank flow events, and potentially lower the water table during the summer. This channel network would require substantial riparian planting to ensure that water temperature issues didn't arise due to the smaller channels and potentially increased exposure to solar radiation. Although there is value it these types of projects, they simply don't address impaired physical processes in the watershed and thus were not prioritized as highly as the projects described above.

Table 36 lists our prioritized restoration projects for the Skokomish Basin. We rank the watershed processes as follows: 1) improved hydraulic energy for sediment transport, 2)

reducing sediment inputs, 3) stabilizing active channel sediment, and 4) increasing habitat complexity. However, prioritization of the individual projects did not follow this process order due to the assumed benefits of those projects relative to projects addressing other processes. The individual projects are discussed below based on process ranking.

Improving the river's hydraulic energy to transport sediment can be accomplished by either increasing the water available to transport sediment, by eliminating channel and floodplain constrictions that result in backwatering during flooding, or by hastening the conversion of the braided channel morphology back to an island-braided morphology with lower width to depth ratio. Water availability has historically been controlled by the Cushman project. However, the recent settlement has provided for minimum summer flows and 'normative' flows during winter. Thus, improvements have been made to the amount of flow available to transport sediments. This leaves removal of hydraulic constraints in the lower Skokomish Basin and reduced width to depth ratios as the only remaining factors that need to be addressed with regard to increasing the rivers hydraulic energy for sediment transport.

Several levees and dikes severely constrain the river and its floodplain. The greatest constrictions occur around Nalley Island, HWY 101, downstream of the Church Dike (constrained against the valley wall), and downstream of the old North Fork Skokomish Confluence (Figure 92). A substantial portion of the constrictions at Nalley Island have been removed. The west side levees were removed in 2007, while all levees except those at the upstream end of Nalley Island were removed in 2010. This remaining levee still results in a significant constriction to the eastern channel at the upstream end of Nalley Island. Ideally, this constriction would be eliminated. This would require the mainland levee to be removed or setback as the remaining section of the Nalley Island levee protects sites of historical significance on the island. This would be our highest priority levee removal/setback project, since a channel constriction at this location will set the gradient and subsequent sediment transport regime for the river upstream.

The second (# 2 on Figure 92) priority for removing channel and floodplain constrictions would be the section at the old North Fork Skokomish confluence. Although we recognize that other channel constrictions lower in the system will set the gradient and associated sediment transport capabilities upstream, this constriction is by far the worst. It also occurs at a very poor location geographically in the river, the confluence of three main drainages (i.e., South Fork Skokomish, Vance Creek, old North Fork Skokomish). The area upstream of this location also shows the worst level of channel instability.

The third priority would be the area just downstream of the Church levee (# 3 on Figure 92). The levee constrains the river against the valley wall at this location and there is evidence of channel instability above this location. Finally, the floodplain fill associated with HWY 101 (#4 on Figure 92) would be the final floodplain constriction to be addressed. There is evidence that this fill and the constrictions resulting from the bridges result in backwatering; however, it does not appear to be as critical as the constrictions discussed previously. In addition, there is limited evidence of channel instability upstream of this location.

Although the primary purpose of eliminating these hydraulic constrictions is to improve sediment transport processes, there will be additional benefits to fisheries resources in the system. These projects will improve habitat connectivity as well. Removal of the Nalley Island levees will dramatically increase the effective estuary size of the Skokomish and Hood Canal

Basins. Although fish have been able to access Nalley Island recently as a result of a levee breach, they were required to navigate to the seaward side of the island and then migrate upstream through the breach. Leaving the island also required them to migrate through this breach. We observe coho fry during our summer sampling at Nalley Island. These fish would be expected to migrate upstream during the winter and rear in the main river channel or off-channel ponds (Miller and Sadro 2003). However, this migration route would have been made difficult as a result of these levees. Similar effects would be expected for estuarine dependent Chinook and chum salmon. Removal or setback of the remaining levees will also increase connectivity with lateral habitats and/or promote their development.

Table 36. Prioritized habitat restoration recommendations from this project describing the project type, process addressed, location, and expected effect.

Priority	Project Type	Process Addressed	Location	Expected Effect
1	Hydrologic Restoration	Hydraulic energy	Cushman Dam	Increased sediment transport capabilities, reduced aggradation, and increased channel stability
2	Remove channel, floodplain constrictiou	Hydraulic energy	1 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
3	Remove channel, floodplain constriction	Hydraulic energy	2 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
4	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	Vance Creek	Reduced sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
5	Remove channel, floodplain constriction	Hydranlic energy	3 on Figure 92	Increased sediment transport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
6	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	South Fork Skokomish and Vance Creek	Reduced sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
7	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	Old North Fork Skokomish Confluence	Reduce sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
8	Stabilize Active Channel Sediment/Increase Habitat Complexity	Sediment Input	South Fork Skokomish	Reduce sediment inputs, improved sediment transport and storage in the channel, reduced aggradation, increased channel stability, increased riparian function, increased habitat complexity
9	Remove channel, floodplain constriction	Hydranlic energy	4 on Figure 92	Increased sediment trausport capabilities, reduced aggradation, increased channel stability, increased habitat connectivity
10	Decommission high risk roads	Sediment Input	South Fork Skokomish and Vance Cr.	Reduced sediment inputs to the river channel, reduced aggradation, increased channel stability and complexity
11	Stabilize eroding slopes	Sediment Input	South Fork Skokomish and Vance Cr.	Reduced sediment inputs to the river channel, reduced aggradation, increased channel stability and complexity

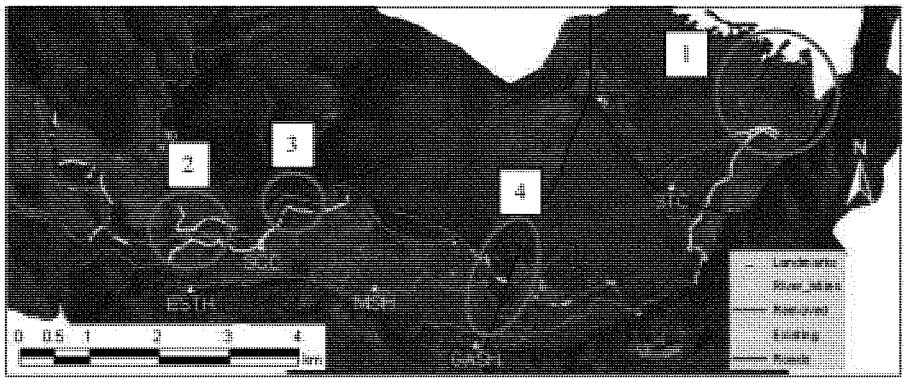

Figure 92. Locations (red circles) where channel and floodplain constrictions likely result in backwatering and reduced hydraulic energy for sediment transport. The red lines reflect levees that have been removed, yellow shows existing levees, and black shows highways with associated fill across the floodplain. The numbers represent our prioritization for restoration work. Landmarks, marked by triangles include, the Skokomish Tribal Center (STC), George Adams Salmon Hatchery (GASH), McKernan Salmon Hatchery (MSH), Skokomish Community Church (SCC), Eels Springs Trout Hatchery (ESTH), High Bridge (HSB), Browns Creek Campground (BCC), Lower Cushman Dam (LCD), and Upper Cushman Dam (UCM).

Reducing sediment inputs to the channel was the second priority process to restore. The focus of this effort would be to stabilize sediment inputs arising from mass wasting in the upper South Fork Skokomish and Vance Creek. The individual projects were ranked lower here, due to the fact that significant work has already been accomplished in the upper Skokomish Basin (Anderson et al. 2007). However, it's unclear exactly how much work remains to be accomplished relative to what has been done. Further analysis of this information will be required during the alternatives selection and evaluation portion of the Skokomish GI.

In our opinion, the final two project types, stabilization of active channel sediment and increase habitat complexity could be addressed using the same tool. We propose the use of Engineered Logjams (ELJs) to stabilize sediments in the active channel with the ultimate goal of developing mid-channel vegetated islands separated and intersected by side channels. We propose three locations for this activity including Vance Creek below the canyon, the old North Fork Skokomish confluence, and the South Fork Skokomish below the canyon (Figure 93). Additional sites would be beneficial and potentially better than the proposed projects; however, their proximity to houses and infrastructure would require either property acquisition and/or owner cooperation. For this reason, we have not included those locations in the proposed project list. In addition, the proposed sites often go dry during the summer, which would permit construction in the 'dry' which would greatly reduce construction impacts to fisheries resources.

The prioritization of the ELJs was based on the fact that although these projects may achieve greater long-term benefits, they present greater potential risks to resources and adjacent property. Thus, we propose to complete the Vance Creek site first, due to its smaller channel size and distance from houses and infrastructure. The North Fork Skokomish confluence was

selected second based on this same criteria. If these projects prove successful, then the final South Fork Skokomish site could be constructed with more confidence. Additional sites could be developed in the South Fork Skokomish and lower mainstem based on the combined success of these three projects. Given the experimental nature of these projects, we suggest that extensive geomorphic, hydraulic, physical habitat and biological monitoring be completed to assure the desired results are obtained and information is gained to improve subsequent projects.

Several design factors must be considered for ELJ installations with the objectives we've proposed. We describe some of these considerations below; however, the design and construction of these projects should be completed following careful geomorphic and hydrologic assessment. Our proposed design (Figure 94) would be to build large bar apex jams (Abbe and Montgomery 1996) at the upstream end of the proposed island locations. The purpose of these jams would be to stabilize the existing sediment and allow for sediment deposition and vegetation growth downstream of the jam (Abbe and Montgomery 1996). Meander jams would then be built along the proposed channel route to help create meandering channels and protect banks from eroding. Relatively large meander jams would be built at the upstream and downstream end of the developed side channel. The purpose of the upstream jam would be to meter flow through the side channel during flooding and maintain flow during low flow periods. The downstream jam would serve to maintain a pool at this location to ensure the channel doesn't fill in and become isolated from the main channel.

Figure 93. Proposed locations (red circles) for engineered logjam (ELJ) installations designed to stabilize active channel sediments, and develop vegetated islands and side channels (i.e., habitat complexity). Landmarks, marked by triangles include the Skokomish Community Church (SCC).

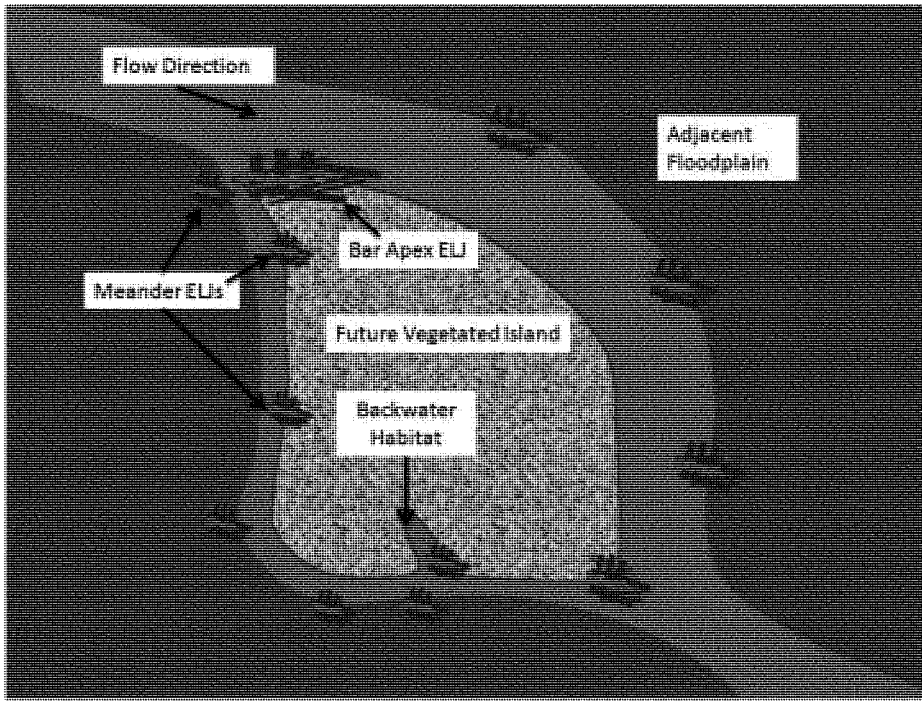

Figure 94. Conceptual design for engineered logjam use to stabilize active channel sediments, promote vegetated island development, and create side channels (i.e., create habitat diversity). The design is conceptual only and would require specific geomorphic and hydrologic evaluation by trained professionals in those fields and is beyond the expertise of the authors and scope of this project.

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SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX B

PUBLIC SCOPING COMMENTS

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

Skokomish General Investigation Study Public Scoping Summary Report

December 2010

US Army Corps of Engineers

Prepared By:

EnviroIssues, Inc.

Tetra Tech, Inc.

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Chapter 1. Introduction

Purpose of Report

The US Army Corps of Engineers (Corps); Mason County; and the Skokomish Indian Tribe, the non-Federal Sponsors; are preparing for the preparation of an Environmental Impact Statement (EIS) for the Skokomish General Investigation (GI) Study in Mason County, Washington. This scoping report describes the public scoping process for the Skokomish General Investigation Study and summarizes the comments received through that process. Included in this report are a brief project history, project purpose, description of alternatives being considered, documents related to the scoping process, and verbatim copies of all comments received.

Project Background

The Skokomish River channel has been filling with sediment for several decades, resulting in frequent flooding and decreasing natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat throughout the Skokomish River Basin. Increased sediment load, reduced flows, and encroachment of the floodplain by man-made structures are leading to continued degradation of natural ecosystem functions and habitat. The degraded riverine and estuarine aquatic habitat has caused a decline in the population of critical fish and wildlife species, including multiple Endangered Species Act (ESA) listed species. Additionally, the channel capacity of the Skokomish River varies significantly. Limited channel capacity causes floodwater to leave the banks at various locations, ultimately causing frequent flooding of local roads, two state highways, agricultural fields, residences, and other structures.

The Skokomish River General Investigation is a basin-wide study; however, numerous constraints limit Corps' involvement to actions primarily in the lower Skokomish River Valley. Problems, opportunities, and objectives will be examined within the context of the entire watershed. Recognizing the relationships between the upper and lower watershed will ensure a comprehensive study overview.

The initial project goals are to:

- Identify impairments to the aquatic ecosystem of the Skokomish River Basin
- Identify flood risk
- Identify and evaluate potential solutions
- Determine federal interest in implementing solutions
- Recommend actions to resolve aquatic ecosystem and flood risk management impairments

Project Purpose

The purpose of the EIS and feasibility study is to evaluate if there is a federal interest in aquatic ecosystem restoration and flood risk management in the Skokomish River Basin.

Study Area

The Skokomish River Basin (Basin) is located in northwest Washington, predominantly in Mason County. The project study area is comprised of the entire drainage basin, including the estuary. The river collects drainage from an approximate 240-square mile drainage basin, and eventually flows into southern Hood Canal, an arm of Puget Sound. The river flows out of three sub-basins (South Fork, North Fork, and Vance Creek) into a broad, flat alluvial plain known as the Skokomish Valley. The Skokomish Indian Reservation is located in the valley along the southeast portion of the Olympic Peninsula. The Basin is defined by the Water Resource Inventory Area (WRIA) 16 and is located within US Congressional District #6 of Washington State. See Appendix A for a map of the study area.

Project Alternatives

The EIS will evaluate build alternatives for aquatic ecosystem restoration and flood risk management as well as a No Action Alternative. Build alternatives that will be evaluated under aquatic ecosystem restoration will include an alternative that uses physical actions to restore the Skokomish basins' habitat-forming processes and/or create habitats that have been lost as a result of historic alterations. Example of actions that could occur under this alternative include: increasing floodplain habitat and connectivity, restoring off-channel habitat for juvenile fish, improving estuarine functions and processes, and increasing emergent and riparian vegetation. Another build alternative that will be considered will focus on benefits to the several listed aquatic species under the Endangered Species Act. Actions under this alternative could include creation of spawning and rearing areas, and additional fish supplementation. The No Action alternative will also be evaluated.

One alternative for flood risk management includes evaluation of the current levee system. Actions under this alternative may include setback levees to improve flood containment. Another alternative would study the effects of sediment removal and actions would include: sediment traps, dredging, and selective gravel removal. Another alternative would focus on nonstructural actions such as flood proofing and education. The No Action alternative will also be evaluated in the EIS.

A range of ecosystem restoration and flood risk management actions will be investigated and more than one option may be included in the Preferred Alternative identified in the EIS. Additionally, a number of potential ecosystem restoration projects could meet ancillary flood risk management goals.

National Environmental Policy Act Requirements for Scoping

The National Environmental Policy Act (NEPA) emphasizes public involvement in government actions affecting the environment by requiring that the benefits and risks associated with the proposed actions be assessed and publicly disclosed. In accordance with NEPA public involvement requirements, opportunities were presented for the public to provide oral or written comments on potentially affected resources, environmental issues to be considered, and the agency's approach to the analysis. Efforts to involve the public in preparing and implementing NEPA procedures included holding and providing public notice of a NEPA-related public scoping meeting, soliciting appropriate information from the

public, and explaining procedures of how interested parties can get information on the NEPA process. A summary of the public involvement activities are provided in the document, including comments received and other underlying documents involved in the public scoping period.

Public Involvement Process

The Corps conducted a public outreach effort as part of scoping, including official notifications, display ads, and the mailing of postcards to the project mailing list, including Skokomish basin landowners.

- A federal **Notice of Intent (NOI)** was published in the Federal Register on September 24, 2010.
- A **postcard** announcing the scoping period and public meeting was:
  - Mailed to residents and stakeholders on the Corps project list and Mason County Assessor property owner data. Postcards were received two weeks prior to the meeting.
  - Mailed to relevant agency and tribal contacts.
- **Print display advertisements** were placed in the following publications approximately three weeks prior to the meeting:
  - Daily Journal of Commerce (9/15/10)
  - Kitsap Sun (9/15/10)
  - Shelton-Mason County Journal (9/16/10)
- A **single point of contact** was provided on all communication materials.
- Outreach materials included **Skokomish Project fact sheet, comment form** and **NEPA fact sheet.**
- The **public scoping meeting** was held at an accessible and central location in the project area.

Notice of Intent

NEPA requires that scoping begin with the publication of a Notice of Intent (NOI) to prepare an environmental impact statement. The NOI for the Skokomish General Investigation Study was published in the Federal Register on September 24, 2010 (see Appendix B). The NOI described the project background, project purpose, project alternatives, public involvement effort, scoping meeting details and environmental review coordination efforts. The NOI also started the scoping period that ended on October 25, 2010. A copy of the NOI is included in Appendix B.

Public Scoping Meeting

A public scoping meeting was held on Thursday, October 7, 2010 within the project area at Mason County Public Works, 100 West Public Works Drive, Shelton, Washington. An open house ran from 4:00 p.m. to 7:00 p.m., with a presentation and opportunity for formal public comment at 5:30 p.m. The public scoping meeting aimed to provide an overview of the Skokomish General Investigation Study, identify project purpose and need, identify preliminary measures, and describe the NEPA process.

The public scoping meeting was announced through postcards that were mailed to nearly 300 contacts, including Skokomish residents, businesses, agencies and tribes. A copy of the postcard is included in

Appendix C. In addition, display ads were placed in the Daily Journal of Commerce, Kitsap Sun, and Shelton-Mason County Journal several weeks prior to the meeting. A copy of the display ad is included in Appendix D.

US Army Corps of Engineers, Mason County, and Skokomish Indian Tribe staff were available during the open house portion of the public meeting to discuss the project and answer questions. Several handouts were available for meeting attendees including the meeting agenda (Appendix E), fact sheet on the NEPA process (Appendix F), and Skokomish Project fact sheet (Appendix G). Additionally, a comment form for meeting attendees to provide feedback was available and attendees were encouraged to leave their comments at the meeting or send the comment form by mail to the address provided. A copy of the comment form is provided in Appendix H. Approximately 40 people attended the public scoping meeting. The sign-in sheets are included in Appendix I.

Various display boards were presented at the open house, including an outline of the project phases, a map of the Skokomish General Investigation study area, description of problems and opportunities, potential measures or solutions, 2-year and 100-year flood maps, and a 1938 aerial photo of the Lower Skokomish River. Copies of the display boards are included in Appendix J.

The Corps and Mason County gave a 30-minute presentation on the Skokomish General Investigation Study. Larry Scudder with the Corps began the presentation with an overview of the study area, Skokomish River problems, and the purpose of the study. Larry described the potential project outcomes, including reduced flood risk and flood damage, restoration of productive farm and agricultural usage, restoration of Skokomish Basin processes and habitats, and creation of spawning and rearing areas beneficial to resident and endangered species.

Rich Geiger, Mason County, presented information on the preliminary measures. He said a management measure is defined as "either a structural element that requires construction or assembly on-site, or a non-structural activity." Rich described the potential management measures the project may have including mainstream measures, sediment measures, infrastructure measures, estuary measures, and non-structural measures. Rich acknowledged other ongoing projects in the basin, including the Skokomish Tribe and Forest Service project to improve salmon habitat and changes in Cushman Dam operations.

Pat Cagney with the Corps explained the NEPA process and its requirements. He said the NEPA process evaluates different project alternatives, presents the analyses of potential environmental effects of the proposed actions, and provides opportunities for public comment during scoping the draft EIS and final EIS. Pat emphasized that meeting attendees' input is valuable and encouraged them to submit comments by, the end of the public scoping period, October 25. Contact information for submitting comments was provided in the presentation. The PowerPoint presentation given during the meeting is included in Appendix K.

The public hearing portion of the meeting followed the presentation, with nine attendees testifying or asking questions. A court reporter was available to record verbal comments during the public hearing and the transcript of the hearing is included in Appendix L.

Media Coverage

The public involvement effort for the public scoping period spurred media coverage in the region outside of deliberate notification and advertisement by the project team. Earned media for the Skokomish General Investigation Study included newspaper articles published prior to the NEPA public scoping meeting. Articles appeared in the following publications. Screenshots of the articles are included in Appendix M.

- The Bellingham Herald – *"Study to focus on Skokomish flooding"* (10/06/2010)
- The News Tribune – *"Study to focus on Skokomish flooding"* (10/06/2010)
- The Olympian – *"Study to focus on Skokomish flooding"* (10/06/2010)
- DredgingToday.com – *"Skokomish River needs dredging"* (10/07/2010)

Chapter 2. Public Scoping Comments

Summary of Comment Statistics

The public scoping period for the Skokomish General Investigation Study allowed for the public to submit comments in person, through email or by mail. While comments were solicited and received on all aspects of the project during scoping, the comment form posed the following specific questions for consideration:

1. **What are the problems and what are the solutions for flooding in the Skokomish River Basin?**
2. **What are the problems with the aquatic environment and what are some possible solutions?**
3. **Is there anything that should be addressed or considered during this study?**

A total of **28** communications were submitted via the following channels:

- **Three** comment forms and one photo were submitted during the scoping meeting.
- **Nine** verbal comments were given during the scoping meeting and recorded by the court reporter.
- **Eight** letters were mailed to Patrick Cagney, Environmental Resources Section, US Army Corps of Engineers, P.O. Box 3755, Seattle, WA 98124.
- **Eight** email communications were emailed to Patrick Cagney at: patrick.t.cagney@usace.army.mil.

The following organizations submitted comments:

- Lodestone Engineering LLC
- Mason Conservation District
- Northwest Steelhead and Salmon Conservation Society (NWSSCS)
- Stillwater Sciences
- Taylor Shellfish Company
- The Wilderness Society
- United States Environmental Protection Agency (EPA) - Region 10

Comment Categories

Each communication may include several comments regarding different elements of the study. These specific comments were analyzed and categorized into themes listed in the table below. A comment may fit into more than one category, and thus may be repeated in several different categories. In some cases it is indicated that a comment is out of scope of the study. This means that while the comment may have mentioned a common theme, the specific comment addresses an issue that falls out of the scope of the Skokomish General Investigation Study. The table below shows the categories in alphabetical order, and the number of received comments per category.

Category Number	Category	Number of Comments
1	Agriculture	10
2	Alternative analysis/selection	8
3	Aquatic ecosystem restoration/channel restoration	10
4	Climate change	1
5	Community issues/public involvement*	4
6	Cultural significance	2
7	Cumulative and indirect impacts	2
8	Cushman Dam*	10
9	Economic benefits*	5
10	Elevated water table	9
11	Endangered species	9
12	Erosion	3
13	Fecal contamination	3
14	Federal interest	4
15	Flooding*	14
16	Forestry*	7
17	Habitat (and specific organisms or animals)	15
18	Other projects in the basin	4
19	Project area	3
20	Recreation/tourism	3
21	Sediment management	13
22	Socioeconomic impacts	3
23	Transportation*	3
24	Water quality	5

*Includes out of scope comments

Common Comment Categories

The categories chosen for comment analysis are those that appeared in five or more comments. The following analysis is a brief summary of the themes and concerns in each of those commonly occurring categories. All of the categorized comments received during the scoping period can be read verbatim following the category analysis. Written comments, as received verbatim, are included in Appendix N.

Agriculture

Organizations and residents alike mentioned agriculture as a significant concern, specifically the declining agricultural productivity in the Skokomish Valley. Numerous issues, including logging, erosion, flooding, and an elevated water table were identified as related to this decline in productivity. Residents said that their fields and their neighbor's fields are flooding more frequently than in the past, affecting their ability to farm the land.

Alternative analysis/selection

Numerous comments referred to the alternatives to be analyzed in the study. Comments specifically asked that the study include or address in the analysis:

- a cost-benefit analysis for the various activities in the Skokomish Basin,
- high groundwater,
- the value of shellfish resources in the valley,
- impacts to endangered, threatened or candidate species listed under the Endangered Species Act (ESA), and
- gravel removal.

Additionally, the EPA requested the inclusion of maps and tables that compare and contrast alternatives.

Aquatic ecosystem restoration/channel restoration

Restoration was a common theme throughout the comments. Several comments specifically mentioned channel restoration to reduce flooding and restore the natural functions of the river. Comments also referred to aquatic ecosystem restoration or habitat restoration and the importance of this habitat to numerous fish species. Other benefits identified as resulting from restoration included reducing erosion, improving the low dissolved oxygen levels in Hood Canal, improving agricultural lands by reducing flooding, and creating recreational and tourism opportunities.

Cushman Dam

Several comments mentioned the Cushman Dam flow regime as a topic to be addressed in the study. Comments and suggestions varied regarding the Cushman Dam and should be individually addressed according to the respondent.

Economic benefits

Economic benefits comments reflected a range of ideas, from the potential for commercial opportunities if restoration occurs, to remarks about the economic benefits to the government from the

forestry practices in the area. Purchasing land holdings from property owners in the flood-prone area was also mentioned as a potential economic benefit.

Elevated water table

Many comments listed a high or elevated water table as a concern due to its impact on flooding and agricultural production in the valley. Comments indicated that the elevated water table is a result of accumulation of gravel in the river bed and, in turn, is causing more flooding and rendering previously farmable land unusable.

Endangered species

With regard to ecological impairments in the Skokomish River Basin, comments identified endangered species, and specifically endangered salmon, as an essential consideration in the study. Comments ranged from recognizing the harm that has been done to salmon populations in the basin, to mentioning other work being done in the basin regarding endangered species. Comments indicated that poor water quality and frequent flooding have compromised endangered species livelihood and habitat in the basin.

Flooding

Numerous comments referred to flooding in the basin as a serious issue affecting residents, fish and habitat, and agricultural productivity in the valley. Comments indicated that the increase in flooding is due to forestry practices in the upper valley and the resulting erosion and sediment buildup in the river. Comments linked the increase in flooding to decreasing water quality, and voiced concern about the potential impacts of increased flooding on endangered species. Social concerns about flooding included the harm flooding has had on farmers and the overall community in the valley. Many comments cited specific instances of flooding as harmful to their personal livelihood as well as the entire landscape.

Forestry

Several comments suggested that the root cause of the increased flooding in the Skokomish Valley is the logging practices in the upper watershed. Comments asserted that the logging led to an increase in erosion, water run-off and sediment build-up in the river.

Habitat (and specific organisms or animals)

In addition to mentioning endangered species, comments also addressed habitat and other species. Along with opportunities resulting from aquatic habitat restoration, respondents also offered comments on the contributing causes of habitat loss. For example, sediment build-up in the river has led to dry spells in the river, blocking river flow. Poor water quality was frequently mentioned as a cause of aquatic life problems in the basin. Flooding and excess nutrient build-up from runoff are suggested as contributors to the poor water quality and low dissolved oxygen levels in the Hood Canal.

Sediment management

Comments suggested sediment management as a potential alternative for flood-risk management in the Skokomish River Basin. Sediment build-up is seen as a result of poor forestry practices and as

contributing to flooding and the degradation of the aquatic environment. Many comments recognized sediment as a concern and several suggested gravel removal or dredging as alternatives to restore the basin. The EPA offered extensive comments on sediment management, stating that "the EIS should discuss the procedure for evaluating sediment quality and discuss how the Washington State 'sediment management standards' would be applied."

Water quality

Comments addressed water quality issues in the Skokomish River, including its link to the Hood Canal and Puget Sound, and the issue of low dissolved oxygen concentrations. The issue of poor water quality and sediment build-up in the Skokomish River is listed as a contributing factor to poor water quality in Hood Canal. Fecal contamination, although its own category, was also mentioned as an aspect of reduced water quality in the Skokomish River Basin and as something that should be addressed in the study.

Comment Analysis

The Skokomish River Basin has been identified as having problems such as frequent flooding, loss of productive agricultural land, and degradation of natural ecosystem habitat. Based on the project purpose, goals and objectives, the scope of the study is to evaluate whether there is a federal interest in aquatic ecosystem restoration and flood risk management. Comments indicate that the community is interested in both flood risk management and aquatic ecosystem restoration.

A large number of comments received addressed issues directly related to flood risk management, including comments related to the elevated water table, flooding, sediment management and water quality issues. Residents are specifically concerned about the frequent flooding and its impact to their property and livelihood, the high water table and its effect on agricultural productivity, and the sediment buildup in the river that is contributing to these issues. Comments suggest that the reduction of flooding would improve agricultural productivity and ultimately improve the economic condition of the valley. The Skokomish General Investigation Study should focus on implementing solutions designed to alleviate flooding and lower the elevated water table to address the concerns of many comments received.

Ecosystem restoration was also a common theme in comments received during the scoping period. Comments acknowledged that the problems facing the Skokomish River Basin have had negative effects on aquatic habitat and species, including endangered salmon. Comments specifically noted that frequent flooding and sediment buildup contribute to poor water quality, negatively affecting certain fish species. Comments encouraged channel restoration to improve habitat, as well as to alleviate flooding. The Skokomish General Investigation Study should focus on designing ecosystem restoration measures to address water quality, sediment management, and channel restoration to provide benefits to the overall health of the Skokomish River Basin aquatic ecosystem.

Several comments were received regarding the cost-benefit analysis that will be conducted for the project. Comments encouraged that the economic benefits from the federal government's past use of the valley be included, specifically the sale of timber from the upper watershed, as well as the benefits received by City the Tacoma for electricity from the valley. Comments also asked that the potential economic benefits from an improved and restored watershed be included, such as improved fishing, increase in tourism, higher property values and better business opportunities.

A number of comments received were beyond the purpose of the project, or out of scope, as mentioned in the table on page 10. Comments identified as out of scope included comments related to the approval for building Cushman Dam, approval for harvesting timber out of the watershed, potential for Lake Cushman Dam failure, and decommissioning old forest roads. Another comment asked that the local flood board be re-instated to give residents in the valley a voice in this issue.

Categorized Scoping Comments

The categorized comments below were received from September 24 – October 25, 2010, and are presented verbatim as received.

Category	Comment	Author
Agriculture	...the fields that we used to farm down in there -- we ran cattle, we cut hay. We did a lot of different things. And those things, like he says, are all under water. You know, I watch our neighbor's fields -- Joe Rigal's -- it used to be up above ground, and it's all down underwater.	Bill Hunter Jr.
Agriculture	I am sure that many others have noted the Skokomish River watershed as a marine mammal shelter area, a river of cultural significance to the native Twana peoples, a migratory bird corridor, drains a Federal Forest and contains important agricultural land for feeding America's families. It is home to ESA salmonid species and is on 303(d) list of impaired water bodies.	Constance Ibsen
Agriculture	But in the past few years, I just -- every year, we go out and try to plow the fields and work everything. And with the flooding, you can't hardly plow a field for fear that we're going to get a flood in the fall that -- that is going to wash topsoil away.	Curt Hunter
Agriculture	There simply is too much gravel and nowhere for the water to go except underground, which raises the water table, rendering many of our fields unfarmable	Jayni Kamin
Agriculture	It appears obvious that agricultural setback berms will solve 90 percent of the river problems. The berms can be constructed by using NRCS standards and local materials such as dry gravel bars.	Jerry Richert
Agriculture	Recent flow regime changes have been implemented through the Federal Energy Regulatory Commission's Project (FERC) #460, mandated conditions for re-licensing of the city of Tacoma's Cushman hydroelectric project on the North Fork. However, in spite of these successful actions, the mid-floodplain dwellers still have concerns that their landscapes have changed, their agricultural	Keith Dublanica

Category	Comment	Author
	practices warrant altering, and that scant attention is being applied there compared to upper and lower basin areas.	
Agriculture	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Agriculture	Fields are becoming permanently unavailable for production, with wetland indicators suggesting an irrevocable loss of arable land	Stillwater Sciences
Agriculture	If we cannot preserve productive agricultural land-not a consequence of intrinsic limitations or natural change, but simply because of our past mismanagement and present inaction-we will all lose.	Stillwater Sciences
Agriculture	Gravel aggradation is elevating the entire river bed, causing water tables to rise. This higher water table eliminates soil water-holding capacity and causes more frequent flooding during the winter. It also makes the soil too wet to plow during the spring and early summer, reducing the amount of tillable ground in the valley by 90 percent and severely limiting agricultural uses of the land. We urge you to consider alternatives and adopt a plan that will effectively address the problem of elevated water tables in the Skokomish Valley.	The Wilderness Society
Alternative analysis/selection	Question: Why should relocation of residences be a last resort measure-particularly if there are willing participants?	Duane Phinney
Alternative analysis/selection	We recommend including maps and diagrams of the area, each alternative, and any other relevant maps that assist in the understanding of the project area and proposed activities. We also recommend including tables that clearly compare and contrast the alternatives and their potential impacts to each resource and subbasin within the overall geographic area, as well as other tables that clearly compare and contrast the costs, benefits, and practicability of alternatives.	EPA

Category	Comment	Author
Alternative analysis/selection	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Alternative analysis/selection	In reviewing the Purpose and Need Statement in the published NOI, I found no mention of high groundwater. Do you intend to use this as a criteria when developing and evaluating alternatives? It would appear that any action which addresses the high groundwater and minimizes flooding will adversely affect the rapidly expanding wetlands in the valley. Are you prepared to develop, evaluate, and implement alternatives in which wetland impact is not fully mitigated?	Steve Thomas, Lodestone Engineering LLC
Alternative analysis/selection	I urge you to include the value of the Hood Canal's shellfish resources in scope of the EIS for the Skokomish GI. A healthy river system can significantly reduce the fecal bacteria/pathogen loading from the river. A number of the alternatives being considered such as off channel rearing habitat, wetland restoration, setback levees and sediment removal improve the function of the river system. These actions will reduce fecal loading and the public health hazard that occurs particularly during flood events when river waters inundate septic systems and wash manure from pastures.	Taylor Shellfish Company
Alternative analysis/selection	Gravel aggradation is elevating the entire river bed, causing water tables to rise. This higher water table eliminates soil water-holding capacity and causes more frequent flooding during the winter. It also makes the soil too wet to plow during the spring and early summer, reducing the amount of tillable ground in the valley by 90 percent and severely limiting agricultural uses of the land. We urge you to consider alternatives and adopt a plan that will effectively address the problem of elevated water tables in the Skokomish Valley.	The Wilderness Society
Alternative analysis/selection	The EIS should disclose whether or not the various alternatives being considered may impact endangered, threatened or candidate species listed under the Endangered Species Act (ESA), their habitats, and/or any of the three states' sensitive species.	EPA
Alternative analysis/selection	I would like to suggest that gravel removal must be included among the alternatives in this study.	Jason Ragan
Aquatic ecosystem restoration/channel restoration	It appears obvious that agricultural setback berms will solve 90 percent of the river problems. The berms can be constructed by using NRCS standards and local materials such as dry gravel bars.	Jerry Richert

Category	Comment	Author
Aquatic ecosystem restoration/channel restoration	To help the flooding and ground water issues we need to restore channel capacity by what ever we want to call it today, habitat restoration, dredging, bar scalping. We need the floor of the river lowered to the level of the 1950s-1960s at a minimum. In our studies during the 90's we showed 12 feet of gravel fill under the Highway 181 bridge. We need to address all drainage for the farms to lower ground water.	Bill Hunter
Aquatic ecosystem restoration/channel restoration	...and it's all just the aggradation in the river. You know, it's -- it's full of bed load. And the best thing we can do is restore the channel, restore the side channels.	Bill Hunter Jr.
Aquatic ecosystem restoration/channel restoration	Estuary restoration activities should be a high priority as restoration of natural estuarine processes would have upstream benefits and would benefit Skokomish River fishes, anadromous fishes from other areas of Hood Canal, waterfowl, shellfish, and water quality in Hood Canal.	Duane Phinney
Aquatic ecosystem restoration/channel restoration	Fish habitat enhancement measures will be a waste of money if sufficient spawning escapement is not allowed into the river to fully utilize available habitat. Commitment from the Washington Department of Fish and Wildlife and Skokomish Tribe to properly manage fisheries under their respective jurisdictions to assure sufficient fish escape to fully seed presently available and enhanced habitat is mandatory.	Duane Phinney
Aquatic ecosystem restoration/channel restoration	A key component of site restoration involves success of revegetation to reduce erosion and impacts to the surrounding environment.	EPA
Aquatic ecosystem restoration/channel restoration	Responses to habitat degradation are being implemented with a number of watershed restoration projects taking place primarily in the upper basin reaches and at the river mouth within the Skokomish Indian Reservation. These projects are being implemented pro-actively by the US Forest Service and the Skokomish Tribe respectively with varied leveraged support.	Keith Dublanica
Aquatic ecosystem restoration/channel restoration	Restoration of the Skokomish watershed is critical to the health of the Hood Canal shellfish resources which are critical to commercial farmers such as Taylor as well as recreation/tourism and the tribes. Please include this in the scope of the EIS.	Taylor Shellfish Company
Aquatic ecosystem restoration/channel restoration	It is critically important for the Corps to recognize that the recovery of endangered salmon populations in Puget Sound and the reversal of low Hood Canal dissolved oxygen levels depend upon the ecological restoration of the Skokomish watershed.	The Wilderness Society
Aquatic ecosystem restoration/channel restoration	Removal of the dikes to return vitally important, natural functions of the Skokomish River estuary	NWSSCS
Climate Change	The EIS should describe the current conditions related to climate and future predictions of climate shifts in the Northwest. Potential effects of climate change may include changes in hydrology, sea level, weather patterns, precipitation rates, and chemical reaction rates. C02 concentrations also lead to preferential fertilization and growth of specific plant species. The cumulative effects analysis should include a discussion on potential changes in precipitation, stream flow, and changes in vegetation.	EPA

Category	Comment	Author
Community issues/public involvement	Hopefully, they can, you know, give us a little more input, more chances for input outside of your public meetings and more chances for information to flow back and forth, you know, outside of your public forum here, with people in the Valley.	Bill Hunter Jr.
Community issues/public involvement	Lack of notification, no evacuation route or signs, warning system in case of Lake Cushman Dam failure that effects the Skokomish community should be considered during the study.	Joseph Leonard
Community issues/public involvement	And I'd like to ask -- I know Ross is here, and I saw two more Commissioners here, but I don't see them now. I'd like to ask them to re-instate our flood board so that the citizens and the residents of our Valley would have someone to talk to and someone to speak for us, especially with issues like this going on.	Paul Hunter
Community issues/public involvement	I hope that you will maintain a strong focus in the General Investigation on the consequences of past mismanagement that are exacting a profound cost on valley residents, as well as on the once-healthy anadromous fishery of this key river system.	Stillwater Sciences
Cultural significance	I am sure that many others have noted the Skokomish River watershed as a marine mammal shelter area, a river of cultural significance to the native Twana peoples, a migratory bird corridor, drains a Federal Forest and contains important agricultural land for feeding America's families. It is home to ESA salmonid species· and is on 303(d) list of impaired water bodies.	Constance Ibsen
Cultural significance	The larger drainage basin is affected by all its tributaries. Hood Canal suffers from low dissolved oxygen levels as do parts of south Puget Sound. Puget Sound Chinook salmon, the most charismatic and ubiquitous of endangered salmon stocks, has areas supporting life history behaviors throughout the Sound including Hood Canal and the Skokomish. Both transient and resident Orca whales transit the Sound and Canal. These water-borne icons are part of the cultural legacies, tied to the landscape as deep as are all the native tribes that call the Salish Sea part of their historical homeland. Shellfish industries are known regionally, nationally, and internationally depend upon healthy water quality.	Keith Dublanica
Cumulative and indirect impacts	Because sediment delivery occurs from uplands that may be a mix of private, tribal, state, and federally owned areas, the EIS should strive to assess cumulative impacts across jurisdictions to disclose the sum of individual effects of all projects on the local environment. Cumulative effects analysis should also consider appropriate mitigation strategies to minimize adverse and to enhance beneficial cumulative effects. Monitoring and evaluation of the mitigation strategies' effectiveness would also be an important component of the proposed action.	EPA
Cumulative and indirect impacts	EPA has issued guidance on how we are to provide comments on the assessment of cumulative impacts, Consideration of Cumulative Impacts in EPA Review of NEPA Documents, which can be found on EPA web site at: www.epa.govlcompliance/resources/nepa.html. The guidance states that in order to assess the adequacy of the cumulative impacts assessment, five key areas should be considered. EPA tries to assess whether the cumulative effects' analysis:	EPA

Category	Comment	Author
	1. Identifies resources if any, that are being cumulatively impacted; 2. Determines the appropriate geographic (within natural ecological boundaries) area and the time period over which the effects have occurred and will occur; 3. Looks at all past, present, and reasonably foreseeable future actions that have affected, are affecting, or would affect resources of concern; 4. Describes a benchmark or baseline; 5. Includes scientifically defensible threshold levels.	
Cushman Dam	Stabilize the flows above the watershed, release it like a faucet all year long, and get that drainage cleaned up.	Art Tozier
Cushman Dam	Lake Cushman was built -- the dams were built when I was a very small youngster. But who made the approvals for that? It wasn't the people in the Valley, it wasn't the Tribe, it wasn't Skokomish Valley. It was all the federal agencies that gave them permission.	Bill Hunter
Cushman Dam	There should be an inventory and evaluation of potential for water storage facilities in South Fork streams and North Fork streams-particularly below the Cushman dams--to reduce the peak of floods and augment flow during the summer low flow period	Duane Phinney
Cushman Dam	Lack of notification, no evacuation route or signs, warning system in case of Lake Cushman Dam failure that effects the Skokomish community should be considered during the study.	Joseph Leonard
Cushman Dam	Recent flow regime changes have been implemented through the Federal Energy Regulatory Commission's Project (FERC) #460, mandated conditions for re-Licensing of the city of Tacoma's Cushman hydroelectric project on the North Fork. However, in spite of these successful actions, the mid-floodplain dwellers still have concerns that their landscapes have changed, their agricultural practices warrant altering, and that scant attention is being applied there compared to upper and lower basin areas.	Keith Dublanica
Cushman Dam	The MCD has seen positive results from restoring streamside protective buffers with conservation efforts, some of which are the largest projects in the Hood Canal basin. The increased flows coming from the North Fork through the Federal Energy Regulatory Commission's Project (PERC) #460, mandated conditions for re-licensing of the city of Tacoma's Cushman hydroelectric project have also influenced this.	Mason Conservation District
Cushman Dam	Restoration of adequate flows in the North Fork Skokomish River from Lake Cushman to sustain wild runs of steelhead trout and Pacific salmon species	NWSSCS
Cushman Dam	I caution against relying on measures proposed in the recently issued FERC decision on the relicensing of Cushman Dam; I have reviewed them in detail, and I am disappointed to report that they provide no basis to assume that recently implemented changes to the flow regime of the North Fork will alleviate gravel build-up in the mainstem or reduce the frequency of overbank flows that regularly inundate the lower valley.	Stillwater Sciences

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Cushman Dam	The FEIS thus affirms that the presence or absence of the project is ultimately irrelevant to channel aggradation, and so any modification to the flow regime that lies between two extremes (namely, near-total diversion and fully uncontrolled flow) will also have no effect on aggradation. The FEIS also uses a purported channel capacity based on a reference over 20 years old (from the FEIS: "Mainstem aggradation has reduced the channel's conveyance capacity. Historically, the channel could convey about 12,000 cfs without flowing over its banks. Today, flooding occurs at flows of about 4,650 cfs or more [Canning, 1988]."). I recently obtained a rating curve directly from USGS personnel in Tacoma for the gage at the US 101 bridge crossing; it reminds us of the magnitude of channel infilling over the last several decades (over 3 feet in the last 27 years). Alas, this problem will not be resolved with old data and wishful thinking.	Stillwater Sciences
Cushman Dam	The new flow regime from Cushman Dam will increase the frequency and duration of overbank flooding; and the current pace of watershed rehabilitation up the South Fork will likely provide watershed-scale improvements several decades too late for anyone to benefit	Stillwater Sciences
Economic benefits	I say the federal government reaped tremendous economic benefit by selling the timber off the upper watershed, causing ruined farmland, flooded homes and barns, decades-old building moratorium that eliminates any new building, even fixing up buildings, in the Valley; also, a choked-up river system.	Jim Hunter
Economic benefits	If we're talking about the whole river system, why aren't we talking about the income from the Forest Service, who, like I say, took millions of board feet of timber. And the City of Tacoma is going on and on, selling electricity. And that should be brought into this cost/benefit ratio in some way.	Jim Hunter
Economic benefits	Purchase land holdings from willing property owners in the Skokomish River valley	NWSSCS
Economic benefits	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Economic benefits	In particular, the Corps' evaluation of federal interest in aquatic ecosystem restoration and flood risk management in the Skokomish River Basin must include the benefits that will accrue to Hood Canal and Puget Sound through restoration and flood reduction in the Skokomish watershed. These benefits include opportunities for improved commercial and recreational salmon fishing, shellfish production, and tourism, as well as higher property values and the	The Wilderness Society

Category	Comment	Author
	enhanced residential and business opportunities associated with a healthy environment in the Hood Canal/Puget Sound region.	
Elevated water table	The ground water level and flooding are killing ag in the valley.	Bill Hunter
Elevated water table	...because of the river channel being so high that it raises the aquifer. And our water table is just -- you dig a posthole and you hit water.	Curt Hunter
Elevated water table	For those of us who call the Skokomish Valley home, the primary issue, besides the frequent flooding and the decades-old building moratorium, is the ever-increasing water table, which is the result of the immense aggregation of the riverbed. The river is spreading underground, like a cancer, across the Valley floor and at an alarming rate, making much of what was once productive land unfarmable. I am concerned that the rising water table was not listed. There simply is too much gravel and nowhere for the water to go except underground, which raises the water table, rendering many of our fields unfarmable.	Jayni Kamin
Elevated water table	You didn't mention the underground water problems that we have. I'd like to just keep bringing that up and driving it home. That is a main concern we have in the Valley, is rising water table. We have many, many acres that are rendered pretty near useless now because of the water table.	Jim Hunter
Elevated water table	You know, we know about the groundwater; we've seen it. You know, we know about the degradation; we see it.	Joseph Pavel
Elevated water table	the root cause of the chronic Skokomish River flooding issues, low flows much of the year and a higher than usual water table is the federal government's (US Forest Service) irresponsible forestry practices (i.e., clear cut logging on unstable slopes) which resulted in destroying the natural processes of water retention (storm water and snowmelt) and the natural release of this water into the Skokomish River throughout the year.	NWSSCS
Elevated water table	In reviewing the Purpose and Need Statement in the published NOI, I found no mention of high groundwater. Do you intend to use this as a criteria when developing and evaluating alternatives? It would appear that any action which addresses the high groundwater and minimizes flooding will adversely affect the rapidly expanding wetlands in the valley. Are you prepared to develop, evaluate, and implement alternatives in which wetland impact is not fully mitigated?	Steve Thomas, Lodestone Engineering LLC
Elevated water table	Gravel aggradation is elevating the entire river bed, causing water tables to rise. This higher water table eliminates soil water-holding capacity and causes more frequent flooding during the winter. It also makes the soil too wet to plow during the spring and early summer, reducing the amount of tillable ground in the valley by 90 percent and severely limiting agricultural uses of the land. We urge you to consider alternatives and adopt a plan that will effectively	The Wilderness Society

Category	Comment	Author
	address the problem of elevated water tables in the Skokomish Valley.	
Elevated water table	The residents of the lower valley, Tribal members and landowners alike, are slowly but inexorably going under water. Reduced channel capacity, overbank flooding, and rising groundwater levels were all explicitly acknowledged at the October 7th meeting, and I hope you will continue to make them centerpieces of the General Investigation.	Stillwater Sciences
Endangered species	I am sure that many others have noted the Skokomish River watershed as a marine mammal shelter area, a river of cultural significance to the native Twana peoples, a migratory bird corridor, drains a Federal Forest and contains important agricultural land for feeding America's families. It is home to ESA salmonid species· and is on 303(d) list of impaired water bodies.	Constance Ibsen
Endangered species	The EIS should disclose whether or not the various alternatives being considered may impact endangered, threatened or candidate species listed under the Endangered Species Act (ESA), their habitats, and/or any of the three states' sensitive species. The draft EIS should describe the critical habitat for the species; identify any impacts the various alternative actions will have on the species and their critical habitats; and describe how the proposed actions will meet all requirements under ESA, including consultation with the appropriate federal agencies and the biological assessments and opinions of that consultation process. In addition to listed species, the EIS should describe the overall flora and fauna in the area and impacts of the project on the biota. Given the watershed approach of this process, the EIS should provide details on the ecological interactions between species and habitats and the effects of the various alternatives on populations, habitats and ecological interactions.	EPA
Endangered species	I would like to suggest that gravel removal must be included among the alternatives in this study. The endangered fish obviously need quality water and habitat to have any chance of recovery. The water is still in the Skokomish Valley, it is just flowing under a massive amount of sediment.	Jason Ragan
Endangered species	The larger drainage basin is affected by all its tributaries. Hood Canal suffers from low dissolved oxygen levels as do parts of south Puget Sound. Puget Sound Chinook salmon, the most charismatic and ubiquitous of endangered salmon stocks, has areas supporting life history behaviors throughout the Sound including Hood Canal and the Skokomish. Both transient and resident Orca whales transit the Sound and Canal. These water-borne icons are part of the cultural legacies, tied to the landscape as deep as are all the native tribes that call the Salish Sea part of their historical homeland. Shellfish industries are known regionally, nationally, and	Keith Dublanica

Category	Comment	Author
	internationally depend upon healthy water quality.	
Endangered species	Sediment buildup in the Skokomish River not only increases the frequency of flooding during the rainy season, it also blocks the river channel to migration and spawning by endangered Puget Sound salmon and trout populations during the late summer and early fall. The bed of the Skokomish River's South Fork has gone completely dry for a period of weeks or months nearly every year since 2003.	The Wilderness Society
Endangered species	I am no less aware of the range of ecological impairments in the lower river, and I applaud ongoing and future efforts to improve conditions for ESA-listed species as well.	Stillwater Sciences
Endangered species	...the ecosystem damage caused by years of natural resource consumption. We see much of this damage as harm to endangered species and their habitats, specifically those of Puget Sound Chinook, Hood Canal summer chum, coastal steelhead, and coastal bull trout.	Mason Conservation District
Endangered species	It is critically important for the Corps to recognize that the recovery of endangered salmon populations in Puget Sound and the reversal of low Hood Canal dissolved oxygen levels depend upon the ecological restoration of the Skokomish watershed.	The Wilderness Society
Endangered species	The Skokomish River floods more frequently than any other river in Washington State, due to aggradation of the river bottom. This flooding directly harms endangered salmon populations and flushes excess nutrients and harmful bacteria into Hood Canal. The degraded water quality conditions contribute to the low dissolved oxygen levels in Hood Canal, resulting in fish kills.	The Wilderness Society
Erosion	Below Highway 101 (and perhaps elsewhere) are areas where old car bodies have been used for rip rap. These should be removed as they generally add to bank erosion rather than alleviate it and are the source of pollutants.	Duane Phinney
Erosion	Many culverts are too small or improperly placed-adding to stream bed and bank erosion and blocking upstream passage of fishes.	Duane Phinney
Erosion	These recommendations that are now nearly a quarter of a century old include: 1. Stabilize failed or failing slopes to help reduce erosion	NWSSCS
Fecal contamination	When the agricultural lands and septic systems of the Skokomish Valley are frequently flooded, there is an increased nutrient load, as well as fecal coliform, that are carried into Annas Bay. The sources of fecal coliform are human, livestock and wildlife.	Jason Ragan

Category	Comment	Author
Fecal contamination	I urge you to include the value of the Hood Canal's shellfish resources in scope of the EIS for the Skokomish GI. A healthy river system can significantly reduce the fecal bacteria/pathogen loading from the river. A number of the alternatives being considered such as off channel rearing habitat, wetland restoration, setback levees and sediment removal improve the function of the river system. These actions will reduce fecal loading and the public health hazard that occurs particularly during flood events when river waters inundate septic systems and wash manure from pastures.	Taylor Shellfish Company
Fecal contamination	Shellfish are filter feeders and as you are no doubt aware require exceptionally clean water to grow them in. Growing areas are regulated by the State Department of Health based on the presence of fecal coliform bacteria and indicator organism used to detect the presence of human pathogens. The beds at the mouth of the Skokomish River have been plagued with pollution closures for years. A TMDL was recently completed and is being implemented to attempt to address the sources of pollution.	Taylor Shellfish Company
Federal interest	And I really think the government needs to step up and, you know, help us out.	Justin Bays
Federal interest	I strongly believe there is wide-spread federal interest in this General Investigation of the Skokomish River.	Keith Dublanica
Federal interest	The Mason Conservation District believes there is wide-spread federal interest in this General Investigation of the Skokomish River.	Mason Conservation District
Federal interest	The MCD believes this is a project demands Congressional attention and the anticipated support for wide-reaching and a comprehensive watershed restoration initiative.	Mason Conservation District
Flooding	Now we see a deep, deep degradation of the drainage and a soft geology, the softest known to man, that, if I stood there and piled up a bucket of dirt and then I took a five-gallon bucket of water and I dumped it on top of it, it would be right down there in a big, muddy mess. Well, that's what we've got today. We've got degradation of everything.	Art Tozier
Flooding	The increase in flooding not only hurts our ag but water quality too. We now have had flooding in every month of the year not just the storm months, including the growing season, harvest season, and summer too.	Bill Hunter
Flooding	TPU is dumping more water in the valley aggravating the ground water situation and flooding. The ground water level and flooding are killing ag in the valley.	Bill Hunter
Flooding	But in the past few years, I just -- every year, we go out and try to plow the fields and work everything. And with the flooding, you can't hardly plow a field for fear that we're going to get a flood in the fall that -- that is going to wash topsoil away.	Curt Hunter
Flooding	I believe that the increased nutrient loads from frequent flood events contribute to the dissolved oxygen problems in Hood Canal. I strongly suggest that the negative effects of frequent flooding on Annas Bay and Hood Canal should be included in the scope of the investigation.	Jason Ragan

Category	Comment	Author
Flooding	When the agricultural lands and septic systems of the Skokomish Valley are frequently flooded, there is an increased nutrient load, as well as fecal coliform, that are carried into Annas Bay. The sources of fecal coliform are human, livestock and wildlife.	Jason Ragan
Flooding	In addition, I have also developed a keen sense of the social challenges this damaged landscape and flooding has had on the communities and families who have settled here. Whether the community has been here since time immemorial, as the Skokomish Tribe believes, since before statehood for homesteaders and later dwellers, or those recently locating to the area, they all share a concern of the landscape's issues and how their respective communities are negatively impacted.	Keith Dublanica
Flooding	The Tribe has experienced flood impacts the longest. This basin continues to flood at lesser precipitation events more frequently, and the dynamic nature of the hydrograph defines this river as the first to flood in the state.	Keith Dublanica
Flooding	the root cause of the chronic Skokomish River flooding issues, low flows much of the year and a higher than usual water table is the federal government's (US Forest Service) irresponsible forestry practices (i.e., clear cut logging on unstable slopes) which resulted in destroying the natural processes of water retention (storm water and snowmelt) and the natural release of this water into the Skokomish River throughout the year.	NWSSCS
Flooding	And I'd like to ask -- I know Ross is here, and I saw two more Commissioners here, but I don't see them now. I'd like to ask them to reinstate our flood board so that the citizens and the residents of our Valley would have someone to talk to and someone to speak for us, especially with issues like this going on.	Paul Hunter
Flooding	The residents of the lower valley, Tribal members and landowners alike, are slowly but inexorably going under water. Reduced channel capacity, overbank flooding, and rising groundwater levels were all explicitly acknowledged at the October 7th meeting, and I hope you will continue to make them centerpieces of the General Investigation.	Stillwater Sciences
Flooding	Gravel aggradation is elevating the entire river bed, causing water tables to rise. This higher water table eliminates soil water-holding capacity and causes more frequent flooding during the winter. It also makes the soil too wet to plow during the spring and early summer, reducing the amount of tillable ground in the valley by 90 percent and severely limiting agricultural uses of the land. We urge you to consider alternatives and adopt a plan that will effectively address the problem of elevated water tables in the Skokomish Valley.	The Wilderness Society
Flooding	Sediment buildup in the Skokomish River not only increases the frequency of flooding during the rainy season, it also blocks the river channel to migration and spawning by endangered Puget Sound salmon and trout populations during the late summer and early fall. The bed of the Skokomish River's South Fork has gone completely dry for a period of weeks or months nearly every year since 2003.	The Wilderness Society

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Flooding	The Skokomish River floods more frequently than any other river in Washington State, due to aggradation of the river bottom. This flooding directly harms endangered salmon populations and flushes excess nutrients and harmful bacteria into Hood Canal. The degraded water quality conditions contribute to the low dissolved oxygen levels in Hood Canal, resulting in fish kills.	The Wilderness Society
Forestry	The other issue is the US Government logged the watershed and flushed the gravel down at an accelerated rate and then walked away. The ground water level and flooding are killing ag in the valley.	Bill Hunter
Forestry	Who approved this obscene yield that harvests the timber in our watershed faster than any other national forest?	Bill Hunter
Forestry	I am very sad to see the forest dying east of Hwy 101.	Doris Wilson
Forestry	the historic rate of logging is unsustainable, clear cuts are large and environmentally damaging, the watershed is replete with logging roads that send huge loads of silt and other material directly into the streams by virtue of lack of proper consideration for storm water management	Duane Phinney
Forestry	I say the federal government reaped tremendous economic benefit by selling the timber off the upper watershed, causing ruined farmland, flooded homes and barns, decades-old building moratorium that eliminates any new building, even fixing up buildings, in the Valley; also, a choked-up river system.	Jim Hunter
Forestry	the root cause of the chronic Skokomish River flooding issues, low flows much of the year and a higher than usual water table is the federal government's (US Forest Service) irresponsible forestry practices (i.e., clear cut logging on unstable slopes) which resulted in destroying the natural processes of water retention (storm water and snowmelt) and the natural release of this water into the Skokomish River throughout the year.	NWSSCS
Forestry	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Habitat (and specific organisms or animals)	I am sure that many others have noted the Skokomish River watershed as a marine mammal shelter area, a river of cultural significance to the native Twana peoples, a migratory bird corridor, drains a Federal Forest and contains important agricultural land for feeding America's families. It is home to ESA salmonid species and is on 303(d) list of impaired water bodies.	Constance Ibsen
Habitat (and specific organisms or animals)	Commitment from the Washington Department of Fish and Wildlife and Skokomish Tribe to properly manage fisheries under their respective jurisdictions to assure sufficient fish escape to fully seed	Duane Phinney

Category	Comment	Author
	presently available and enhanced habitat is mandatory.	
Habitat (and specific organisms or animals)	Fish habitat enhancement measures will be a waste of money if sufficient spawning escapement is not allowed into the river to fully utilize available habitat. Commitment from the Washington Department of Fish and Wildlife and Skokomish Tribe to properly manage fisheries under their respective jurisdictions to assure sufficient fish escape to fully seed presently available and enhanced habitat is mandatory.	Duane Phinney
Habitat (and specific organisms or animals)	Many culverts are too small or improperly placed-adding to stream bed and bank erosion and blocking upstream passage of fishes.	Duane Phinney
Habitat (and specific organisms or animals)	Sections of the lower South Fork go dry during the summer low flow period, inhibiting movement of certain fish species and reducing rearing area for steelhead trout, coho salmon, and other fish species, There should be an evaluation of potential methods to address this problem (wells, for example).	Duane Phinney
Habitat (and specific organisms or animals)	The EIS should disclose whether or not the various alternatives being considered may impact endangered, threatened or candidate species listed under the Endangered Species Act (ESA), their habitats, and/or any of the three states' sensitive species. The draft EIS should describe the critical habitat for the species; identify any impacts the various alternative actions will have on the species and their critical habitats; and describe how the proposed actions will meet all requirements under ESA, including consultation with the appropriate federal agencies and the biological assessments and opinions of that consultation process. In addition to listed species, the EIS should describe the overall flora and fauna in the area and impacts of the project on the biota. Given the watershed approach of this process, the EIS should provide details on the ecological interactions between species and habitats and the effects of the various alternatives on populations, habitats and ecological interactions.	EPA
Habitat (and specific organisms or animals)	Responses to habitat degradation are being implemented with a number of watershed restoration projects taking place primarily in the upper basin reaches and at the river mouth within the Skokomish Indian Reservation. These projects are being implemented pro-actively by the US Forest Service and the Skokomish Tribe respectively with varied leveraged support	Keith Dublanica
Habitat (and specific organisms or animals)	The larger drainage basin is affected by all its tributaries. Hood Canal suffers from low dissolved oxygen levels as do parts of south Puget Sound. Puget Sound Chinook salmon, the most charismatic and ubiquitous of endangered salmon stocks, has areas supporting life history behaviors throughout the Sound including Hood Canal and the Skokomish. Both transient and resident Orca whales transit the Sound and Canal. These water-borne icons are part of the cultural legacies, tied to the landscape as deep as are all the native tribes that call the Salish Sea part of their historical homeland. Shellfish industries are known regionally, nationally, and internationally depend upon healthy water quality.	Keith Dublanica

Category	Comment	Author
Habitat (and specific organisms or animals)	...the ecosystem damage caused by years of natural resource consumption. We see much of this damage as harm to endangered species and their habitats, specifically those of Puget Sound Chinook, Hood Canal summer chum, coastal steelhead, and coastal bull trout.	Mason Conservation District
Habitat (and specific organisms or animals)	Restoration of adequate flows in the North Fork Skokomish River from Lake Cushman to sustain wild runs of steelhead trout and Pacific salmon species	NWSSCS
Habitat (and specific organisms or animals)	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Habitat (and specific organisms or animals)	I hope that you will maintain a strong focus in the General Investigation on the consequences of past mismanagement that are exacting a profound cost on valley residents, as well as on the once-healthy anadromous fishery of this key river system.	Stillwater Sciences
Habitat (and specific organisms or animals)	In particular, the Corps' evaluation of federal interest in aquatic ecosystem restoration and flood risk management in the Skokomish River Basin must include the benefits that will accrue to Hood Canal and Puget Sound through restoration and flood reduction in the Skokomish watershed. These benefits include opportunities for improved commercial and recreational salmon fishing, shellfish production.	The Wilderness Society
Habitat (and specific organisms or animals)	Sediment buildup in the Skokomish River not only increases the frequency of flooding during the rainy season, it also blocks the river channel to migration and spawning by endangered Puget Sound salmon and trout populations during the late summer and early fall. The bed of the Skokomish River's South Fork has gone completely dry for a period of weeks or months nearly every year since 2003.	The Wilderness Society
Habitat (and specific organisms or animals)	The Skokomish River floods more frequently than any other river in Washington State, due to aggradation of the river bottom. This flooding directly harms endangered salmon populations and flushes excess nutrients and harmful bacteria into Hood Canal. The degraded water quality conditions contribute to the low dissolved oxygen levels in Hood Canal, resulting in fish kills.	The Wilderness Society
Other projects in the basin	We recommend that the EIS discuss the other work occurring in the basin and any road blocks that may affect the analysis. As you may be aware the Walla Walla Corps' district is also working on addressing sediment on a watershed scale and they are in the process of developing a supplemental draft EIS for the Lower Snake River. We have a keen interest in both of these projects and understand that characterizing upland sediment sources is complex and coordinating multiple agencies can be a challenge.	EPA

Category	Comment	Author
Other projects in the basin	Responses to habitat degradation are being implemented with a number of watershed restoration projects taking place primarily in the upper basin reaches and at the river mouth within the Skokomish Indian Reservation. These projects are being implemented pro-actively by the US Forest Service and the Skokomish Tribe respectively with varied leveraged support	Keith Dublanica
Other projects in the basin	The MCD has seen positive results from restoring streamside protective buffers with conservation efforts, some of which are the largest projects in the Hood Canal basin.	Mason Conservation District
Other projects in the basin	I hope that you have now been able to obtain and study a copy of our recently completed final draft of the Skokomish River Chinook Salmon Recovery Plan as I believe you will find insightful information as to the diagnosis of altered conditions that have led to the current state we find the river. I believe this information will be complementary to the Corp's findings	Richard Brocksmith
Project area	I urge you to include the estuary and nearshore marine waters of Hood Canal in the General Investigation.	Constance Ibsen
Project area	We recommend including maps and diagrams of the area, each alternative, and any other relevant maps that assist in the understanding of the project area and proposed activities. We also recommend including tables that clearly compare and contrast the alternatives and their potential impacts to each resource and subbasin within the overall geographic area, as well as other tables that clearly compare and contrast the costs, benefits, and practicability of alternatives.	EPA
Project area	Recent flow regime changes have been implemented through the Federal Energy Regulatory Commission's Project (FERC) #460, mandated conditions for re-licensing of the city of Tacoma's Cushman hydroelectric project on the North Fork. However, in spite of these successful actions, the mid-floodplain dwellers still have concerns that their landscapes have changed, their agricultural practices warrant altering, and that scant attention is being applied there compared to upper and lower basin areas.	Keith Dublanica
Recreation/tourism	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Recreation/tourism	Restoration of the Skokomish watershed is critical to the health of the Hood Canal shellfish resources which are critical to commercial farmers such as Taylor as well as recreation/tourism and the tribes. Please include this in the scope of the EIS.	Taylor Shellfish Company

Category	Comment	Author
Recreation/tourism	In particular, the Corps' evaluation of federal interest in aquatic ecosystem restoration and flood risk management in the Skokomish River Basin must include the benefits that will accrue to Hood Canal and Puget Sound through restoration and flood reduction in the Skokomish watershed. These benefits include opportunities for improved tourism.	The Wilderness Society
Sediment management	To help the flooding and ground water issues we need to restore channel capacity by what ever we want to call it today, habitat restoration, dredging, bar scalping. We need the floor of the river lowered to the level of the 1950s-1960s at a minimum. In our studies during the 90's we showed 12 feet of gravel fill under the Highway 181 bridge. We need to address all drainage for the farms to lower ground water.	Bill Hunter
Sediment management	...and it's all just the aggradation in the river. You know, it's -- it's full of bed load. And the best thing we can do is restore the channel, restore the side channels.	Bill Hunter Jr.
Sediment management	Horses used to be used to scoop and remove gravel deposits from the river channel - no one has been doing that for 70 years! Help make a more adequate channel for the river.	Doris Wilson
Sediment management	EPA strongly supports the Corps' strategy to conduct a comprehensive watershed study for assessing sediment sources and planning for reduction of elevated sediment loads. In addition we promote managing sediment as a resource in the river system, working with natural transport processes wherever possible, and a restorative approach to move toward environmentally protective and ecologically sustainable sediment management in the watershed.	EPA
Sediment management	Of particular interest to EPA is the beneficial reuse of sediment removal from the channel or floodplain. Modeling can help develop a better understanding of locations and quantities of sources of sediment suitable for beneficial use and allow us to match sediment sources with potential use locations in advance of dredging or other active sediment management prescriptions.	EPA
Sediment management	The EIS should discuss the procedure for evaluating sediment quality and discuss how the Washington State sediment management standards' would be applied. The EIS should disclose any past sediment characterization, what sediment analyses would be needed, and the presence of any Chemicals of Concern (COCs) that will be considered in the analysis.	EPA
Sediment management	I would like to suggest that gravel removal must be included among the alternatives in this study. The endangered fish obviously need quality water and habitat to have any chance of recovery. The water is still in the Skokomish Valley, it is just flowing under a massive amount of sediment.	Jason Ragan
Sediment management	And I also believe that the solution to this devastation is simple. We must remove the gravel in the middle of the river, which is clogging up the system, preventing fish passage, and destroying our farms.	Jayni Kamin
Sediment management	There simply is too much gravel and nowhere for the water to go except underground, which raises the water table, rendering many of our fields unfarmable	Jayni Kamin

Category	Comment	Author
Sediment management	The solution is simple. Remove the gravel which is destroying the river -- the river, our farms, and our community.	Jim Hunter
Sediment management	Hundreds of feet of alluvium and sediment have been estimated to be deposited in the Skokomish valley floor and the channel has lost conveyance capacity with a great amount of material still in the storage in the upper basin. Gravity and fluvial dynamics will bring that material downstream.	Keith Dublanica
Sediment management	Limited, ongoing dredging to improve natural functions of Skokomish River and its tributaries	NWSSCS
Sediment management	I caution against relying on measures proposed in the recently issued FERC decision on the relicensing of Cushman Dam; I have reviewed them in detail, and I am disappointed to report that they provide no basis to assume that recently implemented changes to the flow regime of the North Fork will alleviate gravel build-up in the mainstem or reduce the frequency of overbank flows that regularly inundate the lower valley.	Stillwater Sciences
Socioeconomic impacts	I am sure that many others have noted the Skokomish River watershed as a marine mammal shelter area, a river of cultural significance to the native Twana peoples, a migratory bird corridor, drains a Federal Forest and contains important agricultural land for feeding America's families. It is home to ESA salmonid species· and is on 303(d) list of impaired water bodies.	Constance Ibsen
Socioeconomic impacts	In addition, I have also developed a keen sense of the social challenges this damaged landscape and flooding has had on the communities and families who have settled here. Whether the community has been here since time immemorial, as the Skokomish Tribe believes, since before statehood for homesteaders and later dwellers, or those recently locating to the area, they all share a concern of the landscape's issues and how their respective communities are negatively impacted.	Keith Dublanica
Socioeconomic impacts	TWS believes that the Skokomish FR/EIS must take into account the environmental and socioeconomic impacts and benefits of Skokomish River flooding and restoration on the natural resources and people not only in the Skokomish watershed, but also in the Hood Canal and Puget Sound, which was designated as an Estuary of National Significance by the U.S. Environmental Protection Agency in 1988.	The Wilderness Society
Transportation	So I've always thought that it would be a good thing to look into raising that road so that the people in the upper Valley can get out, because we -- right now, I go over the 800 line, and -- but the 800 line isn't stable. I mean, it washes out.	Justin Bays
Transportation	Continue to decommission ineffective, failing forest roads.	NWSSCS

Category	Comment	Author
Transportation	When completing your cost/benefit analysis, please consider economic benefits for a wide range of ongoing activities that will be improved by successful completion of these identified measures. These include, but are not limited to, commercial, recreational, and tribal fishing in the river and in Hood Canal proper; agricultural production; shellfish production throughout Hood Canal; tourism and recreation that will be improved by improving ecosystem conditions in the river and Hood Canal proper; sustainable forestry that can be recovered if the lower valley is flood-proofed; and safe transportation corridors up the Skokomish Flats Road and State Highway 161 as they are floodproofed.	Richard Brocksmith
Water quality	Determine sediment levels and water quality monitoring parameters for baseline evaluation. Also, consider 303 (d) listing for Skok.	Constance Ibsen
Water quality	If Washington State Department of Ecology has developed a water quality restoration plan or Total Maximum Daily Load (TMDL) for 303(d) listed waters, EPA recommends that the Corps coordinate with Ecology as the TMDL is implemented. If a TMDL has not yet been established for a 303(d) water body, then the EIS should demonstrate that there will be no net degradation of water quality to the 303(3) listed waters. Antidegradation provisions of the Clean Water Act apply to those waterbodies where water quality standards are currently being met. This provision prohibits degrading water quality unless an analysis shows that important economic and social development necessitates degrading water quality. The EIS should indicate how the antidegradation provisions would be met.	EPA
Water quality	The EIS should include information on the water quality of the Skokomish basin and which, if any, waters are impaired.	EPA
Water quality	The larger drainage basin is affected by all its tributaries. Hood Canal suffers from low dissolved oxygen levels as do parts of south Puget Sound. Puget Sound Chinook salmon, the most charismatic and ubiquitous of endangered salmon stocks, has areas supporting life history behaviors throughout the Sound including Hood Canal and the Skokomish. Both transient and resident Orca whales transit the Sound and Canal. These water-borne icons are part of the cultural legacies, tied to the landscape as deep as are all the native tribes that call the Salish Sea part of their historical homeland. Shellfish industries are known regionally, nationally, and internationally depend upon healthy water quality.	Keith Dubalnica
Water quality	The Skokomish River floods more frequently than any other river in Washington State, due to aggradation of the river bottom. This flooding directly harms endangered salmon populations and flushes excess nutrients and harmful bacteria into Hood Canal. The degraded water quality conditions contribute to the low dissolved oxygen levels in Hood Canal, resulting in fish kills.	The Wilderness Society

Next Steps

The comments received during the NEPA Scoping period were collected, analyzed, and shared with the Corps, Mason County, and Skokomish Indian Tribe. This scoping summary report will also be posted on the project's website at:
http://www.nws.usace.army.mil/publicmenu/menu.cfm?sitename=skokogi&pagename=home.
Pertinent comments will be taken into account as the Skokomish General Investigation Study moves forward.

Public and agency outreach will continue throughout the duration of the project, including information sessions to discuss and present project updates, website updates, and meetings with organizations, agencies and tribal representatives.

There will be a formal review and comment process when the Feasibility Study/Draft Environmental Impact Statement (DEIS) is issued, scheduled for 2014, including an open house and public hearing. Comments made on the Feasibility Study/DEIS will be formally addressed in the Final Environmental Impact Statement. The Feasibility Study/EIS is expected to be completed in 2016.

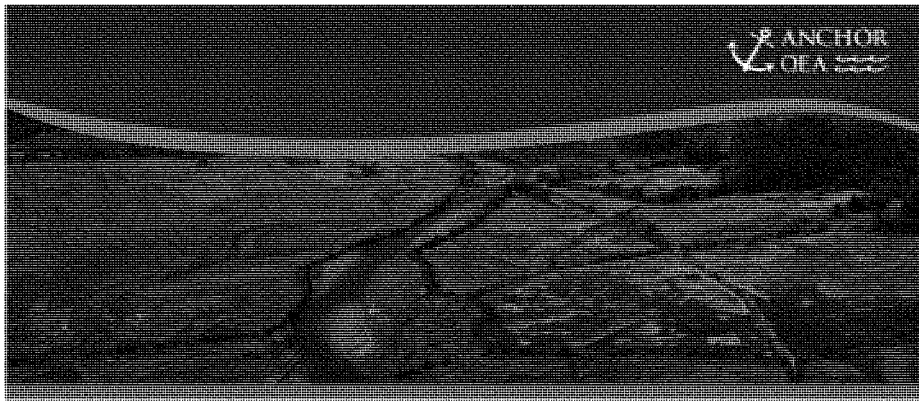
SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX C

WETLANDS INVENTORY

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District



WETLAND INVENTORY AND EVALUATION FOR THE SKOKOMISH BASIN

SKOKOMISH GENERAL INVESTIGATION

Prepared for
U.S. Army Corps of Engineers
Seattle District

Prepared by
Anchor QEA, LLC
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Seattle, Washington 98101

Final Draft
July 2011

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LIST OF ACRONYMS AND ABBREVIATIONS

Corps	U.S. Army Corps of Engineers
General Investigation	Skokomish River Basin Ecosystem Restoration and Flood Risk Management General Investigation
HGM	hydrogeomorphic classification
LiDAR	Light Detection and Ranging
LWD	large woody debris
MLLW	mean lower low water
MVI	modified vegetative index
NDVI	normalized difference vegetation index
NRCS	Natural Resource Conservation Service
NWI	National Wetland Inventory
PEM	palustrine emergent
PFO	palustrine forested
POW	palustrine open water
PSS	palustrine scrub-shrub
SR	state route
TVI	transformed vegetation index
USFWS	U.S. Fish and Wildlife Service
VI	vegetative index

1 INTRODUCTION

This inventory of wetland habitats in the lower Skokomish River valley was conducted by Anchor QEA, LLC (Anchor QEA) at the request of the U.S. Army Corps of Engineers (Corps) to support the Corps' Skokomish River Basin Ecosystem Restoration General Investigation (the General Investigation). The Skokomish River is located on the eastern slopes of the Olympic Peninsula in Mason County, Washington, and flows in to Hood Canal along a fjord with a pronounced bend (Figure 1). The General Investigation addresses ecosystem restoration in the Skokomish River watershed. Mason County, the Skokomish Tribal Nation, and the Corps, along with several other state, federal, and local governmental entities, have been working to develop a plan for restoring the Skokomish River watershed ecosystem. The initial goals of the General Investigation are the creation of a sustainable and restored river channel and the restoration of habitat to aid recovery of endangered salmon species. This wetland inventory documents the existing wetlands and wetland habitats in the Skokomish River Watershed in support of the General Investigation.

Wetlands play an important role in the large river valleys of the Puget Lowlands. Puget Lowlands rivers located in broad low gradient valleys, such as the Skokomish River in the project study area (Figure 2), were characterized prior to human development by a single channel with numerous ox bow lakes and vast floodplain wetlands (Collins et al. 2003). These floodplain wetlands did and still do play a critical role in the morphology, hydrology, and ecology of the lower Skokomish River valley. Wetlands provide flood storage and absorb water run-off, both of which can lessen the peak height of floods. Wetlands also provide key habitats that are critical for a number of species including federally listed endangered species found in the study area. Furthermore, wetlands beneficially impact water quality by absorbing nutrients and pollutants before they enter the Skokomish River. By extension, these water quality functions benefit the water quality of Hood Canal, which suffers from low levels of dissolved oxygen exacerbated by nitrogen loading (Newton 2008).

The previous and most recent inventory of wetlands in the lower Skokomish River valley was the National Wetland Inventory (NWI) that was based on high altitude (1:12,000), color infrared imagery acquired in the 1980s and the soil survey report of Mason County (NRCS 2010; Figure 3). The dynamic channel migration pattern of the Skokomish River and efforts

to restore wetlands and drain agricultural areas have made this data set largely obsolete. Numerous wetland areas in the Skokomish River watershed are not accurately mapped by the NWI. Some of these misclassified areas can be revealed easily by reviewing recently collected contemporary high altitude imagery. To assist in meeting the goals of the General Investigation, wetland areas inventoried in the study area at the time of this report are documented herein. This report was developed using existing aerial topography surveys (stereo interpretation and Light Detection and Ranging [LiDAR]) and mission-specific, low altitude, color infrared imagery. The methods used to determine wetland areas are based on U.S. Fish and Wildlife Service (USFWS) protocols for wetland inventory (USFWS 2009)

This investigation identified nearly 1,000 more acres of wetlands than the NWI including substantially more of all wetland classes with the exception of palustrine forested (PFO) and palustrine open water (POW). The changes can be attributed to several factors, including channel migration of the Skokomish River and its tributaries, land use changes in the floodplain including significant wetland restoration efforts, differences in source data and technology, and the more intensive field investigation associated with this effort. Channel aggradation by several feet over the last 40 years has also resulted in higher groundwater elevation and increased wetland area.

2 BACKGROUND INFORMATION

The Skokomish River watershed drains an area of approximately 247 square miles, with 80 miles of mainstem and over 260 miles of mapped tributaries. It drains the southeast corner of the Olympic Mountains, including portions of Olympic National Park and Olympic National Forest. Elevations of peaks along the watershed boundary range to over 6,000 feet, while most of the lower valley is below 100 feet in elevation. The watershed consists of three major sub-basins: the North Fork, South Fork, and Vance Creek. These systems do not merge until entering the lower Skokomish Valley and floodplain. The North Fork originates in Olympic National Park and flows through Lake Cushman, where a substantial flow is diverted through a spillway to the City of Tacoma Power Generating Facility on Hood Canal. The remaining flow continues down the North Fork and is managed in accordance with existing agreements between Tacoma Power and other parties. The South Fork also originates in Olympic National Park, but flows through a larger proportion of public and private commercial forest before entering the residential areas of the lower Skokomish Valley. The North Fork and South Fork join to form the mainstem about 9 miles upstream of the river mouth. Vance Creek flows through public and private commercial forest until reaching the South Fork less than 1 mile above the confluence with the North Fork.

The Skokomish River has the largest estuary and intertidal delta in the Hood Canal Basin. The delta includes a broad estuarine wetland complex and also supports extensive submerged aquatic vegetation including eelgrass (*Zostera* sp.) beds. The delta is considered critical for numerous species, including salmonids from Skokomish River and other lower Hood Canal systems such as the Tahuya River and Mission Creek. The project area for this wetland inventory includes the entire lower river valley of the Skokomish, including the delta to the approximate limits of the photic zone (-30-feet MLLW). This includes the entire mainstem from valley wall to valley wall as well as the lowest 4 miles of Vance Creek, the lowest 2 miles of the South Fork, and the lowest 1.5 miles of the North Fork (see Figure 1)

2.1 Land Use History

The study area was occupied by native tribes and generally undeveloped until Euro-American settlers began inhabiting the land in the 1840s. At this time, the new settlers began to convert the tidal wetlands and floodplains to land suitable for farming and living.

Conversion of the land happened early and extensively leaving little evidence of conditions prior to settlement (Collins and Sheikh 2005). When European settlers arrived, the land had not been logged and cultivated by farming by the indigenous people that lived there. Most of the currently developed land in the study area is associated with farming and homes descending from the original European settlers. Farming began with the earliest arrival of European immigrants in the early 1800s. Farming took off in the late 1800s and early 1900s, and continues to dominate the land use in the area today (Wilma 2006). Recently, dike breaching projects near the mouth of the Skokomish River have been used to restore agricultural lands to tidal marsh systems.

2.1.1 Roads

There are several main roads that extend throughout the study area. State Route (SR) 101 crosses the Skokomish floodplain about 4 miles upstream of the mouth and then follows the edge of the floodplain to the north continuing, out of the study area, up Hood Canal. SR 106 follows the east valley wall near the mouth of the river, then crosses the valley and merges with SR 101 near the Skokomish Tribal Center. These are the only major traffic routes within the study area. West Skokomish Valley Road runs east and west through the study area until it intersects SR 101. North Skokomish Indian Flats Road runs from SR 101 east toward the delta of the Skokomish River and the Hood Canal. There are numerous scattered smaller paved, gravel, or dirt roads throughout the study area. Most of the paved roads are associated with residences and farms. Many of the dirt roads are also associated with residences and farms, as well as with current and past forestry practices such as logging.

2.1.2 Forest

There are large tracts of evergreen forest surrounding the study area and approximately 1,140 acres of evergreen forest stands within the study area. Many of these forested areas are on the slopes above the valley floor. The area adjacent to the active floodplain is scattered with scrub-shrub forest, defined by woody vegetation less than 6 meters (20 feet) high. There are also areas of deciduous forest dominated mostly by big leaf maple (*Acer macrophyllum*) immediately adjacent to the active floodplain and scrub-shrub forest.

Logging in the watershed to clear space for farming and ranching began in the early 1800s. In the 1880s, the timber industry boomed and logging operations hit full stride when mechanical means were developed to assist in logging and transport. The study area is now heavily deforested due to past logging demands (Wilma 2006). Logging slowed in the 1980s when the Forest Service restricted timber harvesting to protect the northern spotted owl (*Strix occidentalis caurina*).

Currently, the largest forest stands in the study area that are not in industrial timber production include lowland hardwood stands and protected watershed areas dominated by Douglas fir (*Psuedotsuga menziesii*) and Western hemlock (*Tsuga heterophylla*). Also of note are several tracts of land in the floodplain and adjacent to it that are used for commercial Christmas tree farming.

2.1.3 Land Cover Change

Historical aerial photography analyses of the study area reveal noteworthy changes in land cover within the study area. These changes are reported as observed from aerial imagery inspection and are not based on demographic or socioeconomic study. The trend of clearing of forest lands has continued over the last 40 years. In 1938, there were about 1,300 acres in non-forestry agriculture. That number rose to as much as 2,000 acres from the 1960s through the 1980s. The areas that have been deforested in the past several decades are largely associated with historical oxbows and other low-lying (and typically wetland) areas that may not have been suitable for farming without investment in drainage. Other changes such as road building and new structures were relatively limited during this time.

More recent (over the last 20 years) land cover changes are dominated by conversion from agriculture to other land cover. These changes include the conversion of agricultural lands in the lowest portion of the valley back to estuarine marsh habitat by breaching dikes and restoring tidal hydrology to these lands. There are also areas along the mainstem that have reverted from agriculture back to forest. Presumably, many of these areas have become too wet to sustain crops. Currently, there are about 1,640 acres of land used for non-forestry agriculture. Other areas may simply be associated with new residential parcels that are not actively farmed. There are significantly more structures now than in the 1938 imagery,

although the trend of increasing residential density appears not to have persisted through the most recent decades.

2.1.4 Current Land Use

Today, the study area contains scattered areas of medium- and high-intensity development. Most of this development is associated with farming and the floodplain is still farmed today. The highest density development in the study area is the Skokomish Tribal Center, which consists of a casino, office buildings, schools, and residences. Development in this area covers approximately 130 acres.

There are currently approximately 1,640 acres of agricultural lands in the study area. Of these 1,640 acres, about 216 acres, or 13 percent, were identified as wetlands. This estimate may be low due to the difficulty of identifying agricultural wetlands based on visual inspection. Several agricultural fields not identified as wetland in this study showed evidence of standing water, but were not included as wetlands due to a lack of hydrophytic vegetation. Weeds and other "volunteer" vegetation were typically used rather than planted crops in making this distinction.

Another unique land cover in the lower Skokomish Valley is Christmas tree farms. More than 50 acres of Christmas tree farms were identified. This number includes all small trees planted in rows, but other areas had numerous small conifers that could be either young commercial forests or Christmas tree farms.

2.2 Hydrology

The South and the North forks of the Skokomish River flow into the study area and join together as the mainstem Skokomish River, which runs through the remainder of the study area to Hood Canal. Kirkland, Weaver, and Purdy creeks as well as many smaller tributaries flow into the study area from the south to join the Skokomish River. Vance Creek and Fir Creek flow from the north into the south fork of the Skokomish River in the study area before it joins the north fork. Several unnamed tributaries also flow from the north into the study area and join the Skokomish River.

The Skokomish River Valley has experienced notable flooding, sedimentation, and erosion both in its alluvial valley and deltaic environment. While there has been some lateral erosion in the upper valley that has been problematic for some landowners, the biggest problem has been the increased flooding in the lower valley. This increased flooding appears to be related to aggradation in the main channel of the Skokomish River leading to a loss of conveyance for the largest annual flows (Bountry et al. 2009) and higher groundwater elevations. River banks continue to be overtopped each year by smaller and smaller peak discharges, resulting in levee breaches, deep inundation of farmlands and roads, and flood damage to structures in the valley floor (Bountry et al. 2009). Recent geologic evidence also suggests that the uncommonly high rate of channel aggradation and associated flooding in the lower valley could be attributed to tectonic activity (Polenz et al. 2010). This is likely exacerbated by timber harvesting, particularly in the upper watershed of the South Fork, which has increased the supply of fine sediment washing down from the upper watershed and depositing in the floodplain and channel of the lower valley (Bountry et al. 2009).

Solutions to date have come mostly from mechanical means such as the placement of levees to prevent channel avulsions and flooding in the bottomlands along the river and riprap or logs with cables to stabilize banks or lessen the rate of lateral migration.

2.3 Climate and Groundwater

Like many areas within the Puget Sound basin, the Skokomish River Valley has a mild climate. The Puget Sound and Pacific Ocean influence prevailing winds and reduce periods of extreme heat and cold (Ness 1960). Mean daily maximum temperatures range from just over 45° F in December through February to just over 75° F in August (WRCC 2006). Mean daily minimum temperatures range from about 35° F from December through February to around 50° F in August (WRCC 2008).

Annual precipitation in the Skokomish River Valley varies along the reach of the river. In the northeast, annual average precipitation is approximately 65 inches. In the temperate rainforests near the Olympic Mountains, annual precipitation exceeds 250 inches (WRCC 2006; EnviroVision 2003; Golder 2002). The wettest month of the year is December, and the driest month is July (WRCC 2008). Snowfall in the Skokomish River Valley is typically well under 30 inches and stays on the ground for a relatively short period of time. For example,

in the nearby city of Shelton, the average annual snowfall from 1931 to1999 was 9 inches (WRCC 2006). The exception is near the headwaters of the Skokomish River in the Olympic Mountains, which experiences significant winter snowfall. Though severe weather is rare, Puget Sound Region typically has relatively high humidity and has significant cloud cover. In the nearby city of Olympia, the average number of cloudy days is 228 (WRCC 2008).

In the mountainous headwaters of the Skokomish River, the rocky terrain is characterized by sedimentary and basalt rocks with little groundwater storage capacity. Runoff in these areas quickly follows precipitation. In the coastal plain and lower floodplains and estuaries, alluvial and glacial sediments are the site of significant groundwater flow (EnviroVision 2003).

2.4 Habitat

The lower Skokomish River Valley and the adjoining higher altitude forest lands provide habitat for a number of fish and wildlife species native to Western Washington. Impacts to habitat from land uses such as forestry and agriculture have altered these habitats somewhat, but the area still maintains a diversity of species and habitats.

2.4.1 Fish and Shellfish

The Skokomish River watershed provides habitat for a variety of finfish and shellfish species. Depressed fall Chinook salmon (*Oncorhynchus tshawytscha*) populations can be found in Vance Creek and the Skokomish River. Healthy populations of coho salmon (*Oncorhynchus kisutch*) are found in the Skokomish River and most of its tributaries throughout the study area. Fall chum (*O. keta*) can be found in several tributaries and sections of the Skokomish River in the fall. Pink salmon (*O. gorbuscha*) inhabit Vance Creek, the Skokomish River, and most of the small tributaries that enter the study area. The main fork of the Skokomish River hosts a population of summer steelhead (*O. mykiss*). Depressed populations of winter steelhead can also be found in the Skokomish River and Vance Creek. Resident cutthroat (*O. clarkii*) can also be found throughout the study area (see Figure 4) (WDFW 2010a, 2011).

Lamprey (*Petromyzon marinus*) are commonly found in streams and tidal marsh areas of the Skokomish River. Sculpin (*Cottus confuses*) can be found in the Skokomish River and in the

streams and tributaries in the Skokomish floodplain. These species serve as important prey in the diet of larger fish such as trout and salmon.

Small areas near in the tidal waters of the Hood Canal host hardshell clam (*Mercenaria mercenaria*), oyster (*Crassostrea virginica*) beds, and Dungeness crabs (*Cancer magister*). These areas provide free connections with salt water, bluffs, reach substrates, marshes, and eelgrass (WDFW 2010a).

2.4.2 Wildlife

The field investigation conducted as part of this study was not designed specifically to identify the fauna present in the lower Skokomish Valley. It did, however, provide an opportunity to record wildlife sightings, tracks, or other wildlife sign encountered. Most of the species encountered are relatively common in the Puget Lowlands and typically found in the habitats encountered. The wildlife encountered included three species of amphibians, 12 species of mammals, 34 species of birds, and one species of reptile. A complete list of these species is included as Appendix B.

The remainder of this section describes species commonly found in the habitats associated with the study area. The following information about specific wildlife species is generally organized by the habitat types found within the river floodplain and nearshore ecosystems. The first section discusses species generally adapted to wide open areas and multiple habitats types within the study area. Additional species and species groups are also discussed by habitat types found within the study area.

2.4.2.1 Multiple Habitat Species (Forests, Freshwater, Marine)

2.4.2.1.1 Bald Eagles

Bald eagles (*Haliaeetus leucocephalus*) and their nesting areas can be found throughout the study area. They typically select areas with low human disturbance, suitable forest structure, and plenty of prey. They tend to nest along fishable waters because fish are a dominant source of food. When trout and salmon are spawning, those fish make up a large portion of their diet. Bald eagle nests have been identified along the Skokomish River and in some of the large wetland complexes (WDFW 2010a) (see Figure 5).

2.4.2.1.2 Ospreys

The study area contains suitable osprey (*Pandion haliaetus*) habitat, which is always closely associated with bodies of water and a wide variety of fish for food. Ospreys typically forage in wetland, tidal, and agricultural areas near water. Nests are commonly found in dead or open-topped trees located close to the water. The study area provides suitable osprey habitat year round. An osprey nest has been observed south of the salt marsh near a power line on the Skokomish Delta (WDFW 2010; USFWS 2000).

2.4.2.1.3 Great Blue Herons

Great blue herons (*Ardea herodias*) inhabit sheltered, shallow bays and inlets, sloughs, marshes, wet meadows, shores, and rivers with nearby foraging areas. The study area provides a variety of habitats for these birds. When feeding, they are usually found in slow-moving or calm salt, fresh, and brackish water. The marine shoreline habitat of the study area provides habitat for great blue herons. Great blue herons usually nest in trees or bushes that stand in or near water (Seattle Audubon Society 2008). Their nests have been documented in the saltwater marsh area of the project near the Hood Canal. In 2003, 29 nests were reported (WDFW 2011).

2.4.2.1.4 Wood Ducks

The study area offers a diversity of habitats that wood ducks (*Aix sponsa)* use to meet their food and nesting needs, including moist-soil emergent wetlands, forested wetlands, coastal marshes with beds of submerged aquatic vegetation, and flooded agricultural fields. Wood ducks are secondary cavity nesters and require medium to large snags within riparian areas for nesting and roosting.

2.4.2.2 Nearshore and Marine Shoreline Species (Includes Estuary Species)

2.4.2.2.1 Harbor Seals

Harbor seals *(Phoca vitulina)* use specific shoreline areas on a regular basis to haul-out of the water and rest. These resting areas are called seal haul-outs and include: beaches, rocky areas, log booms, and floats. Some haul-outs are used regularly, while others may be used

seasonally or occasionally. Time spent on the haul-outs is essential for seals' survival as they rest, dry out, interact, and regulate their body temperatures. In addition to resting, harbor seals give birth to and nurse their pups on the haul-outs, and undergo an annual molt of their pelage or fur (WDFW 2011).

2.4.2.2.2 Shorebirds

The estuary at the mouth of the Skokomish River creates wetland habitat for shorebirds that are routinely found in the nearshore and marine shoreline areas of the study area. The estuary provides prime food such as crustaceans, mollusks, marine worms, insects, and invertebrates. Shorebird nests are often placed on open areas such as gravel beaches, and stony stream banks (Ecology 2011).

2.4.2.2.3 Mixed Waterfowl

The nearshore and estuaries provide overwintering habitats that consist of roosting and foraging areas for waterfowl. Roosting areas include large bodies of water that provide secure places to loaf, sleep, and forage. Foraging areas include wetlands, tidal marshes, nearshore waters, and occasional agricultural fields. Waterfowl rely on a diverse diet of submerged aquatic vegetation, terrestrial vegetation, benthic organisms, fish, and other food sources during the winter.

2.4.2.3 Forested, Floodplain Vegetation, Stream Islands Species

2.4.2.3.1 Cascades Frog

The forested floodplain within the project site is suitable habitat for the cascade frog (*Rana cascadae*). Cascade frogs inhabit wet areas in open coniferous forests that include small streams and pools. Eggs are laid in the shallow open areas along the banks of the Skokomish River. Tadpoles are bottom feeders that prefer muddy or silty substrates and shallow water (WDNR 2009).

2.4.2.3.2 Band-tailed Pigeon

The wet coniferous forests along the Skokomish floodplain host a population of band-tailed pigeons (*Columba fasciata*). These pigeons are vegetarian, with most of their diet consisting

of grain seeds, wild and domestic fruits, acorns, pine nuts and buds, and flowers of trees and shrubs. Band-tailed pigeons prefer open sites along the forest edges. Their nests are usually located in trees 15 to 40 feet off the ground (Cornell Lab of Ornithology 2009a).

2.4.2.3.3 Wintering Elk

Meadow and forested land in the study area provides important wintering areas for elk (*Cervus elaphus*). When vegetation at higher elevations becomes covered in snow, elk migrate into the study area. The vegetation in the lowland areas of the floodplain provides grasses, sprouts, and branches from shrubs and trees for elk to eat (WDFW 2010)

2.4.2.3.4 Harlequin Ducks

The forested areas along the Skokomish River provide suitable breeding areas for the harlequin duck (*Histrionicus histrionicus*). These ducks prefer fast-moving streams and the gravelly banks for foraging on insects, fish, and marine invertebrates and the gravelly banks for their breeding areas (Cornell Lab of Ornithology 2009b).

3 TOPOGRAPHY AND SOILS

This section includes a review of existing information related to the topographic and soil conditions of the lower Skokomish Valley. These conditions are related to resources that contribute to wetland formation, loss, and habitat quality.

3.1 Geologic and Geomorphic History

The Skokomish River Valley is located at the southeastern end of the Olympic Peninsula near the southernmost extent of the Hood Canal. The Skokomish River flows east from its headwaters in the Olympic Mountains and descends through steep gorges and cascading pools to the Skokomish Valley, which occupies the lowermost 10 miles of the Skokomish drainage. The Skokomish River Valley is situated in between the Olympic Mountains and the Puget Lowlands. The Skokomish River Valley was carved by ice and subglacial fluvial erosion during the Last Glacial Maximum when the continental ice sheet had advanced south and westward into the headwaters of the Skokomish River Valley (Bountry et al. 2009).

The surficial geology of the Skokomish Valley is generally dominated by relatively recent (Holocene to recent Pleistocene) glacial alluvium. This material has accumulated to depths of about 70 feet over the past 8,500 years. This is interrupted by a feature first identified by Brian Collins (Hageruud 2006) and later described by Polenz et al. (2010) as the *lucky dog* berm. The landform consists of a gentle berm that trends roughly northwest to southeast approximately 1.5 miles inland from Hood Canal, resulting from a minor anticline associated with a thrust fault. The topographic crest of the landform lies adjacent to a southwest-facing escarpment and decreases in elevation from 35 feet at its northwest end to 15 feet at its southeast end, where it either plunges beneath or is truncated by the modern Skokomish Channel. Above (southwest of) the lucky dog berm lies a Holocene peat deposit about 1 mile long and 1.5 miles across (the width of the valley). Below (northeast of) the lucky dog structure the area around the active channel is dominated by alluvial marsh sediments. These sediments extend all the way to the tideflats, which are generally finer grained. Farther from the currently active channel (the northwest side of the valley's mouth), the lucky dog anticline exposes older alluvium. This is replaced by a second peat outcrop closer to the current shore of Hood Canal that is bounded on the canal side by older beach deposits.

Recent and older marsh deposits exist between the older beach deposits and the current shoreline beach deposits.

The surficial geology of the slopes above the valley floor contains a mix of glacial deposits from the Vashon Stade of the Fraser glaciation with some outcrops of pre-Fraser deposits. The slopes above the valley also exhibit evidence of Holocene landslide and mass wasting, these are particularly apparent on bare earth LiDAR shaded relief images (see Figure 6). Polenz et al. (2010) note that the base of the Vashon advanced outwash is commonly associated with productive springs. This formation is exposed in many locations along the valley walls. Much of the higher terrace above the valley walls is comprised of lodgment till from the Vashon glaciation.

3.2 Soils

Soils in the lower third of the study area at the mouth of the Hood Canal consist of gravelly loam, silt loam, peat, and peat overlaid by shallow gravel (see Figure 3). At the delta of the Hood Canal and the Skokomish River there is a band of soils consisting of tidal marsh, Mukilteo peat, and Tacoma peat. The next soil layer going inland from the canal consists of Pilchuck gravelly loamy sand, Skokomish silt loam, and grove gravelly loam. The next band consists of Dungeness fine sandy loam, grove gravelly sandy loam, and Indianola loamy sand. The top of the lower third of the study area consists of Puget silt loam, Orcas peat, Mukilteo peat, and Skokomish silt loam. From there the top two thirds of the study area are dominated by Dungeness silt loam and Dungeness fine sandy loam with Puget silt loam, Shelton gravelly loam, and Pilchuck loamy sand scattered throughout. There is a band of Hoodsport gravelly loam that enters the study area adjacent to the North Skokomish River and stretches along the northern edge of the study area to the east and west. Along the South Skokomish River and the Skokomish River there is a band of riverwash on both sides for the entire length of the upstream (western) two thirds of the study area. Most of these soil types are poorly drained except for gravelly loam, which is excessively well drained. All these soils are hydric. The upstream two thirds of the study area consist mostly of fine sandy loam and silt loam. Both of these soils are moderately well drained and not hydric. There is an area of riverwash adjacent to the channel of the Skokomish River to the Hood Canal; it is excessively drained and hydric (NRCS 2010).

Hydric soils are those soils that are sufficiently wet in the upper part to develop anaerobic conditions during the growing season (NRCS 2010). Tidal marsh areas are water saturated, very poorly drained, and intermittently or permanently covered by water. Peat materials are unconsolidated and largely undecomposed organic matter that has accumulated under excess moisture. Gravelly soil material has 15 to 35 percent rounded or angular rock fragments that are not prominently flattened. Loamy soils are 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles. Sandy material is individual rock or mineral fragments from 0.05 to 2.0 millimeters in diameter that makes up 85 percent or more of the soil's composition and is not more than 10 percent clay. Silt is material that is 80 percent or more individual mineral particles that range in diameter from 0.002 to 0.05 millimeter (NRCS 2010). All of these classified soil types are hydric soils.

Soil series identified within the study area that are typically hydric include: Mukilteo, Orcas, Puget, Riverwash, Skokomish, Tacoma, and Tidal Marsh. Series that are not commonly associated with hydric conditions include: Alderwood, Dungeness, Everett, Grove, Hoodsport, Indianola, Rough Mountainous Lands, and Shelton. The Pilchuck series contains both hydric and non-hydric soils.

The following descriptions of the soil series identified within the study area are excerpted from the most recent soil survey conducted by the Soil Conservation Service (1960) and updated by the Natural Resource Conservation Service (NRCS 2010). The following table lists the soils series mapped within the study area.

Table 1
Mapped Soil Series in the Study Area

Non-Hydric Soils	Area in Acres	Hydric Soils	Area in Acres
Alderwood Group	36	Mukilteo Group	30
Dungeness Group	257	Orcas Group	7
Everett Group	2	Pilchuck Group	31
Grove Group	59	Puget Group[1]	57
Hoodsport Group	52	Skokomish Group	84
Indianola Group	8	Tacoma Group	25
Lystair Group	<1	Tidal Marsh[2]	22
Pilchuck Group[1]	32		
Shelton Group	40		
Riverwash	48		
Total Acreage	**534**	**Total Acreage**	**256**

Notes:
1: The Pilchuck Group contains both hydric and non-hydric soils.
2: Does not include intertidal and subtidal portions of the study area.

3.2.1 The Mukilteo Series

The Mukilteo series consists of deep, very poorly drained soils formed in deep organic deposits. Mukilteo soils are mainly in depressional areas on glacial uplands, while some are in river valleys with slopes between 0 and 2 percent. The organic material in which this soil formed ranges in thickness from 52 inches to more than 10 feet. These soils are usually saturated with water and are strongly acid or very strongly acid. Fibers within the soils are mostly sedge and moss (NRCS 2010).

3.2.2 The Tacoma Series

The Tacoma series consists of very deep, very poorly drained soils formed in alluvium on tidal flats, floodplains, and deltas with slopes between 0 and 2 percent. These soils are saturated with water and have a water table near the surface during the winter months and wet periods throughout the year unless they have been artificially drained. The soil is more than 60 inches deep, but rooting depth, other than hydrophytes, is limited by the water table. Some pedons have layers of muck 1 to 4 inches thick with a cumulative total of less

than 16 inches. The weighted organic carbon content is less than 12 percent in the control section. The particle-size control section has 10 to 18 percent clay by weighted average. Below the Ap horizon, reaction is extremely acid to strongly acid throughout (NRCS 2010).

3.2.3 The Pilchuck Series

The Pilchuck series consists of very deep, excessively drained, and somewhat excessively drained soils that formed in gravelly and sandy alluvium. Pilchuck soils are on floodplains with slopes between 0 and 8 percent (NRCS 2010).

3.2.4 The Skokomish Series

The Skokomish series consists of very deep, poorly drained soils formed in alluvium on floodplains with slopes between 0 and 3 percent. These are the Grove soils and the Dungeness Variant soils. Grove soils are on terraces and are well drained and sandy-skeletal. Dungeness Variant soils have a udic moisture regime and are moderately well drained (NRCS 2010).

3.2.5 The Grove Series

The Grove series consists of deep, somewhat excessively drained soils formed in glacial outwash. Grove soils are on terraces and terrace escarpments at elevations of near sea level to 500 feet with slopes between 0 and 50 percent. Coarse fragments, dominantly pebbles, in the particle-size control section range from 55 to 75 percent by volume (USDA 2010). The soil ranges from strongly acid to moderately acid. Some pedons have a thin A horizon (NRCS 2010).

3.2.6 The Indianola Series

The Indianola series consists of very deep, somewhat excessively drained soils formed in sandy glacial drift. Indianola soils are on hills, terraces, terrace escarpments, eskers, and kames of drift or outwash plains at elevations of near sea level to 1,000 feet with slopes between 0 and 70 percent. Depths to diagnostic horizons and features start from the mineral soil surface (NRCS 2010).

3.2.7 The Orcas Series

The Orcas series consists of very deep, very poorly drained organic soils formed from sphagnum moss. Orcas soils occupy depressions on the glacial drift plains and have slopes between 0 and 2 percent. Orcas soils are in depressions on glacial outwash plains at elevations between 0 and 1,000 feet. The soils formed in sphagnum moss with some herbaceous plants. The water table is near the surface most of the year (NRCS 2010).

3.2.8 The Puget Series

The Puget series consists of very deep, poorly drained soils that formed in recent alluvium on floodplains and low river terraces with slopes between 0 and 3 percent. The particle-size control section lacks coarse fragments, has less than 15 percent fine and coarser sand, and has 18 to 35 percent clay (NRCS 2010).

3.2.9 The Shelton Series

The Shelton series consists of moderately deep, moderately well-drained soils that formed in glacial till. Shelton soils are on undulating to rolling glacial moraines. Depth to the Csim horizon ranges between 20 and 40 inches. Rock fragments in the control section exceed 40 percent and average less than 75 percent (NRCS 2010).

3.2.10 The Hoodsport Series

The Hoodsport series consists of moderately well-drained, moderately deep soils formed in glacial till on plains and foothills from sea level to 500 feet. These soils are usually moist, but they are dry in some parts between 8 and 24 inches for 45 to 60 cumulative days. The particle-size control section averages more than 50 percent coarse fragments. The soil ranges from moderately acid to very strongly acid. Depth to the strongly cemented till ranges between 20 and 40 inches (NRCS 2010).

4 METHODS

The wetland analysis was conducted in two phases. First, a GIS-based heads-up digitizing effort was used to identify potential wetland habitats based on 1-foot resolution, ortho-rectified color + infrared imagery acquired on April 23, 2011, that covered the entire study area. The second phase consisted of field verification and adjustment of wetland habitats and boundaries using printed maps (1-inch: 500-foot). Field verification efforts relied heavily on vegetation community assessments and visual hydrology indicators. In general, soils were not investigated or typed.

4.1 GIS-Based Interpretation Methods

Several data sources were used to facilitate the heads-up digitizing of wetland habitats using ArcGIS 10.0 desktop software. These data sources included topography, imagery, and hydrology. Personnel performing the digitizing had training, skills, and experience in GIS imagery interpretation and wetland delineation.

Topographic information was in the form of contours and two versions of a hillshade created from a terrain dataset (Cagney 2010). This terrain dataset was derived based on 1994 photogrammetric Contours (Walker and Associates 1994). LiDAR bare earth points from 2001 (Polenz et al. 2010) and top-of-bank to top–of-bank cross section surveys conducted by the Corps in October 2007. This terrain was also analyzed to define closed depressions (sinks) and to display areas of extremely low slope.

Imagery was displayed in several variations, including true color (RGB) and color infrared (iRGB). Color infrared was the most commonly used, followed by true color. In some cases, neither imagery set provided adequate differentiation between wetland and upland habitats and a project-specific variation on standard vegetation index techniques was used.

Typically, the normalized difference vegetation index (NDVI) is calculated based on the following formula (PSLC and TerraPoint 2002):

$$NDVI = \frac{IR - Red}{IR + Red}$$

The Transformed Vegetation Index (TVI) is calculated based on the following formula (PSLC and Terrapoint 2002):

$$TVI = \left[\frac{IR - Red}{IR + Red} + 0.5\right]^{1/2} * 100$$

Neither of these methods provided optimal differentiation of wetland and upland habitats for use in this assessment. A modified vegetation index (MVI) was adapted for use on the project. That VI was calculated based on the following formula:

$$VI = \log_{10}\left[\frac{IR - Red + 256}{IR + Red}\right]$$

This VI provided better differentiation of the wetness of areas than those vegetation indices mentioned above. The results of this analysis were used in conjunction with green and blue or infrared and green for display purposes.

Other useful, but lower resolution, imagery was also employed to provide recent site history and show seasonal change. This imagery came from a variety of sources including NAIP 2006 and 2009, Google Earth, and Esri.

Hydrology information was obtained from the terrain data set for the mainstem and SalmonScape (WDFW 2010b) for smaller tributaries.

GIS analysts were trained to identify the spectral signatures of confirmed wetland and upland habitats that were documented during a preliminary reconnaissance of the study area. Where spectral signatures were not conclusive in defining the boundary between upland and wetland habitats, topographic cues were used. Available hydrology information was

somewhat outdated and served primarily to identify riverine wetland habitats not associated with the mainstem river.

Initial wetland classification was also completed during this phase. This included identification of the wetland system and sub-system and, where possible, the class (Cowardin et. al. 1979). In several cases, the appropriate wetland class could not be definitively determined using only remotely sensed data, and multiple classes were ascribed to the habitats for the field maps (e.g., forested, scrub-shrub). The results of the initial digitizing effort were reviewed by senior staff twice and updated each time prior to creating field maps for the second phase of the analysis.

4.2 Field Based Interpretation Methods

Field crews used to verify on-the-ground wetland conditions were staffed by two persons, at least one of whom was a senior wetland scientist with 10 or more years of wetland delineation and habitat assessment experience. The crews were equipped with 1 inch:500 foot (1:6,000 inch) scale color and color infrared maps showing the results of the GIS-based analysis. GPS was initially used to locate wetland habitat boundaries, but crews found that they could accurately locate locations on the paper maps without significant difficulty, due to the quality of the imagery.

To perform the floodplain investigation, Anchor QEA biologists identified and documented vegetation communities and habitats within the study area by reviewing existing information, performing an aerial photograph analysis, and conducting reconnaissance-level site visits in April, June, and July, 2011. Because the study area is a very large geographic area with a variety of land uses, parcel sizes, and property ownerships, access within the study area ranged from accessible to no access. Rights of entry to private properties were coordinated and obtained through Mason Conservation District and Mason County. Access to large land holdings and key areas of interest were prioritized to maximize the efficiency of the field effort. Property access was granted by some land owners and denied by others. Physical features such as topography, vegetation density, and waterbodies such as streams and drainages also played a significant role in the ability to traverse parcels within the study area.

Information regarding dominant vegetation communities and habitats in the study area was documented through visual observations (sometimes with binoculars) while walking within parcels or sections of parcels and along public roads. Because a thorough assessment of the entire study area was not practical nor met the goals of the investigation, observations were made while traversing segments of the study and used to both make broad assumptions of large segments of habitat within the study area and compare field observations with the aerial photo analysis. For example, an investigation of a parcel that is 200 feet wide and 1,500 feet long would typically include traversing the 200-foot width to identify habitats, walking a few hundred feet in a perpendicular direction, and then returning to the starting location. Under this approach, vegetation and habitat conditions within parcels could be documented without a more time-consuming process of surveying entire parcels. While this approach allowed for covering large areas within the study area, there is also the possibility that small wetland or upland areas within the study area may have been misidentified.

Preliminary habitat polygons were identified during the investigation based on air photo analysis and corresponded to easily observable variations in the vegetation communities. These analysis segments were outlined on aerial photographs in the field as habitat polygons. Information, such as vegetation communities and hydrology features, was collected within the individual polygons. Data collection measures, such as digging sample plots to identify soil characteristics, were not performed, and wetland boundaries were not flagged or surveyed. Additional analysis typically performed as part of the wetland delineation process, such as wetland ratings and wetland functions and values assessments, were also not performed as part of this investigation. All wildlife species, tracks, and signs observed during the site visits were documented. All observations were qualitative in nature; no quantitative wildlife surveys were performed. Photographs were also taken to document vegetation and habitat conditions of the study area.

Both wetland and upland habitat units have been identified for this analysis, although the upland habitats represent only a subset of all upland areas, whereas the wetland areas identified are intended to be as complete as possible and include all wetlands in the study area. A few areas dominated by upland forested also contained small forested or emergent, depressional wetlands (typically less than 1,000 square feet) that were too indistinct too

identify from the imagery, and too numerous to identify in the field. These are identified in the upland habitat unit dataset as upland/palustrine forested wetland (PFO). The upland habitats identified in the field were useful as a reference when comparing upland and wetland areas of very similar spectral signature during in-office assessment and quality assurance review.

Wetland community types are also discussed, according to the USFWS classification developed by Cowardin et al. (1979) for use in the NWI. Wetland community types found during this investigation were as follows:

- Palustrine forested (PFO) – These wetlands have at least 30 percent cover of woody vegetation that is more than 20 feet high.
- Palustrine scrub-shrub (PSS) – These wetlands have at least 30 percent cover of woody vegetation that is less than 20 feet high.
- Palustrine emergent (PEM) – These wetlands have erect, rooted, herbaceous vegetation present for most of the growing season in most years.
- Palustrine open water (POW) – These wetlands are characterized by open water, such as ponds.

Confidence levels in the polygons established during the site visits and aerial photo analysis have also been identified as part of this investigation to provide a measure of confidence in the habitat assessment. Polygons that were verified with full access in the field are given a high confidence, while areas with limited or no access, or that relied heavily on aerial photo interpretation, are given a less confident or low ranking. Table 1 provides definitions of the confidence rankings.

Wherever possible, vegetation communities were identified in the field for a large subset of the wetland habitats as well as studied upland areas. The dominant vegetation for these areas was recorded and included in Appendix A. Additional vegetation species identified are included in Appendix A. Wildlife observations were also made during the field effort and are included in Appendix B. These were not attributed to specific habitats, and were not evaluated for frequency.

Following the site visits, updates to the GIS methodology were made based on information identified in the field. Habitat units (representing both upland and wetland habitats) were defined by polygons, with each identified polygon representing a specific vegetation community or other distinguishing features. For this investigation, habitat units were identified using a tiered classification system to differentiate the variety of vegetation communities within the study area. Habitat units at the first level are identified as upland (Up) or wetland (W) habitats. The second level is based on forest (1), scrub-shrub or shrub (2), or emergent or grass/herbaceous (3) cover. The third and final level is given a letter designation (e.g., a, b, c) based on a distinctive characteristic, typically associated with the dominant vegetation community. For example, upland riparian forest dominated by big leaf maple is identified as habitat unit Up1a and a riparian emergent wetland system dominated by black cottonwood (*Populus trichocarpa*) in a mosaic with emergent and scrub-shrub species is identified as W3a. Table 1 provides a list of all habitat units identified during the investigation.

Table 2
Habitat Unit Definitions

Habitat Unit	Wetland/Upland	Category	Sub-Category and Species Codes[1]
Up1a	Upland	Forest Deciduous Riparian	Big leaf maple (*Acer macrophyllum*, ACMA) dominant
Up1b	Upland	Forest Deciduous Riparian	Red alder (*Alnus rubra*, ALRU) and black cottonwood (*Populus balsmifera*, POBA) dominant. Some small patches dominated by slough sedge (*Carex obnupta*, CAOB)
Up1c	Upland	Forest Riparian Coniferous	Big leaf maple(*Acer macrophyllum*, ACMA) and Douglas fir (*Psuedatsuga menziesii*, PSME) dominant
Up1d	Upland	Forest Coniferous	Coniferous dominant with Douglas fir (*Psuedotsuga menziesii*, PSME) and Western red cedar (*Thuja plicata*, THPL)
Up1e	Upland	Forest Coniferous	Recent clear cut
Up1f	Upland	Fill prism	Placed fill prisms in estuary, for road use and remnant diking for agricultural practices
Up2a	Upland	Forest Tree Farm	Douglas fir (Psuedotsuga menziesii, PSME) tree farms, variable heights/age classes
Up3a	Upland	Grassland	Meadow buttercup (*Ranunculus acris*, RAAC)

Habitat Unit	Wetland/Upland	Category	Sub-Category and Species Codes[1]
			dominant with grasses, appears to be upland
Up3b	Upland	Grassland	Grass species, unmowed, greater than 2 feet tall
Up3c	Upland	Grassland	Livestock activity, grazed, mosaic with bare ground
W1a	Wetland	PFO Riparian	Mosaic with PSS and PEM
W2a	Wetland	PSS Riparian	Mosaic with PFO and PEM
W3a	Wetland	PEM Riparian	Mosaic with PFO and PSS
W3b	Wetland	PEM Grassland	Common rush (*Juncus effuse*, JUEF) and meadow buttercup (*Ranunculus acris*, RAAC) dominant with grasses, appears to be a wetland/upland mosaic
W3c	Wetland	PEM Grassland	Common rush (*Juncus effuse*, JUEF) dominant with grasses, appears dominant wetland with possible upland patches
W3d	Wetland	PEM Salt Tolerant	Estuary salt marsh
W4a	Wetland	POW	Open water

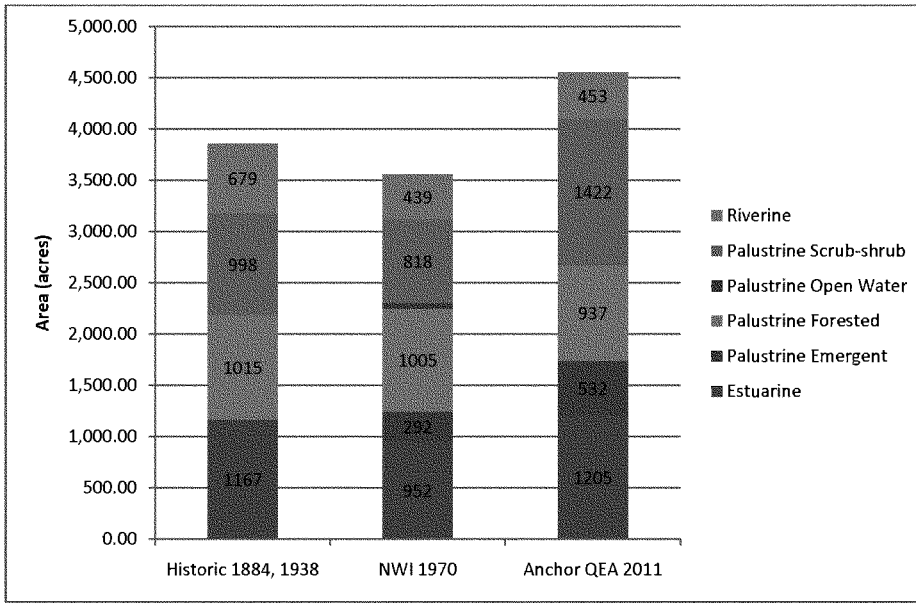
Notes:

1 Species codes (e.g., ACMA, ALRU, etc.) correspond to those used in Appendix A.

Following the field investigation, all identified habitat boundaries were reviewed and updated as necessary in the GIS dataset and then rechecked by both members of the field crew responsible for the particular area. The upland and wetland polygons were split into two separate datasets and are provided as attachments to this report.

5 ANALYSIS RESULTS AND INTERPRETATION

This analysis resulted in the mapping of 231 individual wetland habitat polygons covering 4,553 acres within the study area and an additional 995 acres of subtidal wetland in the Skokomish river delta that are outside of the Corps' study area. This compares to 165 identified polygons covering 3,558 acres in the NWI, and 260 polygons covering 4,790 acres in the historical wetland inventory assessment. The following graph shows the relative amount of wetland in each inventory based on wetland system and sub-system.



Note: This graph is based on the USACE provided project boundary, which does not include the entire subtidal portion of this study. Actual acreage of Estuarine wetland mapped by Anchor QEA 2011 is 2,200 acres.

5.1 Results

Upstream of the SR 101 crossing, wetlands are concentrated along the active channels of the Skokomish River and existing oxbows and side channels. Other wetlands associated with

springs flow from near the base of the valley walls. A few small wetlands appear to be associated with relic channels in the Skokomish floodplain.

Downstream of the SR 101 crossing, wetlands dominate the valley floor from valley wall to valley wall except in the immediate area of the Skokomish Tribal Center. These wetlands are primarily PSS wetlands with areas of PFO and emergent mitigation. At the mouth of the river these are replaced by estuarine wetlands and unvegetated tidal flats.

5.1.1 Wetland Classification

Wetland habitats were classified based on the system described in *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et. al. 1979). This system employs a hierarchical system of classification that is summarized as it applies to the study area below.

5.1.1.1 Estuarine Systems

Estuarine wetlands are found in the area where the Skokomish River enters the Puget Sound (see Figure 7). Analysis of historical maps by Collins and Sheikh (2005) indicate that up to 75 percent of estuarine wetlands were dominated by emergent vegetation. Estuarine scrub-shrub wetlands making up about 13 percent of the complex as compared to current wetland maps showing no scrub-shrub wetlands in the complex (Collins and Sheikh 2005). Recent projects have been initiated to breach dikes around islands in the lower estuary to restore tidal indentation of historic salt marsh areas. These breached areas make up the majority of the PSS wetlands in the estuary.

Estuarine systems are further subdivided as subtidal (generally below MLLW) and intertidal (generally above MLLW and influenced by salinity from Hood Canal). Subtidal habitats were not further interpreted to class or community in this project, but were mapped by Garono et al. 2004). Intertidal habitats were mapped by wetland class based on imagery and very limited field verification due to access issues.

Field investigation to determine the extent of eelgrass in the subtidal estuary was conducted. Eelgrass beds were specifically identified due to their unique habitat value. Eelgrass co-occurs with many small vertebrate and invertebrate organisms that provide prey for larger

species, including juvenile salmon who use the area heavily during their outmigration. Eelgrass beds also provide protective cover for migrating salmon, other fish, and many other kinds of marine life. Additionally, eelgrass supplies organic material to nearshore areas, and its roots stabilize sediments.

This investigation involved walking at approximately MLLW and identifying area waterward where eelgrass was present in large meadows or patches. It was assumed for mapping purposes that these eelgrass meadows extended to deeper water between -10 feet and -30 feet MLLW. The shallow estuary of the Skokomish River ends abruptly where the deltaic shelf gives way to the depth (greater than 200 feet) of Hood Canal.

5.1.2 Palustrine Systems

Palustrine wetlands include non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 parts per thousand. Palustrine wetlands dominate the bottom two thirds of the study area (see Figure 7). These wetlands exist across the entire valley floor in the lower reaches of the valley and are associated with old oxbows and other depressions farther upstream. They are also commonly associated with springs along the valley walls and the valley floor at the toe of slope.

Palustrine wetlands within the study area were further subdivided by wetland class. PSS wetlands were the most commonly found class in the study area. PSS wetlands included some large marshes including the 800–plus-acre system that is located just upstream of the Lucky Dog Fault and SR 101. This depressional system also contains open water, emergent, and forested components. Common vegetation includes various species of willows (e.g., *Salix lasiandra, Salix scouleriana*) and large areas of Douglas spirea (*Spirea douglasii*). Lower, wetter areas contained cattail (*Typha latifolia*) and emergent gramminoids (e.g., *Scirpus* sp., *Juncus* sp.). Other PSS wetlands in the study area are a mix of depressional, riverine, and slope wetlands with an overall average size of 20 acres.

PFO wetlands are widely distributed across much of the study area. They are commonly associated with the riparian corridor of the mainstem and Vance Creek, and are also common

near the valley walls where seeps fed wetlands are common. The most common tree species found in the study area was red alder (*Alnus rubra*), which was commonly associated with black cottonwood and Western red cedar (*Thuja picata*). Common understory species in forested wetlands include willows (e.g., *Salix lasiandra, Salix scouleriana.*), red-osier dogwood (*Cornus stolonifera*), and reed canarygrass (*Phalaris arundinacea*).

PEM wetlands were typically found in the center of the study area, upstream of the larger palustrine scrub-shrub complexes. These wetlands were commonly depressional or slope wetlands and located away from any active channels. Many PEM wetlands were associated with agricultural lands and often were associated with relic channels and other minor depressions in the landscape. The most common species encountered in PEM were reed canarygrass, slough sedge (*Carex obnupta*), soft rush (*Juncus effusus*), and colonial bentgrass (*Agrostis capillaris*).

The least common palustrine class of wetlands encountered was POW; these were typically oxbow wetlands that no longer had a continuous connection to a stream but maintained a water depth sufficiently deep to prevent the dominance of emergent vegetation. All POW wetlands analyzed were depressional and largely unvegetated in the spring of 2011. Floating aquatic vegetation (e.g., duckweed [*Leman minor*]) may appear later in the season. Along the margins, emergent vegetation adapted to continuous inundation, such as cattail, was encountered.

5.1.3 Riverine Systems

Riverine wetlands in the Cowardin classification schema are limited to those wetlands associated with the channel of the Skokomish River and its tributaries within the study area (see Figure 7). Historical maps show the area consisting of nearly 13 percent riverine tidal wetlands. Current maps show that the area of riverine tidal wetlands has grown to 25 percent (Collins and Sheikh 2005). Riverine wetlands mapped in this effort totaled approximately 450 acres, including 100 acres with tidal influence and 350 acres of lower perennial streams, although the range of tidal influence was estimated for this effort. These riverine wetlands are all associated with unconsolidated bottom (active channel) in the mainstem Skokomish River and associated minor channels.

In contrast to riverine wetlands in the Cowardin classification system, this study identified wetlands riverine wetlands under the hydrogeomorphic classification (HGM) system (Brinson 1993). Eighty-six acres of PFO and PSS wetland were identified as most closely associated with riverine hydrology. These wetlands are predominantly associated with the riparian corridors of the lower South Fork Skokomish River and Vance Creek and the mainstem Skokomish River upstream of SR 101. A review of recent aerial photography from the last four decades indicates a trend of increasing wetland area on either side of the active channel associated with riverine hydrology. Lateral migration of channels has also produced wetland areas associated with side channels, and other riverine features (e.g., bars, deltas, and oxbows) during this period.

5.1.4 Comparison to Earlier Inventories

The results of this investigation (see Figure 8) were compared to the historical wetland inventory described previously (see Figure 9) and the NWI (see Figure 10) (USFWS 2011)

5.1.4.1 Comparison to 1884 Mapping and 1938 Imagery

Analysis of historical maps by Collins and Sheikh (2005) was supplemented by digitization of identifiable wetland areas on 1938 aerial images as part of this study to create a wetland map based on the earliest available data. In the upper portion of the study area, Vance Creek and the North and South forks of the Skokomish River all follow markedly different alignments than they do presently. The confluence of all three tributaries is near the present day confluence of the North and South forks. In the 1.5-mile-long reach below this confluence, the channel is very wide (up to 2,000 feet), with a braided morphology indicating that rapid deposition of sediment is occurring and the channel is actively migrating. Several forested, oxbow wetlands are identifiable on either side of the channel in the 1938 images.

The majority of the wetlands identified in the 1938 images upstream of present day SR 101 are forested, while a few are scrub-shrub. The 1938 imagery is from summertime and emergent wetlands in the upper floodplain may not be identifiable, but may be present in the agricultural lands.

In the areas between present day SR 101 and SR 106, channel migrations between 1938 and 2011 are fewer. In general, wetland areas are more consistent, with the exception of areas behind a levee (or training dikes), such as on the left bank of the river just downstream of SR 101 that were presumably constructed after 1938 to provide suitable drainage for pasture or other agricultural uses. Other attempts at agriculture in this area appear to have been abandoned, specifically just upstream of the large scrub-shrub wetland (identified as #44 on Figure 11c). In the areas between SR 106 and Hood Canal, the changes between 1884 (as described in analysis of historical maps by Collins and Sheikh [2005]) and 2011 are relatively minor. The majority of the differences may be attributed to map interpretation. Channel locations are generally similar on the 1884 maps, 1938 imagery, and recent imagery. Conversion of delta wetlands to agriculture is identifiable on the 1938 imagery, although many of these areas have since been restored to estuarine wetlands.

5.1.4.2 Comparison to National Wetland Inventory Mapping

NWI data or the Lower Skokomish Valley (USFWS 2010) was based on color infrared imagery acquired in the early 1980s. This provides a comparison of the changes to wetland areas that have occurred in the past three decades. It is important to note that the methodologies of the two studies differ. This study made use of higher resolution imagery and extensive field reconnaissance not generally conducted as part of the NWI.

Above the confluence of the North and South forks, the channel alignments for riverine wetland locations are generally consistent. The 2011 imagery reveals several large riparian forested wetland (PFO) along Vane Creek and the South Fork Skokomish that are not identified in the NWI. Several small channels were also identified from the 2011 imagery. On the lower North Fork Skokomish River some areas identified as scrub-shrub in the NWI (PSS) were mapped as forested (PFO) in 2011 owing to the establishment of young trees in higher areas of the delta.

This mapping effort shows considerably more wetland areas in the reach between the confluence of the North and South forks and SR 101. These include wetland riverine, depressional, and slope wetlands that are associated generally with the channel and the larger riparian corridor. There are also extensive areas of emergent (PEM) slope and

depressional wetlands identified across the floodplain, with smaller units of PSS and PFO wetlands as well. These represent a major increase in wetland area between the two inventories.

The total wetland area between SR 101 and SR 106 appears relatively consistent between the NWI and this inventory. There are, however, notable differences in the vegetation classification. This appears to be related to several phenomena. First, some forested areas around the large PSS wetland (identified as 44 on Figure 11c) have died off and been replaced by PSS and emergent vegetation, probably as a result of increased wetness and persistent standing water. In other areas, PEM has replace PSS vegetation; again, this is likely due to rising water levels that no longer support woody vegetation. Some small areas of wetlands were also identified that do not appear in the NWI, either because these areas were not wet enough to support wetlands in the 1980s, or because of differences in technique and scale of the two assessments.

The most notable changes in the area between SR 106 and Hood Canal are related to restoration efforts that have restored wetlands in the delta of the Skokomish River. These efforts appear to have also resulted in the conversion of wetlands from palustrine to emergent systems; however, this difference may also be attributed to differences in mapping technique.

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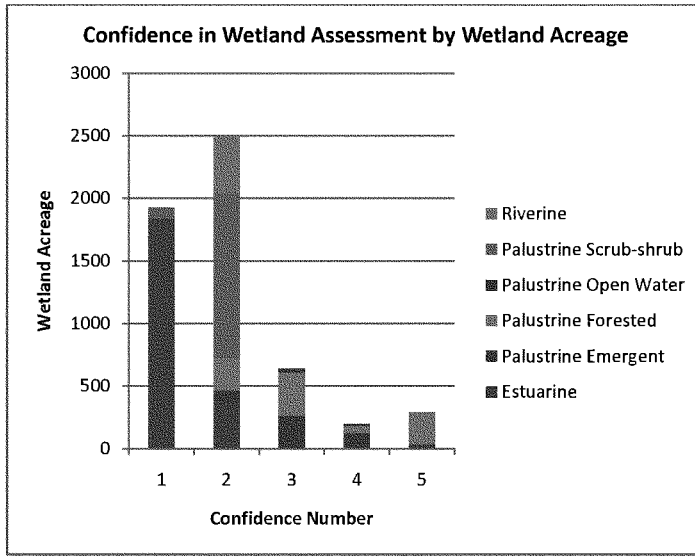
6 ESTIMATE OF ANALYSIS ACCURACY AND REPEATABILITY

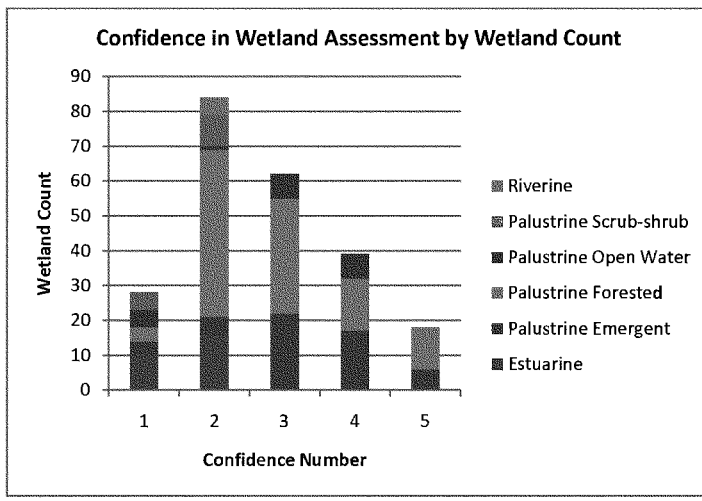
Field verification was used to the extent practicable, but was limited by site access (some areas are relatively inaccessible) and by landowner willingness to allow site access. Therefore a confidence was established for each polygon based on best professional judgment of the accuracy of the methods employed in determining the polygon boundary. These ranged between 95 percent and 70 percent (Table 2). These results are further represented in the following graphs.

Table 3
Confidence Ranking Definitions

Confidence Number	Confidence Description	Estimate of Accuracy[1]	Confidence Definition
1	High	95%	Investigation included parcel access and thorough analysis of area.
2	High	95%	Investigation limited to estuarine and riverine systems and one very large palustrine system, all characterized by very distinct topographic and spectral signatures. A representative subset of these polygons were investigated during field verification.
3	Medium to High	85%	Investigation included limited parcel access. Analysis included comparing observations with high confidence areas with similar habitats and aerial photo interpretation.
4	Medium	80%	Investigation limited to visual observations from adjacent parcels or public roads. Analysis included comparing observations with higher confidence areas with similar habitats and aerial photo interpretation.
5	Low	70%	No access and no opportunity for observations from adjacent parcels. Analysis limited to aerial photo interpretation.

Notes:
1 Estimate that areas within the polygon are jurisdictional wetland and areas proximate to the polygon are uplands.





Notes:

(1) Investigation included parcel access and thorough analysis of area.

(2) Limited to estuarine and riverine systems and one very large palustrine system characterized by very distinct topographic and spectral signatures. A representative subset of these polygons was investigated during field verification.

(3) Investigation included limited parcel access. Analysis included comparing observations with high confidence areas with similar habitats and aerial photo interpretation.
(4) Investigation limited to visual observations from adjacent parcels or public roads. Analysis included comparing observations with higher confidence areas with similar habitats and aerial photo interpretation.
(5) No access and no opportunity for observations from adjacent parcels. Analysis is limited to aerial photo interpretation.

7 OPPORTUNITIES FOR RESTORATION

The same data sources used for the wetland inventory were also reviewed by experienced geomorphologists and restoration ecologists with experience in river and floodplain restoration. Several opportunities for restoration were identified. These are shown in the annotated graphics on Figures 12a through 12d.

The opportunities for habitat restoration are intended to be integrated with restoration of natural process. The mainstem Skokomish River is highly dynamic and depositional in nature, regardless of ongoing geologic processes (change in base level at the mouth) and anthropogenic modification. Successful restoration projects must consider the geomorphic setting and approach conceptual project development from a systematic point of view, working with ongoing processes to achieve long-term benefits and minimize the potential for project failure. Restoration actions should address the following:

- Dispersion of floodwaters, and dissipation of energy in the channel and along banks
- Promoting natural distribution of sediment load
- Allowing the channel to achieve a more natural planform by eliminating constraints on channel migration where possible.
- Where it is not possible to remove these constraints, opportunities should be sought to address the of hardened banks by distributing erosive energy
- Creating channel complexity by adding roughness (e.g., large woody debris [LWD]) and diversifying the channel planform (e.g., side channels)

The first priority for restoration should focus on maximizing opportunities for natural channel migration. High rates of sediment deposition in the channel have resulted in a river that requires a very wide, somewhat shallow, active channel. Lateral constraints on the river in the form of levees and revetments have limited habitat, especially off-channel habitat in the river. Ideally, the maximum channel migration zone width available, given infrastructure constraints, will provide more opportunity for restoration of habitat than smaller specific projects that do not address the constraints on channel migration.

The second priority for restoration after removing constraints on channel migration would be adding instream complexity with LWD. Based on the aerial photos, there appears to be

very little wood in the reach. Upstream, near the channel confluences where deposition is greatest and the active channel is relatively wide, LWD would split flow and encourage forested islands and riparian habitat to develop over time, and would also encourage the scour of pools. Downstream, where the channel is more confined, LWD would add refuge and cover for fish and encourage more diversity in bedform to develop.

There are also numerous opportunities to create off-channel areas, but maintaining fish access to those channels over the long term will be a concern. Off-channel habitat would provide important rearing habitat and refugia during the frequent high flow events that occur in the system. This wetland inventory identifies numerous long, linear wetlands in relic channels on the valley floor that could be reconnected to the mainstem. These connections could be maintained, at least temporarily, with engineered log jams used to create scour near the channel mouths.

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APPENDIX A
INDEX OF VEGETATION OBSERVED DURING FIELD VERIFICATION

Appendix A
Vegetation Data

Scientific Name	Common Name	Indicator	2a	2b	2c	2d	4a	4b	4c	4d	4e	4f	4g	4h	4i	6a	6b	6c	7a	7b	7c	7d	8a	8b	8c	9a	9b	10a	10b	11a	11b	11c	11d	11e	11f	12a	12b	13a	13b	14a	14b	14c	15a	15b	16a	16c	16d	16e	16f	16g	18a	18b	18c	18d	18e	20a	21a	21b	19	20	21	22	i	ii	iii	iv	v
Trees																																																																			
Abies procera	Noble fir	NI																																								x																									
Acer macrophylum	Big-leaf maple	FACU	x	x		x	x				x			x	x	x		x			x	x	x	x					x	x			x	x							x		x											x			x	x									
Alnus rubra	Red alder	FAC	x	x	x	x	x		x			x				x					x	x		x	x		x	x		x			x	x			x			x		x	x	x		x	x	x										x	x									
Crataegus douglasii	Black hawthorn	FAC																									x													x																											
Fraxinus latifolia	Oregon ash	FACW																																																																	
Malus domestica	Domestic apple	NI																																																																	
Picea sitchensis	Sitka spruce	FAC															x																				x																														
Populus trichocarpa	Black cottonwood	FAC		x	x																			x	x			x		x			x	x									x					x																					
Prunus emarginata	Bitter cherry	FACU																																						x		x									x		x															
Pseudotsuga menziesii	Douglas fir	FACU	x	x																			x																		x																										
Rhamnus purshiana	Cascara	FAC-		x														x					x																																												
Salix lasiandra	Pacific willow	FACW+						x	x			x						x			x				x			x		x			x	x								x		x	x	x	x	x	x									x										
Salix scouleriana	Scouler willow	FAC							x												x				x			x		x			x	x								x		x	x	x	x		x									x										
Thuja plicata	Western red cedar	FAC		x							x			x	x							x	x	x			x		x								x																														
Tsuga heterophylla	Western hemlock	FACU-																																																																	
Shrubs																																																																			
Acer circinatum	Vine maple	FAC-	x		x	x					x			x	x						x	x	x	x																x																											
Cornus sericea	Red-osier dogwood	FACW															x				x									x			x				x					x	x	x		x			x								x	x									
Corylus cornuta	Beaked hazelnut	FACU	x															x				x	x	x																x																											
Cytisus scoparius	Scot's broom	UPL																																									x																								
Gaultheria shallon	Salal	FACU																					x																																												
Hedera hibernica	English ivy	UPL																			x			x					x																																						
Ilex aquifolium	Holly	FACU																																																																	
Kalmia spp.	Laurel	UPL																																																																	
Lonicera involucrata	Twinberry	FAC+																																									x																								
Mahonia aquifolium	Tall Oregon grape	UPL				x																	x																																												
Oemleria cerasiformis	Indian plum	FACU	x	x	x						x			x	x									x					x											x																		x										
Philadelphus lewisii	Mock orange	FACU																						x																			x																								
Polygonum cuspidatum	Japanese knotweed	FACU																				x		x									x																																		
Rosa nutkana	Nootka rose	FAC														x	x	x						x			x													x		x	x								x		x														
Rubus armeniacus	Himalayan blackberry	FACU		x	x											x		x			x	x					x			x			x	x						x	x	x	x														x										
Rubus parviflorus	Western thimbleberry	FAC-			x						x			x	x								x	x					x													x																										
Rubus spectabilis	Salmonberry	FAC+	x		x	x					x			x	x						x	x		x					x	x			x	x								x																x									
Rubus ursinus	Trailing blackberry	FACU				x																	x	x																x																											
Sambucus racemosa	Red elderberry	FACU			x						x			x	x						x	x								x			x							x		x																x									
Spiraea douglasii	Spirea	FACW																																									x																								
Symphoricarpos albus	Snowberry	FACU	x	x	x		x				x			x	x									x			x													x		x															x	x									
Vaccinium ovatum	Evergreen huckleberry	UPL																					x																																												
Vaccinium parvifolium	Red huckleberry	UPL																					x																																												
Grass, Ferns, & Herbaceous																																																																			
Agrostis capillaris	Colonial bentgrass	FAC														x	x	x																	x																												x	x	x		x
Athyrium filix-femina	Lady fern	FAC+							x												x							x		x			x				x						x															x									
Atriplex patula	Fat-hen saltbush	FACW																																		x																															
Carex deweyana	Dewey sedge	FACU																																																																	
Carex obnupta	Slough sedge	OBL																x										x									x								x		x		x																		
Cirsium arvense	Canadian thistle	FACU+														x	x	x																													x																				
Epilobium watsonii	Watson's willow-herb	FACU-																																																																	
Equisetum arvense	Field horsetail	FAC																																															x																		
Equisetum telmateia	Giant horsetail	FACW																						x																																											
Festuca rubra	Red fescue	FAC+														x	x	x																	x												x			x	x	x												x	x	x		x
Grasses Misc.																										x					x	x			x						x				x																				x	x	x	x	x
Grindelia integrifolia	Entire-leaved gumweed	FACW																																		x		x																	x												
Holcus lanatus	Common velvet grass	FAC														x	x	x																															x															x		x
Iris pseudacorus	Yellow-flag iris	OBL																										x		x			x										x																								
Jaumea carnosa	Fleshy jaumea	OBL																																				x	x													x															
Juncus acuminatus	Tapertip rush	OBL																																		x															x				x												
Juncus effusus	Soft rush	FACW																x								x					x	x			x										x				x						x								x			x
Lotus corniculatus	Birds-foot trefoil	FAC																																															x																		
Lysichiton americanus	Skunk cabbage	OBL							x																			x		x			x										x														x	x									
Maianthemum dilatatum	False-lily-of-the-valley	FAC																																																																	
Nuphar polysepalum	Yellow water lilly	OBL																																									x																								

Appendix A
Vegetation Data

Scientific Name	Common Name	Indicator	2a	2b	2c	2d	4a	4b	4c	4d	4e	4f	4g	4h	4i	6a	6b	6c	7a	7b	7c	7d	8a	8b	8c	9a	9b	10a	10b	11a	11b	11c	11d	11e	11f	12a	12b	13a	13b	14a	14b	14c	15a	15b	16a	16c	16d	16e	16f	16g	18a	18b	18c	18d	18e	20a	21a	21b	19	20	21	22	i	ii	iii	iv	v
Oenanthe sarmentosa	Water-parsley	OBL																																																																				
Phalaris arundinacea	Reed canarygrass	FACW						x				x						x			x						x			x	x		x	x									x	x		x	x		x	x					x	x										
Phleum protense	Timothy grass	FAC-														x	x	x																																																	
Plantago lanceolata	English plantain	FAC																																																																			
Plantago major	Common plantain	FACU+																																																																			
Plantago maritima	Sea plantain	FACW+																																				x	x													x				x												
Poa pratensis	Kentucky bluegrass	FAC																																	x																													x	x	x		x
Polystichum munitum	Sword fern	FACU		x	x	x	x				x			x	x								x					x												x																		x								
Potentilla anserina	Silverweed	OBL																																		x			x															x													
Pteridium aquilinum	Bracken fern	FACU																					x												x																														x			
Puccinellia nutkaensis	Pacific alkali grass	OBL																																				x	x															x			x										
Ranunculus acris	Tall buttercup	FACW-																								x					x	x			x																x											x	x			
Ranunculus repens	Creeping buttercup	FACW																			x									x			x																							x										
Rorippa palustris	Marsh yellowcress	OBL																																																																		
Salicornia virginica	Pickleweed	OBL																																				x	x															x			x											
Scirpus acutus	Hardstem bulrush	OBL																										x																																							
Scirpus americanus	Common threesquare	OBL																																								x																									
Scirpus microcarpus	Small-fruited bulrush	OBL																																									x		x	x	x		x	x						x											
Tanacetum vulgare	Common tansy	UPL																																																																		
Taraxacum officinale	Common dandelion	FACU														x	x	x																																													x			x
Tolmiea menziesii	Piggyback plant	FAC																																																																		
Trifolium pratense	Red clover	FACU																																																															x			x
Trifolium repens	White clover	FAC														x	x	x																																													x		x		
Trillium ovatum	Western trillium	FACU																																																																		
Typha latifolia	Cattail	OBL																x										x		x			x			x							x	x						x							x										
Urtica dioica	Stinging nettle	FAC+																												x			x																																		

500

APPENDIX B
WILDLIFE OBSERVATIONS DURING FIELD VERIFICATION

Appendix B
Wildlife Species, Track, or Sign Observed During the Investigation

Scientific Name	Common Name
Amphibians	
Northwestern salamander	*Ambystoma gracile*
Pacific chorus frog	*Pseudacris regilla*
Pacific giant salamander	*Dicamptodon tenebrosus*
Mammals	
Beaver	*Castor canadensis*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Eastern gray squirrel	*Sciurus carolinensis*
European rabbit	*Oryctolagus cuniculus*
House mouse	*Mus musculus*
Long-tailed weasel	*Mustela frenata*
Mule deer	*Odocoileus hemionus*
Raccoon	*Procyon lotor*
River otter	*Lutra canadensis*
Townsend's mole	*Scapanus townsendii*
Western red-backed vole	*Clethrionomys occidentalis*
Reptiles	
Western garter snake	*Thamnophis elegans*
Birds	
American crow	*Corvus brachyrhynchos*
American dipper	*Cinclus mexicanus*
American goldfinch	*Carduelis tristis*
American robin	*Turdus migratorius*
Bald eagle	*Haliaeetus leucocephalus*
Barn swallow	*Hirundo rustica*
Belted kingfisher	*Ceryle alcyon*
Black-capped chickadee	*Parus articapillus*
Bushtit	*Psaltriparus minimus*
California gull	*Larus californicus*
California quail	*Callipepla californica*
Canada goose	*Branta canadensis*
Common yellowthroat	*Geothlypis trichas*
Dark-eyed junco	*Junco hyemalis*
Double-crested cormorant	*Phalacrocorax auritus*
Downy woodpecker	*Picoides pubescens*
European starling	*Sturnus vulgaris*
Gadwall	*Anas strepera*
Glaucous-winged gull	*Larus glaucescens*
Golden-crowned kinglet	*Regulus satrapa*
Great blue heron	*Ardea herodias*
House sparrow	*Passer domesticus*
Killdeer	*Charadrius vociferus*
Mallard	*Anas platyrhynchos*
Marsh wren	*Cistothorus palustris*
Osprey	*Pandion haliaetus*
Red-breasted sapsucker	*Sphyrapicus ruber*

Appendix B
Wildlife Species, Track, or Sign Observed During the Investigation

Scientific Name	Common Name
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Rock dove	*Columba livia*
Rufous hummingbird	*Selasphorus rufus*
Spotted towhee	*Pipilo erythrophthalmus*
Steller's jay	*Cyanocitta stelleri*
White-breasted nuthatch	*Sitta caralinensis*

SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX D

CULTURAL RESOURCES

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

Appendix D

Skokomish River Basin General Investigation Study

Cultural Resources

U.S. Army Corps of Engineers

Seattle District

April 2011

US Army Corps
of Engineers®
Seattle District

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5.0 Cultural Resources in the Study Area 9

1.0 Cultural Resources

"Cultural resources" is a general utilitarian term coined by the National Park Service in the early 1970s to encompass a wide range of heritage assets, including places with evidence of past human activities on the landscape. It is widely used to characterize diverse management activities, i.e. "cultural resource management". The term has no statutory definition, but the related term "historic properties" is defined at law (*16 U.S.C. 470w)* and regulation (see *36 CFR Part 800.16 - Definitions*) and may be considered as a special case of "cultural resources".
"Historic Properties" generally includes any material remains that are at least 50 years old and have met tests of archaeological, historical, or cultural significance and consequently would be eligible for listing in the National Register of Historic Places (NRHP). Examples of historic properties include (but are not limited to) archaeological sites such as lithic scatters, villages, procurement areas, resource extractions sites, rock shelters, rock art, shell middens; and historic era sites such as trash scatters, homesteads, railroads, ranches, logging camps, and any structures or buildings that are over 50 years old.

In addition to archaeological or historical sites, properties that are associated with cultural practices or beliefs of a living community and are both rooted in that community's history and are important in maintaining its cultural identity are also defined as cultural resources (Parker and King 1998). Commonly referred to as Traditional Cultural Properties (TCP), these areas are afforded the same consideration as other cultural resources. They must meet the same criteria for significance, and if found to be eligible for NRHP they are afforded the same protection.

There are three main standards that a resource must meet to qualify for listing on the NRHP (36 CRR 60): age, integrity, and significance. To meet the age criteria, a resource generally must be at least 50 years old. Properties under 50 years of age can be found eligible when the resource is of exceptional significance (36CFR60.4). To meet the integrity criteria, a resource must possess integrity of location, design, setting, materials, workmanship, feeling, and association. Finally, a resource must be significant according to one or more of the following criteria:

(a) be associated with events that have made a significant contribution to the broad patterns of our history; or

(b) be associated with the lives of persons significant in our past; or

(c) embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

(d) have yielded, or may be likely to yield, information important in prehistory or history

Section 106 of the National Historic Preservation Act (NHPA) provides a regulatory framework for the identification, documentation, and evaluation of cultural resources that may be affected by federal undertakings. Federal undertakings include those actions either preformed by the federal government, require a federal license or permit, occur on federally managed land, or receive federal monies. Under the NHPA, federal agencies must consider the effects of federal undertakings on cultural resources that are eligible for listing on the NRHP.

Regulations in 36 CFR 800 outline the process through which Section 106 of the NHPA is administered. In general, the regulatory process can be broken into four steps. These are 1) defining the undertaking and assessing if it has the potential to affect historic properties included on, or eligible for inclusion on the NRHP; 2) making a good faith effort to identify those properties within the area of potential effect; 3) assessing the undertaking's effects on those resources; and 4) taking steps to avoid or mitigate adverse effects if present.

A review of existing primary and secondary resources was conducted in order to provide an overview of cultural resources either known to exist within the Valley or that are likely to be present. As outlined in the Programmatic Agreement (PA) and agreed to by all consulting parties, project specific cultural resource inventories will be completed prior to final project approval.

The following assessment relies on information about recorded archaeological and historical sites on file with the Washington Department of Archaeology and Historic Preservation (DAHP), ethnographic sources, historical maps, and secondary sources.

2.0 Prehistoric Overview

The cultural sequence of the Olympic Peninsula, as with the Pacific Northwest in general, is poorly understood. The lack of securely dated sites along with a general paucity of data about the early and middle prehistoric periods, has led to a very nebulous understanding of shifting cultural patterns through time.

While general cultural chronologies exist for Puget Sound (Kidd 1964; Fladmark 1982; Wessen and Stilson 1986; Ames and Maschner 1999) the division of the prehistoric period into temporally discrete phases is often arbitrary and rarely rooted in clearly definable technological or cultural transitions. Few sites dating prior to 3000 BP have been identified and securely dated let alone investigated in any meaningful way. The predominance of acidic soils in Western Washington has led to poor preservation of organic materials; which in turn, has led to a general lack of secure radiocarbon dates. Furthermore, if the region's earliest inhabitants focused on marine, littoral, and riverine resources then it is likely that any habitation sites would have been "located directly landward of the mean high tide where they would be subject to inundation with sea level rise" (Wessen and Stilson 1987:19). Consequently, much of the data known about the earliest periods in western Washington comes from a small set of sites that currently cannot address the gamut of intersite variability that surely existed.

The chronology presented here was developed specifically for the Olympic Peninsula by Bergland (1983; 1988). These dates are tentative and are subject to change as more information becomes available.

Early Prehistoric (12,000-6000 BP)

This phase begins with the earliest human occupation of the Olympic Peninsula. These first inhabitants were most likely highly mobile hunters and gathers, who utilized a wide variety of

resources (Bergland 1983:21; Wessen1990:25). The Manis Mastodon site is the most cited example from this time period on the Olympic Peninsula. Located south of Sequim, the site contains the remains of a butchered mastodon with a bone projectile point embedded in a rib (Gustafson et al 1979; Morgan et al. 1999). Radiocarbon dates place the site around 12,000 BP (Rice and Stilson 1987). In contrast to contemporaneous sites in eastern Washington, few lithic artifacts were found in association with the mastodon.

Bergland (1983) includes Olcott type sites in his Early Prehistoric Phase. The term Olcott has been used to define sites that date between 5000 and 9000 years BP and that generally correspond with Cascade Phase sites in Eastern Washington. Butler (1961) first presented the idea of the "Old Cordilleran Culture" or Olcott as an early culture of generalized hunters and gatherers that utilized a relatively basic assemblage of tools. In general, Olcott tool assemblages include large thick willow or laurel leaf shaped projectile points, flakes, leaf shaped bifaces-often with serrated edges, cobble choppers, scrapers, and graving tools. Basalt appears to be a preferred toolstone type in the Early Prehistoric (Rice and Stilson 1987:6; Bergland and Marr 1988:27).

Amongst the archaeological community there is a general acceptance that small side notched and triangular points appear later than large lanceolate or leaf shaped points. However, large points made of coarse local materials, crude flakes, and core tools like those associated with Olcott aged sites appear in later deposits as well (Wessen and Stilson 1987). Hence, these tool types are characteristic but are not diagnostic of the earliest occupation period in Western Washington.

Middle Prehistoric (6000-3000 BP)

By 6400 BP, sea levels were within two to three meters of their present levels (Ames and Maschner 1999:88). As sea levels stabilized, estuarine and delta habitats began to develop and evidence suggests that marine resource utilization intensified during this period (Morgan et al 1999). There are few known archaeological sites dating to the Middle Prehistoric on the Olympic Peninsula so most the information about this phase comes from sites in the Gulf of Georgia and the Fraser Valley.

Artifact assemblages from this time period include medium-sized notched and contracting stem triangular projectile points; ground slate bayonet points; and limited stone and wood carvings (Morgan et. al 1999:3.7). The first evidence of a developed ground stone industry occurs at the Esilao Village site in the lower Fraser Canyon about 5000 BP (Bergland 1983:32). While "Olcott" type artifacts continue to appear until approximately 4000 BP, there is a general decrease in point size and cobble choppers become rarer (Bergland 1983:32).

Sea level stabilization may have provided the environment for large, consistent salmon runs in spawning streams throughout the Northwest Coast. Red cedar, previously rare in the area, was present in forests by 5500 BP. While it is problematic to make direct correlations between climate shifts and culture change, it is unlikely these new resources did not affect subsistence strategies and prehistoric technologies.

Early Maritime (3000-1000 BP)

The Early Maritime Phase continues many of the trends first noted in the Middle Prehistoric Phase. Marine resources continue to be a major component of subsistence patterns. Investigated sites have revealed "large quantities of shell, fish, and sea mammal remains" in addition to terrestrial faunal (Morgan et al 1999:3.8). Subsistence activities appear to become more sophisticated and specialized at this time. An offshore hook-and-line fishery is present at the Hoko River site dating between 2200 and 2700 BP (Bergland 1983:37; Wesson 1990:26). Basketry and wood implements appear such as carved projectile points and adzed cedar fragments; meanwhile, the frequency of lithics begins to decline (Bergland 1983: 42; Morgan et al 1999).

Beginning about 3000 B.P., there is a general increase in the size and frequency of shell middens along the Northwest coast which has been viewed as evidence of increasingly larger and more sedentary populations (Moss 1993:631). This inferred population increase also corresponds to ethnographically known populations; hence, the potential exists to link variations in shellfish harvesting, preparation, and consumption with specific cultural groups. Evidence suggests that the winter village pattern with specialized seasonal camps also appears during this phase. The remains of dwellings have been identified; however, they are much smaller than the cedar plank long house typically associated with the Pacific Northwest (Matson and Coupland 1995).

Sites dating to this phase on the Olympic Peninsula include the Ozette Village Site (Daugherty 1970; Wessen 1982), the Hoko River Site (Croes and Blingman 1980), White Rock Village (Kirk and Daugherty 1978), Pitshap Point (Wessen 1984), and Washington Harbor Site (Blukis-Onat and Larson 1984).

Prehistoric Northwest Coast Pattern (1000-200 BP)

This time period is fairly well understood, both on the Olympic Peninsula and within the larger Puget Sound area. The Prehistoric Northwest Coast Pattern differs from the Early Maritime Phase in degree rather than kind. Native inhabitants are practicing the same adaptive strategies and utilizing the same technologies; however, these are becoming more elaborate and specialized. According to Bergland (1983) this period commences with the appearance of the multi-season village and its cedar plank long houses. However, his claim is mostly based on negative evidence e.g. the lack of identified multiseason villages. Recently, evidence for smaller plank houses has been documented earlier in archaeological record indicating the multi-season village may predate 1000 BP (Matson and Coupland 1995).

Also during this phase, lithic tools almost entirely disappear from the archaeological record and are replaced by wood, fiber, bone, and antler tools. Well-preserved sites on the Olympic Peninsula like Ozette provide tremendous detail about the cultural assemblage as well as evidence for social stratification (Daugherty 1970). The households investigated at Ozette revealed intra-household organization through domestic task areas, storage baskets, children's toys, gaming pieces, carved wooden decorations as well as inter-household organization through the development of elaborate drainage systems (Bergland 1983).

3.0 Ethnographic Overview

At the time of Euro American contact, the Skokomish River Basin was occupied by a group of interrelated native peoples who collectively referred to themselves as *tuwa'duxa*, a term later anglicized to Twana (Elmendorf 1960:1). Traditional Twana territory comprised the entire length of Hood Canal to the headwaters of all of the rivers and streams draining into the Canal (Bouchard and Kennedy 1994:36). The northern boundary extended to the Squamish Harbor and Port Gamble and the southern boundary continued to "the height of land between Shelton and the 'Great Bend' of Hood Canal" (Bouchard and Kennedy 1994:36).

The US government applied the name Skokomish to all of the native inhabitants of the watershed beginning in 1855 with the signing of the Point No Point Treaty. Prior to 1855, the name Skokomish referred to one of the nine winter villages within the watershed. As was typical at the time, the name of one community was extended to a larger group of native peoples living within a definable territory and to the major river along which that community was located (Lane 1973:1).

The Twana are one of the most studied tribes in the Pacific Northwest. Much of our current knowledge about pre-contact Twana culture comes from Dr. W.W. Elmendorf's early work with the Skokomish Tribe and his subsequent publications including his seminal ethnography *The Structure of Twana Culture* (1960). The majority of Elmendorf's fieldwork was completed in 1939 and 1940. Next to Elmendorf, the most prolific early accounts of the Twana were completed by the Reverend Myron Eells. Eells lived amongst the Skokomish for 33 years beginning in the 1870s, and while Eells was not a trained ethnographer and his interpretations of Twana culture were influenced by his role as a missionary, his eyewitness accounts of late nineteenth century Twana customs have proven invaluable.

Other studies of note include Edward Curtis's (1913) volume on the Salishan Tribes of the Coast; T.T. Waterman's (1920) collection of over 120 Twana place names in the vicinity of Hood Canal; Nile Thompson's (1979a, 1979b, 1985) examination of the Twana language and Karen James' (1980) ongoing work with the Skokomish. With the exception of Elmendorf's and Waterman's work, the previous studies have not attempted to identify and delineate locations that are strongly associated with traditional, cultural or religious practices.

In 1991, Tacoma Public Utilities (TPU) contracted with Randy Bouchard and Dorothy Kennedy to compile, collect, and analyze an extensive amount of information relating to the Twana in order to identify potential TCPs. This effort was a direct result of TPU's relicensing application filed with the Federal Energy Regulatory Commission (FERC) in the early 1990s. Bouchard and Kennedy reviewed and analyzed existing literature pertaining to the Twana and interviewed twenty-two Skokomish tribal members in 1991-1992. They identified 72 potential sites of concern.

Overall the Twana exhibited a generally cohesive culture pattern that has been broadly classified as part of the Southern Coast Salish group. Twana population estimates during the contact period hover around 1000 (Elmendorf 1960; Bouchard and Kennedy 1994). However, population levels

were likely much higher prior to the mid nineteenth century. Like other Southern Coast Salish Groups, the Twana practiced a seasonal round "which consisted of spring, summer, and fall migrations to fishing grounds, berry and root patches, and shell fishing areas" and a yearly return to a permanent winter village (Larson and Lewarch 1995:1-15). The winter villages were the primary economic and social units and were typically comprised of extended kin groups cohabitating in plank houses.

Elmendorf (1960) identified nine winter village-communities: "Dabop, Quilcene, Dosewallips and Duckabush, in the lower, northern Hood Canal area; Hoodsport, Skokomish, and Vance Creek, near the mouth of the Skokomish River or in its drainage; and Tahuya and Duhlelap, on the upper, southern arm of Hood Canal" (1). Slight cultural variations surely existed amongst these winter villages; however, by the time that Elmendorf began his ethnographic work the Twana had been living on the Skokomish Reservation for over 60 years, and village comparisons were no longer possible.

The Twana spoke a Salishan language that was unintelligible to the other members of the Salishan language family such as the Lushootseed speakers along southern Puget Sound (Elmendorf 1960; Lane 1973; Bouchard and Kennedy 1994). Only slight dialect differences have been noted across the Twana territory. These have been classified into three clusters: around the entrance to Hood Canal; near the mouth of the Skokomish River; and at the end of Hood Canal (Bouchard and Kennedy 1994:35). These dialect clusters corresponds to a common division of the Twana into three regional groups: the Duhlelips, Skokomishes, and the Quilceeds (Wesson 1987; Suttles and Lane 1990).

Typical of other tribes in the Pacific Northwest, the Twana had a dietary reliance on salmon. Four species were common in Hood Canal and the Skokomish River: Chinook, coho, chum, and pinks. James (1980) states that sockeye were also prevalent in the Skokomish River, but Elmendorf's (1960) data does not support this. The majority of salmon were caught with weirs, dip nets, and harpoons during late summer and fall runs. Most of the catch would be dried and stored for use during the winter. Other fish that featured prominently in their diet included: winter and summer steelhead, skate, flounder, sole, rock cod, and halibut at the northern end of Hood Canal (Elmendorf 1960:57). After fish, the Twana's food resources are ranked in order of importance as sea mammals, mollusks, waterfowl, land game, and vegetable products (Elmendorf 1960:56).

Fishing and hunting were predominately male pursuits while women harvested mollusks, gathered plant foods, and made baskets, blankets, and cordage. The Twana believed that specialized skills were bestowed on individuals by supernatural powers or guardian spirits. Typically this occurred as a result of vision questing, but there was evidence of some skills being inherited. There was more ritualized behavior associated with hunting than fishing despite the fact that fish was a more important food source.

The Twana had a unique belief system regarding the afterlife. For the Twana, each living person contained two souls: a life soul and a heart soul. At death, the heart soul died with the body and the life soul, with the exception of the souls of infants, went to the first land of the dead. Each village had a corresponding village in the land of the dead, only the conditions were opposite of

what they were in this world, e.g. summer is winter and day is night. After a certain amount of time, the life soul would die a second death and be reborn as an infant in this world. Meanwhile, the life soul of an infant would leave the cycle of rebirth and become a guardian spirit (Suttles and Lane 1990:496).

4.0 Historical Overview

The first recorded Euro American expedition into the project area begins with Captain George Vancouver who arrived in Hood Canal and named it in 1792. The Hudson Bay Company traders visited the area in the 1830s and established a trading post in the Union area. In 1853, the first white settler to file a donation land claim in Mason County, Hugh Goldsborough, was drawn by the vast stands of Douglas fir and cedar that soon spawned timber mills in nearby Shelton. A Skokomish Valley settler, Thomas Webb, made an 1855 donation land claim in what is now called the Nalley Ranch. Other Euro American settlers rapidly joined Webb, many arriving from Middle West states of the country. Those faced with carving a life from the dense forests found ample building materials in the valley's stands of cedar and Douglas fir, though the survival of such period structures is presently unknown.

Like much of western Washington in the mid to late nineteenth century, the dwellings of Euro American settlers consisted of rudimentary single story cabins consisting of whole or hewn logs laid horizontally. Depending on cultural affiliation and economic status, log construction and corner joinery ranged from simple log buts, to finer dove tail variations reflecting Scandinavian traditions. Presently, it is not known whether the valley retains any examples of settlement era log buildings. Given the river bottom environment was previously thick with cedar forests, any original settlement era buildings would likely incorporate cedar materials in log, framing, and roof cladding.

Skokomish maple and alder fed the growing timber industry and stocked three hardwood mills located in the valley. As the Skokomish River bottom was cleared of timber, subsistence farming and dairying quickly replaced milling, making the survival of mill related structures unlikely. During the valley's development stage in the late nineteenth century (1880-1910), railroad systems and booming saw mills introduced a variety of new building materials of standardized dimension. Some of the first homes, barns, and outbuildings built during this period incorporated vertical plank construction with battens, sometimes set into channeled groove. Because of the high vulnerability of such structures due to constant flooding and re-development of the valley floor for over a century, examples of this plank system are unlikely to be found in the remaining stock of buildings.

Several mining claims were filed on these lands in the late 1880s, on word of copper, manganese, and iron ore deposits on the North Fork of the Skokomish River. One of the early companies was the Mason County Mining and Development Company. Mining efforts continued through World War II, to little effect. Of the 400 claims filed, only eighteen showed metallic mineral in the assay samples. Future historic property inventories of the valley may encounter remnants structures, features or objects relating to these short lived mining ventures.

Roads were built throughout the valley to support logging, ranching, and recreation and tourism, which flourished alongside the less environmentally friendly industries. Timber bridges were first employed for river crossings, and later replaced with concrete versions in the 1920s. In 1890, a resort hotel was built on Lake Cushman. The hotel, the valley and the new community of Hoodsport were connected by a road that same year. Visitors flocked to the hotel, and other resort stations in the area.

By the early 1900s, both Seattle and Tacoma had realized a need for more power. Interest arose in the hydroelectric potential of the Skokomish River. Seattle pursued an electric franchise in and around 1912, but issues with transmission routes put the project on hold. Eight years later, in 1920, the City of Tacoma obtained a permit for the same site. Despite protestations from the Skokomish Tribe and other landowners, the project went forward. Land within the proposed reservoir was cleared, building were razed and burned. Cushman Number 1 Dam, built by the A. Guth[e]rie Company of Portland, Oregon, became operational in 1925. At that time, the dam was the largest structure of its type; its reservoir the second largest in the west. Another milestone was the establishment of the Olympic National Park in 1938 (Begland and Marr 1988), which withdrew much timber land from the private domain.

By the 1920s, farming practices were expanded to include berry and grape cultivation, anticipated to be the dominant industries in the valley. Structures associated with this agricultural output are presently unknown but may be anticipated in future survey efforts. Aggressive plowing and seeding continued in the 1920s, elevating the importance of Skokomish Valley agriculture beyond other river valleys in the county. Many surviving houses and agricultural buildings are associated with this period.

One of the most visually prominent buildings reflecting community prosperity during this period is former Middle Skokomish Valley School, today known as the Grange Hall. Built in 1923, the two-story building consolidated the earlier 1915 Upper Skokomish School, which was moved next to the new building. The valley's educational history includes the Indian Boarding School era, which founded the Lower Skokomish Valley School in 1869 to matriculate Native Americans. By 1871, the Skokomish Reservation was under charge of the Congregational Church, with Edwin Eells assigned as government Indian agent. Eells' brother Myron was appointed as church missionary and chronicled the lives of the native peoples he served. The agency school was eventually used as a tribal community center, however its status and historic integrity are not known. Another structure tangentially associated with the theme of Native American culture and education – built by Maine emigrant and carpenter, Michael Fredson – was the Tom Webb house on the Skokomish River, the status of which is also unverified.

In the first decades of the twentieth century, building patterns reflected balloon frame construction of dimension lumber. Examples mostly exhibit horizontal lap, or drop siding. Roof types are generally gabled, and feature unfinished soffits with exposed rafter tails. Latent influences of the Craftsman period are evident in the use of knee brace brackets, shingle cladding, and integrated or projecting bungalow porches.

Until the valley floor was deforested, logging was an important industry from both Euro American settlers and Native Americans. The Skokomish people participated in these local

industries, independently and as hired labor. The Skokomish Tribe continued to fish and gather shellfish for both personal use and sale. Land development, in the form of diking and plowing, severely affected these traditional resources. With deforestation, land previously too expensive to clear became available. Wetlands gave way to farmlands, resulting in the loss of sweet grass and other traditional use plants. Increased sediment deposits from upland logging and the State of Washington's claims of jurisdiction over tidelands limited the development of shellfish species and restricted the Skokomish peoples' access to those resources.

5.0 Cultural Resources in the Study Area

Compliance with regulations affecting cultural resources requires the definition of an area of potential effect (APE). The APE is defined as the geographic area or areas within which an undertaking may directly or indirectly cause changes in the character or use of historic properties. For the Skokomish River Basin General Investigation, specific projects have not been identified, designed or located on the landscape; subsequently, project specific APEs have not been delineated. Because projects could occur anywhere within the study area, archival data were collected to determine the nature and location of prehistoric, historic, and architectural resources present within the entire study area.

A search was made of the Washington Department of Archaeology and Historic Preservation's online database WISAARD. The database lists all archaeological sites that have been officially recorded and sent to DAHP. The database also shows areas that have been inventoried since 1995, but does not provide a comprehensive list of inventories conducted prior to 1995. The majority of inventories known to have occurred in the study area have been small in scale, typically under one acre or linear surveys that simply bisected the study area.

The largest inventories that have occurred in the study area are associated with the FERC relicensing of the Lake Cushman Hydroelectric Dam, and consequently, have clustered around Lake Cushman and the North Fork of the Skokomish River. A total of 17 archaeological sites have been recorded in the study area. Eleven of these are prehistoric sites with shell middens and small lithic scatters being the predominant site type.

Site #	Site Period	Eligibility Determination
45MS050	Prehistoric	Unevaluated
45MS051	Prehistoric	Unevaluated but Recommended Eligible
45MS053	Prehistoric	Unevaluated
45MS055	Prehistoric	Unevaluated
45MS056	Multicomponent	Unevaluated
45MS108	Prehistoric	Unevaluated
45MS109	Prehistoric/ Contact	Unevaluated
45MS126	Prehistoric	Unevaluated
45MS128	Prehistoric	Unevaluated
45MS129	Prehistoric	Unevaluated
45MS130	Historic	Unevaluated
45MS131	Historic	Unevaluated
45MS132	Prehistoric	Unevaluated

45MS135	Historic	Unevaluated
45MS136	Historic	Unevaluated
45MS190	Prehistoric	Unevaluated
45MS191	Prehistoric	Unevaluated

Table 1: Recorded Archaeological Sites within the Study Area

In addition to the cultural resource inventories, Bouchard and Kennedy (1994) completed an extensive ethnographic study of the basin. They interviewed twenty-two Skokomish tribal members in 1991-1992 and identified 72 areas of tribal concern. These areas were recorded on TCP forms. Bouchard and Kennedy recommended that 24 of these areas met the National Register criteria; however, an official determination of eligibility was never made by a federal agency.

While a comprehensive architectural survey has not been completed, a reconnaissance survey of the valley revealed that the survival of the early built environment is limited. Not surprisingly, extensive flooding, land clearing for logging and later agricultural pursuits, have swept away many of these properties. A cursory review of the valley's most accessible structures and buildings suggests that those that remain are products of accelerated agricultural growth in the early part of the twentieth century, the general period, 1920-1940. There is also the strong possibility that some of these homes and agricultural buildings are the products of pattern books or "pre-cut and assemble" building packages selected from local hardware stores and shipped by train. Examples of the types of structures and associated historic themes to address in future project phases include:

Agriculture – Farm Houses, Barns, Outbuildings:

- Barn and chicken coop located on Skokomish Valley Road
- McKeman Fish Hatchery (1947 complex)
- Hunter Family Farm Buildings

Residential – Bungalow/Craftsman Dwellings:

- Two Small bungalows located on Skokomish Valley Road

Education

- Skokomish Grange (1923)

Native American History/Culture

- Eells Hill Rd./Vance Creek Rd.: Eells House

Transportation

- Four Skokomish River bridges (1920-1932)

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SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX E

MONITORING AND ADAPTIVE MANAGEMENT PLAN

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

Skokomish River Basin General Investigation

Monitoring and Adaptive Management Plan

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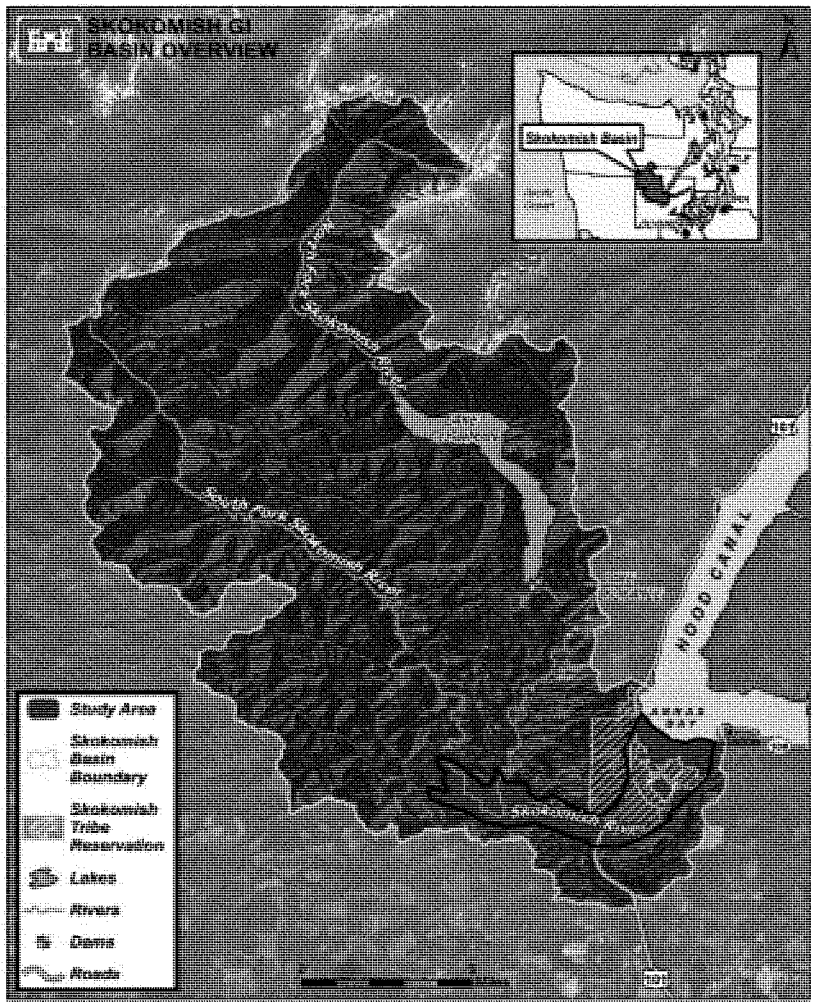
1 Introduction to the Project

The Skokomish River Basin is located on the Olympic Peninsula in northwestern Washington. The study area is approximately 11 square miles comprised of the lower Skokomish watershed, the Skokomish Valley, and Skokomish River estuary (Figure 1). The area is characteristic of the enormous beauty and versatile environment of Hood Canal and Puget Sound.



Alteration of the river environment and encroachment on the floodplain by human-made structures have degraded and continue to affect natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat throughout the basin. The degraded stream, wetland, and

riparian habitat cannot support a healthy population of critical fish and wildlife species. Specific anthropogenic impacts to the Skokomish River Basin include the following:

- Removal of large woody debris (LWD) simplified the stream habitat by reducing the occurrence of pools, caused loss of nutrients and substrate to support aquatic insects, and removed the complex rootwad structures that allow juvenile fish to hide from predators.
- Removal of the riparian forest has reduced the supply of LWD, overhanging vegetation that provides food sources for terrestrial and aquatic insects, and shade cover (approximately 62% of the mainstem is sparsely vegetated).
- Intensive logging activities that disturbed and destabilized the stream banks reduced streamside vegetation due to erosion.
- Protection of agricultural lands from erosion led to construction of bank protection measures. Those measures stopped natural channel migration, which reduces the rate of habitat creation in the river and in the floodplain.
- Logging activities in the South Fork and Vance Creek watersheds may have increased the upper basin sediment supply that is accumulating in the river reaches of the study area. This accumulation of gravel in the riverbed has resulted in cutting off access to aquatic habitats in the floodplain.
- The Cushman Dam Project, channel straightening, and levees have, to varying degrees, reduced ecosystem functions and habitat availability for all riverine fish species and the aquatic-oriented mammals such as beaver, river otter, and mink.
- The removal of LWD, disturbance of the stream banks, bank protection, and side-channel closures have all contributed to altering the bedload transport and deposition in the South Fork, Vance Creek, and the mainstem Skokomish River. In addition, flow regulation and reservoirs constructed by the Cushman Project has altered bedload supply from the North Fork, and bedload transport and deposition in the mainstem Skokomish River. A significant problem of the sediment accumulation is that the river dries up for a mile for nearly two months each year in the late summer. This poses a total block for upstream and downstream fish migration, and can prevent salmon from reaching their spawning grounds in time to spawn before dying.
- The U.S. Highway 101 and State Route 106 road embankments disrupt overbank flood flows and reduce habitat connectivity.

1.1 Project Planning Objectives

The project delivery team (PDT) for the Skokomish River Basin Ecosystem Restoration Feasibility Study formulated the following objectives to address some of the problems listed above:

1. Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
2. Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary networks 50-year period of analysis.

3. Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.
4. Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

1.2 Proposed Action

Based on the project objectives listed above, the PDT screened a list of potential management measures, restoration sites, and an array of alternatives. Through this process, the PDT selected a recommended plan that includes the following measures:

- Confluence Levee removal will open the river's largest constriction and redirects flow around the reach that goes dry. This achieves planning objective 1 by providing year-round fish passage via high quality habitat in the lowest reach of the North Fork.
- LWD installation on the South Fork throughout river miles 9 to 11 will create pools and complex habitat. This achieves planning objective 4 with increased number and quality of pools and habitat complexity.
- Reconnection of remnant side channel and associated wetlands will provide high flow seasonal access to rearing and refuge habitat for fish and amphibians by constructing an inlet and outlet. This achieves planning objectives 2 and 3 with the floodplain reconnection and prime over-wintering rearing habitat.
- Floodplain wetland restoration by breaching two agricultural berms and constructing wetland embankments away from the river for a widened channel migration zone and wetland restoration.
- Riparian restoration and re-vegetation in various areas associated with the other measures will improve riparian zone habitat quality. This achieves planning objective 3 with greatly increased native vegetation in the riparian zone.

These proposed measures are the basis for this monitoring and adaptive management plan.

2 Corps Guidance on Monitoring

Monitoring guidance for Corps projects was detailed in ER1105-2-100 in 2000 (USACE 2000). Since then, Implementation Guidance for Section 2039 of WRDA 2007- Monitoring of Ecosystem Restoration (USACE 2007) was issued and supersedes the 2000 guidance. The 2007 guidance states that a plan for monitoring ecological success must be included in the decision document, must include the rationale for monitoring, and must identify key project-specific parameters and how they relate to achieving the desired outcomes for making a decision about the next phase of the project. The guidance also states that the monitoring and adaptive management costs will be included in the project cost estimate and cost-shared accordingly; allowing for a monitoring period of up to, but not exceeding, ten years. The monitoring plan should also identify the criteria for success and when adaptive management is needed.

3 Purpose of the Plan

As described in the previous section on Corps guidance, the purpose of this plan is to demonstrate ecological success of the project. This success is determined by monitoring metrics that are specifically tied to project objectives, and setting performance targets. In addition, the plan identifies what adaptive management is proposed if the performance targets are not met.

This plan presents the framework for the above methodology, and will be refined in collaboration with the non-Federal sponsors, as well as other stakeholders who may take responsibility for monitoring ecological variables in the watershed.

4 Project Monitoring

As a restoration project, it is expected that this site will be dynamic and evolve. Thus, for some parameters, strict achievement of predetermined performance standards will not necessarily predict the success or reveal the failure of the restoration effort. The monitoring and evaluation will focus on determining whether the overall project objectives of the restoration are being met. Monitoring efforts will be performed by using monitoring metrics listed in section 5 (Evaluation of Specific Objectives). All post-construction monitoring will be performed by qualified biologists and hydraulic engineers.

Evaluating the evolution of restored habitats will be based on the establishment of the targeted habitat within the restoration site and on the ecological functioning of those habitats. All post-construction monitoring will be cost shared between the Corps and the non-Federal sponsors for the first 10 years of monitoring. The non-Federal sponsors may choose to monitor beyond this ten-year period, although the cost would be 100% their responsibility. Data collection will be used to determine success of the project with the focus on the development of in-stream and riparian habitats. The Corps and the non-Federal sponsors will use the knowledge gained through this monitoring to adaptively manage the project sites.

The following section lists monitoring metrics, performance targets, and potential adaptive management associated with the effectiveness monitoring, which aims to demonstrate how well the habitat is developing according to performance criteria.

5 Evaluation of Specific Objectives

The monitoring metrics listed below are grouped by the project objectives listed in section 1.1.

5.1 Evaluation of Objective 1

Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.

5.1.1 Monitoring Metric 1: Year-round flow

Methods and Timing: Along the reach where Confluence Levee is removed, measure cross-sectional flows in the North Fork during summer low flows (early July through late September). Walk channel profile at low flow and survey channel bottom and water surface every 100 feet and identify any dry reaches. Include notes on morphological feature extents in profile (pool, riffle, glide). Include field observations of passage barriers (such as dry or shallow areas) and note with GPS coordinates. These parameters will be monitored once per year in years 1, 2, and 5 after construction to verify project success of providing year-round passage, which is at greatest risk of being blocked during summer low flow.

Performance Target: Chinook salmon will be used for this metric since their arrival overlaps the most with the summer low-flow period and they are the largest of the Pacific salmon and therefore require the most water for passage. According to the peer-reviewed literature, Chinook salmon require at least a 0.8-foot depth of water over at least 25% of the wetted channel for upstream passage (Reiser and Bjornn 1979). Raleigh et al. (1986) indicates a minimum depth of 0.4 feet for passage at velocities less than 2 feet per second (ft/s). The more conservative of the two will be used as the performance target. Channel geometry combined with flow affects fish passage, so channel cross-sections and discharges will need to be taken along with depths. Calculations can be done from cross section surveys to determine whether the there is adequate flow to provide 0.8-foot of depth across 25% of the wetted channel (Pacific Northwest Monitoring Partnership 2014).

Adaptive Management: If target flows for passage in the North Fork are not achieved, then additional removal of ground surface where the levee stood may be needed, more excavation at the small existing breach may be necessary to divert more water to the North Fork, or additional engineered logjams to divert flows may need to be installed. Finally, the design team should have a discussion on "following the channel" if a new channel forms or changes position during the monitoring period. The metric will be met as long as one continuous wetted channel occurs and provides ample flow for fish passage, regardless of its location.

5.2 Evaluation of Objective 2

Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary networks for the 50-year period of analysis.

5.2.1 Monitoring Metric 2: Depth and width of opened channels, and seasonal velocity

Methods and timing: Measure seasonal depths and widths in inlet and outlet of restored side channel in winter, spring, summer, and fall. These parameters will be monitored 4 times per year in years 1, 2, and 5 after construction to verify project success.

Performance Target: Seasonal usage of the reconnected side channel by coho salmon will be used for this metric since they tend to spawn and rear in smaller streams and juveniles spend a full year in freshwater before out-migrating to the ocean. Coho are the primary species anticipated to benefit from the Side Channel Reconnection, although steelhead, cutthroat trout, and Chinook salmon will likely use the habitat as well. The following performance criteria apply:

- Rearing capability (to be measured in the spring, summer, and early fall): >30 cm depth, <30 cm/s velocity through the constructed openings at the inlet and outlet channels (Thompson 1972, Nickleson and Reisenbichler 1977)
- Maintenance of at least 80% of design width and depth of post-construction channels (measured in late fall and winter during minimum flows for activation of channels). Design criteria are provided in drawing sheets and monitoring criteria will also use as-built drawings after construction.

Through annual channel change, more valuable habitat will develop as high flows influence the shape of the constructed channels. Locations of measurement may change based on re-arrangement of side channel(s) by floods, increased flow, sedimentation, vegetation growth, etc.

Adaptive Management: If target depths, widths, and velocities are not achieved by the 7th year after construction, or if depth and width are less than 80% of the design criteria, then wood may need to be added to encourage microhabitat or additional excavation may be necessary to route more water through the opened channels.

5.2.2 Monitoring Metric 3: Riparian canopy coverage in areas re-planted after construction disturbance at Confluence Levee removal area and Side Channel Reconnection riparian zones

Methods and timing: Measure percent survival and percent coverage of the riparian corridor during late summer/early fall. The timing assumes that the contractor will be responsible for 100% survival of planted vegetation. Post-construction monitoring will occur in years 2, 3, and 6. The U.S. Fish and Wildlife Service recommends monitoring at least through year 3. Year 6 is included to provide a reasonable amount of time for shrubs to reach maturity so the Corps can determine whether sufficient ground coverage has been achieved or whether an adaptive management measure must be implemented.

Performance Target: It is expected that coverage will increase as planted and volunteer species grow. Planted and desirable volunteer trees and shrubs should be healthy and have a high percentage of ground coverage compared to bare dirt or invasive species. Performance targets include the following:

- Year 2: at least 80% survival of planted species
- Year 3: at least 70% survival of planted species
- Year 6: at least 80% ground coverage of native species

Adaptive Management: If the above targets are not met, then additional plantings could be implemented and/or changes in species planted from original planting plan if survival of certain species

is low. Additional irrigation of plants may need to be provided if they appear to be water stressed during the first three years.

Monitoring for invasive species must occur annually and treatment with monitoring must occur semiannually if invasive plants are detected. The duration of treatment and monitoring for invasive plants must continue until native plants are well established and would be the responsibility of the non-Federal sponsor.

5.2.3 Monitoring Metric 4: Overhanging vegetation and in-stream cover at the Side Channel Reconnection inlet and outlet channels

Methods and timing: Measure percent cover, including overhanging vegetation, boulders, and logs, during late summer/early fall in a standardized section of stream that is adjusted for width. Post-construction monitoring will occur in years 2, 3, and 6.

Performance Target: Cover is expected to increase as the vegetation grows and LWD recruits along the banks. The performance target for this metric is based on a suitability index of 0.8 for 10% cover for juvenile steelhead (Raleigh et al. 1984) and a suitability index of 0.8 for 20% cover for juvenile Chinook (Raleigh et al 1986). The targets in a standardized section of stream are the following:

- Year 2: at least 80% survival of planted species
- Year 3: at least 70% survival of planted species
- Year 6: at least 20% in-stream cover

Adaptive Management: If target cover is not met, then more plantings may be necessary and/or the addition of more LWD to achieve the target of 20% in-stream cover.

5.3 Evaluation of Objective 3

Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.

5.3.1 Monitoring Metric 5: Maintenance of remnant side channel/wetland to the inlet during high flows and outlet year-round.

Methods and timing: Observe for hydraulic connection of inlet during late fall/early winter, and connection of the outlet in spring, summer, fall, and winter. Measure depths in the side channel inlet and outlet in winter and spring. This parameter will be monitored in years 1, 2, and 5 after construction to verify project success.

Performance Target: Connection at the inlet during typical higher flows that occur regularly October through April and connection at the outlet year-round. Rearing depths >30 cm depth (based on juvenile coho rearing).

Adaptive Management: If connections are not observed during indicated periods, then additional excavation at the inlet and/or outlet may be required. Additional stabilizing logs at the opening may be needed.

5.3.2 Monitoring Metric 6: Establishment of native vegetation at the re-planted areas of Confluence Levee removal and at the wetland embankments for Wetland Restoration at River Mile 9 and Grange

Methods and timing: Measure percent survival and percent coverage of the riparian corridor during late summer/early fall. The timing assumes that the contractor will be responsible for 100% survival of planted vegetation. Post-construction monitoring will occur in years 2, 3, and 6. The U.S. Fish and Wildlife Service recommends monitoring through at least year 3. Year 6 is included to provide a reasonable amount of time for shrubs to reach maturity so the Corps can determine whether sufficient ground coverage has been achieved or whether an adaptive management measure must be implemented.

Performance Target: It is expected that coverage will increase as planted and volunteer species grow. Planted and desirable volunteer trees and shrubs should be healthy and have a high percentage of ground coverage compared to bare dirt or invasive species. Performance targets include the following:

- Year 2: at least 80% survival of planted species
- Year 3: at least 70% survival of planted species
- Year 6: at least 80% ground coverage of native species

Adaptive Management: If the above survival and coverage targets are not met, then additional plantings could be implemented and/or changes in species planted from original planting plan if survival of certain species is low. Additional irrigation of plants may be needed in the first three years if the plants appear to be stressed. The invasive species removal effort may need to increase if they appear to be outcompeting native species.

5.4 Evaluation of Objective 4

Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

5.4.1 Monitoring Metric 7: Number of LWD structures in the wetted areas of the channel

Methods and Timing: Check all installed LWD structures and record the number that still have some of their structure under water during the summer low-flow period (July-September). This metric would be measured annually for 10 years during low flow to capture the most critical period for providing pool habitat for fish. Incidental observations of surrounding riverbank and sediment conditions would be recorded for an overall assessment of habitat changes in the treated reach.

Performance Target: The design target is to have 64 "key" LWD pieces per mile with a minimum of 21 key pieces remaining wetted by mainstem river flow during the driest summer months to mimic nearby less degraded rivers. One of the purposes of LWD is to provide greater complexity of habitat under water, and an important season to achieve this is during warm summer months when juvenile salmonids will be seeking cool water refuge in pools. This objective is balanced with another purpose for the LWD structures, which is to create bar-apex logjams to split the flow around a gravel bar. The number of LWD structures still under water during low flows will depend on their placement and the hydrology of the location. The initial performance target is to have 50% of LWD installed for the purpose of complex pool

habitat to be remaining in the wetted channel at least in the first year after construction. Monitoring of the Upstream LWD installation in river miles 9-11 plus an additional rivermile downstream will occur annually. This will determine whether the performance target has been met and will help determine whether unanticipated reach-scale effects are occurring that may require adjustment of LWD installations. The duration of monitoring will be long enough to capture at least 2 channel-forming flows (approximately 17,000 cfs). Since this flow is equivalent to the 0.5 Annual Chance of Exceedance, it is anticipated that the monitoring end point will be less than 10 years post construction.

Adaptive Management: Adaptive management may involve relocating or adding more wood if the performance target of 50% of LWD installed or 21 key pieces in the river is not met.

5.4.2 Monitoring Metric 8: Pool development around the Upstream LWD installed in river miles 9-11

Methods and Timing: Measure pool depth and size adjacent to LWD installations and any pools that form throughout the treated reach. Note rough quantities of debris accumulation on LWD installations. Measure dimensions of recruited debris. Both of these metrics would be measured annually for 10 years during low flow to capture the most critical period for providing pool habitat for fish. Incidental observations of surrounding riverbank and sediment conditions would be recorded for an overall assessment of habitat changes in the treated reach.

Performance Target: In rivers, the largest and greatest number of pools tend to be associated with LWD (Abbe and Montgomery 1996). Pool development is expected to increase as the river scours the bed surrounding the logjams. The performance targets are as follows:

- achieve 40% pool habitat throughout the treated reach
- each logjam installation has a pool that is equal to the full length of that installation
- pools associated with each logjam installation are at least one foot deep.

Monitoring of the Upstream LWD installation in river miles 9-11 plus an additional rivermile downstream will occur annually. This will determine whether these three performance targets have been met and will help determine whether unanticipated reach-scale effects are occurring that may require adjustment of LWD installations. The duration of monitoring will be long enough to capture at least 2 channel-forming flows (approximately 17,000 cfs). Since this flow is equivalent to the 0.5 Annual Chance of Exceedance, it is anticipated that the monitoring end point may be less than 10 years post construction.

Adaptive Management: Adaptive management may include reorienting LWD or adding more pieces to the structures or to the treated reach of the river. Low water years could inhibit the formation of pools around LWD by limiting scour; therefore, effects caused by weather conditions such as floods or droughts should be considered before adaptive management is undertaken.

6 Contingency Planning and Implementation

Contingency measures (adaptive management) will be implemented if the monitoring program (or any other documented observations by qualified personnel) indicates performance targets are not being met and cannot be explained by extraneous variables. The Corps and the non-Federal sponsor would

then assess monitoring metric parameters and initiate the implementation of corrective actions to address the identified issue. Monitoring and adaptive management activities in this plan will be refined in preconstruction, engineering, and design phase. Additional metrics, methods, performance targets, and adaptive management measures may be added if needs are identified. The overall timeline for meeting performance targets is 10 years after construction. This is estimated to be ample time to determine ecological success through measurement of the physical and biological parameters outlined in this monitoring and adaptive management plan.

7 Cost

The following table summarizes a total cost estimate for the monitoring efforts in this plan:

Table 1. Estimated cost of monitoring effort for the Skokomish GI

Type of Monitoring	Monitoring Metric	Time frame	Cost
Physical Monitoring	MM1: Year round flow	summer	$231,000
	MM2: Depth, width, and velocities	winter, spring, summer, fall	
	MM4: Overhanging vegetation and in-stream cover	late spring	
	MM5: Maintenance of remnant side channel/wetland network	winter, spring, summer, fall	
	MM7: LWD structures in the water	summer	
	MM8: Pool development and recruitment around LWD	spring	
Biological Monitoring	MM3: Riparian Canopy coverage in planted areas	late summer/early fall	20,000
	MM6: Establishment of native vegetation along the river and floodplain	late summer/early fall	
Vehicles and equipment			$4,000
Travel			$23,000
Monitoring Total			**$278,000**
Grand Total	Contingency of 35% added to monitoring total (See Appendix K of the Final FR/EIS for additional information)		**$375,000**

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SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX F

ECOSYSTEM OUTPUTS MODEL

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

SKOKOMISH RIVER ECOSYSTEM RESTORATION PROJECT ENVIRONMENTAL BENEFITS ANALYSIS

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SKOKOMISH RIVER ECOSYSTEM RESTORATION PROJECT ENVIRONMENTAL BENEFITS ANALYSIS

1 INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (Corps) is conducting a General Investigation (GI) to propose alternative plans for aquatic ecosystem restoration in the Skokomish River Basin, Mason County, Washington. That process follows a prescribed series of steps to formulate and evaluate specific proposed measures, and involves working with various local entities and other state and Federal agencies. Ecosystem restoration of the Skokomish River includes multiple potential actions that are intended to improve the condition and function of the river system, with an emphasis on factors that limit anadromous fish reproduction, refuge, and rearing habitat. The proposed restoration measures range from site-specific engineering actions to altering basic ecosystem processes. There are multiple possible combinations of these measures, and it is the responsibility of the Corps to identify the most efficient configuration as the recommended restoration plan. For the Corps' ecosystem restoration mission, the assessment of project alternatives is directed toward quantifying complex environmental benefits. Ideally, the process of assessing alternatives should be sufficiently broad-based that it captures the major ecological implications of proposed project actions, while being easily understood, and producing outputs that can be used in the context of standard planning and decision-making procedures.

The purpose of the Environmental Benefits Analysis described here is to provide quantification of the potential ecological improvement of proposed restoration actions so that the actions can be compared to each other, and to compare alternative suites of actions in the cost effectiveness and incremental cost analysis. This assessment method is structured to address the objectives and limitations of the Skokomish River as defined in the Section 905(b) Water Resources Development Act Analysis Report and as identified in subsequent follow-up planning meetings for this project. It is consistent with guidelines set by the Corps (USACE 1999; ER 1165-2-501).

1.1 STUDY AREA

The study area for the Skokomish River GI is approximately 11 square miles and is limited to the Lower Skokomish River Valley, the floodplain and channel of the lower mainstem and lower South Fork of the Skokomish (divided into five study reaches), and a major tributary, Vance Creek (Figure 1). It specifically excludes the North Fork and areas upstream of the lower valley due to various constraints, but recognizes that many of the problems that afflict the lower river originate elsewhere in the system. The 905(b) report identifies a variety of agencies and other entities (e.g. US Forest Service [USFS] or Tacoma Public Utilities [TPU]) that may have restoration projects underway throughout the watershed to address some of those issues, and specifies that the Corps will coordinate with them.

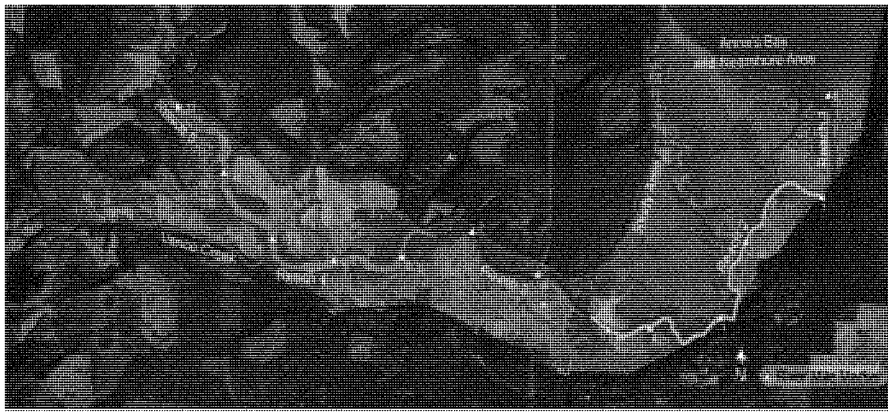

Figure 1. Study Area and Assessment Reaches

1.2 PROBLEM IDENTIFICATION

The Skokomish River Basin was the subject of extensive field investigations beginning more than a decade ago. The Washington Department of Fish and Wildlife and Point No Point Treaty Council conducted habitat assessments focusing on Hood Canal summer chum salmon recovery planning (WDFW and PNPTC 2000), and Correa (2003) described the condition of the area in terms of factors limiting the availability and condition of habitat for all species in the Salmonidae family that are present in the Skokomish basin (Chinook, chum, coho, pink, steelhead, sea run and resident cutthroat, rainbow trout, and bull trout). A more recent study (Peters et al. 2011) revisited the basin and provided a comprehensive characterization of aquatic and riparian habitat conditions. These reports noted that each salmonid species differs in the timing of critical life history events and the way it uses various habitats, but that all of the anadromous fish in the system have the same basic requirements:

- Adequate water quality and appropriate water temperatures;
- Balanced sediment budget;
- Stable spawning gravels;
- Pools and instream structure including large boulders and logs;
- A functional riparian zone;
- Connected freshwater migratory and refuge habitats; and
- A complex of healthy estuarine and nearshore habitats to allow transition from freshwater to seawater.

All of these critical factors were found to be compromised or lacking to some extent. Much of the degradation originates from excess sediments in the channel system, changes in flows, and disconnection of the floodplain and off-channel wetlands by levees.

During the problem identification phase of the feasibility study, the frequent fish stranding that occurs during overbank flows of the Skokomish River was named as a high priority issue. The flood frequency

of overbank flow has increased to a return interval of more than once per season, often as many as four times in one winter. The high flow events coincide with the fall migration of Chinook, coho, and steelhead, as well as the incubation of eggs and alevin stage in the redds. The flooding causes adult fish to become stranded in the fields adjacent to the river. For fish that have been able to spawn in the river, the late winter and early spring floods scour the redds causing mortality of incubating eggs, and strand juvenile fish in the fields.

Change in disturbance regime has been identified as an anthropogenic stressor to many salmon populations (Waples et al. 2009). For example, over the past 80 years in the Stillaguamish River, the discharge that had a return interval of 10 to 20 years has become a one- to two-year event (Waples et al. 2008). Seiler et al. (2002) found a strong correlation between high discharge and low egg-to-migrant fry survival. Naturally occurring high flows cause a certain rate of mortality, but viable salmon populations have the resilience to rebuild after loss during rare events. However, the increased frequency from anthropogenic causes may now be too frequent for the salmonid populations to be able to adapt (Waples et al. 2009).

The sedimentation rate in the Skokomish River has exceeded the river's ability to transport sand and gravel, which has led to reduced channel capacity. The river's discharge capacity is now only approximately 25% of the two-year return interval discharge. Flood frequency is multiple times per winter. This flood frequency regime causes such frequent and substantial mortality to the annual returns of migrating salmon that the populations may no longer have the abundance to withstand such losses.

Another characteristic of the Skokomish River is that the variety of habitat types has been significantly reduced mainly by the removal of large wood decades ago, and the filling of pools due to wood removal and excessive sedimentation. This reduction in habitat diversity leads to reduced resilience of the river's salmon populations (Waples et al. 2009).

Table 1. Habitat factors affecting salmonid habitat in Hood Canal Rivers with supporting information. AM is adult migration, S is spawning, I is incubation, R is rearing (WDFW and PNPTC 2000).

Habitat Factors	Impacts to Channel Processes and Summer Chum	Life History Stages	Supporting Literature
Winter high flow	Redd scour through increased sediment transport	I	McNeil 1964, Tripp and Poulin 1986, Thorne and Ames 1987, Nawa and Frissell 1993, Chamberlain et al. 1991, Schuett-Hames et al. 1994, Montgomery et al. 1996
Summer low flow	Prevention or delay of upstream passage, reduction of available spawning area	AM, S	Chamberlain et al. 1991, Johnson et al. 1997
Water temperature	Elevated temperatures impede adult passage, cause direct mortality, and accelerate development during incubation leading to diminished survival in subsequent life stages	AM, SI, I	Beschta et al. 1987, Holtby and Scrivener 1989, Bjornn and Reiser 1991, PNPTC 1998 unpublished data
Dissolved oxygen	Low dissolved oxygen results in direct egg suffocation and diminished survival of subsequent life stages	I	Mason 1969, Koski 1975, Bams and Lam 1983, Chapman 1988, Bjornn and Reiser 1991, Peterson and Quinn 1994b
Fine sediment	Suffocation of developing embryos, entombment of fry in the gravel bed, compaction and cementing of spawning beds	S, I	Koski 1975 and 1981, Chapman 1988, Salo 1991, McHenry et al. 1994, Peterson and Quinn 1994a
Coarse sediment	Channel aggradation leads to egg/fry entombment, redd dislocation	S, I	Madej 1978, Tripp and Poulin 1986
Large woody debris (LWD)	Low levels may increase redd scour, contribute to channel instability, and limit availability of adult holding pools and rearing capacity	AM, S, I, R	Bilby 1984, Sedell and Froggatt 1984, Dolloff 1986, Lisle 1986a and 1986b, Bisson et al. 1987, Bilby and Ward 1989, Montgomery et al. 1995
Channel condition	Reduced holding pool quality and availability renders adults vulnerable to predation/harassment; reduced channel complexity increases frequency and severity of redd scour; limited rearing	AM, S, I, R	Osborn and Ralph 1994, Beschta et al. 1995, Spence et al. 1996
Loss of side channels	Limits adult holding areas, and confines spawning to main channel areas where redds are prone to scour, limits rearing habitat	AM, S, I, R	Sedell and Luchessa 1982, Sedell and Froggatt 1984, Hirshi and Reed 1998
Channel instability	Increased substrate mobility resulting in redd scour/entombment or de-watering of redds	AM, S, I	Nawa and Frissell 1993, Osborn and Ralph 1994, Beschta et al. 1995

Habitat Factors	Impacts to Channel Processes and Summer Chum	Life History Stages	Supporting Literature
Riparian Condition (species composition, age, and extent)	Removal and modification of native riparian forests increases water temperatures, reduces stability of floodplain landforms, and reduces LWD recruitment to stream channels (see above)	AM, S, I	Bisson et al. 1987, FEMAT 1993, Beschta 1995
Floodplain and wetland loss	Concentrates flood flows in main channel, increases peak flow volumes, and results in increased redd scour; loss of wetlands reduce summer low flow volumes (see above)	AM, S, I	Henegar and Harmon 1971, Spence et al. 1996
Fish passage and Access	In-channel structures obstruct or impede adult passage; tidegates/dikes limit juvenile access to rearing and feeding habitats	AM, R	Evans and Johnson 1980, Toews and Brownlee 1981, Furniss et al. 1991

1.3 RESTORATION MEASURES

Initial planning documents (project objectives, constraints, and measures) focus on reversing habitat degradation for the most sensitive species in the Salmonidae family, which is in fact an ecosystem restoration perspective in that the anadromous fish species of the Pacific Northwest depend on essentially all components of their native ecosystem, including patterns of stream flow and sediment deposition, riparian forest distribution and structure, properly functioning wetlands, and the spatial arrangement and interconnectedness of aquatic as well as terrestrial habitats. A comprehensive restoration plan for species in the Salmonidae family, as keystone species, effectively restores habitat and nutrient input for a broad suite of over 130 other native plant and animal species (Cederholm et al. 2000). Restoration planning centered on habitat for the Salmonidae family reinstitutes dynamic processes that tend to maintain ecosystem characteristics, and increases primary production and carbon export. The rationale for employing restoration measures and their corresponding assessment metrics that focus on restoring habitat for the many species of the Salmonidae family is that all watersheds in the Pacific Northwest ecoregion are home to these fish that serve as an indicator of the overall health of not only the aquatic environment where they dwell, but also the connected riparian, wetland, and upland habitats. The assessment approach presented here adopts that perspective and frames restoration measures in terms of their effects on salmonids.

Systemic problems that originate outside of the study area are being addressed using a watershed approach by other entities such as USFS and TPU in areas that are closely tied to their respective missions and in areas where they are the principal land managers. For instance, sedimentation is a significant issue in the South Fork of the Skokomish River Basin. Much of this land ownership is with the USFS and a private company, Green Diamond Timber Company (formerly Simpson Lumber). Green Diamond is addressing sedimentation issues through inclusion of larger riparian buffer areas and limiting the amount of new logging roads through a Habitat Conservation Plan that was developed in cooperation with the Washington State Department of Natural Resources (WDNR). The USFS has developed a restoration plan for the upper basin that includes decommissioning roads, revegetation, replacement of culverts and construction of engineered log jams to trap sediment within the main channel. The study area for the Skokomish GI is downstream of these areas; the Corps recognizes that any restoration activities need to be coordinated with these other watershed improvements.

Most of the restoration measures that have been developed by the Corps and various stakeholders for possible inclusion in this effort are commonly used approaches to multispecies habitat restoration in the region (Beechie et al. 2008, Roni et al. 2008). Reconnection of isolated habitats and floodplains, floodplain and riparian reforestation, and instream habitat improvements are frequently recommended, and are among the proposed measures for Skokomish River restoration. In addition to these typical restoration measures, the Corps has proposed excavating a significant quantity of riverbed substrate to increase flood flow capacity, which would also serve to open blocked tributary mouths. Therefore, the assessment system described here is focused on a specific suite of physical manipulations within the defined study area as they are expected to affect the distribution, availability, and quality of habitats used by anadromous fish for reproduction, refuge, and rearing. Some measures are intended to address immediate critical problems, such as removing barriers to migration, even though channel movement or sediment redistribution may undo the intended effects eventually. These are referred to as the "Base Options" in this document because they are considered the first and most important actions to undertake

to address immediate needs. Still other measures, such as reconnecting forested floodplain areas, can be expected to have immediate and permanent effects. These secondary measures are referred to as "Increments" as they will be added on to the Base Options. Measures that involve planting trees will accrue benefits gradually as the planted vegetation matures, but the effects will be permanent, and will eventually replace lost stream processes by contributing large wood to the channel and reestablishing channel dynamics, thus making future direct interventions to improve passage less necessary. When all of these measures are implemented as a coordinated effort across the study area, they constitute a comprehensive ecosystem restoration approach that will benefit a broad suite of terrestrial and aquatic plant and animal species. This process-based restoration serves to restore the typical ecosystem structures of Pacific Northwest river valleys, which in turn supports the valued ecosystem functions and services.

1.4 MODEL APPROACH

None of the models that are Corps-certified or approved for use for assessing restoration effectiveness is appropriate for use in the case of the Skokomish GI study. The Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980) have been employed in traditional planning studies for decades, but the models available for any species in the Salmonidae family are complex and require highly specific and intensive data collection (e.g., McMahon 1983) that is well beyond the scope of a multi-project planning study. Terrell et al. (1982) acknowledged this limitation and suggested ways to simplify the process, but did not significantly reduce the need for an elaborate and prolonged field data collection program. More to the point, however, the Habitat Suitability Index (HSI) models for salmonid species are highly focused on site-specific in-stream conditions, particularly those affecting spawning. Habitat requirements for the Salmonidae family make a good surrogate for overall ecosystem health only when they reflect the full range of anadromous fish habitat requirements, including off-channel habitats, food web interactions, and spatial relationships among habitats. Clearly, the available HSI models were not developed with that perspective in mind.

A recently proposed restoration prioritization approach, the Biodiversity Security Index (Cole 2010), addresses Corps planning requirements by focusing on the relative scarcity or vulnerability of affected plant and animal species. In the case of the Skokomish GI study, where various federally protected species are affected, this approach would certainly show a strong justification for implementing a restoration effort when compared to other ecosystem restoration proposals elsewhere in the nation where few or no rare species are involved. However, it will not usefully discriminate among any of the project alternatives likely to be proposed for the Skokomish, all of which will positively affect the same group of highly vulnerable species.

Another approach to assessing ecosystem health and recovery is to focus on fundamental processes, such as primary production. Several measures proposed for the Skokomish River include re-establishment of native vegetation across agricultural lands or early-successional communities, which often contain a large component of non-native species. This has beneficial effects not only on a broad suite of fish and wildlife species within the project area, but also on the health of the Puget Sound and marine ecosystems beyond, which receive organic carbon produced in the basin via export by the river. The elevated functionality per unit area of restoration can be directly represented by the differences in primary productivity between native and non-native plant communities. Where pasture (temperate grassland) is restored to palustrine

forest or to emergent wetland, and where weedy, non-forested riparian areas (scrub-shrub) are restored to native riparian or palustrine forest, primary productivity can be expected to double or triple (Whittaker 1975). Thus, the restoration effectiveness of those actions can be expressed as the change in productivity multiplied by the area (acres) restored. However, this approach does not adequately capture the other roles played by these native systems in providing critical in-stream refuge habitats, shading and cooling stream systems, initiating and maintaining sediment dynamics, and other elements of a truly ecosystem-based restoration approach. Nor is it applicable to the assessment of restoration measures that do not much affect primary production but address other objectives, such as creation of pool habitats for fish. For the purposes of this project, it is desirable to use reasonably comparable metrics to assess the effects of all of the various proposed restoration measures, which are aimed at holistic ecosystem restoration.

The approach described here is designed to integrate some of the features and advantages of the methods described above without incorporating some of the disadvantages. It takes into consideration the habitat needs of particular sensitive species, the basic productivity and structure of Pacific Northwest native communities, and the fundamental dynamics of stream ecosystems by grouping restoration actions in ways that reflect key ecosystem attributes, such as the connections between aquatic and terrestrial systems. The selected attributes are assessed in a series of stream reaches, which allows recognition of variation in the extent and types of restoration required in different parts of the ecosystem. The response metrics can be considered at various levels of summation, including across all reaches for a particular set of measures, or across all assessment criteria, or both. In this way, the assessment system can be used to identify whether a particular set of measures or alternatives are weaker or stronger than another with respect to any particular critical habitat components, or to identify key spatial gaps in a restoration plan, while also providing the kind of simplified comprehensive "habitat units" that traditionally feed into the Corps planning process.

A major strength of this approach is that it is based on studies and resource inventories in the Skokomish basin and the region that document the past effectiveness of the proposed restoration measures, provide metrics for evaluating the assessment variables, and provide baseline data that can be used to estimate the effectiveness of project alternatives relative to the existing condition. Another advantage is that the basic steps and logic of the approach have a long history of use in the USACE planning process, including ecosystem restoration applications.

1.5 ASSESSMENT METHOD OVERVIEW

This assessment procedure involves comparing the calculated benefits of proposed project alternatives (future with-project) to the future without-project conditions, using information about the baseline condition as a starting point. The period of analysis (i.e. the project life) is 50 years following construction. This assessment method to quantify project benefits has been tailored to the specific types of management measures that have emerged from the plan formulation process. There are several components to the approach:

- Identify the key limiting factors associated with the stream reaches of the study area illustrated in Figure 1.
- Identify assessment metrics to measure success at addressing key limiting factors.

- Identify specific restoration measures and project sites, the areas affected, and applicable limiting factor(s) to evaluate the sites.
- Determine which projects are combinable or mutually exclusive for combining projects into alternative plans.
- Evaluate the existing habitat quality and future without-project habitat quality over the period of analysis (average annual without-project habitat quality), and estimate the average annual with-project habitat quality over the period of analysis for each of the assessment metrics. The difference between the average annual habitat quality with-project and without-project is the average annual habitat quality benefit for each assessment metric.
- Given the impacts of sedimentation on significantly reduced river capacity and frequent fish stranding, determine relative benefits to address either capacity and/or summer low flow conditions.
- Calculate the average annual habitat units (AAHUs) for each project as a function of the change in habitat quality (or average annual habitat benefit) and the area affected.
- Evaluate specific proposed combinations of projects using the gain in AAHUs associated with each project to identify cost-effective ecosystem restoration alternatives that address the complex life history requirements of anadromous species throughout the study area.

These components are described in the following sections.

2 ESTABLISHING EXISTING AND FUTURE WITHOUT-PROJECT AND WITH-PROJECT CONDITIONS AND PRINCIPAL LIMITING FACTORS WITH ASSESSMENT METRICS

Figure 1 illustrates the locations of five mainstem and South Fork Skokomish stream reaches and the tributary Vance Creek. The stream reaches correspond to those established for a comprehensive geomorphological study conducted by the Bureau of Reclamation (Bountry et al. 2009) and can be generally correlated with reach designations used in Correa (2003) and in Peters et al. (2011). Each of these reaches or areas can be characterized in terms of lacking key habitat requirements (including connectivity) that affect various aspects of anadromous fish life stage requirements as identified in the previous comprehensive studies (WDFW and PNPTC 2000, Correa 2003, Peters et al. 2011). For the purpose of this Environmental Benefits Analysis, we have focused on five assessment metrics that have been identified as indicators of limiting factors as discussed below. The assessment metrics included in this report were selected due to 1) their priority among components of the ecosystem that need restoration, 2) their general rating as being in poor condition compared to metrics that were not selected for measurement, and 3) the availability of empirical information on their existing condition. The existing condition information and projections of future conditions form the basis of our future without-project condition, to which proposed actions in the basin are compared to determine if they could have a measurable change to the environment. Table 2 provides a summary of the assessed ecosystem attributes, the types of restoration measures proposed to address deficiencies, the metrics employed to evaluate them, the applicable portions of the study area, and selected pertinent references.

Channel Habitat Quality: This assessment criterion is measured as the total area of channel with complex habitats (LWD, pools, side channels) and with sufficient depth to allow fish migration during the late summer, when flows in the Skokomish River are typically at their lowest point (Skokomish Indian Tribe and WDFW 2010). Proposed measures to address deficiencies in this factor involve direct removal and/or trapping of excess sediments in the system to create pool habitat, and construction of Engineered Log Jams (ELJs) or anchoring large logs with rootwads in various configurations. The ELJs and anchored logs are expected to initiate and maintain channel dynamics that will be self-sustaining. In addition to creating deeper channels, pools, islands, side channels, and other habitat features for some distance downstream, channel migration initiated by ELJs will recruit additional woody material from the banks, which in turn will form new logjams to replace the engineered structures as they deteriorate. Restored channel habitat is considered to include all channel areas likely to be affected by any of these restoration actions, including areas affected by restored channel dynamics well downstream of the sites where specific measures are applied. Channel area is calculated as the total affected channel length multiplied by the average channel bankfull width as scaled from satellite images.

Floodplain Habitat Quality: Natural floodplain features are important components of the fish habitat that serves to represent overall ecosystem health. Floodplain features are typically structurally complex with aquatic connectivity among these features that include abandoned channels, pools, small tributaries and distributaries, oxbows, side channels, and the wetlands and forested areas that export invertebrates and

organic material as well as provide direct refuge habitat during high flows. A fully functional riverine system would normally have a mix of these conditions in varying proportions along its length. Conversion of floodplain to urban and agricultural uses tends to eliminate or degrade the access to and quality of these aquatic features. Proposed restoration measures in this category focus on restoring degraded habitats and reconnecting habitats rendered inaccessible due to sedimentation, levees, and similar obstructions. Restored floodplain habitat is defined by the area of reconnected forest and wetlands, reforested floodplain, and restored aquatic habitats within floodplains including their associated buffer zones.

Mainstem River Channel Capacity: Historically, rivers around the Puget Sound basin typically experience overbank flooding once every 1.5 to two years. The many species of the Salmonidae family present in this ecosystem have evolved with this disturbance regime. Excessive aggradation has caused more frequent overbank flooding that has been shown to be harmful to multiple life stages of these fish. A properly functioning hydrologic regime would exhibit the less frequent flooding such that the anadromous fish could successfully spawn within the riverbed and the offspring could survive to migrate downstream to the estuary. Restored channel capacity is defined as achieving at least a 1.33-year return interval to attempt to achieve more than one generation of successful spawning and rearing, and preferably the two-year flow capacity so that multiple generations of fish can begin to rebuild their stocks.

Table 2. Limiting Factors and Associated Assessment Metrics

Limiting Factor	Assessment Metric	Applicable Restoration Measures	Applicability	Reference
Channel Habitat	Pools Woody Debris	Sediment removal and trapping; placement of structures to maintain channel dynamics, scour channels and maintain in-stream habitat complexity	Reaches 2,3,4, 5, Vance Creek	Bountry et al., 2009; Bjornn and Reiser, 1991; Smith, 1973; Stover and Montgomery, 2001
Floodplain Habitat	Riparian Cover Connectivity	Opening of side channels and tributaries; providing access to existing floodplain forests and wetlands; levee removal; floodplain and riparian reforestation	Reaches 2,3,4,5, Vance Creek	Bountry et al., 2009; Buffington et al., 2002; House and Boehne, 1985; MacDonald and Keller, 1987; McMahon, 1983.
Channel Capacity	Flow Capacity	Sediment removal; providing flood storage capacity; providing fish access to large wetlands	Reaches 1,2,3,4	Bountry et al. 2009; Seiler et al. 2002; Beamer et al. 2005

2.1 ESTABLISHING BASELINE CONDITIONS

The starting point for quantifying benefits of restoration actions is to determine the baseline conditions of the study area. For environmental benefits evaluations, it is important to evaluate environmental parameters that are measurable and that change with the proposed alternatives. While it is difficult and costly to measure all parameters that could change with restoration work, it is important to capture a few key indicators that can serve as a proxy for the host of environmental changes that could be expected. This analysis focuses on three limiting factors as those key indicators: floodplain habitat with the parameters of riparian cover and habitat connectivity, main channel habitat with the parameters of large

woody debris (LWD) and pool habitat, and in-channel flood flow capacity with the parameter of survival of species in the Salmonidae family from egg stage to migrant fry stage.

2.1.1 Habitat Quality Assessments of the Skokomish River GI Study Area

Following is a review of available references used to determine the quality ratings of the five assessment metrics of riparian zone, LWD, pool frequency, floodplain connectivity, and channel capacity for features of the Skokomish River GI reaches. Specific selections from the reports were used to establish baseline conditions to be able to compare future with- and without-project conditions, and to quantify the Average Annual Habitat Units.

Three primary reports provide assessments of baseline conditions for the Skokomish watershed (see: WDFW and PNPTC 2000, Correa 2003, and Peters et al. 2011). The first two reports were used in developing conservation plans for restoration of summer run chum salmon and for watershed restoration planning in the Hood Canal while Peters et al. (2011) was a habitat assessment study conducted specifically for the Skokomish GI. Table 3 is a summary of the qualitative ratings by habitat factor for the Skokomish River; the results from all reports are discussed by factor below. These reports were used for the habitat quality scores for the first four assessment metrics listed in Table 2 and described in detail in section 2.1.2.

The channel capacity assessment metric was developed through use of a Bureau of Reclamation report on the geomorphology of the Skokomish River (Bountry 2009), and two reports on the effects of channel aggradation in other rivers in the Pacific Northwest. These describe the negative effects of excessive sedimentation and how decades of channel aggradation can decrease survival rate of salmonid eggs to the migrant fry stage (Seiler 2002, Beamer 2005). This is described further in section 2.1.2.5.

Table 3. General rating of impacts to habitat factors and associated habitat quality equivalents in the Skokomish watershed (including all tributaries) affecting chum salmon from WDFW and PNPTC (2000; Table 3.17).

Habitat Factor	Specific Factor	Impact	Habitat Quality Equivalent
Flow	Winter	High	Poor
	Summer	High	Poor
Water Quality	Temperature	Low	Good
	Nutrients/DO	Low	Good
Sediment	Aggradation	High	Poor
Channel Complexity	LWD	High	Poor
	Channel Condition	High	Poor
	Loss of side channel	High	Poor
	Channel instability	High	Poor
Riparian Condition	Species Composition	High	Poor
	Age	High	Poor
	Extent	Moderate	Fair
Floodplain Loss	Floodplain Loss	High	Poor

The WDFW and PNPTC (2000, including 2000a, 2000b, 2000c) report was completed for summer chum salmon recovery planning in Hood Canal; Appendix 3.6 of that report provides watershed descriptions in the basin based on impacts to habitat within those watersheds. Chapter 3.4 is a qualitative description of freshwater habitat conditions in watersheds of Hood Canal and how those conditions were developed, while Appendix 3.7 has specific watershed conditions for the Skokomish River. The report provides a ranking of impacts to habitats critical to various life stages of chum salmon and those impacts are rated low, moderate, and high. Correa (2003) includes a similar habitat rating matrix (Table 16 of that report) that includes a rating system for various habitat characteristics with a range of poor, fair, and good, and areas without data (data gaps), which used various data sources and interpretation by the author or other agency biologists to identify each condition. Additionally, the USFWS completed their own monitoring and evaluation of the Skokomish River and tributaries specifically for the GI but also discussed previous work. The USFWS report (Peters et al. 2011) refers to Correa (2003) in their characterization of the Skokomish River habitat features of interest to the benefits analysis, and used the impact rating established by Correa (2003) to provide the basis for the poor (high impact), fair (moderate impact) and good (low impact) habitat quality rankings.

Peters et al. (2011) described four main effects or threats to juvenile salmon habitat in the Skokomish watershed as the result of the changes in physical process throughout the watershed including 1) habitat availability, 2) habitat connectivity, 3) habitat stability, and 4) habitat quality. The methods used and the locations of study sites for selected habitat features are described in Appendices. The USFWS used standard measurements for habitat conditions, and they created their quality rankings based on Correa (2003). The Correa (2003) report summarizes work from WDFW and PNPTC (2000) with additional input from other agency biologists, but with little mention as to how the results were derived. The WDFW and PNPTC report with various appendices was reviewed to identify information not found in other sources, including an assessment summary of impacts for the Skokomish Watershed habitat conditions (Appendix 3.6), and methods used to gather data for the riparian assessment and other freshwater habitats of the Skokomish found in Appendices 3.7 and 3.8 of that report.

Chapter 3.4 in WDFW and PNPTC (2000) is the freshwater habitat assessment; the methods are described as a compilation of field knowledge of watershed conditions in Hood Canal watersheds to identify factors that were determinants of quality of summer chum habitat. Habitat factors included winter high flow and summer low flow, temperature, nutrient loading, fine and coarse sediment, LWD presence, channel condition, loss of side channels, channel instability, riparian forest size, extent and species composition, floodplain wetland loss, and fish access and passage. These habitat factors were used to determine habitat quality for the following life stages: freshwater migration, spawning, incubation, rearing, and saltwater migration. For each watershed, the biologists as a group rated the condition of each habitat factor according to the severity of impact (none, low, moderate, and high) and identified habitat-related factors for decline (Appendix Report 3.6). Data were used, when available, to rate habitat quality against that found in relatively undegraded basins. Information gaps were filled with the habitat biologists' field knowledge of each basin. Ratings for riparian condition were based on the results of the riparian assessment (Appendix Report 3.7). Appendix Report 3.8 includes a summary of freshwater habitat data and how the data were rated. Background information for the ratings and watershed narratives included State of Washington Timber Fish and Wildlife ambient monitoring data; completed state and Federal (USFS) watershed analyses; and temperature, sediment, and stream discharge data.

2.1.2 References for Quality Ratings of Ecosystem Conditions

The five assessment metrics selected for this model were chosen based on their priority need for restoration in the GI study area. Ecosystem components that are often used as metrics such as water quality and quantity are either rated as good (water quality) or are not a component that the Corps can change as part of the proposed project (water quantity). Table 4 summarizes the baseline conditions as compiled from the major source documents described above in section 2.1.1, as well as the target conditions to be achieved through engineering and design of the proposed project sites.

Table 4. Assessment metrics with parameters measured for baseline condition assessment and target conditions for restoration.

Assessment Metric	Parameters	Baseline Condition (Overall)	Target Condition
Pool Habitat[1]	Number of pools greater than 1-meter depth, good cover, and cool water	Less than 35% of surface area is pool habitat	Pool to riffle ratio of 1:1, or 40-60% surface area in pools
Large Woody Debris[2]	Pieces of LWD per meter of channel length	Less than 0.2 pieces of LWD per meter	75th percentile of natural conditions; 0.6 LWD pieces per meter
Riparian Cover[3]	Species composition, average stand diameter, density, width	High impact (poor) conditions for 62% of the mainstem and 32% of Vance Creek; riparian buffers less than 66 feet wide; 30-70% canopy cover	150-foot riparian buffer width, with 100% canopy cover
Floodplain Connectivity/ Access[4]	Percentage of aquatic habitat remaining connected to the mainstem	General floodplain access has less than 50% connection; certain sites have no connection	100% connection
Channel Capacity[5]	Frequency of overbank flow at specific discharge return interval; fish survival	Overbank flows typically four times per year; correlation between aggradation and reduced egg-to-migrant survival with likely 33% reduction in Skokomish	Two-year flow capacity within bankfull width

[1] Peters et al. (2011)
[2] Peters et al. (2011) and Fox et al. (2003)
[3] WDFW and PNPTC (2000a)
[4] Correa (2003)
[5] Beamer et al. (2005)

2.1.2.1 *Pool Conditions*

Observations made during a July 1998 float trip from the lower end of the South Fork Skokomish River canyon (South Fork RM 3.0) downstream to mainstem Skokomish River RM 4.0 (total distance of nine miles) revealed a lack of pools, long glides, and riffles and a scarcity of wood, particularly large wood and jams (WDFW and PNPTC 2000). Habitat surveys conducted in 1994 in the lower three miles of Vance Creek found 39% pools and a range of 1.5 to 2.6 channel widths between each pool (Skokomish DNR and PNPTC 1994). Because the surveys were conducted when the stream was dry, the data may be skewed (Keith Dublanica, personal communication 1998, cited in WDFW and PNPTC 2000).

Reviewing the description of the mainstem, the Correa report was found to reference the WDFW and PNPTC (2000) report, which relied on that single float trip in 1998 between RM 4 and 9; this showed a general lack of pools upstream of RM 4. The lower four miles of the mainstem were not monitored as part of any previous study so it appears that USFWS (Peters et al. 2011) assumed that reach to be the same as above RM 4. The same table did provide poor pool condition rankings for Hunter, Weaver, and Vance Creeks, good rating for Richert Springs, and data gap for Purdy Creek. Correa (2003) states that an interagency technical advisory group (TAG) rated streams (with no empirical data collected) as follows: 1) Purdy Creek and Hunter Creek can be characterized as one long pool with low habitat quality; 2) Hunter Creek is dredged periodically and acts as one long pool; and 3) Vance Creek was surveyed for pools in 1994 but ratings may be skewed, and the pool quality is reduced to gravel pockets except in a lower stream section with numerous deep pools with adequate cover. Figure 20 in Peters et al. (2011) provides a classification of pool quality in the same reaches with mainstem and tributaries again shown as poor quality. Pool quality was classified as the number of pools greater than 1-meter depth, good cover, and cool water; poor quality as no deep pools; fair with some deep pools; and good with sufficient deep walls. Correa (2003) states, "pool quality is unknown" for the entire lower Skokomish. Site visits conducted by the study team resulted in a consensus that there is a severe lack of pools, and all pools located were deemed poor quality according to the parameters described above.

Peters et al. (2011) created their Figure 19, which shows pool condition defined by percent pool habitat throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of poor, fair, and good that they state is modified from Correa (2003). The lower Skokomish and tributaries are shown in the figure as having a poor percentage of pool habitats. Correa (2003) includes a summary table showing all values for pools (percent pools, pool frequency) as "data gaps" with no rating for the mainstem. The quality rankings identified percent pools as poor at less than 35% surface area as pool habitat, 35-50% surface area is fair, and greater than 50% surface area as pool habitat as good.

Peters et al. (2011) described that in their study they measured four metrics to evaluate pool quality, including average thalweg depth, maximum thalweg depth, average residual pool depth, and maximum residual pool depth. They describe that the four metrics allow for comparisons of pool depths to overall reach depths. Overall, they found that deep-water habitats commonly associated with pools made up between 25% and 44% of the habitat. However, deep-water habitats were absent or in low abundance in several study reaches. In addition, deep-water habitats, which are very important habitats during the winter, were in lowest abundance during that period. Based on WDNR watershed analysis indices (WDNR 1997), the habitat quality rating for percent pool (using percent deepwater as percent pools) would be poor for nine of 21 summer sites, fair for six sites, and good for the other six sites. For winter sites, 20 of 23 sites would be rated as poor, two sites would be rated as fair, and one site would be good. The percentage of deep-water habitats tended to be greater in the stream estuary ecotone, tributaries, and the North Fork Skokomish than in the South Fork Skokomish during the summer and greatest in tributaries and the North Fork during the winter (Figure 21 in Peters et al. 2011).

Overall, the percent of the habitat that consists of pools to provide summer and winter rearing habitat for juvenile salmonids is rated as poor in most areas of the Skokomish River. Based on the available data from Peters et al. (2011) for the mainstem and best professional judgment from the TAG for the tributaries, it appears that mainstem and tributary study reaches should be considered as poor quality. Additionally, Skokomish GI technical team members have walked sections of the mainstem river and

viewed tributary conditions on multiple site visits with the same general conclusions that there is a severe lack of pools in the mainstem and the pool habitat in tributaries is generally poor quality.

No empirical data collection was conducted for the purpose of this ecosystem benefits model; therefore, a simple metric that does not require extensive fieldwork is needed for this decision-making tool. The simplest metric for calculating pool habitat condition is to estimate the percent surface area that is pool habitat. It has long been held that a pool to riffle ratio of 1:1, or 40 to 60% surface area in pools is considered desirable for salmon spawning and rearing reaches (Needham 1969). All of these ratings indicate a linear relationship between percent surface area in pools and the categorized quality ratings. The pools metric in this model mimics the Habitat Suitability Index for Chinook salmon (Raleigh et al. 1986). The assumption is that even with no pools, there is still water present, and therefore no zero score is possible; likewise, with 100% pool, essentially a lake, there is still usable habitat area. Achieving anywhere within the range of 40 to 60% surface area in pools achieves a score of 1 (Figure 2).

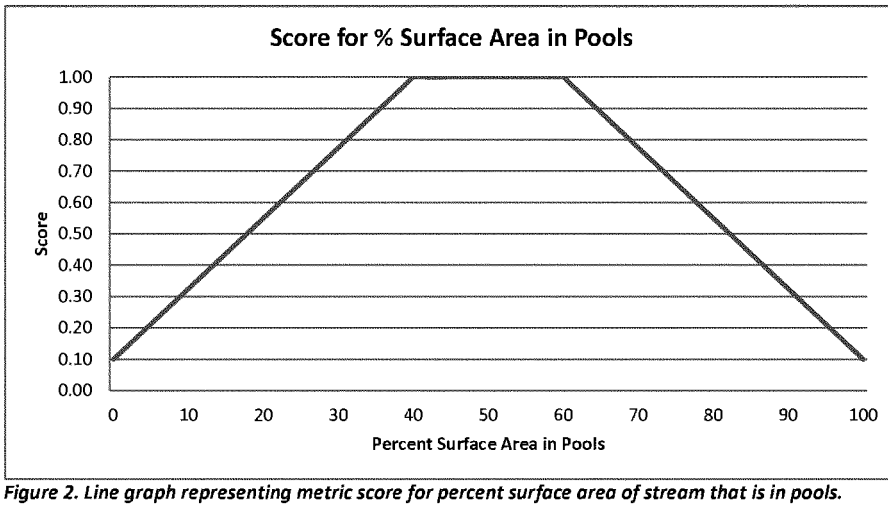

Figure 2. Line graph representing metric score for percent surface area of stream that is in pools.

2.1.2.2 *Large Woody Debris*

Several studies have assessed large wood levels within the Skokomish Basin and have identified reaches where wood levels are below the established standard for undisturbed streams in the Pacific Northwest. Reductions in large wood input to the river channel occur as the active channel width increases. According to WDFW and PNPTC (2000), despite the history of studies in the Skokomish basin, there is little data available on instream habitat for the mainstem and major tributaries to the lower river, although wood loading has been characterized previously as poor in most channel segments (Skokomish DNR and PNPTC 1994; USFS 1995; Simpson Timber Co. and WDNR 1997). Habitat surveys conducted in 1994 in the lower three miles of Vance Creek showed LWD counts ranged from 0.02 to 0.15 pieces of LWD per meter with much of the wood perched above the wetted perimeter, stranded on exposed gravel terraces (Skokomish DNR and PNPTC 1994). Standardized monitoring data has not been collected for the mainstem of the Skokomish River with data limited to observations from a single float trip in 1998, which indicated a scarcity of wood, particularly large wood and logjams (WDFW and PNPTC 2000).

Peters et al. (2011) measured woody debris metrics and attempted to compare those measurements with Fox et al. (2003), who developed recommended large wood quantities and volumes for western Washington rivers (Table 8 in Peters et al. 2011). They determined that large wood was limited in many sites of lower Vance Creek, the South Fork Skokomish, and the mainstem. The number of large debris piles (LDP) per bankfull width was very low for all sites sampled. In particular, the Vance Creek site in this study had no LDP during either summer or winter surveys. Peters et al. (2011) indicated that relative to other fish habitat cover elements, fine wood and vegetative cover were the most common cover elements available in the reaches evaluated, and large wood and large wood debris piles were present at intermediate levels to other cover elements. They did not state how their measurements were broken into quality rankings of low, fair, and good, or how their measurement of LDP could be compared with the work by Fox et al. (2003), who did not use such a metric.

Peters et al. (2011) referenced Correa (2003) in creating their Figure 17, which shows classification levels of LWD, and stating that habitat conditions are poor relative to LWD in the mainstem Skokomish, and Hunter, Weaver, and Vance creeks with the information summarized in the figure. In review of Correa (2003) for the Skokomish GI, it was noted above there has been little or no monitoring of the mainstem and many of the streams, so the rating factor is based on best professional judgment from the author or cooperating biologists (i.e., Purdy Creek has plentiful LWD in the wetland, and upstream of the hatchery, with no wood in ditched areas, [Marty Ereth, pers. comm., 2003]). The quality ratings for LWD were identified as pieces of LWD per meter of channel length with poor defined as less than 0.2, fair 0.2 to 0.4, and good more than 0.4 pieces/m of channel length. These ratings are used for guidance in scoring the LWD assessment metric for this model. Based on Correa's (2003) ratings, the value of LWD in the stream has a linear relationship to the ecosystem benefits score (Figure 3).

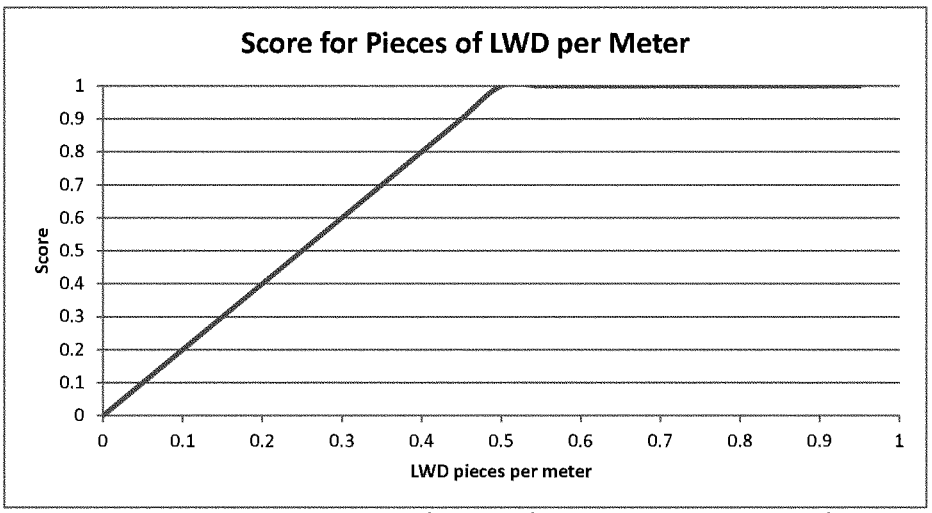

Figure 3. Line graph representing metric score for pieces of large woody debris per meter of channel.

As there are no specific descriptions of quality factors for LWD from USFWS, all reaches in the Skokomish GI benefits analysis should be considered as in poor condition as rated in the other reports

unless specifically identified otherwise. Site visits by Corps staff confirmed the conditions are as described in Skokomish DNR and PNPTC (1994) in that there are relatively few pieces and most are perched atop gravel bars and sills, too high to provide in-stream complexity or slower velocity refuge. Riparian plantings implemented for this project would eventually provide recruitment material for in-channel LWD, but this would not be expected to occur until after the 50-year study period. Upstream supply is out of Corps control, but LWD installed as part of the Corps project is expected to accumulate and trap more material. Benefits are only scored for what the Corps plans to install, not for an unpredictable quantity of recruitment. Design guidance provided to the engineers recommends targeting the 75th percentile of natural conditions according to Fox and Bolton (2007); this will result in approximately 0.6 LWD pieces per meter for a score of 1in the future with-project condition.

2.1.2.3 *Riparian Conditions*

In WDFW and PNPTC (2000), Appendix 3.7 describes the methods used to identify impacts to riparian areas in Hood Canal rivers and streams; this level of analysis is not available for LWD, floodplain connectivity, or pool condition. As part of the analysis of habitat limiting factors, aerial photo interpretation was employed to evaluate the condition of riparian forests along summer chum streams in Hood Canal and the eastern Strait of Juan de Fuca. For each segment, the forested riparian buffer width, average stand diameter, species composition, and stand density were noted and the dominant, stream-adjacent land use recorded. They modified the methodology outlined under the Washington State Watershed Analysis Riparian Module to consider both riparian conditions and dominant land use within 200 feet of stream channels. The quality rankings used to evaluate riparian areas are summarized in Table 3.7.1 taken directly from the WDFW and PNPTC (2000) report shown below in Table 5.

WDFW and PNPTC (2000a) describes the Skokomish River (RM 0 to 9) as meeting high impact conditions (poor conditions) for 62% of the mainstem as it is covered by agricultural fields, sparsely vegetated, and/or has a forested riparian buffer less than 66 feet wide. The Vance Creek riparian forest is in better condition overall with 32% as sparsely vegetated or less than 66 feet wide. The majority of Purdy Creek flows through a large intact wetland system, except for the hatchery area above Hwy 101.

Table 5. Summary of riparian assessment impact categories. Riparian buffer density was added to riparian buffer extent to calculate that rating (WDFW and PNPTC 2000, Table 3.7.1).

Riparian assessment category	Low Impact	Moderate Impact	High Impact
Species composition	Conifer dominated (>70% of the canopy)	Mixed conifer/deciduous (both < 70%)	Deciduous dominated (>70% of the canopy) or no tree cover
Average stand diameter	>20 in dbh[1]	12-20 in dbh	<12 in dbh
Density	<33% ground exposure	33-80% ground exposure	>80% ground exposure
Width	>132 ft wide forested buffer	66-132 ft wide forested buffer	<66 ft wide forested buffer

[1] dbh, diameter at breast height

Peters et al. (2011) refer to past studies (e.g. Correa 2003) and data collected during their own study that riparian vegetation appears to be degraded within the Skokomish Basin, with the greatest degradation occurring in the lower Skokomish watershed and in mainstem channels relative to tributaries. Correa (2003) provides a habitat rating matrix (Table 16 in that report) that includes a rating system for riparian

vegetation (criteria were riparian composition, buffer width, and channel type) for poor, fair, and good, and areas without data (data gaps) that used various data sources and interpretation by the author or other agency biologists to identify a condition. The figure USFWS created (Figure 11 in Peters et al. 2011) appears to have used scores from Table 16 and shows all parts of the mainstem in poor condition as were Weaver Creek, Hunter creek, and the lower South Fork Skokomish (RM 0 to 3). Purdy Creek was classified as poor to good, while Richert Springs was classified as fair to good. In reviewing Correa, the riparian habitat condition described repeats the WDFW and PNPTC (2000) description but includes that Vance Creek had a data gap for riparian conditions. Based on Correa and WDFW and PNPTC reports, the overall riparian condition should be considered poor with greater than 60% of the mainstem having little canopy cover, a narrow buffer, and limited LWD recruitment.

Using USFWS data collected for the GI (Peters et al. 2011), riparian vegetation conditions in the mainstem were described as severely degraded but healthy in other locations. It appears they rated riparian conditions based on percent canopy cover along the bank and in the middle of the channel as measured by their study team. They described that the conditions were based on mature riparian vegetation cover, and that riparian conditions along the banks were most degraded (less than 30% cover) in the Skokomish mainstem from Highway 101 to the confluence with Vance Creek (RM 4.5 to 9.0), in the upper South Fork and in Hunter Creek. Mature riparian cover varied in Vance Creek, McTaggert Creek, and North Fork, and was generally over 70% canopy cover in the lower mainstem below Highway 101 (RM 0 to 4.5). However, in the lower mainstem, riparian cover in the mid-channel islands was less than 30%. An analysis of the rating systems and ranking of habitats found in Peters et al. (2011), WDFW and PNPTC (2000), and Correa (2003), suggest a linear relationship between percent canopy cover and a benefit metric score (Figure 4).

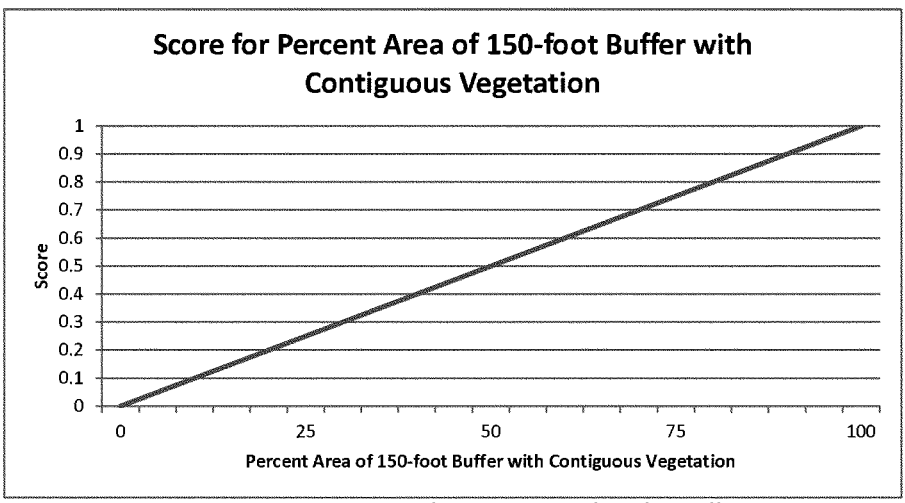

Figure 4. Line graph representing metric score for percent area of 150-foot buffer with continuous vegetation.

The Corps used the following method to calculate the riparian condition metric for existing conditions, and future with-project conditions. Assumptions are that there is a linear relationship between percent

canopy cover and the ecosystem benefits score, a target buffer width should be 150 feet for wetlands and stream channels, and that an appropriately detailed assessment can be achieved through aerial photography analysis with calculations in GIS software. The steps are as follows:

1) Identified the seven sites for riparian buffer analysis
2) Created 150-foot individual buffers around each of the sites to be analyzed
3) Within the 150-foot buffer starting at the line representing the project site footprint and extending outward, all contiguous vegetation was identified using one-foot resolution orthophotography that was flown on 22 April 2011. This was done by heads-up-digitizing feature classes that delineated only the contiguous naturally vegetated areas of each site. Natural vegetation versus un-natural vegetation or non-vegetated features were discerned by classifying un-natural as houses, roads, agricultural areas, disturbed ground, fence lines, clear property boundaries, and the border of tree and shrub canopy cover. Grass in residential areas was not counted as natural canopy cover.
4) Calculated the percent area of contiguous vegetation that borders the project footprint by dividing the area of contiguous vegetation by the total buffer area.

The total potential range of this metric is 0 to 100%; the actual calculated percentages for existing conditions are 6 to 81% among the seven project sites that were analyzed. Future without-project conditions are assumed to be the same as existing conditions because land use is not expected to change, and no significant developments are planned for the project sites. To calculate the future with-project conditions, the same steps were applied as listed above with an exception for the assumption that all grass would be planted and all houses, roads, and other unplantable surfaces remained the same. For two of the sites in agricultural fields, it was assumed that the plantable buffer would be constrained at 75 feet instead of 150 due to potential landowner concerns with land use conversion away from agriculture to wetland.

2.1.2.4 *Floodplain Connectivity/Access*

As described in WDFW and PNPTC (2000) and Peters et al. (2011), the majority of the mainstem Skokomish and portions of the South Fork and Vance Creek have been diked and /or channelized, reducing channel complexity and sinuosity, eliminating important side channels, simplifying the remaining habitat, and disconnecting these streams floodplain sloughs and side channels. The mainstem below the confluence is low gradient and has an extensive floodplain. However, the river has been hydraulically disconnected from this floodplain in many areas by levees, bank armoring, channelization, and excessive sedimentation and aggradation (Bountry et al. 2009).

According to Peters et al. (2011; Figure 10, detailed table in Appendix B), loss of floodplain connectivity appears to be worse in the lower watershed than the upper watershed. Further, they reference Correa (2003) to show that habitats in the mainstem Skokomish, the South Fork Skokomish from RM 9.0 to RM 12.0, and Hunter, Weaver, and Vance Creeks are the most degraded, in terms of floodplain connectivity. The mainstem Skokomish River has a hydraulic barrier when a reach goes dry in the summer and an artificial barrier when fish are stranded on the other side of Skokomish Valley Road during winter flooding. In the follow-up review of Correa (2003) for the Skokomish GI benefits analysis, Table 16 in that report shows floodplain access has 50% or more disconnection. The table shows connectivity as good in Purdy Creek and Richert Springs, but more than 50% disconnected in Hunter, Weaver, and Vance Creeks. The report simply describes the majority of the lower mainstem as diked and/or channelized, which disconnected the important side channels and wetlands. Correa (2003, with the data source from

WDFW and PNPTC 2000) described tributary conditions including that 1) Purdy Creek flows through a large intake wetland, although portions of the wetland are isolated by roads, 2) Weaver Creek and Hunter Creek are incised cutting off lower stream sections from the floodplain; and 3) the majority of Vance Creek has been diked and/or channelized, which has eliminated access to important side channels and wetland habitats.

Peters et al. (2011) measured several habitat metrics of the lower Skokomish and noted the severe loss of side channels, mainstem islands, and limited connection of the river to the floodplain, but did not provide an overall ranking for the quality of floodplain connectivity in the mainstem and major tributaries that could be applied to the Skokomish GI benefits analysis. Correa (2003) provided a rating of floodplain connectivity based on what percentage of aquatic habitat in the floodplain has become disconnected. The ratings of percent of aquatic habitat remaining connected to the mainstem in which less than 50% connected warrants a rating of poor, 50 to 90% connected is rated as fair, and 90% or better earns a rating of good indicate a generally linear relationship between percent connectivity and benefits score (Figure 5). The Correa (2003) ranking using the WDFW and PNPTC (2000) data source is used in the assessment of baseline conditions for the Skokomish GI as these reports provide ratings for some of the individual tributaries where projects will occur, or broader river reaches in which the sites lie. To score each project site, either its individual assessment was used, or the general rating from its river reach was used. Connectivity for inlets and outlets described as good in the habitat assessment documents are assumed to be available year round except for in especially dry summers as may occur at intervals greater than two years. For the future with-project score, we assume that project design and construction will result in a site having hydraulic connection year round, again except for unusually dry summer conditions.

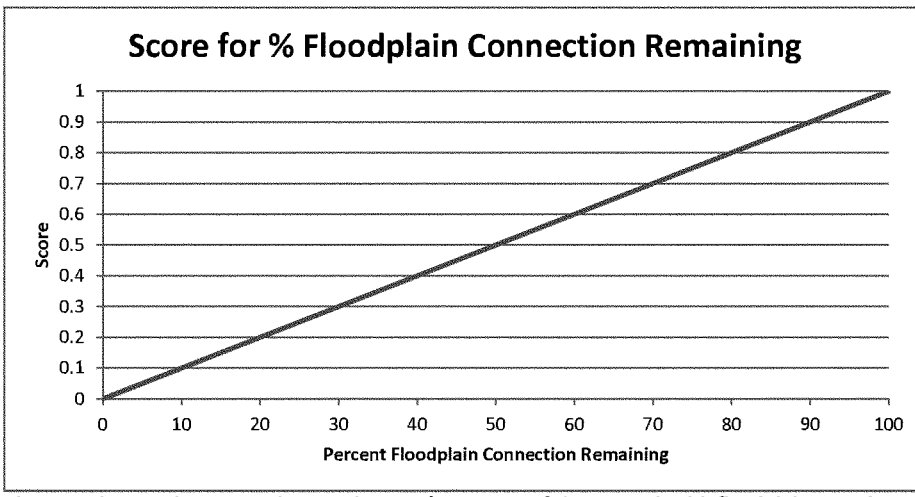

Figure 5. Line graph representing metric score for percent of site or reach with floodplain aquatic habitat connection to mainstem river.

The proposed project sites are completely disconnected, but will become 100% connected after construction. For scoring any other sites, one would assess either the total area of possible connection for

wetlands and levee setbacks, or the inlet and outlet for side channels and estimate the percent that has year-round connection along the length of the site or through inlets and outlets as appropriate to the site.

2.1.2.5 *Mainstem River Channel Capacity*

Increased sediment supply and reduced channel capacity negatively affect several anadromous fish life stages. Excess sediment supply in river channels is associated with instability of substrate, which causes scour of redds (eggs in nests) or sediment deposition reducing egg-to-fry survival; it also reduces available rearing and refuge habitat for recently emerged fry and young juveniles. In the Skokomish, the lack of channel capacity for even the one-year return interval discharge causes displacement of fry and juveniles during overbank flows in which they become stranded in floodplain areas without access to return to the river. Those that remain in the channel have little refuge habitat and are therefore forced downstream to the lower river and estuary where they become vulnerable to predators or are unable to survive in saltwater as they have not yet smolted (changed physiology for saltwater life stage). The lack of channel capacity and increased sediment supply result in several impacts to adult salmonids from stranding in floodplain areas. Every year in the Skokomish River, some proportion of the adult salmon runs stray into floodplain areas during overbank flow, and these fish have no return channel to the river (Figure 6). The impacts from this are that the adults may become stranded in floodplain areas where they die before spawning, or they are forced to spawn in areas that become dewatered killing the eggs, or the offspring that do survive in isolated ponds are unable to return to the river to rear.

Figure 6. ESA-listed adult salmon become stranded when overbank flows coincide with spawning migrations.

In natural conditions, rivers of the Puget Sound region see overbank flooding every 1.5 to two years; however, flood frequency in the Skokomish has increased to a return interval of more than once per

season. During the problem identification phase of the Skokomish GI, the frequent fish stranding that occurs during overbank flows of the Skokomish River was named as a high priority issue.

The purpose of the channel capacity assessment metric is to quantify benefits of each of the four base options for restoration, because the benefits of these are different from the areas of improved quality as measured by the other four assessment metrics. The benefits are that 1) anadromous fish on their spawning migration would be able to access upstream habitat at the time they arrive, 2) the redds would be less likely to be scoured out due to the gravel instability caused by excessive sediment, and 3) eggs can survive better to the migrant fry life stage.

The scoring for this assessment metric is based on what is deemed natural conditions in Puget Sound area rivers (Figure 7). As stated earlier, rivers around the Puget Sound region typically flood every 1.5 to two years. This is also supported by the substantially improved rate of survival for salmon from the egg to migrant fry stage for which we have data, as well as the assumption that preventing fish stranding mortality will aid in population recovery. These benefits are assumed to have a linear relationship with the improvement in capacity.

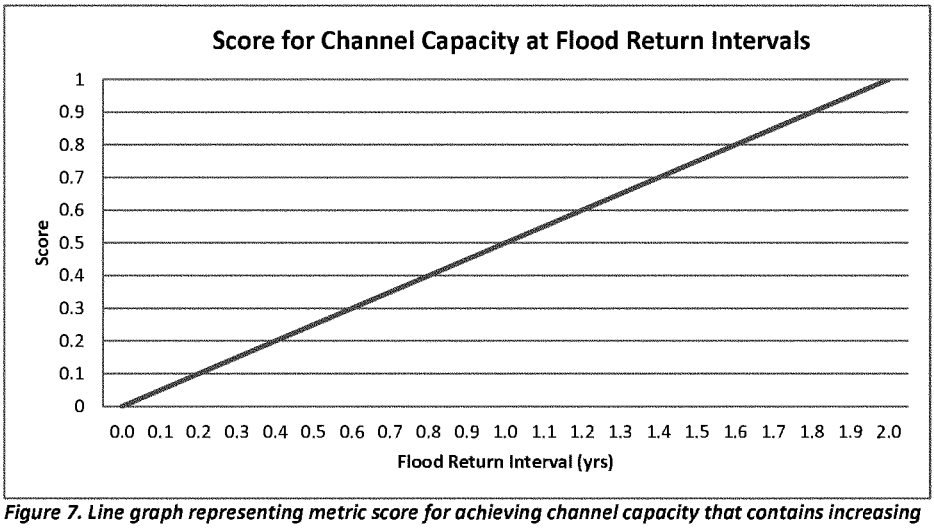

Figure 7. Line graph representing metric score for achieving channel capacity that contains increasing quantities of river flow.

We are assuming the action of removing excess sediment from the channel in combination with the other proposed restoration actions and work by others will restore the Skokomish River mainstem for several decades to a semblance of a functioning river channel. Sediment removal will provide an immediate improvement by increasing the channel capacity while the other proposed project actions will provide increasing benefits as the ecosystem responds to the enhancement features or structure removals, which will improve river and floodplain processes. Targeting a specific flow capacity is recognized as an appropriate goal and the two-year flow, corresponding to typical bankfull width as well as the dominant flow, is often recommended as the target (Copeland and Hall 1998, Millar and MacVicar 1998).

According to Shields et al. (2003), the approach of restoring a river channel to a specific return interval discharge, often corresponding to a two-year return interval as a bankfull discharge, is appropriate when applied to situations with relatively stationary hydrologic conditions. Since the Skokomish floodplain does not have rapidly developing human infrastructure, but is relatively stable as low development and widespread agricultural use, we assume the approach of returning the river to a specific flood flow capacity is appropriately applied.

Supporting information on Salmonid Life Stage of Egg to Fry Survival

The egg-to-migrant fry survival issue supports the target condition of achieving the two-year flow capacity in the mainstem river channel. Data from the Skagit and North Fork Stillaguamish Rivers show that egg-to-migrant fry survival is strongly influenced by peak flow during the egg incubation period and that impairments to watershed processes will decrease egg-to-migrant fry survival of Chinook salmon (Beamer et al. 2005). Seiler et al. (2003) have correlated high discharge with low egg-to-migrant survival with an R^2 value of 0.82. A comparison between functional (natural conditions) and impaired (aggraded) conditions for egg-to-fry-migrant survival is shown in Figure 8 (from Beamer et al. 2005). Although the Skokomish River is in worse condition than other Puget Sound rivers for flood frequency, we believe the reported values are appropriate for the benefits analysis.

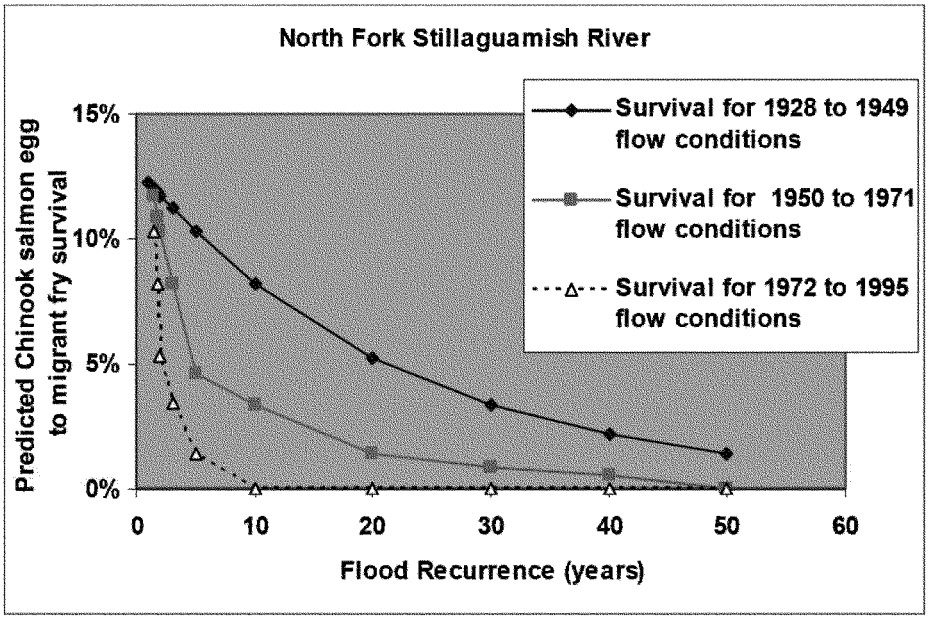

Figure 8. Estimated egg-to-migrant fry survival for the North Fork Stillaguamish River used as a surrogate for Skokomish River chum and Chinook salmon (from Beamer et al. 2005).

Skokomish Chinook salmon spawn in an area over 10 miles long from river mile (RM) 2.2 to RM 12.7; Fall Chum salmon spawn from RM 0 up to RM 11.5 (WDFW 2012).We compared the channel capacity assessment metric to potential increase in egg-to-fry survival using numeric values from Figure 8. While

the egg-to-fry survival calculations are not used for the assessment metric, the evidence of improved survival supports the use of channel capacity as a metric and supports the linear relationship between the capacity and the benefits score.

2.2 DETERMINE THE ESTIMATED IMPROVEMENT IN HABITAT QUALITY ASSOCIATED WITH EACH PROJECT

Gains in habitat units associated with projects and specific measures are calculated as Average Annual Habitat Units (AAHUs). They are based on projected changes in habitat quality and affected area, which requires that baseline, future without-project, and future with-project conditions be described quantitatively. This is usually accomplished with an index of habitat quality, where a value of 0.0 indicates that no suitable habitat is available, and an index of 1.0 represents optimum habitat conditions. For the purposes of this environmental benefits analysis, no single index of quality is available or appropriate because of the multiple limiting factors of concern and their varying importance in different parts of the ecosystem. Therefore, multiple indicators have been selected to represent the baseline habitat quality (the existing condition and projected change in habitat quality 50 years into the future over the period of analysis) and to estimate future with-project habitat quality.

As described in section 2.1.1, the indicators used to characterize channel and floodplain habitat quality are derived from the summary data presented in three habitat assessment reports. Figure 9 reproduces an example figure reporting the rating assigned for floodplain connectivity throughout the Skokomish River basin. The study area for this Environmental Benefits Analysis is outlined on that map. Some of the habitat quality ratings are established at the reach scale rather than at the individual project scale. In the example (Figure 9), all of the mainstem, South Fork, and Vance Creek channels are rated "poor" with regard to floodplain connectivity, meaning there is less than 50% connection between the mainstem river and the aquatic habitats in the floodplain.

Each river reach defined in Bountry (2009) and shown in Figure 9 below has roughly the same quality of habitat, so any proposed project increment that is not individually described starts with the same score as the whole reach. All future with-project and future without-project scores are based on the reports as described in section 2.1.2. Personal reconnaissance by project team members verified that the quality ratings for the proposed project sites are not substantially different from the general reach ratings, nor have conditions changed significantly except for the reach that now goes dry during summer low flow. Assessing the habitat quality for each project site would require individual site assessments of significant fieldwork effort, and would very likely result in the same assessment as the previous baseline reports.

The indicators selected to characterize baseline habitat quality are not intended to fully describe conditions in the study area, but rather to represent key elements of habitat structure and dynamics. Additionally, these metrics are ecosystem components that can be affected directly by management measures implementable by the Corps. The assumption is that the condition of those key elements will reflect overall ecosystem structure and function, and that they serve as reasonable surrogates for a broad suite of possible habitat measurements, many of which would be beyond the scope of a planning-level environmental benefits assessment. The indicators used and their scaling and applicability are described below.

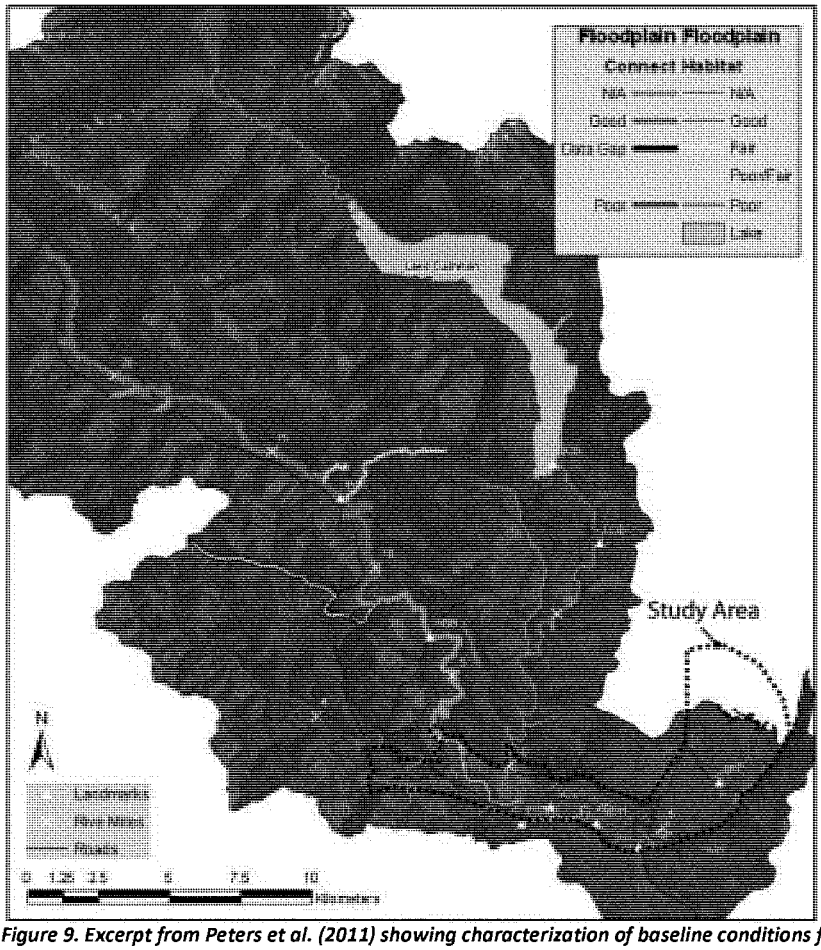

Figure 9. Excerpt from Peters et al. (2011) showing characterization of baseline conditions for floodplain connectivity in the Skokomish basin. GI study area outline added for reference.

Each of the five assessment metrics described in sections 2.1.1 to 2.1.5 use curves to represent the existing and future without-project condition, and future with-project curve. They are projected 50 years into the future over the period of analysis. To estimate the quality achieved at different points in the 50-year period of analysis, it was not possible to rate the individual project sites according to the precise measurement of each assessment metric as this information was not available through the general reach-scale habitat assessments provided in the baseline conditions reports. Each future with-project curve takes into consideration how long a given habitat feature will take to achieve benefits, with a continuous linear function of habitat gain/loss from one notable point in time to the next (i.e. habitat quality is interpolated between these noted points). Habitat quality scores are averaged over the period of analysis to estimate a future without-project (FWOP) and future with-project (FWP) average annual habitat quality index (HQI) score. The difference between the future without-project and future with-project HQI scores is taken as

the average annual HQI benefit. Average annual habitat units (AAHUs) are estimated as the product of the affected acreage and the average annual HQI score. This average annual HQI benefit is multiplied by the affected acreage to estimate AAHUs for a given project as shown below.

Average Annual Habitat Units (AAHUs) = Affected Acreage x Average Annual HQI Score

The average annual benefit for a project alternative is the difference in AAHUs from the FWP and FWOP condition for the project's assessment area, as shown below.

Benefits of with project for assessment area (in AAHU) = AAHU (with project) – AAHU (without project)

2.2.1 Pool Habitat

All riverine life stages of the many salmonid species benefit from abundant pool habitat. Juveniles use pools for a significant portion of their time for feeding and rearing, while adults rest in pools during their arduous upstream migration to spawning grounds. As described in section 1.3 regarding baseline conditions of the Skokomish River, the severe lack of pools is unanimously rated as poor among all entities that have analyzed the river habitat. While the habitat quality rating expresses percent surface area in pools for large reaches of river, the purpose of each assessment metric is to score the change at specific project sites. Therefore, this assessment metric aims to calculate the improvement of percent surface area in pools achieved within each project site's footprint. Each project will be designed to optimize habitat quality. Sediment transport is a very active process in this river with no indication that any reach of the substrate is embedded; therefore, pools are expected to begin developing immediately after construction and especially during the first high water event after construction.

The assumptions for the future without-project time curve are the following:

- we assume that the existing conditions of approximately five percent surface area in pools will remain the same without any manual intervention for improvement
- continued aggradation will likely reduce pool depth, but LWD in the upper watershed may move into the study area and be a countervailing effect. The pools are formed by local hydraulic effects and are not likely to be reduced by the overall deposition trend.
- the severe and obvious lack of pools in the mainstem river is about as poor of habitat as possible; the two large pools identified by study team members appear relatively stable, so we assume conditions are not likely to significantly worsen.

The assumptions that went into the shape of the future with-project time curve are the following:

- based on the supporting literature used to determine the baseline conditions, the mainstem river has only about 5% surface area in pools, so the starting score is 0.21 for any in-channel projects
- floodplain projects have either no pools, or they are characterized as one large pool with no riffle habitat (0% or 100%), therefore their starting score is 0.1;
- pools would be excavated during construction. The target is 40 to 60%; we assume each site will have 30% surface area in pools within 5 years after construction for a score of 0.78;

- habitat-forming processes occur during two-year to 10-year flood events (Knighton 1998), so we assume that at least one of these will occur in the first 10 years and that this will cause the pool habitat to achieve the target of 40% surface area for a score of 1.0 at 10 years;
- pools around LWD will be formed by localized hydraulics; because this is a localized effect, and sediment movement is dynamic in this river, these pools are not prone to as much in-filling from the aggradation effects seen in other areas of the river. Benefits of the new pool habitat will be significant and should be stable for the remainder of the period of analysis, assuming a moderate effort at post-project maintenance.

Figure 10 displays the time curves for the pool assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for pools as shown in Table 6.

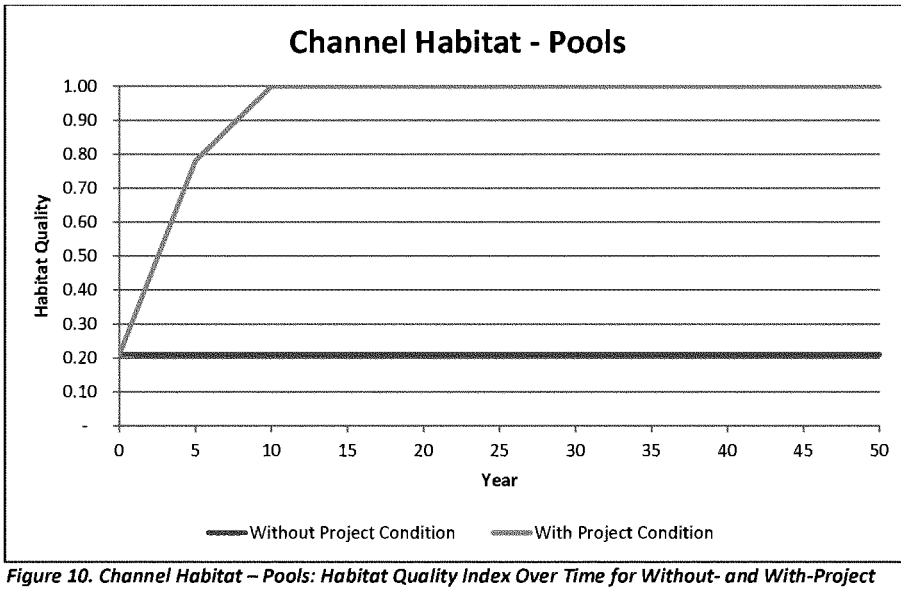

Figure 10. Channel Habitat – Pools: Habitat Quality Index Over Time for Without- and With-Project Conditions

Table 6. Pools Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project

Habitat Quality Index Scores - Pools	Score (0-1.0)
Existing Condition	0.21
Average Annual Without Project (Baseline) Condition	0.21
Average Annual With Project Condition	0.93
Average Annual Benefit With Project	0.72

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Channel – Pools HQI'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.2 Large Woody Debris

Large woody debris (LWD) in the active and wetted area of a river channel benefits all life stages of salmonids, but perhaps more so for juveniles as it provides refuge from high velocity flows, cover from predators, rearing area in pools, and surfaces for aquatic insects that become prey items for the juvenile fish. LWD also serves to stabilize substrate and stream banks to prevent too much erosion or instability during the spawning and egg incubation phases. Redd scour from unstable substrate and redd suffocation from bank erosion can be reduced with increased LWD.

Literature on baseline conditions indicates that the quantity of LWD within the wetted channel or low on banks is poor with a count of only 0.06 pieces of LWD per meter. Although there are large logs with root wads present in the riverbed, they are perched high on the gravel bars formed by the excessive sediment in the system.

The assumptions for the future without-project condition time curve are the following:

- LWD is pushed to the channel margins during the numerous floods each year, the logs along the riverbed margins will remain out of reach of average river flows,
- the rate of input from upstream sources will remain the same for the next 50 years as it has been for the past 20 years, which may be biased toward underestimating since forest practices have been improving over the past 20 years and older trees allowed to stand within a buffer zone may be recruited at a higher rate over the next 50 years

The assumptions for the future with-project time curve are the following:

- poor baseline conditions warrant a starting score of 0.1 for 0.06 pieces of LWD per meter;
- construction measures would add the recommended number of key pieces per river mile (Fox and Bolton 2007);
- since LWD exerts its influence nearly immediately, we assume that pieces placed during construction added to material already present in the channel will be actively providing benefits within the first 5 years after construction, for a score of 0.8;
- benefits of bank and substrate stabilization and pool expansion around root wads will continue to accrue at a relatively stable rate. After the 5-year point, we assume that LWD available in the aquatic habitat have recruited additional woody debris and that the restored reaches have accumulated at least the target of .6 pieces per meter for a score of 1.0 by the 10-year mark.
- pool formation around LWD will occur with the first high water flows after construction. Pools around LWD will be formed by local hydraulics and are therefore not as prone to aggradation effects as reaches of the river that have been lacking LWD. We expect the LWD and pools to be self-maintaining for the 50-year study period.

Figure 11 displays the time curves for the LWD assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI and the average annual HQI benefit for LWD as shown in Table 7.

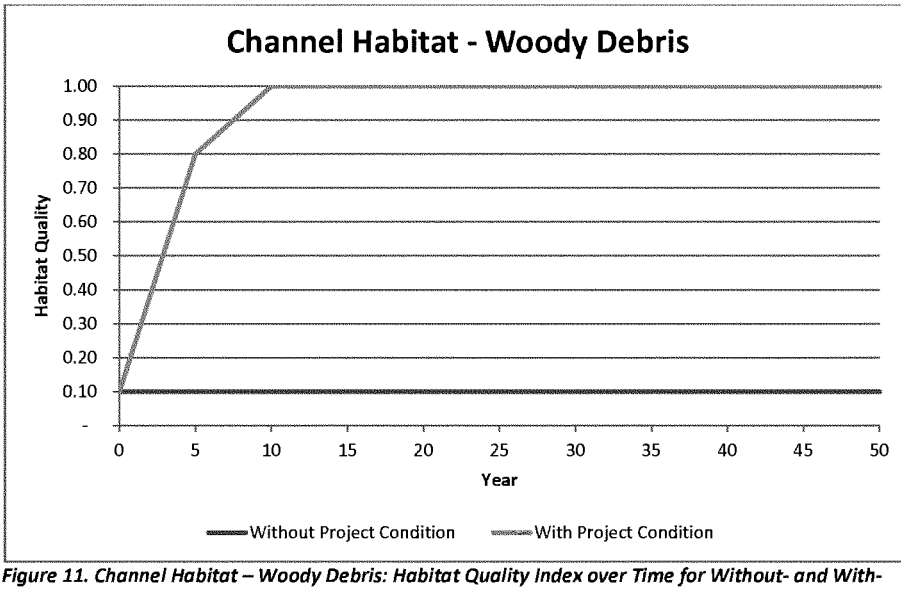

Figure 11. Channel Habitat – Woody Debris: Habitat Quality Index over Time for Without- and With-Project Conditions

Table 7. Woody Debris Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit with Project

Habitat Quality Index Scores – Woody Debris	Score (0-1.0)
Existing Condition	0.10
Average Annual Without Project (Baseline) Condition	0.10
Average Annual With Project Condition	0.93
Average Annual Benefit With Project	0.83

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Channel Habitat – Woody Debris'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.3 RIPARIAN COVER

Condition of the riparian zone vegetation is important for overall health of all river ecology and therefore all riverine life stages of salmonids. The recent Skokomish habitat assessments (WDFW and PNPTC 2000, Correa 2003, Peters et al. 2011) use species composition, buffer width, ground coverage, and age, with a resulting rating of the lower mainstem river as poor. Some areas are described as severely degraded while other areas with wide buffers and a high percentage of canopy cover are rated as healthy.

As described in Section 2.1.2.3, the Corps conducted a spatial analysis of the proposed project sites using ArcGIS for the existing conditions and future with-project conditions. Figure 12 shows the existing conditions with the percent of each 150-foot riparian buffer that has contiguous vegetation. Figure 13 shows the future with-project areas that would be planted during construction; we assume achieving 100% canopy cover within all areas that would be planted. Not all areas within the 150-foot buffer of each project can be planted. Areas that are roads, houses, or otherwise non-plantable are assumed to remain in that condition. For the two sites that occur in agricultural fields, we assumed buffer size would be limited to 75 feet surrounding the project footprint as these are on private property and landowner willingness to convert agriculture to wetland is unknown at this time.

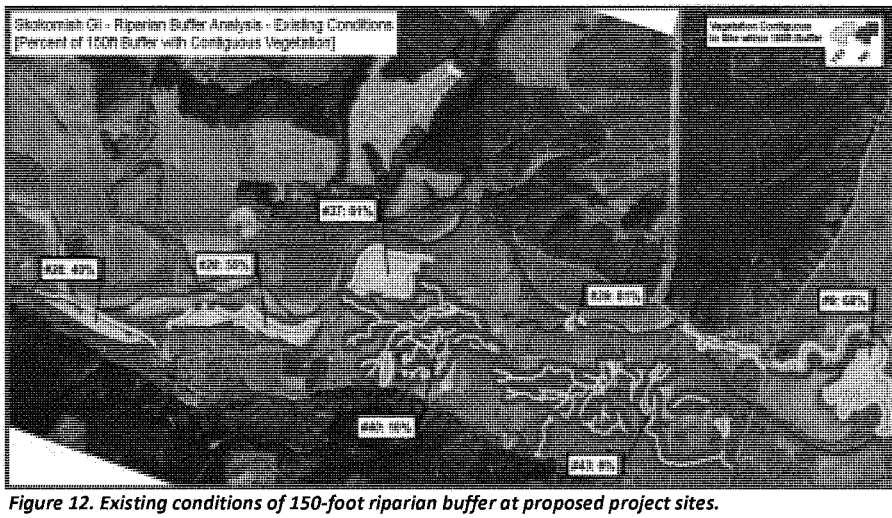

Figure 12. Existing conditions of 150-foot riparian buffer at proposed project sites.

The assumptions for the future without-project condition time curve are the following:

- present land uses would remain the same at each project site, so each site uses the existing conditions score as derived from the spatial analysis
- the present density of canopy cover as viewed in the aerial photographs has reached its full maturity and is not likely to become significantly more dense over the next 50 years, which may be biased toward overestimating present vegetation and underestimating future vegetation.

The assumptions for the future with-project condition are the following:

- the starting score for the time curve is derived from the spatial analysis for existing conditions;
- construction measures that open stream channels for fish access to forested and shrubby wetland areas provide immediate benefits associated with healthy riparian zones as fish access is restored;
- new plantings will be implemented across as much of the plantable area as possible at a density of four to six feet on center for shrubs and 10 to 12 feet on center for trees. Sites are near the river, so recruitment of cottonwoods and alders is expected.
- plantings would have approximately 10% canopy cover immediately after construction, around 80% canopy cover at five years after construction, and are expected to have 100% canopy cover at 10 years after construction.

Figures 14-20 display the time curves for the riparian assessment metric for each of the assessment areas with floodplain habitat limiting factors. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for pools as shown in Table 8.

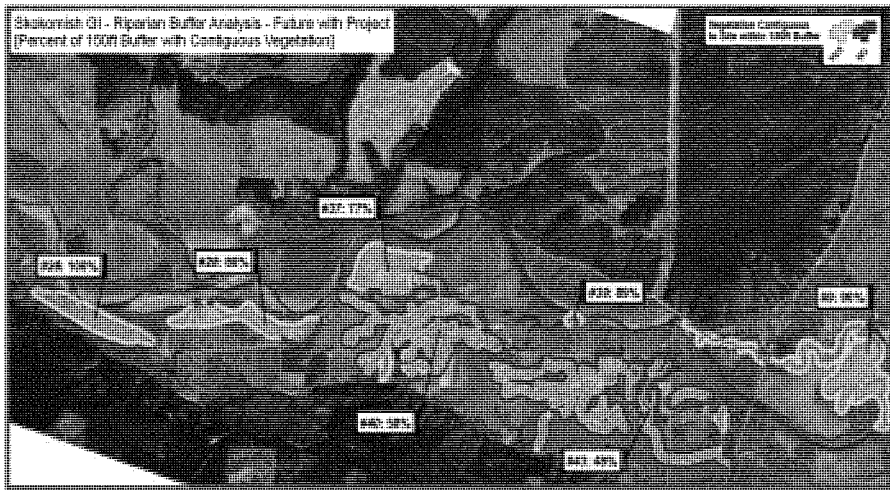

Figure 13. Future with-project conditions of 150-foot riparian buffer at proposed project sites.

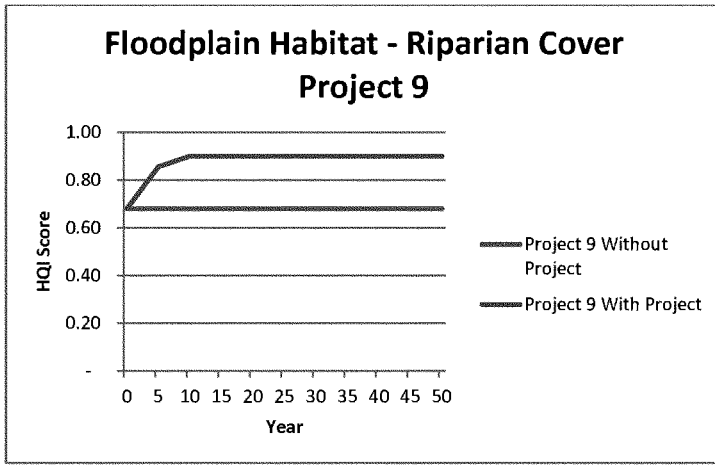

Figure 14. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 9

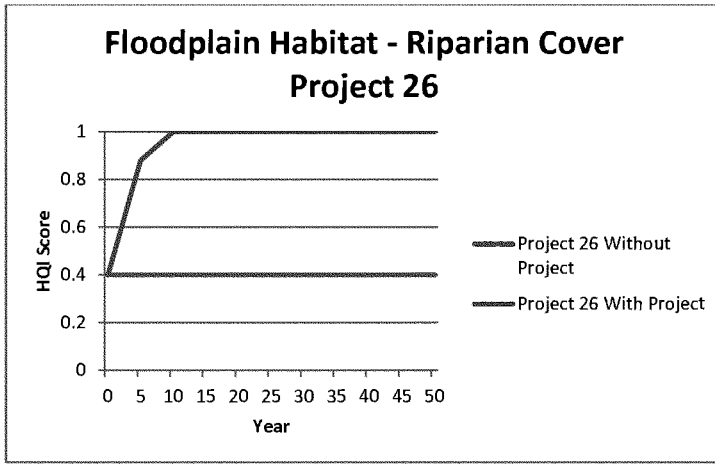

Figure 15. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 26

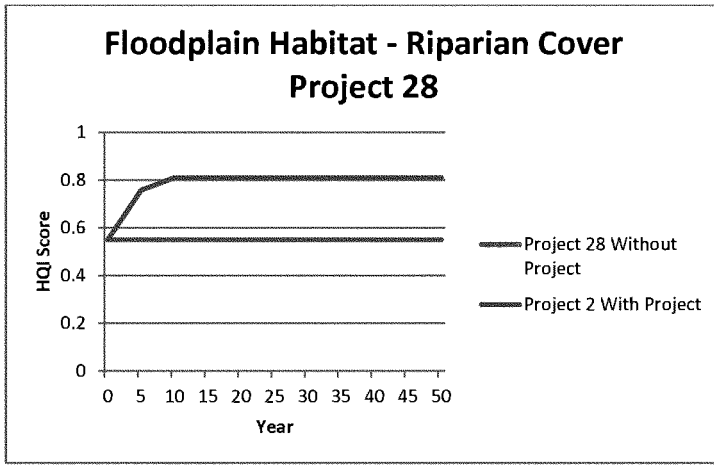

Figure 16. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 28

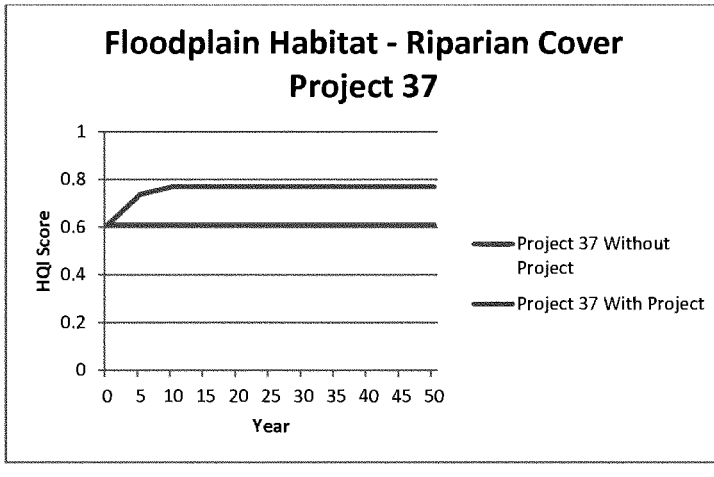

Figure 17. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 37

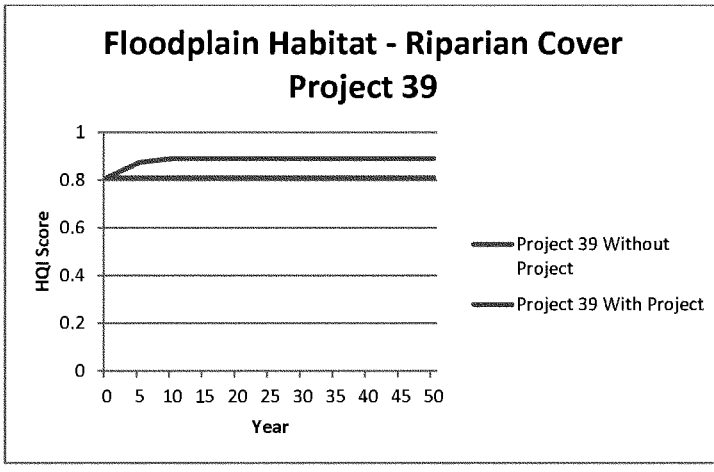

Figure 18. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 39

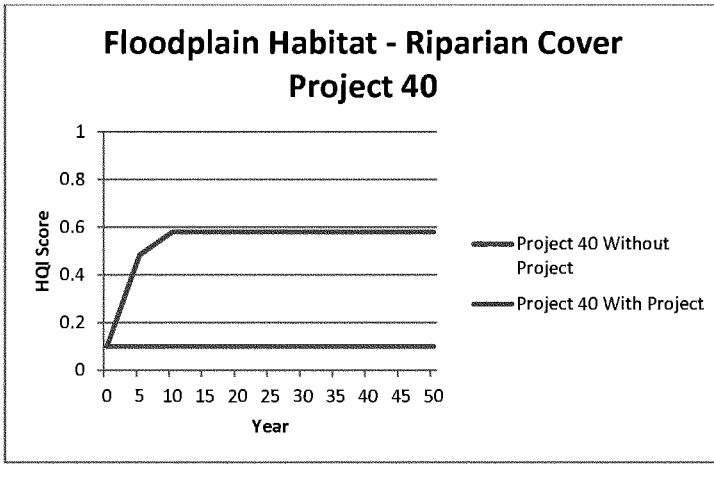

Figure 19. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 40

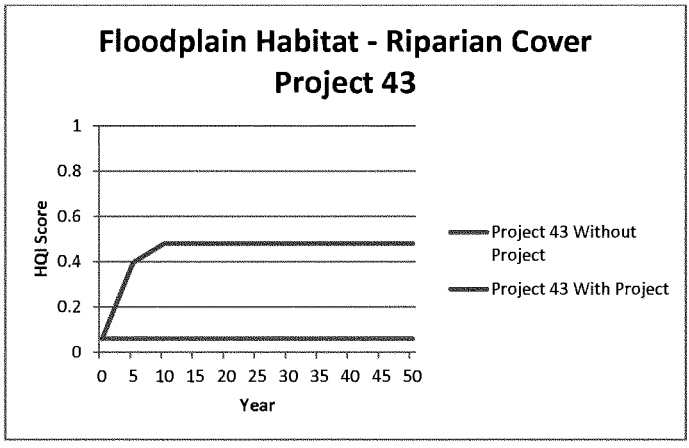

Figure 20. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 43

Table 8. Riparian Cover Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project by Project Assessment Area

Habitat Quality Index Scores – Riparian Cover	Project ID						
	9	26	28	37	39	40	43
Existing Condition	0.68	0.40	0.55	0.61	0.81	0.10	0.06
Average Annual Without Project (Baseline) Condition	0.68	0.40	0.55	0.61	0.81	0.10	0.06
Average Annual With Project Condition	0.88	0.95	0.79	0.76	0.88	0.54	0.45
Average Annual Benefit With Project	0.20	0.55	0.24	0.15	0.07	0.44	0.39

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Floodplain – Riparian Cover'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.4 FLOODPLAIN CONNECTIVITY

Loss of connections between tributaries, wetlands, off-channel ponds, and secondary side channels have resulted in a rating of poor for habitat conditions in the low-gradient mainstem Skokomish floodplain area. This affects all riverine life stages of salmonids due to the reduction of available spawning, incubation, rearing, and over-wintering habitats. This disconnection is caused partly by diking and

draining, as well as the excessive sedimentation that has cut off the mouths of tributaries such that fish passage is blocked.

The assumptions for the future without-project condition time curve are the following:

- Correa (2003) recorded that each of this study's proposed floodplain restoration sites is disconnected,
- reconnaissance through some of the study team's site visits verified that creek mouths may be blocked during summer low flow
- this condition is expected to continue as sediment continues to accumulate and block channels, and because the present land uses are expected to endure.

The assumptions for the future with-project are the following:

- existing conditions documentation states that the specific proposed project sites are disconnected for fish access from the mainstem river, so the starting point for the time curve is a score of 0;
- construction measures will include removing blockages at tributary mouths, opening fish passage and flowing channels through wetlands, ponds, and secondary side channels, and setting back levees providing immediate access and benefits
- we assume that within five years after the re-connection occurs during construction, the habitat will be 100% connected for a score of 1 because of high water events positively affecting the new connected habitat and the ancillary benefits accruing within five years of the re-connection.

Figure 21 displays the time curves for the connectivity assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for connectivity as shown in Table 9.

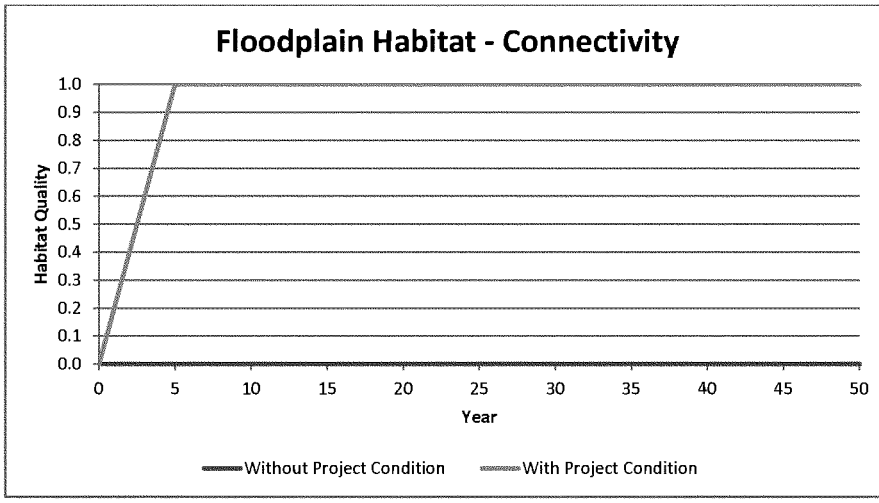

Figure 21. Floodplain Habitat – Connectivity: Habitat Quality Index over Time for Without and With Project Conditions

Table 9. Connectivity Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project

Habitat Quality Index Scores - Connectivity	Score (0-1.0)
Existing Condition	0
Average Annual Without Project (Baseline) Condition	0
Average Annual With Project Condition	0.94
Average Annual Benefit With Project	0.94

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Floodplain – Connectivity'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.5 Channel Capacity

Based on the information presented in section 2.1.2.5 regarding potential benefits to salmon from reducing flood frequency, this assessment metric was developed to show relative benefits of one base alternative plan to another. The two-year flood recurrence interval was considered for this analysis because this capacity could have many benefits on the fish populations due to reduced fish stranding.

Another reason for selecting the two-year flow capacity is based on written records of flooding in the Skokomish valley summarized in a USACE report on flooding and sediment baseline conditions (USACE 2011). According to local records, flooding occurred annually in the early part of the 1900s at flows of

roughly 13,000 cubic feet per second. Significant logging had already occurred along the South Fork Skokomish with bed elevation decreasing there while aggradation was occurring during the same period downstream from there in the mainstem (Stover and Montgomery 2001). As documented in Stover and Montgomery (2001), review of aerial photographs and meticulously kept U.S. Geological Survey (USGS) records reveals potential causes of changes in channel width and bed elevation over their study years of the 1930s to the 1990s. These USGS records show periods of significant aggradation paired with evidence of specific land use management activities. The target capacity of 17,000 cfs corresponds to approximately a two-year flood return interval, and is likely the approximate capacity that the river contained prior to significant human manipulation of the surrounding watershed. Furthermore, the typical return interval at which low gradient, pool-riffle Puget Sound area rivers experience bankfull discharge in natural conditions is the 1.5 to two-year return interval (Buffington et al. 2003); therefore, this seems to be a reasonable target.

Not all base alternatives achieve two-year capacity, rather they address capacity on a smaller scale, or they only address summer low flow concerns near the confluence where flow goes subsurface in the summer and fish are not able to access habitat upstream. Other capacities were considered but not evaluated due to the cost prohibitive nature of the sediment removal for greater capacities and disruptions to any existing habitat in the Skokomish River.

The Skokomish River typically floods an average of four times each winter, so the flood return interval is 0.25. This corresponds to a score of 0.125 (rounded to 0.13 in Table 10 below) according to the metric devised for benefits calculation. At the current rate of aggradation, frequency of flooding is expected to worsen to a condition in which the river is almost constantly avulsing.

Table 10. Flow Capacity Habitat Quality Index Scares for Existing, Withaut and With Project Conditions, and Average Annual Benefit with Project

Base #	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Change in HQI from FWOP to FWP
1 and 5	0.13	0.03	1.00	0.97
2 and 3	0.13	0.03	0.50	0.47

The average future without-project score is anticipated to be lower than the existing conditions as sediment continues to accumulate and the problems identified with channel capacity become worse. The assumptions for the projection of future without-project are based on the following information:

- Channel aggradation would continue with a sediment input rate of approximately 30,000 to 40,000 cubic yards per year
- Aggradation is expected to cause a major channel avulsion within the next 20 years. The most likely location for an avulsion is near the old North Fork confluence. The river could divert either to the north or to south sides at this location. A diversion to the south would send the river on a five-mile path across agricultural fields to rejoin the existing channel near RM 3. An avulsion is also possible near RM 3.5, where the river could be diverted into the wetland on the north side of the river.

- The wide, shallow river channel will continue to provide poor pool and riffle conditions necessary for spawning.
- Unstable riverbed conditions will continue to disturb spawning sites by scouring redds and reducing the survival of emergent fry.
- Future sediment deposits may have a smaller grain size distribution that includes an increasing amount of fines, reducing the suitability for salmon spawning.

2.3 Summary of Limiting Factor Assessment Metric Habitat Quality for Existing, FWOP, and FWP Conditions

Table 11 summarizes the existing, FWOP, and FWP HQI scores, and the average annual HQI benefit for each of the limiting factors. This table is contained in the 'Assessment Metric HQI' worksheet and is populated from computations of the individual assessment metric worksheets ('Channel Habitat – Pools', Channel Habitat – 'Woody Debris', 'Floodplain – Riparian Cover', and 'Floodplain – Connectivity'. This table is used to lookup average annual HQI benefit scores for benefit evaluation computations in the 'CEICA INPUT DATA' worksheet of the model.

Table 11. Average annual habitat quality index ratings assigned to channel and floodplain limiting factors for existing, future without-project and future with-project conditions, and net difference (average annual HQI benefit).

Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index (HQI) Score	Average Annual FWOP HQI	Average Annual FWP HQI	Average Annual HQI Benefit
Channel Habitat	Pools	all	N/A	0.21	0.21	0.93	0.72
	Woody Debris	all	N/A	0.10	0.10	0.93	0.83
Floodplain Habitat	Riparian Cover	all	9	0.68	0.68	0.88	0.20
		all	26	0.40	0.40	0.95	0.55
		all	28	0.55	0.55	0.79	0.24
		all	37	0.61	0.61	0.76	0.15
		all	39	0.81	0.81	0.88	0.07
		all	40	0.10	0.10	0.54	0.44
		all	43	0.06	0.06	0.45	0.39
	Connectivity	all	N/A	0.00	0.00	0.94	0.94
Channel Capacity	Flow Capacity	1	N/A	0.13	0.03	1.00	0.97
		2	N/A	0.13	0.03	0.50	0.47
		3	N/A	0.13	0.03	0.50	0.47
		5	N/A	0.13	0.03	1.00	0.97

3 IDENTIFY PROJECTS, THE AREAS AFFECTED, AND LIMITING FACTORS ADDRESSED

An initial array of alternatives has been formulated based on initial data collection and best professional judgment including input from Mason County, the Skokomish Tribe, and local, state, and Federal agencies. The study team identified over 25 management measures (features or activities that can be implemented at a specific geographic site) as possibly implementable in the study area. Management measures include large-scale sediment removal, construction of setback levees, placement of large woody debris, side channel restoration, and riparian plantings. Each measure was qualitatively assessed and a determination was made as to whether it should move forward in the formulation of alternative plans.

After preliminary screening, 19 management measures were carried forward to the next plan formulation step: identification of potential restoration sites. The study team identified approximately 60 potential sites where one or more measures could be implemented to address the unique problems of the study area. Sites were selected based on locations of severe degradation within the study area; the team used best professional judgment to determine what measure(s) would function at each site for intended benefits.

To guide alternatives formulation, the study team identified the study's highest priorities. If these priorities are not met, the study will fail to address the most severe biological needs of the system. The study has six priorities:

1. Increase channel capacity
2. Address river reach that runs dry during summer months
3. Reduce sediment accumulation
4. Reconnect side channels and tributaries
5. Restore floodplain riparian buffer zone
6. Improve habitat complexity and functionality

The initial array of alternatives was formulated based on initial data collection and best professional judgment. The study team identified which of the approximately 60 potential restoration sites address the highest study priorities. This exercise led to the development of alternatives that include a "base" measure. The "bases" are key measures at specific sites or reaches of the river that address the highest priorities of the study area (increasing channel capacity, improving sediment transport, and addressing summer low flow; ultimately keeping fish in the river to spawn, rear, and migrate). The bases are large projects with no separable elements; they are also mutually exclusive from other bases. Developing alternatives around these base measures ensures the critical needs of the study area are addressed. An alternative cannot be considered complete, acceptable, or effective unless one of these bases is included. The base alternatives include two large-scale sediment removal options that reach across multiple river reaches plus two smaller-scale restoration projects within specific reaches of the river.

Increments will be added to the focused array of four base alternatives to capture supplementary benefits associated with restoration of additional channel and floodplain habitat features. Potential increments considered for addition to the base plans were selected from the list of 19 proposed management measures

and 60 potential restoration sites using best professional judgment. These increments are generally smaller and can be added to whichever base option becomes the preferred alternative. The first increment added to base plans includes placement of LWD. This measure was identified to be the first critical habitat feature that should be included in a recommended plan in addition to the base; LWD helps establish pools, trap excessive sediment, improves stream habitat complexity, and serves as a substrate for aquatic invertebrates that salmon rely on as a food source. Next, additional in-channel increments were considered to address the highest study priorities (increasing channel capacity, improving sediment transport, addressing summer low flow connectivity). Finally, additional floodplain increments were considered as lower priority restoration features. Potential floodplain increments include removal of blockages at the mouths of tributaries, restoration of side channel habitat, creation of new side channels, and levee setbacks.

Of the approximately 60 potential restoration sites, eight sites were identified by the study team as high priority in-channel or floodplain increments that would optimize the environmental benefits for an alternative plan. A cost-effectiveness/incremental cost analysis (CE/ICA) will determine the appropriate number and scale of cost effective increments. The combinability of projects to base plans is further described in Chapter 4 along with the overall CE/ICA framework for the study.

Table 12 includes key information about the base alternatives in blue and the additional channel and floodplain increments in green including project name, description, reach or reaches affected, limiting factor addressed, and affected acreage (acres calculated using GIS). Figure 22 shows a map of the study area with all of the projects being carried forward in the environmental benefits analysis at this point in the plan formulation process. Finally, Figures 23 through 26 show conceptual drawings of the four proposed base plans: Bases 1, 2, 3, and 5, respectively.

At the time that this model was under development, the project team was using local site names to refer to each site where measures could be implemented and scored for comparison. During the project's feasibility-level design phase, site names were formalized in the Final Feasibility Report and Environmental Impact Statement; therefore, some site names have changed, but none were added.

Table 12. Potential restoration projects including notes regarding their design. The assessment metrics (limiting factors addressed), affected areas and reaches are identified. Where a single project spans more than one reach, the affected acreage is allocated accordingly.

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
"BASE" ACTIVITIES							
29	4-8	BASE #1 Complete Channel Capacity Design with LWD	Aggradation reduces fish access and migration. Limited LWD in river system.	Design from RM 4 to RM 8 to complete mainstem design. Place several pools of LWD or Rootwads in the main channel to provide additional fish habitat.	Channel capacity and In-channel habitat	118	3-4
30	3	BASE #2 Confluence Channel Connection with LWD	Sediment from West limited connectivity to upper North Fork due to aggradation. Limited LWD in river system.	Dredging and installation of LWD or a fish weir near the confluence. Place several pools of LWD or Rootwads in the main channel near the original confluence or near RM 1 of the North Fork. LWD placement would provide additional fish habitat.	Channel capacity and In-channel habitat	26	4
31	1	BASE #3 Reach North Fork Confluence Cut Bank Lower Dredging with LWD	Cut bank erosion and channel buffer and bank habitat connectivity to side channels and floodplain. Limited LWD in river system.	Removal of high flow & recreation channel on North Fork. Install one or two rootwads near the North Fork. Place several pieces of LWD or Rootwads in the North Fork. Channel have the original configuration and capacity of the 1 of the North Fork.	Channel capacity and In-channel habitat	63	4
32	3.5-9	BASE #4 RM 3.5-9 Dredge with LWD	Aggradation reduces fish access and migration. Limited LWD in river system.	Dredge from RM 3.5 to RM 9. Place several pieces of LWD or Rootwads in the main channel to provide additional fish habitat.	Channel capacity and In-channel habitat	132	3-4

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
ADDITIONAL INCREMENTS TO BASE ALTERNATIVES							
9	4	River Channel	Rearing and migration opportunities are significantly limited in a remnant river channel with a poor connection to the mainstem.	Improve the hydraulic connection of an existing abandoned channel to make it more accessible for fish habitat. This improvement would occur at both the upstream and downstream ends of the channel. The channel would provide slower velocity habitat and higher flow connection, will not carry river flows year round. Because there is existing riparian vegetation in the channel, limited LWD placement or plantings would occur if necessary and be focused near the agricultural field in the area. The channel would retain the old culvert at the downstream end of the site.	Floodplain habitat	45	2 / 3
26	10	Elips Rd	West Valley Road acts as a physical barrier to riparian habitat connectivity.	Relocate a small area of West Valley Road near the Elips to the West Valley Trail. Remove road surface, scarify roadbed, breach embankments at select locations where the roadbed is higher than the ground elevation, and remove riprap to create a higher functioning riparian habitat and reconnected riparian zone.	Floodplain habitat	17	4
32	4	Large Levee Setback	The connection to riparian habitats is restricted by a levee near the mainstem bank.	Setback levee to provide access to additional riparian habitats including an overwintering pool. Assume existing levee breach will remain open (do not repair this area).	Floodplain habitat	25	4
35	11	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of LWD in the upstream reaches of the Skokomish River.	Place LWD structures to create pools and provide cover.	In-channel habitat	107	4 / 5
37	4	Grange Dike Setback	The connection to riparian habitats is restricted by the Grange Dike near the mainstem bank.	Set levee back to provide access to additional riparian habitat including a pool.	Floodplain habitat	34	4 / 3
39	6	Hunter Creek Mouth	There is a poor connection between the mouth of Hunter Creek and the mainstem.	Small scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river.	Floodplain habitat	0.5	3

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
40	6	Hunter Creek Side Channel Restoration	Fish stranding commonly occurs at this site due to limited side channels off Hunter Creek; spawning and rearing opportunities are significantly limited in Hunter Creek.	Excavate remnant channels identified by LIDAR to provide improved side channel habitat, including refuge for juvenile fish during high flows. Riparian buffer plantings would also occur at this site.	Floodplain habitat	29	3
41	6	Wagner Creek Side Channel Restoration	A lack of juvenile salmonid rearing habitat & stranded fish during high flow events.	Limited excavation of remnant channels identified by LIDAR to provide improved side channel habitat, including refuge for juvenile fish during high flows. Riparian buffer plantings would also occur at this site.	In-channel habitat	25	3

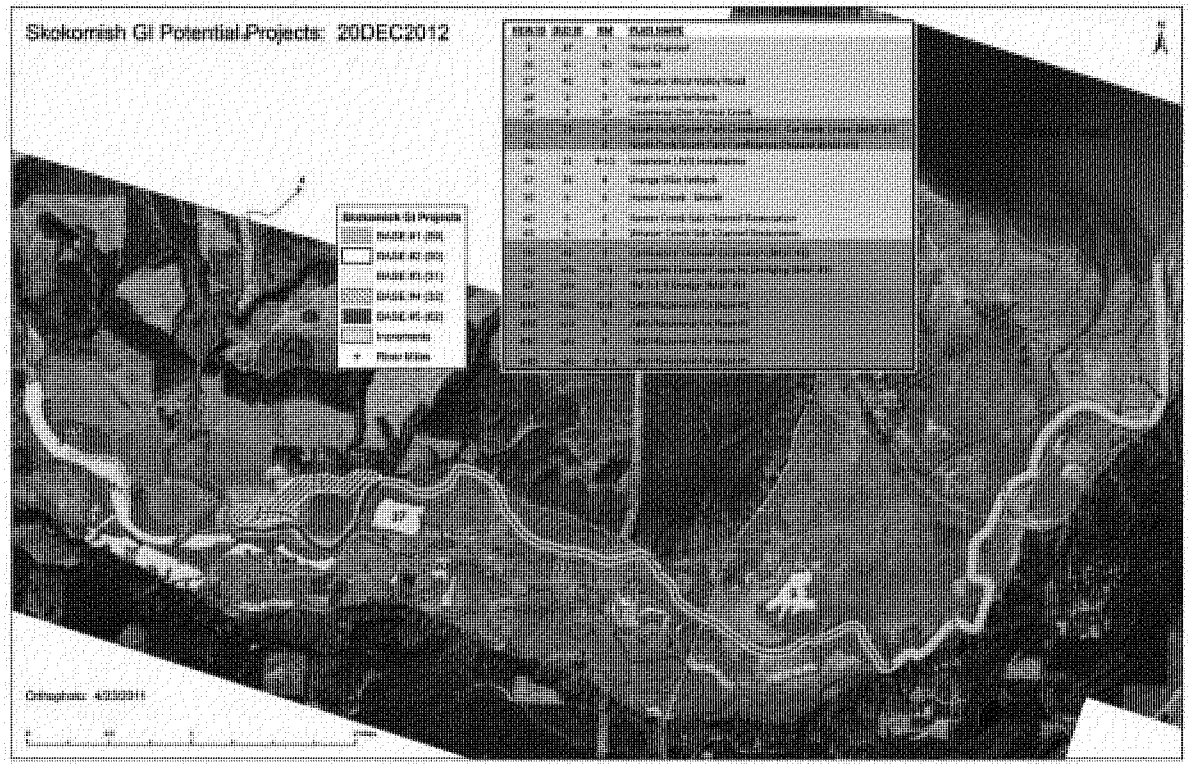

Figure 22. Skokomish GI screened base plans and incremental projects

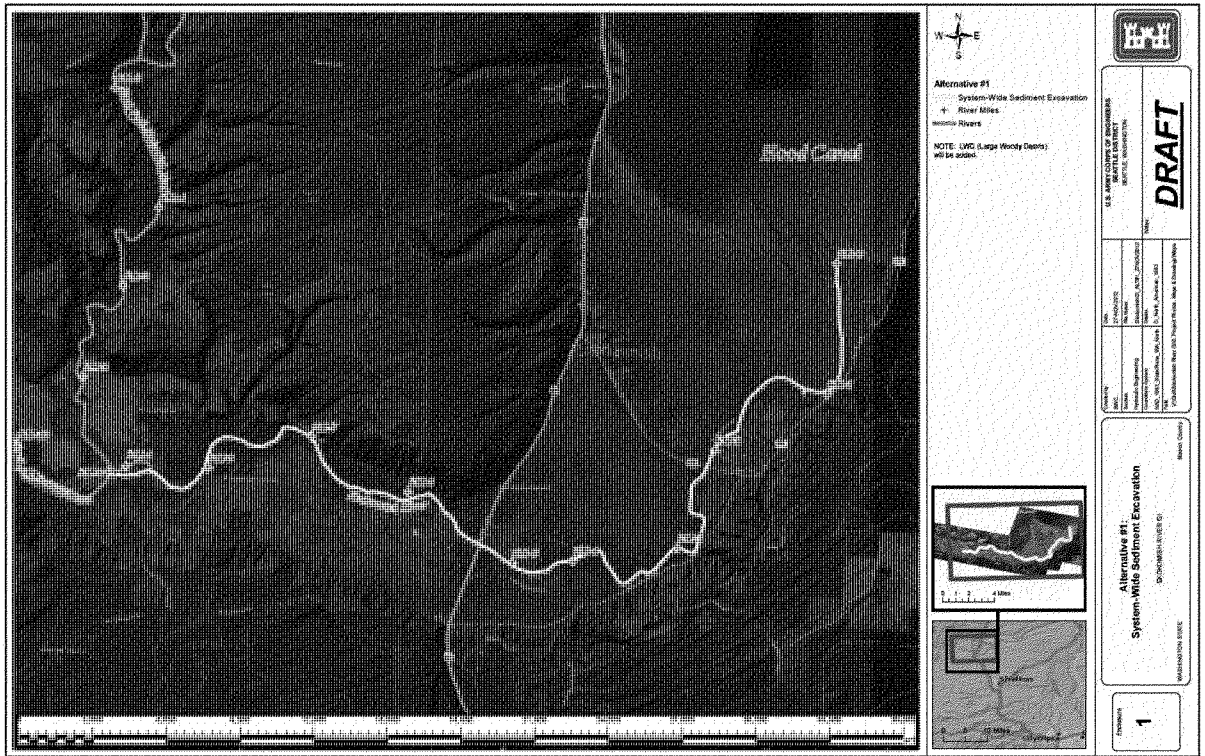

Figure 23. Base Alternative #1 - System-Wide Sediment Excavation from River Mile 0 to 9 and LWD

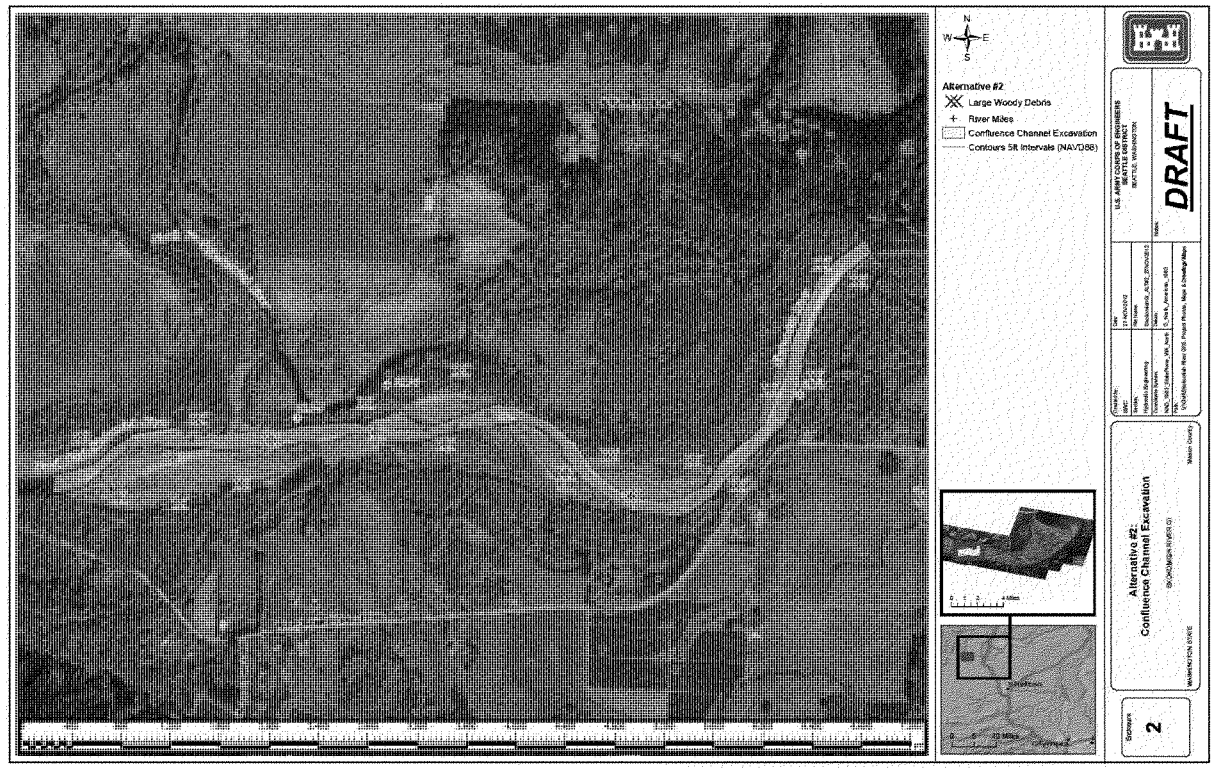

Figure 24. Base Alternative #2 - North Fork Confluence Channel Excavation and LWD

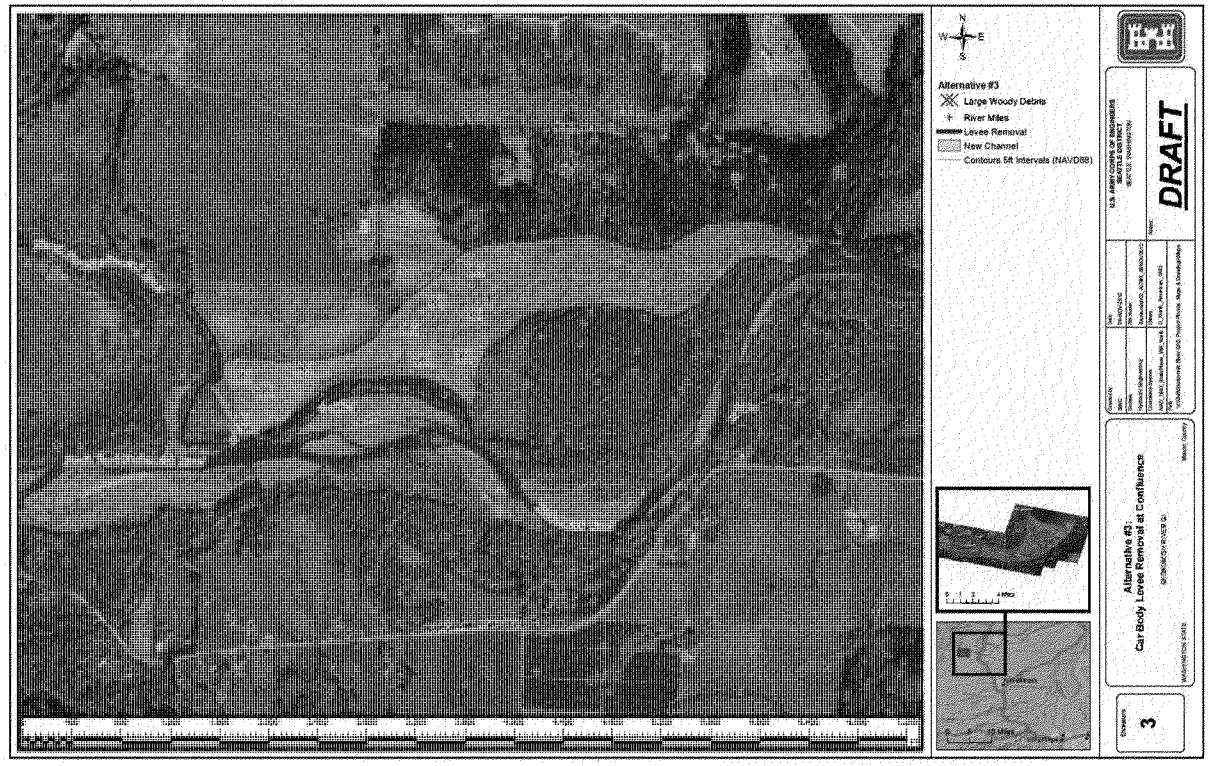

Figure 25. Base Alternative #3 - North Fork Confluence Car Body Levee Removal and LWD

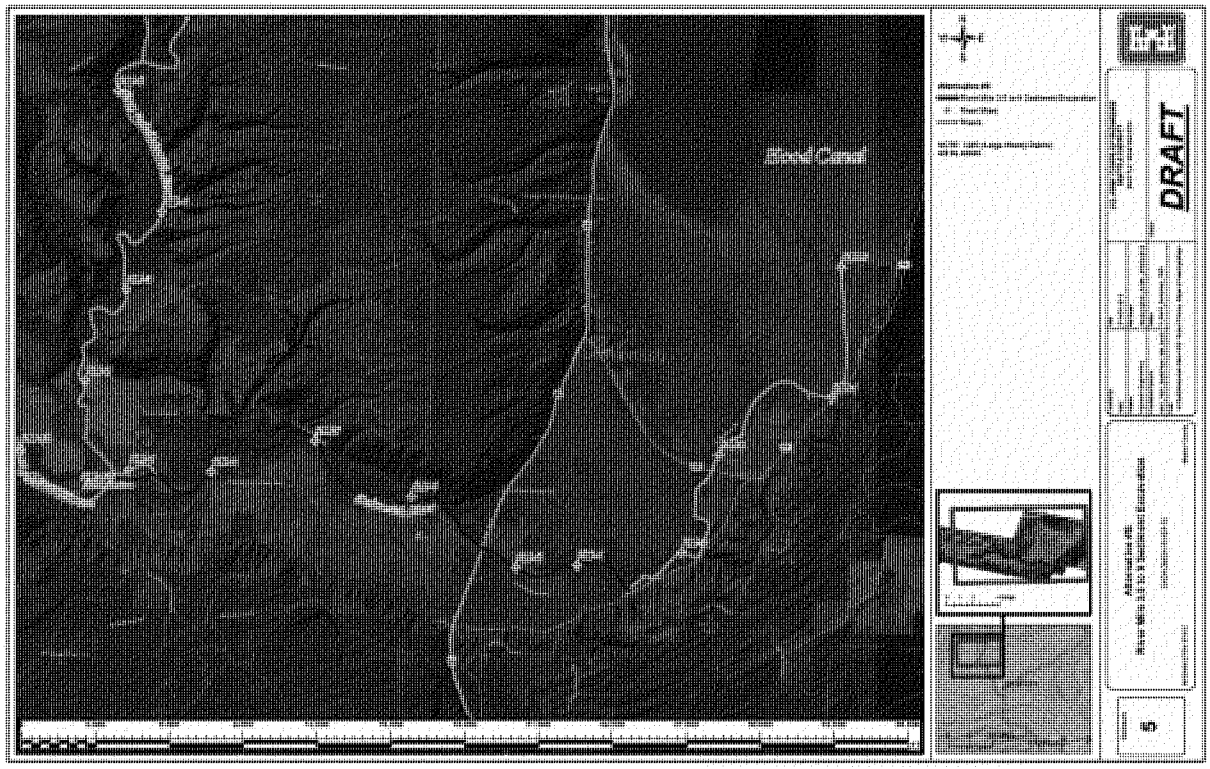

Figure 26. Base Alternative #5 - Sediment Excavation from River Mile 3.5 to 9 and LWD

4 EVALUATE SPECIFIC PROPOSED COMBINATIONS OF PROJECTS

An exercise was done to determine which projects are combinable and which are mutually exclusive. No two base plans are combinable and are therefore mutually exclusive. The capacity dredging with large woody debris base alternatives (Projects 59, 50, 31, and 62) are the first increments for any one alternative plan. In IWR Planning Suite, there will be a rule that each incremental project is dependent on one of the base alternatives and no two base alternatives are combinable.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

Table 13 summarizes the combinability of increments to base plans, denoted with a 'Y' for combinable and 'N' for not combinable. This table is included in the Environmental Benefits Analysis spreadsheet model in the worksheet titled 'CombinabilityBasePlans' and informed the project increments in Table 14. The increments are included in the worksheet 'IncrementstoBases' in the Environmental Benefits Analysis spreadsheet model. Habitat benefits for each of these project increments are evaluated in the worksheet 'CE ICA INPUT DATA'.

For each proposed restoration action, it was first determined whether the project assessment area for that action would result in measureable change to the channel capacity, in-channel habitat, or floodplain habitat limiting factors. After determining applicable limiting factor(s) for a project assessment area, the without project and with project habitat quality index scores for relevant assessment metrics were estimated. For example, a project that would address in-channel habitat only would be evaluated using the in-channel habitat assessment metrics for LWD and percent surface area in pools.

Many of the proposed projects have multiple types of benefits and may include LWD and pool formation even though they are considered a floodplain connection project. The rationale for not scoring a project on all four assessment metrics that represent the floodplain and in-channel limiting factors is that most of the projects will not include all four components or contribute to enhancing all of the habitat features represented by all four assessment metrics. In general, the side channel projects are scored as benefiting connectivity, and the levee setback projects are score as contributing to riparian habitat. The LWD installation is scored under the in-channel habitat limiting factor; as an in-channel measure, it will not contribute to floodplain connectivity. Additionally, the effort applied to calculating the relative area of effect of more than two different components does not provide a commensurate level of precision in scoring, nor is this level of precision necessary to compare the projects.

The channel capacity limiting factor with its assessment metric of flow capacity is reserved for application to the base options. The rationale for this is that the incremental projects do not accomplish flow capacity because of their small size compared to the volume of floodwater or because of their location being different from where the problematic flooding occurs.

Table 13. Combinability of Incremental Projects with Base Alternatives

Project Number	Project Name	Base #1	Base #2	Base #3	Base #5
59	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	Y	N	N	N
50	BASE #2 Confluence Channel Excavation with LWD	N	Y	N	N
31	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	N	N	Y	N
62	BASE #5 RM 3.5-9 Dredge with LWD	N	N	N	Y
9	River Channel	Y	Y	Y	Y
26	Dips Road	Y	Y	Y	Y
28	Large Levee Setback	Y	Y	Y	Y
35	Upstream LWD Installation	Y	Y	Y	Y
37	Grange Dike	Y	Y	Y	Y
39	Hunter Creek Mouth	N	Y	Y	N
40	Hunter Creek Side Channel Habitat Reconnection	Y	Y	Y	Y
43	Weaver Creek Side Channel	Y	Y	Y	Y

Table 14. Project Increments Assigned to Base Alternatives Based on Combinability

Project Number	Base # Assignment	Project Number/ Base	Project Name	Affected Reach(es)	Affected Acres	Limiting Factor
59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	0-4	219	Channel Capacity and In-Channel Habitat
50	2	L1	BASE #2 Confluence Channel Excavation with LWD	4	26	Channel Capacity and In-Channel Habitat
31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	4	68	Channel Capacity and In-Channel Habitat
62	5	N1	BASE #5 RM 3.5-9 Dredge with LWD	2-4	132	Channel Capacity and In-Channel Habitat
9	all	B1	River Channel	2-3	45	Floodplain Habitat
26	all	C1	Dips Road	4	17	Floodplain Habitat
28	all	D1	Large Levee Setback	4	23	Floodplain Habitat
35	all	F1	Upstream LWD Installation	4-5	107	In-Channel Habitat
37	all	G1	Grange Dike	3-4	34	Floodplain Habitat
39	2 and 3	H1	Hunter Creek Mouth	3	0.5	Floodplain Habitat
40	all	I1	Hunter Creek Side Channel Habitat Reconnection	3	29	Floodplain Habitat
43	all	J1	Weaver Creek Side Channel	3	25	In-Channel Habitat

The following flow diagram in Figure 27 shows the assessment metrics (labeled V1 to V5), limiting factors and three paths to compute habitat quality index depending on which of the limiting factors apply for a given assessment area.

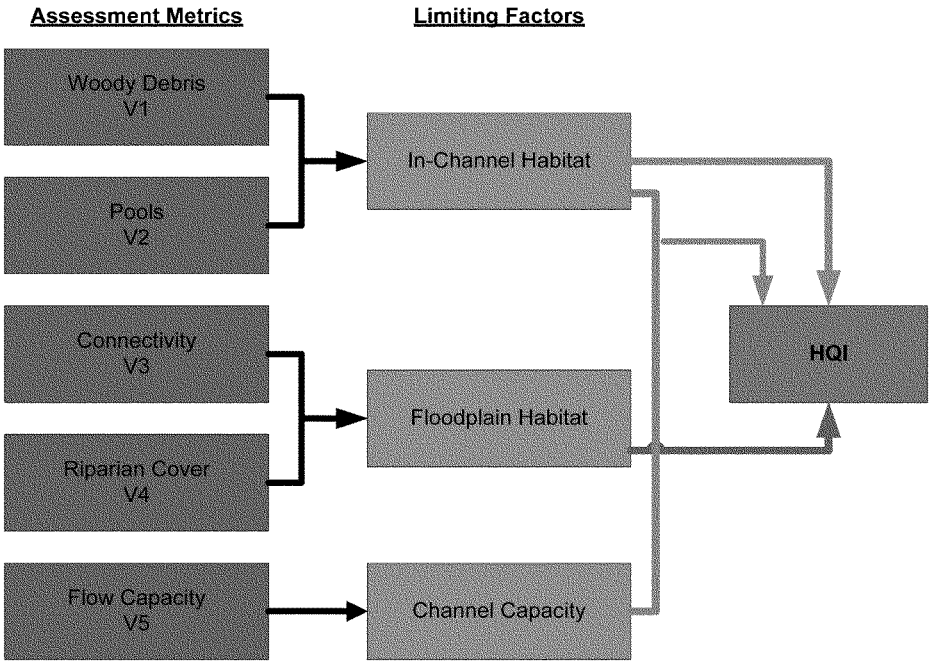

Figure 27. Flow diagram of HQI computation based on assessment area limiting factor(s) and assessment metrics

HQI is equal to one of three equations depending on the limiting factor(s) that apply to a given assessment area:

- $HQI = \frac{V1+V2+V5}{3}$ for assessment areas which evaluate both channel capacity and in-channel habitat limiting factors;
- $HQI = \frac{V1+V2}{2}$ for assessment areas which evaluate the in-channel habitat limiting factor only; and
- $HQI = \frac{V3+V4}{2}$ for assessment areas that evaluate the floodplain habitat limiting factor only.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

Tables 15 to 17 show the evaluation of assessment areas by limiting factor(s) proposed project increments address. Table 15 includes computation of AAHUs for project increments that evaluate channel capacity and in-channel habitat limiting factors; Table 16 evaluates project increments for the floodplain habitat limiting factor only, and Table 17 evaluates project increments for the in-channel habitat limiting factor only. For each assessment area, three evaluations are presented. The first line is the evaluation of the without project condition for the assessment areas and is denoted by a letter followed by 0. It is scored based on the applicable limiting factor(s) and HQI is computed using the applicable HQI equation. The second line is for the project increment (with-project action) and is denoted with the same project letter followed by 1. It evaluates the habitat quality associated with the proposed action and is scored using the same assessment metrics used in the without project condition. Lastly, the third line presents the benefits of the proposed action. The benefits are taken as the change in HQI score multiplied by the affected area of the project.

$$Benefits\ (in\ AAHU) = Change\ in\ HQI\ Score\ (With\ Project - Without\ Project)\ x\ Affected\ Area$$

Table 15. HQI scoring and AAHU's for assessment areas with channel capacity and in-channel habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	Base # Assignment	Project Number/Base	Affected Reach(es)	Primary Reach Affected	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
Limiting Factors for Assessment Area = Channel Capacity and In-Channel Habitat HQI = (V1 + V2 + V5)/3												
59	1	K0	0-4	N/A	219	0.10	0.21	N/A	N/A	0.03	0.11	24.5
59	1	K1	0-4	N/A	219	0.93	0.93	N/A	N/A	1.00	0.95	208.7
59	***1***	***K1***	***0-4***	***N/A***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***184.2***
50	2	L0	4	N/A	26	0.10	0.21	N/A	N/A	0.03	0.11	*2.9*
50	2	L1	4	N/A	26	0.93	0.93	N/A	N/A	0.50	0.79	20.4
50	***2***	***L1***	***4***	***N/A***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***17.5***
31	3	M0	4	N/A	68	0.10	0.21	N/A	N/A	0.03	0.11	*7.6*
31	3	M1	4	N/A	68	0.93	0.93	N/A	N/A	0.50	0.79	*53.5*
31	***3***	***M1***	***4***	***N/A***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***45.9***
62	5	N0	2-4	N/A	132	0.10	0.21	N/A	N/A	0.03	0.11	*14.8*
62	5	N1	2-4	N/A	132	0.93	0.93	N/A	N/A	1.00	0.95	*125.8*
62	***5***	***N1***	***2-4***	***N/A***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***111.0***

Table 16. HQI scoring and AAHU's for assessment areas with floodplain habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	Base # Assignment	Project Number/Base	Affected Reach(es)	Primary Reach Affected	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
Limiting Factors for Assessment Area = Floodplain Habitat HQI = (V3 + V4) / 2												
9	all	B0	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	15.3
9	all	B1	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	41.0
9	***all***	***B1***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
26	all	C0	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.4
26	all	C1	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
26	***all***	***C1***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
28	all	D0	4	4	23	N/A	N/A	-	0.55	N/A	0.28	6.3
28	all	D1	4	4	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
28	***all***	***D1***	***4***	***4***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
37	all	G0	3-4	4	34	N/A	N/A	-	0.61	N/A	0.31	10.4
37	all	G1	3-4	4	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
37	***all***	***G1***	***3-4***	***4***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
39	2 and 3	H0	3	3	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
39	2 and 3	H1	3	3	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
39	***2 and 3***	***H1***	***3***	***3***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
40	all	I0	3	3	29	N/A	N/A	-	0.10	N/A	0.05	1.5
40	all	I1	3	3	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
40	***all***	***I1***	***3***	***3***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***

Table 17. HQI scoring and AAHU's for assessment areas with in-channel habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	Base # Assignment	Project Number/Base	Affected Reach(es)	Primary Reach Affected	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
Limiting Factors for Assessment Area = In-Channel Habitat HQI = (V1 + V2) / 2												
9	all	B0	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	16.6
9	all	B1	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	99.5
9	***all***	***B1***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***82.9***
26	all	C0	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.9
26	all	C1	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	23.2
26	***all***	***C1***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***19.4***

5 SUMMARIZED CE/ICA INPUT DATA FOR IWR-PLANNING SUITE

For the purposes of comparing and evaluating alternatives, the AAHUs will be used in IWR-Planning Suite to evaluate the cost effectiveness and incremental cost of the base alternatives in combinations with the additional incremental projects. Total AAHU for incremental projects are equal to the difference in AAHU's for the without-project condition and the with-project condition for a given assessment area. Table 18 summarizes the benefits for each project increment to be used for the cost effectiveness and incremental cost analysis (CE/ICA) in IWR-Planning Suite.

Table 18. Summary of project increment benefits for CE/ICA in IWR-Planning Suite

Project Number	Base # Assignment	Project Number/Base	Project Name	Limiting Factor	Affected Reach(es)	Affected Acres	HQI	AAHU (Affected Acres * HQI)
59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	Channel Capacity and In-Channel Habitat	0-4	219	0.84	184.2
50	2	L1	BASE #2 Confluence Channel Excavation with LWD	Channel Capacity and In-Channel Habitat	4	26	0.67	17.5
31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	Channel Capacity and In-Channel Habitat	4	68	0.67	45.9
62	5	N1	BASE #5 RM 3.5-9 Dredge with LWD	Channel Capacity and In-Channel Habitat	2-4	132	0.84	111.0
9	all	B1	River Channel	Floodplain Habitat	2-3	45	0.57	25.7
26	all	C1	Dips Road	Floodplain Habitat	4	17	0.75	12.7
28	all	D1	Large Levee Setback	Floodplain Habitat	4	23	0.59	13.6
35	all	F1	Upstream LWD Installation	In-Channel Habitat	4-5	107	0.77	82.9
37	all	G1	Grange Dike	Floodplain Habitat	3-4	34	0.54	18.5
39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	3	0.5	0.51	0.3
40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	3	29	0.69	20.1
43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	3	25	0.77	19.4

6 HOW CE/ICA INPUT DATA WILL BE USED IN IWR PLAN FOR CE/ICA ANALYSIS

It is intended that the AAHU will be used in IWR Planning Suite, certified version 2.0.6.0. Conceptual level costs are being developed for each of the incremental projects and their annualized costs will be used in the model for the cost component. Alternatives will be evaluated using the annualized construction first costs and annual operations and maintenance (O&M) costs, and the total average annual cost, which considers life cycle costs of the project.

It is anticipated that the base plans will have a large cost range and the suite of alternatives generated will show large jumps in incremental cost from one base to another. Total project cost and habitat improvement will be considered in the identification of alternatives to carry forward analysis under the National Environmental Policy Act. It may be worthwhile to carry forward a single alternative plan for each of the base alternatives that reasonably meet both sponsor cost share capability and priority habitat needs in the basin.

7 SENSITIVITY ANALYSIS

A sensitivity analysis of the habitat outputs (AAHUs) was performed to consider different weighting of the assessment metrics for the three HQI equations. Lack of channel capacity is a priority problem in the Skokomish study area and is only addressed to some extent with the base alternatives. Both the channel capacity and in-channel habitat limiting factors apply to the computation of HQI scores for the four base alternatives using the following equation:

$$HQI = \frac{V1 + V2 + V5}{3}$$

If we were to prioritize the channel capacity and weight flow capacity (V5) higher than the other two in-channel habitat assessment metrics (woody debris or V1, and pools or V2) such that flow capacity is twice as important as both V1 and V2, the HQI equation for channel capacity and in-channel habitat limiting factors would be modified as follows:

$$HQI = \frac{V1 + V2 + (2 \times V5)}{4}$$

Table 19 presents the change in HQI scores that result from weighting flow capacity twice as important as woody debris and pools for the four base alternatives. Overall change in the benefit evaluations result in a change of -7.4% to +4.0% for each affected acre. Because the scale, costs, and benefits for each of the base alternatives are greatly different, the minor changes in overall habitat quality associated with weighting capacity higher than the other two metrics would have no affect on the cost effectiveness and incremental cost analysis for these base alternatives.

Table 19. Sensitivity analysis: Weighting flow capacity (V5) twice as great as woody debris (V1) and pools (V2) for HQI computations of channel capacity and in-channel habitat limiting factors

Scenario	HQI	Scenario	HQI	Scenario	HQI	Scenario	HQI
Base 1, equal weighting of metrics	0.84	Base 2, equal weighting of metrics	0.67	Base 3, equal weighting of metrics	0.67	Base 5, equal weighting of metrics	0.84
Base 1, capacity weighted 2x	0.87	Base 2, capacity weighted 2x	0.62	Base 3, capacity weighted 2x	0.62	Base 5, capacity weighted 2x	0.87
Change in Base 1 HQI	+0.03	Change in Base 2 HQI	-0.05	Change in Base 3 HQI	-0.05	Change in Base 5 HQI	+0.03
% Change in AAHU	+4.0%	% Change in AAHU	-7.4%	% Change in AAHU	-7.4%	% Change in AAHU	+4.0%

For assessment areas that only evaluate one of the limiting factors, in-channel habitat or floodplain habitat, a sensitivity analysis on the HQI score was performed to consider weighting of one the assessment metrics to be two times more important than the other assessment metric. The equations used for the computation of in-channel habitat (woody debris or V1, and pools or V2) and floodplain habitat

(connectivity or V3, and riparian habitat or V4) considered equal weighting of each of the metrics with the following equations:

- $HQI = \frac{V1+V2}{2}$ for in-channel habitat, and
- $HQI = \frac{V3+V4}{2}$ for floodplain habitat.

Weighing one assessment metric twice as great as the other assessment metric modifies these two equations as follows:

- $HQI = \frac{(2\times V1)+V2}{3}$ for in-channel habitat where V1 is twice as great as V2;
- $HQI = \frac{V1+(2\times V2)}{3}$ for in-channel habitat where V2 is twice as great as V1;
- $HQI = \frac{(2\times V3)+V4}{3}$ for floodplain habitat where V3 is twice as great as V4; and
- $HQI = \frac{V3+(2\times V4)}{3}$ for floodplain habitat where V4 is twice as great as V3.

Table 20 presents the HQI computations for project increments that address either in-channel habitat or floodplain habitat limiting factors for each of the weightings and compare the changes to HQI computations where assessment metrics are equally weighted. Overall change in the benefit evaluations result in a change of -28.5% to +28.5% for each affected acre. The project increments for these assessment areas are of much smaller scale than the base alternatives and would not affect the cost effectiveness and incremental cost analysis of the bases, but may result in minor changes to the overall cost effectiveness of the additional project increments in combination with the base alternatives.

Table 20. Sensitivity analysis: Weighting one assessment metric twice as great as other assessment metric for HQI computations of in-channel or floodplain habitat limiting factors

Project ID	V1 = V2	V1 = 2 x V2	V2 = 2 x V1	Project ID	V3 = V4	V3 = 2 x V4	V4 = 2 x V3
F1	0.77	0.79	0.76	B1	0.57	0.70	0.45
J1	0.77	0.79	0.76	C1	0.75	0.81	0.68
				D1	0.59	0.71	0.47
				G1	0.54	0.68	0.41
				H1	0.51	0.65	0.36
				I1	0.69	0.77	0.61

Because the overall sensitivity to the weighting of metrics is likely to have minor effects on the cost effectiveness and incremental cost analysis, and because there is no basis found in literature to weight the measures, the team will perform the analysis assuming equal weighting of the metrics for each of the three HQI equations.

8 MODEL UNCERTAINTIES AND LIMITATIONS

With any attempt to quantify ecosystem benefits of restoration, the method will have inherent uncertainties and limitations. We have identified several in the process of developing this ecosystem benefits model. They are summarized as follows:

1) Amount of benefits not quantified

    a. We use the Salmonidae family as a "keystone species," and as the most important ESA-listed species, for calculating habitat benefits. This assumes the majority of benefits are quantified through the metrics focused on salmonid habitat needs. The model has only five different assessment metrics, so this leaves entire categories of salmon habitat benefits unquantified.

    b. We assume that other benefits will accrue for avian, mammal, insect, and bivalve species; however, the model does not include direct predictive measurements, so there is some unknown quantity of benefits for these other biota. This is identified as one of the limitations of this model in that it is not a comprehensive accounting of all classes of biota that are expected to experience benefits.

    c. The biggest limitation of this model is that combining the unrelated qualities represented by the capacity metric versus the in-channel and floodplain metrics, then taking the average of these metrics, reduces the value of providing the critical population survival component afforded by the channel capacity measure. The results severely underestimate the value of the two alternatives that provide increased channel capacity that would reduce annual fish mortality from stranding outside the channel.

2) Benefits beyond the project footprint

    a. Successful restoration is expected to enhance salmon habitat and thereby help to increase their populations, which occupy and traverse through areas well outside of the project footprint. Salmon are a prey item for many other species, and influence structure and function throughout their spawning range, as well as provide marine derived nutrients back to the land-based, freshwater ecosystem. This model uses project footprint as the area component, which is smaller than the total area of influence of the anticipated increase in biological benefits as salmon move upstream and downstream from the project areas.

    b. Another limitation of this model is that it does not calculate the potential change in process and structure upstream and downstream from the project footprint that may accrue due to placement of LWD or removal of significant quantities of sediment. Risk and uncertainty of these actions are analyzed in the Draft Feasibility Report/Environmental Impact Statement and other project documents to ensure human safety and minimized environmental impacts; however, the benefits calculation is limited

to the project footprint due to uncertainty of scope of benefits outside of the immediate project area.

3) Project design and implementation results

   a. We assume that significant sediment removal from the aggraded river to the two-year flood flow capacity will have significant short-term impacts, such as turbidity during construction, but will significantly reduce the overbank flooding that causes adult and juvenile salmonids to become stranded in the agricultural fields. The model bases benefits on the concept that this will increase the survival rate of the egg-to-migrant fry life stage. Since there have been no before-after-control-impact studies to quantify this increase in survival rate, we have a large degree of uncertainty regarding the quantification of this expected improvement in the Skokomish River.

   b. Design guidance was provided from the project fish biologist to the design engineers regarding appropriate and target quantities of LWD placement. We assume that adding LWD to the river to achieve the target based on best available science in the most recent literature on LWD loading in Pacific Northwest streams will achieve the desired effects (see: Fox et al. 2003, Fox and Bolton 2007). LWD that is anchored during construction is expected to recruit and trap other woody debris that travels downstream from the forested upper watershed. One of the limitations of this model is that there is no quantification of benefits from the growing mass of LWD recruited post construction due to uncertainty of rate and quantities.

   c. The most likely scenario for operations and maintenance of the project is to implement a recurring dredging program. This is assumed the most efficient and least environmentally damaging, compared to other options such as a sediment trap, because a regular dredging program would only remove what deposits. A sediment trap would induce deposition and require dredging every year. A trap may fill during a large flood and then bypass sediment for the rest of the year. A sediment trap is a continuous operation (trapping or removing) and may be an obstruction to fish passage. Compared to a sediment trap, periodic dredging would occur much less frequently, only when needed. For Base Options 1 and 5, a multi-year dredging plan could be implemented, rotating the dredging location. Current estimates are that dredging every 20 years could maintain capacity between the 1.33 to two-year flood return intervals for the larger dredging alternatives. For the Base Option that dredges at the North Fork confluence, dredging every 10 years would be required to maintain capacity because the confluence area is shallower than other reaches of the river.

4) Predictability of inputs from the upper watershed above the study area

   a. Water: We have large uncertainty regarding the flood flows that will occur during and after construction. We can only calculate the probability of any flow level based on history of exceedances, but cannot predict what will occur during and after construction.

b. LWD: The upper watershed of the Skokomish basin has large logjams and is largely forested across most of the landscape. LWD inputs into the study area are difficult to predict, but may be improving as landscape management of commercial forestry practices improves.

c. Sediment: The Corps estimates that the bedload inflow from the upper watershed is approximately 30,000 to 40,000 cubic yards per year. The primary source is natural erosion with some contribution from landslides that may occur due to present or past timber harvests on steep slopes or logging roads that cause erosion and sedimentation. The contributions from forestry practices are assumed to be decreasing as roads are being decommissioned on public lands and more erosion prevention measures are used in public and private timber harvests. However, the primary source is a natural occurrence and the rate cannot be precisely predicted for any given year, only in averages and trends.

5) Operational modifications at Cushman Dam on the North Fork Skokomish River

a. Seattle District is familiar with the provisions of the relicensing agreement and will continue to coordinate with the settlement parties as alternative plans are developed. The settlement agreement places no legal restrictions or responsibilities on the Corps.

b. The settlement agreement has established monthly base flows that are being implemented by the operating project; flushing flows are not being implemented at this time due to a lack of channel capacity to carry the flows (flushing flows would induce flooding downstream of the dam).

c. Operation of upstream reservoirs has been taken into consideration during the alternatives formulation process; the without project condition and future without project includes the current and likely future flow regimes from Cushman Dam. Future flow modifications from Cushman Dam could increase flows in the North Fork (e.g., implementation of North Fork flushing flows), though the impacts of these flows would minimally affect the alternatives proposed under the GI. The recommended plan may allow for the future implementation of flushing flows but the Corps will not formulate, evaluate, or select a plan based on this effect. Dam flows from the North Fork enter the study area at RM 7.5, while the study area extends upstream to RM 12.

6) Habitat development after construction

a. Each metric has assumptions stated for the temporal scale of how benefits will accrue after construction. These are based on literature, best professional judgment, and Corps staff's personal observations of similar projects.

b. Primary uncertainty lies within the prediction of stability of the riverbed after significant quantities of sediment are removed. There is no metric to score for more or less stability.

c. Quantity and velocity of water will affect development of habitat after construction, so this ties back to the inability to predict when and what level of high flow events will occur after construction.

7) Predicting future with-project and future without-project

   a. Uncertainties regarding predicting the future have largely been covered previously in this chapter. One of the limitations specific to the scores for future without project is that using the relationship derived from historical data to predict the future assumes that there are certain steady-state conditions among the complex ecosystem processes, structures, and functions. We assume that the degrading habitat will continue to degrade at the same rate, or that it is already as bad as it can get and therefore the score for the future without-project is the same as the existing conditions.

   b. Predicting the future with-project scores relies on the assumption that the project will function as designed and therefore deserves the score it is given according to the metric. There is unquantifiable uncertainty in this outcome, but a Monitoring and Adaptive Management Plan will be designed to maximize benefits.

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Appendix A: Skokomish Environmental Benefits Analysis Spreadsheet – A Guide to the Worksheets and Computations

The intent of this appendix is to support the documentation of the main model documentation report and provide a guide to the worksheets contained within the Skokomish Environmental Benefits Analysis Spreadsheet. Tables and information contained within the worksheet are provided here, along with the formulas used to derive environmental outputs for project increments considered for the Skokomish River General Investigation at this time. Each Section corresponds to a single worksheet within the model, which also corresponds to the ID's in Section 1, Table of Contents.

Background to the assessment metrics, valuations, and equations are contained in the main report. The functions used within the model are directly related to the information provided in the main report. Much of the information contained within the spreadsheet was derived from team input and no computations were required. The table found in the 'CE ICA INPUT DATA' worksheet contains the majority of the computations that will feed the cost effectiveness and incremental cost analyses (CE/ICA) for the study.

1 TABLE OF CONTENTS

A table of contents worksheet is included to provide links to the individual worksheets within the model. A total of 12 worksheets are included and are summarized as follows.

ID	Worksheet	Content Description
1	Table of Contents	This tab describes the contents of each of the worksheets included in the Skokomish Environmental Benefits Analysis (EBA) Spreadsheet Model. The EBA Model is used to derive the environmental outputs needed to evaluate alternatives in IWR-Planning Suite for cost effectiveness and incremental analysis. The procedures, environmental basis for the outputs, and the plan formulation are described in the model certification document that accompanies this report.
2	INPUT DATA	These are the project increments/measures identified by the project development team (PDT) to address degraded habitat in the lower Skokomish River Basin. Included are the project number, project name, affected reach or reaches, a primary affected reach, affected acreage, and a designation of which limiting factors apply to the assessment area. This project data is carried forward in the development of average annual habitat units and is included in several other worksheets including 'CombinabilityBasePlans', 'IncrementstoBases', and 'CE ICA INPUT DATA'.

ID	Worksheet	Content Description
3	CombinabilityBasePlans	The PDT conducted an exercise to identify combinability of projects and measures to the bases. No two incremental projects are mutually exclusive, and all other project increments are combinable with exception of the four base alternatives.
4	IncrementstoBases	This worksheet carries forward the project information from the 'INPUT DATA' worksheet and the project relationships from the 'CombinabilityBasePlans' worksheet to show all of the possible incremental projects and the bases they may be combined with. Projects are denoted by a letter and number for CE/ICA in IWR-Planning Suite.
5	Assessment Metric HQI	The assessment metric existing, future without-project, and future with-project condition, and average annual HQI benefit scores (or change from the without project condition to the with project condition) are summarized here. The existing, future without-project, and future with-project scores are derived in worksheets for each of the assessment metrics ('Channel – Pools HQI', 'Channel - Woody Debris HQI', 'Floodplain - Riparian Cover HQI', and 'Floodplain – Connectivity HQI'). These HQI scores are used for computation of average annual habitat units in the 'CE/ICA INPUT DATA' worksheet.
6	Capacity HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the flow capacity assessment metric over the study period for each of the base alternatives.
7	Channel – Pools HQI	This worksheet documents the computations of the existing future without-project, and future with-project HQI scores by assessing change in habitat quality for the pool assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
8	Channel - Woody Debris HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the woody debris assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.

ID	Worksheet	Content Description
9	Floodplain - Riparian Cover HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the riparian cover assessment metric over the study period for each of the assessment areas. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
10	Floodplain – Connectivity HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the connectivity assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
11	CE ICA INPUT DATA	This worksheet contains the computations of AAHU by assessment area and net benefits for each of the project increments. The benefits will be used for cost effectiveness and incremental cost analyses (CE/ICA) analysis in IWR-Planning Suite.
12	CE ICA Sensitivity Analysis	This worksheet presents a sensitivity analysis of the change in HQI and AAHU when one assessment metric is weighted greater than the other one or two assessment metrics for the three HQI equations.

2 'INPUT DATA' WORKSHEET

These are the project increments/measures identified by the study team to address degraded habitat in the lower Skokomish River Basin. Items included are the project number, project name, affected reach or reaches, a primary affected reach, affected acreage, and applicable limiting factor(s) for the assessment area. This project data is carried forward in the development of average annual habitat units and is included in several other worksheets including 'CombinabilityBasePlans', 'IncrementstoBases', and 'CE ICA INPUT DATA'. This table is included as Table 14 in the main model documentation report.

3 'COMBINABILITYBASEPLANS' WORKSHEET

The PDT went through an exercise to identify combinability of projects/measures to the bases. No two incremental projects are mutually exclusive, and thus all incremental projects combinable with a base were also combinable with one another. This table is included as Table 13 in the main model documentation report.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

4 'INCREMENTSTOBASES' WORKSHEET

This worksheet carries forward the project information from the 'INPUT DATA' worksheet and the project relationships from the 'CombinabilityBasePlans' worksheet to show all of the possible increments of projects and the bases to which they may be assigned. This was a planning exercise and no formulas are included in this worksheet. This table is included as Table 13 in the main model documentation report.

5 'ASSESSMENT METRIC HQI' WORKSHEET

The assessment metric existing, future without-project and future with-project condition, and average annual HQI benefit (or change from the without project condition to the with project condition) are summarized here. The existing, future without-project, and future with-project scores are derived in worksheets for each of the assessment metrics ('Capacity HQI', 'Channel – Pools HQI', 'Channel - Woody Debris HQI', 'Floodplain - Riparian Cover HQI', and 'Floodplain – Connectivity HQI'). The formulas or locations for each of the values are provided to the right in the following table.

Row /Column	B	C	D	E	F	G	H	I	*F*	*G*	*H*	*I*
4	Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)*
5												
6	Channel Habitat	Pools	all	N/A	0.21	0.21	0.93	0.72	*='Channel - Pools HQI'!B6*	*='Channel - Pools HQI'!B58*	*='Channel - Pools HQI'!C58*	*=H6-G6*
7		Woody Debris	all	N/A	0.10	0.10	0.93	0.83	*='Channel - Woody Debris HQI'!B6*	*='Channel - Woody Debris HQI'!B58*	*='Channel - Woody Debris HQI'!C58*	*=H7-G7*
8	Floodplain Habitat	Riparian Cover	all	9	0.68	0.68	0.88	0.20	*='Floodplain - Riparian Cover HQI'!B7*	*='Floodplain - Riparian Cover HQI'!B59*	*='Floodplain - Riparian Cover HQI'!C59*	*=H8-G8*
9			all	26	0.40	0.40	0.95	0.55	*='Floodplain - Riparian Cover HQI'!D7*	*='Floodplain - Riparian Cover HQI'!D59*	*='Floodplain - Riparian Cover HQI'!E59*	*=H9-G9*
10			all	28	0.55	0.55	0.79	0.24	*='Floodplain - Riparian Cover HQI'!F7*	*='Floodplain - Riparian Cover HQI'!F59*	*='Floodplain - Riparian Cover HQI'!G59*	*=H10-G10*
11			all	37	0.61	0.61	0.76	0.15	*='Floodplain - Riparian Cover HQI'!H7*	*='Floodplain - Riparian Cover HQI'!H59*	*='Floodplain - Riparian Cover HQI'!I59*	*=H11-G11*
12			all	39	0.81	0.81	0.88	0.07	*='Floodplain - Riparian Cover HQI'!J7*	*='Floodplain - Riparian Cover HQI'!J59*	*='Floodplain - Riparian Cover HQI'!K59*	*=H12-G12*

Row /Column	B	C	D	E	F	G	H	I	*F*	*G*	*H*	*I*
4	Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)*
13			all	40	0.10	0.10	0.54	0.44	*='Floodplain - Riparian Cover HQI'!L7*	*='Floodplain - Riparian Cover HQI'!L59*	*='Floodplain - Riparian Cover HQI'!M59*	*=H13-G13*
14			all	43	0.06	0.06	0.45	0.39	*='Floodplain - Riparian Cover HQI'!N7*	*='Floodplain - Riparian Cover HQI'!N59*	*='Floodplain - Riparian Cover HQI'!O59*	*=H14-G14*
15		Connectivity	all	N/A	0.00	0.00	0.94	0.94	*='Floodplain - Connectivity HQI'!B6*	*='Floodplain - Connectivity HQI'!B58*	*='Floodplain - Connectivity HQI'!C58*	*=H15-G15*
16	Channel Capacity	Flow Capacity	1	N/A	0.17	0.17	1.00	0.83	*='Capacity HQI'!E6*	*='Capacity HQI'!F6*	*='Capacity HQI'!G6*	*=H16-G16*
17		Flow Capacity	2	N/A	0.17	0.17	0.50	0.33	*='Capacity HQI'!E7*	*='Capacity HQI'!F7*	*='Capacity HQI'!G7*	*=H17-G17*
18		Flow Capacity	3	N/A	0.17	0.17	0.50	0.33	*='Capacity HQI'!E8*	*='Capacity HQI'!F8*	*='Capacity HQI'!G8*	*=H18-G18*
19		Flow Capacity	5	N/A	0.17	0.17	1.00	0.83	*='Capacity HQI'!E9*	*='Capacity HQI'!F9*	*='Capacity HQI'!G9*	*=H19-G19*

6 'CAPACITY HQI' WORKSHEET

This worksheet documents the computations of the existing, future without- and future with-project HQI scores by assessing change in habitat quality for the flow capacity assessment metric over time. This is assessed by base alternative. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without- and future with-project conditions.

All base alternatives have an existing condition aggraded score of less than the one-year score, with flood recurrence at approximately four times per year in the existing condition and approaching no flood capacity by year 20 in the without project condition. With restoration, Bases 1 and 5 will provide approximately two-year flow capacity with a score equal to 1; Bases 2 and 3 will provide approximately one-year capacity with a score equal to 0.5. These values are displayed in the table below and are populated in the 'Assessment Metric HQI' worksheet.

Row / Column	B	C	D	E	F	G	H	*E*	*F*	*G*	*H*
4	Limiting Factor	Assessment Metric	Base	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Change in HQI from FWOP to FWP	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Change in HQI from FWOP to FWP*
6	Channel Capacity	Flow Capacity	1	0.13	0.03	1.00	0.97	*=$B$40*	*=$B$92*	*=1/1*	*=G6-F6*
7	Channel Capacity	Flow Capacity	2	0.13	0.03	0.50	0.47	*=$B$40*	*=$B$92*	*=1/2*	*=G7-F7*
8	Channel Capacity	Flow Capacity	3	0.13	0.03	0.50	0.47	*=$B$40*	*=$B$92*	*=1/2*	*=G8-F8*
9	Channel Capacity	Flow Capacity	5	0.13	0.03	1.00	0.97	*=$B$40*	*=$B$92*	*=1/1*	*=G9-F9*

Row/Column	A	B	C	*B*	*C*
35	**WORKSHEET**				
36	**Quality index scores over the period of analysis**				
37	**Limiting Factor**	**Channel Capacity**			
38	**Assessment Metric**	**Flow Capacity**			
39	**Year**	**Without Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***
40	0	**0.13**		**=1/8**	
41	1	0.12	-0.6%	=B40+$C$41	=(B60-B40)/(A60-A40)
42	2	0.11		=B41+$C$41	

Row/Column	A	B	C	*B*	*C*
35	**WORKSHEET**				
36	**Quality index scores over the period of analysis**				
37	**Limiting Factor**	**Channel Capacity**			
38	**Assessment Metric**	**Flow Capacity**			
39	**Year**	**Without Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***
43	3	0.11		=B42+$C$41	
44	4	0.10		=B43+$C$41	
45	5	0.09		=B44+$C$41	
46	6	0.09		=B45+$C$41	
47	7	0.08		=B46+$C$41	
48	8	0.08		=B47+$C$41	
49	9	0.07		=B48+$C$41	
50	10	0.06		=B49+$C$41	
51	11	0.06		=B50+$C$41	
52	12	0.05		=B51+$C$41	
53	13	0.04		=B52+$C$41	
54	14	0.04		=B53+$C$41	
55	15	0.03		=B54+$C$41	
56	16	0.03		=B55+$C$41	
57	17	0.02		=B56+$C$41	
58	18	0.01		=B57+$C$41	
59	19	0.01		=B58+$C$41	
60	20	-		0	
61	21	-		0	
62	22	-		0	
63	23	-		0	
64	24	-		0	
65	25	-		0	
66	26	-		0	
67	27	-		0	
68	28	-		0	
69	29	-		0	
70	30	-		0	
71	31	-		0	
72	32	-		0	
73	33	-		0	
74	34	-		0	
75	35	-		0	
76	36	-		0	
77	37	-		0	
78	38	-		0	
79	39	-		0	
80	40	-		0	
81	41	-		0	
82	42	-		0	
83	43	-		0	
84	44	-		0	
85	45	-		0	
86	46	-		0	
87	47	-		0	
88	48	-		0	
89	49	-		0	
90	50	-		0	
91		**Without project condition**		**Without project condition**	
92	Average	0.03		=AVERAGE(B40:B90)	

7 'CHANNEL – POOLS HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the pool assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with project HQI scores can be found within in the main report.

Row/ Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Pools**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	**0.21**	**0.21**		**0.21**	**0.21**	
7	1	0.21	0.32		0.21	=C6+$D$9	
8	2	0.21	0.44		0.21	=C7+$D$9	
9	3	0.21	0.55	11.40%	0.21	=C8+$D$9	=(C11-C6)/(5-0)
10	4	0.21	0.67		0.21	=C9+$D$9	
11	5	0.21	**0.78**		0.21	**0.78**	
12	6	0.21	0.82	4.40%	0.21	=C11+$D$12	=(C16-C11)/(A16-A11)
13	7	0.21	0.87		0.21	=C12+$D$12	
14	8	0.21	0.91		0.21	=C13+$D$12	
15	9	0.21	0.96		0.21	=C14+$D$12	
16	10	0.21	**1.00**		0.21	**1**	
17	11	0.21	1.00		0.21	1	
18	12	0.21	1.00		0.21	1	
19	13	0.21	1.00		0.21	1	
20	14	0.21	1.00		0.21	1	
21	15	0.21	1.00		0.21	1	
22	16	0.21	1.00		0.21	1	
23	17	0.21	1.00		0.21	1	
24	18	0.21	1.00		0.21	1	
25	19	0.21	1.00		0.21	1	
26	20	0.21	1.00		0.21	1	
27	21	0.21	1.00		0.21	1	
28	22	0.21	1.00		0.21	1	
29	23	0.21	1.00		0.21	1	
30	24	0.21	1.00		0.21	1	
31	25	0.21	1.00		0.21	1	
32	26	0.21	1.00		0.21	1	
33	27	0.21	1.00		0.21	1	
34	28	0.21	1.00		0.21	1	

Row/ Column	A	B	C	D	B	C	D
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Pools**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
35	29	0.21	1.00		0.21	1	
36	30	0.21	1.00		0.21	1	
37	31	0.21	1.00		0.21	1	
38	32	0.21	1.00		0.21	1	
39	33	0.21	1.00		0.21	1	
40	34	0.21	1.00		0.21	1	
41	35	0.21	1.00		0.21	1	
42	36	0.21	1.00		0.21	1	
43	37	0.21	1.00		0.21	1	
44	38	0.21	1.00		0.21	1	
45	39	0.21	1.00		0.21	1	
46	40	0.21	1.00		0.21	1	
47	41	0.21	1.00		0.21	1	
48	42	0.21	1.00		0.21	1	
49	43	0.21	1.00		0.21	1	
50	44	0.21	1.00		0.21	1	
51	45	0.21	1.00		0.21	1	
52	46	0.21	1.00		0.21	1	
53	47	0.21	1.00		0.21	1	
54	48	0.21	1.00		0.21	1	
55	49	0.21	1.00		0.21	1	
56	50	0.21	1.00		0.21	1	
57		**Without project condition**	**With Project Condition**		**Without project condition**	**With Project Condition**	**Without project condition**
58	Average	0.21	0.93		=AVERAGE(B6:B56)	=AVERAGE(C6:C56)	=AVERAGE(B6:B56)
59	**Average change (benefit)**		0.72			=C58-B58	

8 'CHANNEL – WOODY DEBRIS HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the woody debris assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row/Column	A	B	C	D	B	C	D
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Woody Debris**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	**0.10**	**0.10**		**0.1**	**0.1**	
7	1	0.10	0.24	14%	0.1	=C6+$D$7	=(C11-C6)/(A11-A6)
8	2	0.10	0.38		0.1	=C7+$D$7	
9	3	0.10	0.52		0.1	=C8+$D$7	
10	4	0.10	0.66		0.1	=C9+$D$7	
11	5	0.10	**0.80**		0.1	**0.8**	
12	6	0.10	0.84	4%	0.1	=C11+$D$12	=(C16-C11)/(A16-A11)
13	7	0.10	0.88		0.1	=C12+$D$12	
14	8	0.10	0.92		0.1	=C13+$D$12	
15	9	0.10	0.96		0.1	=C14+$D$12	
16	10	0.10	**1.00**		0.1	**1**	
17	11	0.10	1.00		0.1	=IF(C16+$D$7>1,1,C16+$D$7)	
18	12	0.10	1.00		0.1	=IF(C17+$D$7>1,1,C17+$D$7)	
19	13	0.10	1.00		0.1	=IF(C18+$D$7>1,1,C18+$D$7)	
20	14	0.10	1.00		0.1	=IF(C19+$D$7>1,1,C19+$D$7)	
21	15	0.10	1.00		0.1	=IF(C20+$D$7>1,1,C20+$D$7)	
22	16	0.10	1.00		0.1	=IF(C21+$D$7>1,1,C21+$D$7)	
23	17	0.10	1.00		0.1	=IF(C22+$D$7>1,1,C22+$D$7)	
24	18	0.10	1.00		0.1	=IF(C23+$D$7>1,1,C23+$D$7)	
25	19	0.10	1.00		0.1	=IF(C24+$D$7>1,1,C24+$D$7)	
26	20	0.10	1.00		0.1	=IF(C25+$D$7>1,1,C25+$D$7)	
27	21	0.10	1.00		0.1	=IF(C26+$D$7>1,1,C26+$D$7)	
28	22	0.10	1.00		0.1	=IF(C27+$D$7>1,1,C27+$D$7)	
29	23	0.10	1.00		0.1	=IF(C28+$D$7>1,1,C28+$D$7)	
30	24	0.10	1.00		0.1	=IF(C29+$D$7>1,1,C29+$D$7)	
31	25	0.10	1.00		0.1	=IF(C30+$D$7>1,1,C30+$D$7)	
32	26	0.10	1.00		0.1	=IF(C31+$D$7>1,1,C31+$D$7)	
33	27	0.10	1.00		0.1	=IF(C32+$D$7>1,1,C32+$D$7)	
34	28	0.10	1.00		0.1	=IF(C33+$D$7>1,1,C33+$D$7)	
35	29	0.10	1.00		0.1	=IF(C34+$D$7>1,1,C34+$D$7)	
36	30	0.10	1.00		0.1	=IF(C35+$D$7>1,1,C35+$D$7)	
37	31	0.10	1.00		0.1	=IF(C36+$D$7>1,1,C36+$D$7)	
38	32	0.10	1.00		0.1	=IF(C37+$D$7>1,1,C37+$D$7)	
39	33	0.10	1.00		0.1	=IF(C38+$D$7>1,1,C38+$D$7)	
40	34	0.10	1.00		0.1	=IF(C39+$D$7>1,1,C39+$D$7)	
41	35	0.10	1.00		0.1	=IF(C40+$D$7>1,1,C40+$D$7)	
42	36	0.10	1.00		0.1	=IF(C41+$D$7>1,1,C41+$D$7)	
43	37	0.10	1.00		0.1	=IF(C42+$D$7>1,1,C42+$D$7)	
44	38	0.10	1.00		0.1	=IF(C43+$D$7>1,1,C43+$D$7)	
45	39	0.10	1.00		0.1	=IF(C44+$D$7>1,1,C44+$D$7)	
46	40	0.10	1.00		0.1	=IF(C45+$D$7>1,1,C45+$D$7)	
47	41	0.10	1.00		0.1	=IF(C46+$D$7>1,1,C46+$D$7)	
48	42	0.10	1.00		0.1	=IF(C47+$D$7>1,1,C47+$D$7)	
49	43	0.10	1.00		0.1	=IF(C48+$D$7>1,1,C48+$D$7)	
50	44	0.10	1.00		0.1	=IF(C49+$D$7>1,1,C49+$D$7)	
51	45	0.10	1.00		0.1	=IF(C50+$D$7>1,1,C50+$D$7)	
52	46	0.10	1.00		0.1	=IF(C51+$D$7>1,1,C51+$D$7)	
53	47	0.10	1.00		0.1	=IF(C52+$D$7>1,1,C52+$D$7)	
54	48	0.10	1.00		0.1	=IF(C53+$D$7>1,1,C53+$D$7)	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Woody Debris**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
55	49	0.10	1.00		0.1	=IF(C54+$D$7>1,1,C54+$D$7)	
56	50	**0.10**	1.00		**0.1**	=IF(C55+$D$7>1,1,C55+$D$7)	
57							
58	Average	0.10	0.93		=AVERAGE(B6:B56)	=AVERAGE(C6:C56)	
59	Average change (benefit)		0.83			=C58-B58	

9 'FLOODPLAIN – RIPARIAN COVER HQI' WORKSHEET

This worksheet documents the computations of the existing, future without- and future with-project HQI scores by assessing change in habitat quality for the riparian cover assessment metric over time. Habitat quality is assessed by assessment area for each of the project increments. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves for each of the assessment areas over the period of analysis. Formulas for each of the cells are contained in the second table. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	WORKSHEET														
2	Quality index scores over the period of analysis														
3	Limiting Factor	Floodplain Habitat													
4	Assessment Metric	Riparian Cover													
5	Project Assessment Area	9	9	26	26	28	28	37	37	39	39	40	40	43	43
6	Year	Project 9 Without Project	Project 9 With Project	Project 26 Without Project	Project 26 With Project	Project 28 Without Project	Project 28 With Project	Project 37 Without Project	Project 37 With Project	Project 39 Without Project	Project 39 With Project	Project 40 Without Project	Project 40 With Project	Project 43 Without Project	Project 43 With Project
7	0	0.68	0.68	0.4	0.4	0.55	0.55	0.61	0.61	0.81	0.81	0.1	0.1	0.06	0.06
8	1	0.68	0.72	0.4	0.50	0.55	0.59	0.61	0.64	0.81	0.82	0.1	0.18	0.06	0.13
9	2	0.68	0.75	0.4	0.59	0.55	0.63	0.61	0.66	0.81	0.84	0.1	0.25	0.06	0.19
10	3	0.68	0.79	0.4	0.69	0.55	0.67	0.61	0.69	0.81	0.85	0.1	0.33	0.06	0.26
11	4	0.68	0.82	0.4	0.78	0.55	0.72	0.61	0.71	0.81	0.86	0.1	0.41	0.06	0.33
12	5	0.68	0.86	0.4	0.88	0.55	0.76	0.61	0.74	0.81	0.87	0.1	0.48	0.06	0.40
13	6	0.68	0.86	0.4	0.90	0.55	0.77	0.61	0.74	0.81	0.88	0.1	0.50	0.06	0.41
14	7	0.68	0.87	0.4	0.93	0.55	0.78	0.61	0.75	0.81	0.88	0.1	0.52	0.06	0.43
15	8	0.68	0.88	0.4	0.95	0.55	0.79	0.61	0.76	0.81	0.88	0.1	0.54	0.06	0.45
16	9	0.68	0.89	0.4	0.98	0.55	0.80	0.61	0.76	0.81	0.89	0.1	0.56	0.06	0.46
17	10	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
18	11	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
19	12	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
20	13	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
21	14	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
22	15	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
23	16	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
24	17	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
25	18	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
26	19	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
27	20	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
28	21	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
29	22	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
30	23	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
31	24	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
32	25	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
33	26	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
34	27	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
35	28	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
36	29	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
37	30	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
38	31	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
39	32	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
40	33	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
41	34	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
42	35	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
43	36	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
44	37	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
45	38	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
46	39	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
47	40	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
48	41	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
49	42	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
50	43	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
51	44	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
52	45	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
53	46	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	WORKSHEET														
2	Quality index scores over the period of analysis														
3	Limiting Factor	Floodplain Habitat													
4	Assessment Metric	Riparian Cover													
5	Project Assessment Area	9	9	26	26	28	28	37	37	39	39	40	40	43	43
6	Year	Project 9 Without Project	Project 9 With Project	Project 26 Without Project	Project 26 With Project	Project 28 Without Project	Project 28 With Project	Project 37 Without Project	Project 37 With Project	Project 39 Without Project	Project 39 With Project	Project 40 Without Project	Project 40 With Project	Project 43 Without Project	Project 43 With Project
54	47	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
55	48	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
56	49	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
57	50	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
58		9 WOP	9 WP	26 WOP	26 WP	28 WOP	29 WP	37 WOP	37 WP	39 WOP	39 WP	40 WOP	40 WP	43 WOP	43 WP
59	Average	0.68	0.88	0.40	0.95	0.55	0.79	0.61	0.76	0.81	0.88	0.10	0.54	0.06	0.45
60	Average change (benefit)		0.20		0.55		0.24		0.15		0.07		0.44		0.39

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	WORKSHEET														
2	Quality index scores over the period of analysis														
3	Limiting Factor	Floodplain Habitat													
4	Assessment Metric	Riparian Cover													
5	Project Assessment Area	9	9	26	26	28	28	37	37	39	39	40	40	43	43
6	Year	Project 9 Without Project	Project 9 With Project	Project 26 Without Project	Project 26 With Project	Project 28 Without Project	Project 28 With Project	Project 37 Without Project	Project 37 With Project	Project 39 Without Project	Project 39 With Project	Project 40 Without Project	Project 40 With Project	Project 43 Without Project	Project 43 With Project
7	0	0.68	0.68	0.4	0.4	0.55	0.55	0.61	0.61	0.81	0.81	0.1	0.1	0.06	0.06
8	1	0.68	=C7+((C$12-C$7)/($A$12-$A$7))	0.4	=E7+((E$12-E$7)/($A$12-$A$7))	0.55	=G7+((G$12-G$7)/($A$12-$A$7))	0.61	=I7+((I$12-I$7)/($A$12-$A$7))	0.81	=K7+((K$12-K$7)/($A$12-$A$7))	0.1	=M7+((M$12-M$7)/($A$12-$A$7))	0.06	=O7+((O$12-O$7)/($A$12-$A$7))
9	2	0.68	=C8+((C$12-C$7)/($A$12-$A$7))	0.4	=E8+((E$12-E$7)/($A$12-$A$7))	0.55	=G8+((G$12-G$7)/($A$12-$A$7))	0.61	=I8+((I$12-I$7)/($A$12-$A$7))	0.81	=K8+((K$12-K$7)/($A$12-$A$7))	0.1	=M8+((M$12-M$7)/($A$12-$A$7))	0.06	=O8+((O$12-O$7)/($A$12-$A$7))
10	3	0.68	=C9+((C$12-C$7)/($A$12-$A$7))	0.4	=E9+((E$12-E$7)/($A$12-$A$7))	0.55	=G9+((G$12-G$7)/($A$12-$A$7))	0.61	=I9+((I$12-I$7)/($A$12-$A$7))	0.81	=K9+((K$12-K$7)/($A$12-$A$7))	0.1	=M9+((M$12-M$7)/($A$12-$A$7))	0.06	=O9+((O$12-O$7)/($A$12-$A$7))
11	4	0.68	=C10+((C$12-C$7)/($A$12-$A$7))	0.4	=E10+((E$12-E$7)/($A$12-$A$7))	0.55	=G10+((G$12-G$7)/($A$12-$A$7))	0.61	=I10+((I$12-I$7)/($A$12-$A$7))	0.81	=K10+((K$12-K$7)/($A$12-$A$7))	0.1	=M10+((M$12-M$7)/($A$12-$A$7))	0.06	=O10+((O$12-O$7)/($A$12-$A$7))
12	5	0.68	**=0.8*(C17-C7)+C7**	0.4	**=0.8*(E17-E7)+E7**	0.55	**=0.8*(G17-G7)+G7**	0.61	**=0.8*(I17-I7)+I7**	0.81	**=0.8*(K17-K7)+K7**	0.1	**=0.8*(M17-M7)+M7**	0.06	**=0.8*(O17-O7)+O7**
13	6	0.68	=C12+((C$17-C$12)/($A$17-$A$12))	0.4	=E12+((E$17-E$12)/($A$17-$A$12))	0.55	=G12+((G$17-G$12)/($A$17-$A$12))	0.61	=I12+((I$17-I$12)/($A$17-$A$12))	0.81	=K12+((K$17-K$12)/($A$17-$A$12))	0.1	=M12+((M$17-M$12)/($A$17-$A$12))	0.06	=O12+((O$17-O$12)/($A$17-$A$12))
14	7	0.68	=C13+((C$17-C$12)/(A	0.4	=E13+((E$17-E$12)/(A	0.55	=G13+((G$17-G$12)/(A	0.61	=I13+((I$17-I$12)/(A	0.81	=K13+((K$17-K$12)/(A	0.1	=M13+((M$17-M$12)/($A	0.06	=O13+((O$17-O$12)/(A

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Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	WORKSHEET														
2	Quality index scores over the period of analysis														
3	Limiting Factor	Floodplain Habitat													
4	Assessment Metric	Riparian Cover													
5	Project Assessment Area	9	9	26	26	28	28	37	37	39	39	40	40	43	43
6	Year	Project 9 Without Project	Project 9 With Project	Project 26 Without Project	Project 26 With Project	Project 28 Without Project	Project 28 With Project	Project 37 Without Project	Project 37 With Project	Project 39 Without Project	Project 39 With Project	Project 40 Without Project	Project 40 With Project	Project 43 Without Project	Project 43 With Project
			17-$A$12))		17-$A$12))		17-$A$12))		17-$A$12))		17-$A$12))		$17-$A$12))		17-$A$12))
15	8	0.68	=C14+((C$17-C$12)/($A$17-$A$12))	0.4	=E14+((E$17-E$12)/($A$17-$A$12))	0.55	=G14+((G$17-G$12)/($A$17-$A$12))	0.61	=I14+((I$17-I$12)/($A$17-$A$12))	0.81	=K14+((K$17-K$12)/($A$17-$A$12))	0.1	=M14+((M$17-M$12)/($A$17-$A$12))	0.06	=O14+((O$17-O$12)/($A$17-$A$12))
16	9	0.68	=C15+((C$17-C$12)/($A$17-$A$12))	0.4	=E15+((E$17-E$12)/($A$17-$A$12))	0.55	=G15+((G$17-G$12)/($A$17-$A$12))	0.61	=I15+((I$17-I$12)/($A$17-$A$12))	0.81	=K15+((K$17-K$12)/($A$17-$A$12))	0.1	=M15+((M$17-M$12)/($A$17-$A$12))	0.06	=O15+((O$17-O$12)/($A$17-$A$12))
17	10	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
18	11	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
19	12	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
20	13	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
21	14	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
22	15	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
23	16	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
24	17	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
25	18	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
26	19	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
27	20	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
28	21	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
29	22	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
30	23	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
31	24	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
32	25	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
33	26	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
34	27	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
35	28	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
36	29	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
37	30	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
38	31	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
39	32	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
40	33	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
41	34	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
42	35	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
43	36	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
44	37	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
45	38	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
46	39	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
47	40	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
48	41	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
49	42	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
50	43	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
51	44	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
52	45	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	WORKSHEET														
2	Quality index scores over the period of analysis														
3	Limiting Factor	Floodplain Habitat													
4	Assessment Metric	Riparian Cover													
5	Project Assessment Area	9	9	26	26	28	28	37	37	39	39	40	40	43	43
6	Year	Project 9 Without Project	Project 9 With Project	Project 26 Without Project	Project 26 With Project	Project 28 Without Project	Project 28 With Project	Project 37 Without Project	Project 37 With Project	Project 39 Without Project	Project 39 With Project	Project 40 Without Project	Project 40 With Project	Project 43 Without Project	Project 43 With Project
53	46	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
54	47	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
55	48	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
56	49	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
57	50	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
58		9 WOP	9 WP	26 WOP	26 WP	28 WOP	28 WP	37 WOP	37 WP	39 WOP	39 WP	40 WOP	40 WP	43 WOP	43 WP
59	Average	0.68	=AVERAGE(C7:C57)	=AVERAGE(D7:D57)	=AVERAGE(E7:E57)	=AVERAGE(F7:F57)	=AVERAGE(G7:G57)	=AVERAGE(H7:H57)	=AVERAGE(I7:I57)	=AVERAGE(J7:J57)	=AVERAGE(K7:K57)	=AVERAGE(L7:L57)	=AVERAGE(M7:M57)	=AVERAGE(N7:N57)	=AVERAGE(O7:O57)
60	Average change (benefit)		=C59-B59		=E59-D59		=G59-F59		=I59-H59		=K59-J59		=M59-L59		=O59-N59

10 'FLOODPLAIN – CONNECTIVITY HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project and future with-project HQI scores by assessing change in habitat quality for the connectivity assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without-project and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Floodplain Habitat**					
4	**Assessment Metric**	**Connectivity**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	-	-		*0*	*0*	
7	1	-	0.20	0.20	*0*	*=C6+$D$7*	*=(C11-C6)/(A11-A6)*
8	2	-	0.40		*0*	*=C7+$D$7*	
9	3	-	0.60		*0*	*=C8+$D$7*	
10	4	-	0.80		*0*	*=C9+$D$7*	
11	5	-	**1.00**		*0*	*1*	
12	6	-	1.00		*0*	*1*	
13	7	-	1.00		*0*	*1*	
14	8	-	1.00		*0*	*1*	
15	9	-	1.00		*0*	*1*	
16	10	-	1.00		*0*	*1*	
17	11	-	1.00		*0*	*1*	
18	12	-	1.00		*0*	*1*	
19	13	-	1.00		*0*	*1*	
20	14	-	1.00		*0*	*1*	
21	15	-	1.00		*0*	*1*	
22	16	-	1.00		*0*	*1*	
23	17	-	1.00		*0*	*1*	
24	18	-	1.00		*0*	*1*	
25	19	-	1.00		*0*	*1*	
26	20	-	1.00		*0*	*1*	
27	21	-	1.00		*0*	*1*	
28	22	-	1.00		*0*	*1*	
29	23	-	1.00		*0*	*1*	
30	24	-	1.00		*0*	*1*	
31	25	-	1.00		*0*	*1*	
32	26	-	1.00		*0*	*1*	
33	27	-	1.00		*0*	*1*	
34	28	-	1.00		*0*	*1*	
35	29	-	1.00		*0*	*1*	
36	30	-	1.00		*0*	*1*	
37	31	-	1.00		*0*	*1*	

Row/Column	A	B	C	D	B	C	D
1	WORKSHEET						
2	Quality index scores over the period of analysis						
3	Limiting Factor	Floodplain Habitat					
4	Assessment Metric	Connectivity					
5	Year	Without Project Condition	With Project Condition	Slope	*Without Project Condition*	*With Project Condition*	*Slope*
38	32	-	1.00		*0*	*1*	
39	33	-	1.00		*0*	*1*	
40	34	-	1.00		*0*	*1*	
41	35	-	1.00		*0*	*1*	
42	36	-	1.00		*0*	*1*	
43	37	-	1.00		*0*	*1*	
44	38	-	1.00		*0*	*1*	
45	39	-	1.00		*0*	*1*	
46	40	-	1.00		*0*	*1*	
47	41	-	1.00		*0*	*1*	
48	42	-	1.00		*0*	*1*	
49	43	-	1.00		*0*	*1*	
50	44	-	1.00		*0*	*1*	
51	45	-	1.00		*0*	*1*	
52	46	-	1.00		*0*	*1*	
53	47	-	1.00		*0*	*1*	
54	48	-	1.00		*0*	*1*	
55	49	-	1.00		*0*	*1*	
56	50	-	1.00		*0*	*1*	
57							
58	Average	-	0.94		*=AVERAGE(B6:B56)*	*=AVERAGE(C6:C56)*	
59	Average change (benefit)		0.94			*=C58-B58*	

11 'CE ICA INPUT DATA' WORKSHEET

This worksheet summarizes scoring for without and with project conditions for each of the assessment areas, with computation of average annual habitat units (AAHUs) for the without project condition listed in the first row, computation of with project AAHUs in the second row, and the difference (or benefit, with – without project) displayed in the third row. The difference, or benefits, for each of the assessed projects will be used for cost effectiveness and incremental cost analysis (CE/ICA) in IWR-Planning Suite.

Projects are listed by applicable limiting factors. The first four projects, or base alternatives, address capacity and in-channel habitat and the average habitat quality index (HQI) score is computed by taking the average of V1 (woody debris), V2 (pools) and V5 (capacity), or (V1+V2+V5)/3. Six incremental projects address floodplain habitat and the average annual HQI score is computed by taking the average of V3 and V4, or (V3+V4)/2. Finally, two projects address in-channel habitat only and the average annual HQI score is computed by taking the average of V1 and V2, or (V1+V2)/2.

The first table shows the values for each of the assessed projects. The second table includes the formulas for scoring assessment metrics, computation of average annual HQI scores, and AAHUs.

Row/ Column	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
2									QI Scores for Applicable Variables						
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Reach(es)	Primary Reach Affected	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
4				Limiting Factors Assessed for Assessment Area = Channel Capacity and In-Channel Habitat (HQI = (V1+V2+V5)/3)											
5	59	1	K0	BASE #1 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	0-4	N/A	219	0.10	0.21	N/A	N/A	0.17	0.16	24.5
6	59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) - LWD	Channel Capacity and In-Channel Habitat	0-4	N/A	219	0.93	0.93	N/A	N/A	1.00	0.95	208.7
7	***59***	***1***	***K1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***0-4***	***N/A***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.83***	***0.79***	***184.2***
8	50	2	L0	BASE # 2 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	4	N/A	26	0.10	0.21	N/A	N/A	0.17	0.16	2.9
9	50	2	L1	BASE #2 Confluence Channel Excavation + LWD	Channel Capacity and In-Channel Habitat	4	N/A	26	0.93	0.93	N/A	N/A	0.50	0.79	20.4
10	***50***	***2***	***L1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***4***	***N/A***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.33***	***0.63***	***17.5***
11	31	3	M0	BASE #3 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	4	N/A	68	0.10	0.21	N/A	N/A	0.17	0.16	7.6
12	31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal + LWD	Channel Capacity and In-Channel Habitat	4	N/A	68	0.92	0.93	N/A	N/A	0.50	0.79	53.5
13	***31***	***3***	***M1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***4***	***N/A***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.33***	***0.63***	***45.9***
14	62	5	N0	BASE #5 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	2-4	N/A	132	0.10	0.21	N/A	N/A	0.17	0.16	*14.8*
15	62	5	N1	BASE #5 RM 3.5-9 Dredge + LWD	Channel Capacity and In-Channel Habitat	2-4	N/A	132	0.93	0.93	N/A	N/A	1.00	0.95	*125.8*
16	***62***	***5***	***N1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***2-4***	***N/A***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.83***	***0.79***	***111.0***
17				Limiting Factors Assessed for Assessment Area = Floodplain Habitat (HQI = (V3+V4)/2)											
18	9	all	B0	River Channel Assessment Area Base/FWOP Condition	Floodplain Habitat	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	15.3
19	9	all	B1	River Channel	Floodplain Habitat	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	41.0
20	***9***	***all***	***B1***	***Benefit (With-Without)***	***Floodplain Habitat***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
21	26	all	C0	Dips Road Assessment Area Base/FWOP Condition	Floodplain Habitat	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.4
22	26	all	C1	Dips Road	Floodplain Habitat	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
23	***26***	***all***	***C1***	***Benefit (With-Without)***	***Floodplain Habitat***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
24	28	all	D0	Large Levee Setback Assessment Area Base/FWOP Condition	Floodplain Habitat	4	4	23	N/A	N/A	-	0.55	N/A	0.28	6.3
25	28	all	D1	Large Levee Setback	Floodplain Habitat	4	4	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
26	***28***	***all***	***D1***	***Benefit (With-Without)***	***Floodplain Habitat***	***4***	***4***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
27	37	all	G0	Grange Dike Assessment Area Base/FWOP Condition	Floodplain Habitat	3-4	4	34	N/A	N/A	-	0.61	N/A	0.31	10.4
28	37	all	G1	Grange Dike	Floodplain Habitat	3-4	4	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
29	***37***	***all***	***G1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3-4***	***4***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
30	39	2 and 3	H0	Hunter Creek Mouth Assessment Area Base/FWOP Condition	Floodplain Habitat	3	2	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
31	39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	3	3	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
32	***39***	***2 and 3***	***H1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3***	***3***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
33	40	all	I0	Hunter Creek Assessment Area Base/FWOP Condition	Floodplain Habitat	3	3	29	N/A	N/A	-	0.10	N/A	0.05	1.5
34	40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	3	3	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
35	***40***	***all***	***I1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3***	***3***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***
36				Limiting Factors Assessed for Assessment Area = In-Channel Habitat (HQI = (V1+V2)/2)											
37	35	all	F0	Upstream LWD Assessment Area Base/FWOP Condition	In-Channel Habitat	4-5	5	107	0.10	0.21	N/A	N/A	N/A	0.16	16.6
38	35	all	F1	Upstream LWD Installation	In-Channel Habitat	4-5	5	107	0.93	0.93	N/A	N/A	N/A	0.93	99.5
39	***35***	***all***	***F1***	***Benefit (With-Without)***	***In-Channel Habitat***	***4-5***	***5***	***107***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***82.9***
40	43	all	J0	Weaver Creek Assessment Area Base/FWOP Condition	In-Channel Habitat	3	3	25	0.10	0.21	N/A	N/A	N/A	0.16	3.9
41	43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	3	3	25	0.93	0.93	N/A	N/A	N/A	0.93	23.2
42	***43***	***all***	***J1***	***Benefit (With-Without)***	***In-Channel Habitat***	***3***	***3***	***25***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***19.4***

	B	C	D	E	F	J	I	K	L	M	N	O	P
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Acres	V1 – Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
4				Limiting Factors Assessed for Assessment Area = Channel Capacity and In-Channel Habitat (HQI = (V1+V2+V5)/3)									
5	59	1	K0	BASE #1 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	219	=IF(OR(F5="In-Channel Habitat",F5="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F5="In-Channel Habitat",F5="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F5="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F5="Floodplain Habitat",VLOOKUP(B5,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F5="Channel Capacity and In-Channel Habitat",VLOOKUP(C5,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F5="Channel Capacity and In-Channel Habitat",(J5+K5+N5)/3,IF(F5="In-Channel Habitat",(J5+K5)/2,IF(F5="Floodplain Habitat",(L5+M5)/2)))	=O5*I5
6	59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) + LWD	Channel Capacity and In-Channel Habitat	219	=IF(OR(F6="In-Channel Habitat",F6="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F6="In-Channel Habitat",F6="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F6="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F6="Floodplain Habitat",VLOOKUP(B6,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F6="Channel Capacity and In-Channel Habitat",VLOOKUP(C6,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F6="Channel Capacity and In-Channel Habitat",(J6+K6+N6)/3,IF(F6="In-Channel Habitat",(J6+K6)/2,IF(F6="Floodplain Habitat",(L6+M6)/2)))	=O6*I6
7	***59***	***1***	***K1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***219***	***=IF(OR(F7="In-Channel Habitat",F7="Channel Capacity and In-Channel Habitat"),J6-J5,"N/A")***	***=IF(OR(F7="In-Channel Habitat",F7="Channel Capacity and In-Channel Habitat"),K6-K5,"N/A")***	***=IF(F7="Floodplain Habitat",L6-L5,"N/A")***	***=IF(F7="Floodplain Habitat",L6-L5,"N/A")***	***=IF(F7="Channel Capacity and In-Channel Habitat",N6-N5,"N/A")***	***=O6-O5***	***=O7*I7***
8	50	2	L0	BASE # 2 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	26	=IF(OR(F8="In-Channel Habitat",F8="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F8="In-Channel Habitat",F8="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F8="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F8="Floodplain Habitat",VLOOKUP(B8,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F8="Channel Capacity and In-Channel Habitat",VLOOKUP(C8,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F8="Channel Capacity and In-Channel Habitat",(J8+K8+N8)/3,IF(F8="In-Channel Habitat",(J8+K8)/2,IF(F8="Floodplain Habitat",(L8+M8)/2)))	=O8*I8
9	50	2	L1	BASE #2 Confluence Channel Excavation + LWD	Channel Capacity and In-Channel Habitat	25	=IF(OR(F9="In-Channel Habitat",F9="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F9="In-Channel Habitat",F9="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F9="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F9="Floodplain Habitat",VLOOKUP(B9,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F9="Channel Capacity and In-Channel Habitat",VLOOKUP(C9,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F9="Channel Capacity and In-Channel Habitat",(J9+K9+N9)/3,IF(F9="In-Channel Habitat",(J9+K9)/2,IF(F9="Floodplain Habitat",(L9+M9)/2)))	=O9*I9
10	***50***	***2***	***L1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***26***	***=IF(OR(F10="In-Channel Habitat",F10="Channel Capacity and In-Channel Habitat"),J9-J8,"N/A")***	***=IF(OR(F10="In-Channel Habitat",F10="Channel Capacity and In-Channel Habitat"),K9-K8,"N/A")***	***=IF(F10="Floodplain Habitat",L9-L8,"N/A")***	***=IF(F10="Floodplain Habitat",L9-L8,"N/A")***	***=IF(F10="Channel Capacity and In-Channel Habitat",N9-N8,"N/A")***	***=O9-O8***	***=O10*I10***
11	31	3	M0	BASE #3 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	68	=IF(OR(F11="In-Channel Habitat",F11="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F11="In-Channel Habitat",F11="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F11="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F11="Floodplain Habitat",VLOOKUP(B11,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F11="Channel Capacity and In-Channel Habitat",VLOOKUP(C11,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F11="Channel Capacity and In-Channel Habitat",(J11+K11+N11)/3,IF(F11="In-Channel Habitat",(J11+K11)/2,IF(F11="Floodplain Habitat",(L11+M11)/2)))	=O11*I11
12	31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal + LWD	Channel Capacity and In-Channel Habitat	58	=IF(OR(F12="In-Channel Habitat",F12="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F12="In-Channel Habitat",F12="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F12="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F12="Floodplain Habitat",VLOOKUP(B12,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F12="Channel Capacity and In-Channel Habitat",VLOOKUP(C12,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F12="Channel Capacity and In-Channel Habitat",(J12+K12+N12)/3,IF(F12="In-Channel Habitat",(J12+K12)/2,IF(F12="Floodplain Habitat",(L12+M12)/2)))	=O12*I12
13	***31***	***3***	***M1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***68***	***=IF(OR(F13="In-Channel Habitat",F13="Channel Capacity and In-Channel Habitat"),J12-J11,"N/A")***	***=IF(OR(F13="In-Channel Habitat",F13="Channel Capacity and In-Channel Habitat"),K12-K11,"N/A")***	***=IF(F13="Floodplain Habitat",L12-L11,"N/A")***	***=IF(F13="Floodplain Habitat",L12-L11,"N/A")***	***=IF(F13="Channel Capacity and In-Channel Habitat",N12-N11,"N/A")***	***=O12-O11***	***=O13*I13***
14	62	5	N0	BASE #5 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	132	=IF(OR(F14="In-Channel Habitat",F14="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F14="In-Channel Habitat",F14="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F14="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F14="Floodplain Habitat",VLOOKUP(B14,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F14="Channel Capacity and In-Channel Habitat",VLOOKUP(C14,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F14="Channel Capacity and In-Channel Habitat",(J14+K14+N14)/3,IF(F14="In-Channel Habitat",(J14+K14)/2,IF(F14="Floodplain Habitat",(L14+M14)/2)))	=O14*I14
15	62	5	N1	BASE #5 RM 3.5-9 Dredge + LWD	Channel Capacity and In-Channel Habitat	132	=IF(OR(F15="In-Channel Habitat",F15="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F15="In-Channel Habitat",F15="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F15="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F15="Floodplain Habitat",VLOOKUP(B15,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F15="Channel Capacity and In-Channel Habitat",VLOOKUP(C15,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F15="Channel Capacity and In-Channel Habitat",(J15+K15+N15)/3,IF(F15="In-Channel Habitat",(J15+K15)/2,IF(F15="Floodplain Habitat",(L15+M15)/2)))	=O15*I15
16	***62***	***5***	***N1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***132***	***=IF(OR(F16="In-Channel Habitat",F16="Channel Capacity and In-Channel Habitat"),J15-J14,"N/A")***	***=IF(OR(F16="In-Channel Habitat",F16="Channel Capacity and In-Channel Habitat"),K15-K14,"N/A")***	***=IF(F16="Floodplain Habitat",L15-L14,"N/A")***	***=IF(F16="Floodplain Habitat",L15-L14,"N/A")***	***=IF(F16="Channel Capacity and In-Channel Habitat",N15-N14,"N/A")***	***=O15-O14***	***=O16*I16***
17				Limiting Factors Assessed for Assessment Area = Floodplain Habitat (HQI = (V3+V4)/2)									
18	9	all	B0	River Channel Assessment Area Base/FWOP Condition	Floodplain Habitat	45	=IF(OR(F18="In-Channel Habitat",F18="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F18="In-Channel Habitat",F18="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F18="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F18="Floodplain Habitat",VLOOKUP(B18,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F18="Channel Capacity and In-Channel Habitat",VLOOKUP(C18,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F18="Channel Capacity and In-Channel Habitat",(J18+K18+N18)/3,IF(F18="In-Channel Habitat",(J18+K18)/2,IF(F18="Floodplain Habitat",(L18+M18)/2)))	=O18*I18
19	9	all	B1	River Channel	Floodplain Habitat	45	=IF(OR(F19="In-Channel Habitat",F19="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F19="In-Channel Habitat",F19="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F19="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F19="Floodplain Habitat",VLOOKUP(B19,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F19="Channel Capacity and In-Channel Habitat",VLOOKUP(C19,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F19="Channel Capacity and In-Channel Habitat",(J19+K19+N19)/3,IF(F19="In-Channel Habitat",(J19+K19)/2,IF(F19="Floodplain Habitat",(L19+M19)/2)))	=O19*I19
20	***9***	***all***	***B1***	***Benefit (With-Without)***	***Floodplain Habitat***	***45***	***=IF(OR(F20="In-Channel Habitat",F20="Channel Capacity and In-Channel Habitat"),J19-J18,"N/A")***	***=IF(OR(F20="In-Channel Habitat",F20="Channel Capacity and In-Channel Habitat"),K19-K18,"N/A")***	***=IF(F20="Floodplain Habitat",L19-L18,"N/A")***	***=IF(F20="Floodplain Habitat",L19-L18,"N/A")***	***=IF(F20="Channel Capacity and In-Channel Habitat",N19-N18,"N/A")***	***=O19-O18***	***=O20*I20***
21	26	all	C0	Dips Road Assessment Area Base/FWOP Condition	Floodplain Habitat	17	=IF(OR(F21="In-Channel Habitat",F21="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F21="In-Channel Habitat",F21="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F21="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F21="Floodplain Habitat",VLOOKUP(B21,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F21="Channel Capacity and In-Channel Habitat",VLOOKUP(C21,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F21="Channel Capacity and In-Channel Habitat",(J21+K21+N21)/3,IF(F21="In-Channel Habitat",(J21+K21)/2,IF(F21="Floodplain Habitat",(L21+M21)/2)))	=O21*I21
22	26	all	C1	Dips Road	Floodplain Habitat	17	=IF(OR(F22="In-Channel Habitat",F22="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F22="In-Channel Habitat",F22="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F22="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F22="Floodplain Habitat",VLOOKUP(B22,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F22="Channel Capacity and In-Channel Habitat",VLOOKUP(C22,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F22="Channel Capacity and In-Channel Habitat",(J22+K22+N22)/3,IF(F22="In-Channel Habitat",(J22+K22)/2,IF(F22="Floodplain Habitat",(L22+M22)/2)))	=O22*I22

	B	C	D	E	F	I	J	K	L	M	N	O	P
1	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
23	26	all	C1	Benefit (With-Without)	Floodplain Habitat	17	=IF(OR(F23="In-Channel Habitat",F23="Channel Capacity and In-Channel Habitat"),J22-(21,"N/A")	=IF(OR(F23="In-Channel Habitat",F23="Channel Capacity and In-Channel Habitat"),K22-K21,"N/A")	=IF(F23="Floodplain Habitat",L22-L21,"N/A")	=IF(F23="Floodplain Habitat",L22-L21,"N/A")	=IF(F23="Channel Capacity and In-Channel Habitat",N22-N21,"N/A")	=O22-O21	=O23*I23
24	26	all	D0	Large Levee Setback Assessment Area Base/FWOP Condition	Floodplain Habitat	23	=IF(OR(F24="In-Channel Habitat",F24="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F24="In-Channel Habitat",F24="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F24="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F24="Floodplain Habitat",VLOOKUP(E24,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F24="Channel Capacity and In-Channel Habitat",VLOOKUP(E24,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F24="Channel Capacity and In-Channel Habitat",(J24+K24+H24)/3,IF(F24="In-Channel Habitat",(J24+K24)/2,IF(F24="Floodplain Habitat",(J24+H24)/2)))	=O24*I24
25	28	all	D1	Large Levee Setback	Floodplain Habitat	23	=IF(OR(F25="In-Channel Habitat",F25="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F25="In-Channel Habitat",F25="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F25="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F25="Floodplain Habitat",VLOOKUP(E25,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F25="Channel Capacity and In-Channel Habitat",VLOOKUP(E25,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F25="Channel Capacity and In-Channel Habitat",(J25+K25+H25)/3,IF(F25="In-Channel Habitat",(J25+K25)/2,IF(F25="Floodplain Habitat",(J25+H25)/2)))	=O25*I25
26	28	all	D2	Benefit (With-Without)	Floodplain Habitat	23	=IF(OR(F26="In-Channel Habitat",F26="Channel Capacity and In-Channel Habitat"),J25-(24,"N/A")	=IF(OR(F26="In-Channel Habitat",F26="Channel Capacity and In-Channel Habitat"),K25-K24,"N/A")	=IF(F26="Floodplain Habitat",L25-L24,"N/A")	=IF(F26="Floodplain Habitat",L25-L24,"N/A")	=IF(F26="Channel Capacity and In-Channel Habitat",N25-N24,"N/A")	=O25-O24	=O26*I26
27	37	all	G0	Grange Dike Assessment Area Base/FWOP Condition	Floodplain Habitat	34	=IF(OR(F27="In-Channel Habitat",F27="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F27="In-Channel Habitat",F27="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F27="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F27="Floodplain Habitat",VLOOKUP(E27,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F27="Channel Capacity and In-Channel Habitat",VLOOKUP(E27,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F27="Channel Capacity and In-Channel Habitat",(J27+K27+H27)/3,IF(F27="In-Channel Habitat",(J27+K27)/2,IF(F27="Floodplain Habitat",(J27+H27)/2)))	=O27*I27
28	37	all	G1	Grange Dike	Floodplain Habitat	34	=IF(OR(F28="In-Channel Habitat",F28="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F28="In-Channel Habitat",F28="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F28="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F28="Floodplain Habitat",VLOOKUP(E28,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F28="Channel Capacity and In-Channel Habitat",VLOOKUP(E28,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F28="Channel Capacity and In-Channel Habitat",(J28+K28+H28)/3,IF(F28="In-Channel Habitat",(J28+K28)/2,IF(F28="Floodplain Habitat",(J28+H28)/2)))	=O28*I28
29	37	all	G2	Benefit (With-Without)	Floodplain Habitat	34	=IF(OR(F29="In-Channel Habitat",F29="Channel Capacity and In-Channel Habitat"),J28-(27,"N/A")	=IF(OR(F29="In-Channel Habitat",F29="Channel Capacity and In-Channel Habitat"),K28-K27,"N/A")	=IF(F29="Floodplain Habitat",L28-L27,"N/A")	=IF(F29="Floodplain Habitat",L28-L27,"N/A")	=IF(F29="Channel Capacity and In-Channel Habitat",N28-N27,"N/A")	=O28-O27	=O29*I29
30	39	2 and 3	H0	Hunter Creek Mouth Assessment Area Base/FWOP Condition	Floodplain Habitat	0.5	=IF(OR(F30="In-Channel Habitat",F30="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F30="In-Channel Habitat",F30="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F30="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F30="Floodplain Habitat",VLOOKUP(E30,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F30="Channel Capacity and In-Channel Habitat",VLOOKUP(E30,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F30="Channel Capacity and In-Channel Habitat",(J30+K30+H30)/3,IF(F30="In-Channel Habitat",(J30+K30)/2,IF(F30="Floodplain Habitat",(J30+H30)/2)))	=O30*I30
31	39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	0.5	=IF(OR(F31="In-Channel Habitat",F31="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F31="In-Channel Habitat",F31="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F31="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F31="Floodplain Habitat",VLOOKUP(E31,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F31="Channel Capacity and In-Channel Habitat",VLOOKUP(E31,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F31="Channel Capacity and In-Channel Habitat",(J31+K31+H31)/3,IF(F31="In-Channel Habitat",(J31+K31)/2,IF(F31="Floodplain Habitat",(J31+H31)/2)))	=O31*I31
32	39	2 and 3	H2	Benefit (With-Without)	Floodplain Habitat	0.5	=IF(OR(F32="In-Channel Habitat",F32="Channel Capacity and In-Channel Habitat"),J31-(30,"N/A")	=IF(OR(F32="In-Channel Habitat",F32="Channel Capacity and In-Channel Habitat"),K31-K30,"N/A")	=IF(F32="Floodplain Habitat",L31-L30,"N/A")	=IF(F32="Floodplain Habitat",L31-L30,"N/A")	=IF(F32="Channel Capacity and In-Channel Habitat",N31-N30,"N/A")	=O31-O30	=O32*I32
33	40	all	I0	Hunter Creek Assessment Area Base/FWOP Condition	Floodplain Habitat	29	=IF(OR(F33="In-Channel Habitat",F33="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F33="In-Channel Habitat",F33="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F33="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F33="Floodplain Habitat",VLOOKUP(E33,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F33="Channel Capacity and In-Channel Habitat",VLOOKUP(E33,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F33="Channel Capacity and In-Channel Habitat",(J33+K33+H33)/3,IF(F33="In-Channel Habitat",(J33+K33)/2,IF(F33="Floodplain Habitat",(J33+H33)/2)))	=O33*I33
34	40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	29	=IF(OR(F34="In-Channel Habitat",F34="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F34="In-Channel Habitat",F34="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F34="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F34="Floodplain Habitat",VLOOKUP(E34,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F34="Channel Capacity and In-Channel Habitat",VLOOKUP(E34,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F34="Channel Capacity and In-Channel Habitat",(J34+K34+H34)/3,IF(F34="In-Channel Habitat",(J34+K34)/2,IF(F34="Floodplain Habitat",(J34+H34)/2)))	=O34*I34
35	40	all	I1	Benefit (With-Without)	Floodplain Habitat	29	=IF(OR(F35="In-Channel Habitat",F35="Channel Capacity and In-Channel Habitat"),J34-(33,"N/A")	=IF(OR(F35="In-Channel Habitat",F35="Channel Capacity and In-Channel Habitat"),K34-K33,"N/A")	=IF(F35="Floodplain Habitat",L34-L33,"N/A")	=IF(F35="Floodplain Habitat",L34-L33,"N/A")	=IF(F35="Channel Capacity and In-Channel Habitat",N34-N33,"N/A")	=O34-O33	=O35*I35
36				Limiting Factors Assessed for Assessment Area = In-Channel Habitat (HQI = (V1+V2)/2)									
37	35	all	F0	Upstream LWD Assessment Area Base/FWOP Condition	In-Channel Habitat	107	=IF(OR(F37="In-Channel Habitat",F37="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F37="In-Channel Habitat",F37="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F37="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F37="Floodplain Habitat",VLOOKUP(E37,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F37="Channel Capacity and In-Channel Habitat",VLOOKUP(E37,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F37="Channel Capacity and In-Channel Habitat",(J37+K37+H37)/3,IF(F37="In-Channel Habitat",(J37+K37)/2,IF(F37="Floodplain Habitat",(J37+H37)/2)))	=O37*I37
38	35	all	F1	Upstream LWD Installation	In-Channel Habitat	107	=IF(OR(F38="In-Channel Habitat",F38="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F38="In-Channel Habitat",F38="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F38="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F38="Floodplain Habitat",VLOOKUP(E38,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F38="Channel Capacity and In-Channel Habitat",VLOOKUP(E38,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F38="Channel Capacity and In-Channel Habitat",(J38+K38+H38)/3,IF(F38="In-Channel Habitat",(J38+K38)/2,IF(F38="Floodplain Habitat",(J38+H38)/2)))	=O38*I38
39	35	all	F2	Benefit (With-Without)	In-Channel Habitat	107	=IF(OR(F39="In-Channel Habitat",F39="Channel Capacity and In-Channel Habitat"),J38-(37,"N/A")	=IF(OR(F39="In-Channel Habitat",F39="Channel Capacity and In-Channel Habitat"),K38-K37,"N/A")	=IF(F39="Floodplain Habitat",L38-L37,"N/A")	=IF(F39="Floodplain Habitat",L38-L37,"N/A")	=IF(F39="Channel Capacity and In-Channel Habitat",N38-N37,"N/A")	=O38-O37	=O39*I39
40	43	all	J0	Weaver Creek Assessment Area Base/FWOP Condition	In-Channel Habitat	25	=IF(OR(F40="In-Channel Habitat",F40="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$G$7,"N/A")	=IF(OR(F40="In-Channel Habitat",F40="Channel Capacity and In-Channel Habitat"),Assessment Metric HQI!$H$8,"N/A")	=IF(F40="Floodplain Habitat",Assessment Metric HQI!$G$13,"N/A")	=IF(F40="Floodplain Habitat",VLOOKUP(E40,Assessment Metric HQI!$G$8:$H$14,3),"N/A")	=IF(F40="Channel Capacity and In-Channel Habitat",VLOOKUP(E40,Assessment Metric HQI!$G$8:$H$14,4),"N/A")	=IF(F40="Channel Capacity and In-Channel Habitat",(J40+K40+H40)/3,IF(F40="In-Channel Habitat",(J40+K40)/2,IF(F40="Floodplain Habitat",(J40+H40)/2)))	=O40*I40

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	B	C	D	E	F	I	J	K	L	M	N	O	P
1	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Area	V1 – Woody Debris	V2 - Roots	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQ	AAHU (Affected Acres * HQ)
41	40	a1	J1	Weaver Creek Side Channel	In-Channel Habitat	25	=IF(OR(F41="In-Channel Habitat",F41="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQ'!$H$7,"N/A")	=IF(OR(F41="In-Channel Habitat",F41="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQ'!$H$6,"N/A")	=IF(F41="Floodplain Habitat','Assessment Metric HQ'!$H$15,"N/A")	=IF(F41="Floodplain Habitat",VLOOKUP(B41,'Assessment Metric HQ'!$B$8:$H$14,6,"N/A")	=IF(F41="Channel Capacity and In-Channel Habitat",VLOOKUP(C41,'Assessment Metric HQ'!$B$16:$H$19,5,"N/A")	=IF(F41="Channel Capacity and In-Channel Habitat",(J41+K41+L41+M41)/5,IF(F41="In-Channel Habitat",(J41+K41+L41)/3))	=O41*I41
42	42	a2	J1	Beneficial (With-Without)	In-Channel Habitat	25	=IF(OR(F42="In-Channel Habitat",F42="Channel Capacity and In-Channel Habitat"),J41-J40,"N/A")	=IF(OR(F42="In-Channel Habitat",F42="Channel Capacity and In-Channel Habitat"),K41-K40,"N/A")	=IF(F42="Floodplain Habitat",L41-L40,"N/A")	=IF(F42="Floodplain Habitat",L41-L40,"N/A")	=IF(F42="Channel Capacity and In-Channel Habitat",M41-M40,"N/A")	=O41-O40	=O42*I42

12 CE ICA SENSITIVITY ANALYSIS

This worksheet presents the sensitivity analysis from Section 8 of the main report. It evaluates the changes in HQI scores and overall AAHU benefits with weighting of one variable for each of the three HQI equations. The following weight changes to HQI equations were evaluated:

- $HQI = \frac{V1+V2+(2\times V5)}{4}$ for channel capacity and in-channel habitat where V5 (capacity) is twice as great as V1 (woody debris) and V2 (pools);
- $HQI = \frac{(2\times V1)+V2}{3}$ for in-channel habitat where V1 is twice as great as V2;
- $HQI = \frac{V1+(2\times V2)}{3}$ for in-channel habitat where V2 is twice as great as V1;
- $HQI = \frac{(2\times V3)+V4}{3}$ for floodplain habitat where V3 (connectivity) is twice as great as V4 (riparian cover); and
- $HQI = \frac{V3+(2\times V4)}{3}$ for floodplain habitat where V4 is twice as great as V3.

HQI scores and AAHUs for the weighting of metrics in the equations above are presented in columns Q through Y and are compared to the equal weighting of metrics for the three equations that will be used for evaluating the cost effectiveness and incremental cost analysis of project increments.

SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX G

ECONOMICS

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

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1. Overview

This appendix describes the cost effectiveness and incremental cost analysis (CE/ICA) performed for the Skokomish River Basin General Investigation (GI) integrated feasibility report and environmental impact statement (FR/EIS, or feasibility report). This process helps in the formulation of efficient and effective restoration solutions in the Skokomish River Basin. Because there is no currently accepted method for quantifying environmental benefits (or environmental outputs) in monetary terms, it is not possible to conduct a traditional benefit-cost analysis for the evaluation of project alternatives. Cost effectiveness and incremental cost analyses offer approaches that are consistent with the Principles and Guidelines (U.S. Water Resources Council, 1983; referred to as the "P&G") planning paradigm. Cost effectiveness will ensure that the least cost solution is identified for each possible level of environmental output. Subsequent incremental cost analysis will reveal changes in cost for increasing levels of environmental outputs. While these analyses will usually not lead, and are not intended to lead, to a single best solution (as in economic benefit-cost analysis), they will improve the quality of decision making by ensuring that a rational, supportable, focused and traceable approach is used for considering and selecting alternatives for environmental restoration.

This report briefly summarizes some of the plan formulation and modeling of environmental outputs that focused the scope and inputs of the cost effectiveness and incremental cost analyses. The contents of this appendix are as follows:

- Section 2, Plan Formulation and Identification of Restoration Projects
- Section 3, Evaluation of Project Benefits
- Section 4, Evaluation of Project Costs
- Section 5, IWR Planning Suite Model Inputs
- Section 6, Cost Effectiveness and Incremental Cost Analysis (CE/ICA) Alternatives Evaluation
- Section 7, Final Array of Alternatives
- Section 8, Sensitivity Analysis
- Section 9, Recommended Plan
- Section 10, References

2. Plan Formulation and Identification of Restoration Projects

The planning process which includes the identification of problems, opportunities, objectives and constraints, as well as the identification of management measures, siting of management measures, and screening is documented in Chapter 2 of feasibility report.

Based on the problems identified in the study area, planning objectives include the following:

- Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
- Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary networks including Hunter and Weaver Creeks for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

The initial array of alternatives was formulated based on initial data collection and best professional judgment. This exercise led to the development of alternatives that include a "base" measure. The bases are key measures at specific sites or reaches of the river that address the highest priorities of the study area (improve the quantity, quality, and complexity of pools and provide a year-round channel for fish passage). The bases are large projects with no separable elements; they are also mutually exclusive from other bases. Developing alternatives around these base measures ensures the critical needs of the study area are addressed. An alternative cannot be considered complete, acceptable, efficient, or effective unless one of these bases is included. The bases include two large-scale sediment removal options that reach across multiple river reaches plus two smaller-scale restoration projects within specific reaches of the river.

Increments will be added to the focused array of four bases to capture supplementary benefits associated with restoration of additional channel and floodplain habitat features. These increments are generally smaller and can be combined with any of the base alternatives. Increments include in-channel habitat improvements which address the highest study priorities (increasing channel capacity and restoring year-round passage near the confluence). Finally, floodplain habitat increments were considered as lower priority restoration features. Potential floodplain increments include removal of blockages at the mouths of tributaries, restoration of side channel habitat, creation of new side channels, and levee setbacks.

Of the approximately 60 potential restoration sites, eight sites were identified by the study team as high priority in-channel or floodplain increments that in combination with one of the bases would address restoration needs in the basin. Key information about the bases and increments are described in the feasibility report. A map of the focused array of bases and potential increments is shown in Figure 2-1.

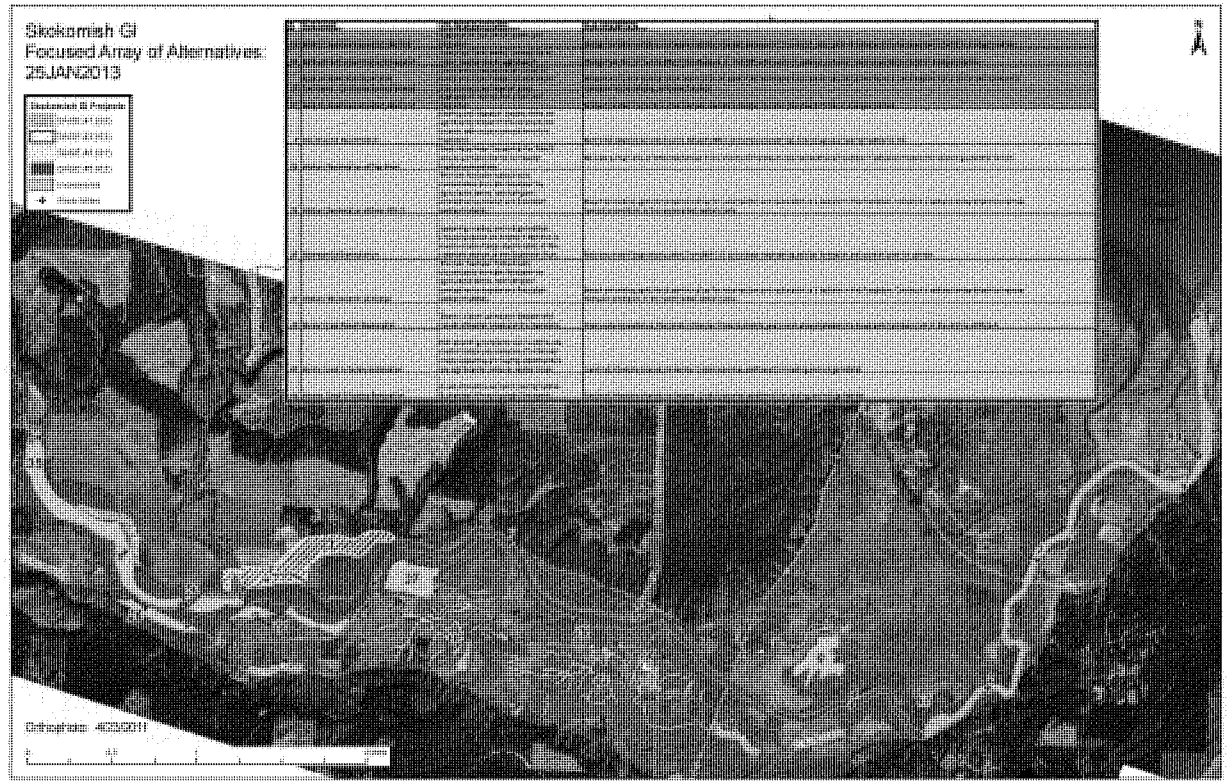


Figure 2-1. Focused Array of Bases and Potential Increments

3. Evaluation of Project Benefits

The study team developed an environmental outputs model (EO Model) to estimate benefits of proposed restoration actions in the Skokomish GI. This model was approved for one-time use approval in October 2013. The model documentation, including the biological and ecological rationale and quantification of benefits can be found in Appendix F, Ecosystem Benefits Model Documentation.

For each proposed restoration action, it was first determined whether the project assessment area for that action would result in measureable change to the channel capacity, in-channel habitat, or floodplain habitat limiting factors. After determining applicable limiting factor(s) for a project assessment area, the without project and with project habitat quality index scores for relevant assessment metrics were estimated. Two assessment metrics were used for in-channel habitat: woody debris (V1) and pools (V2). Two assessment metrics were used for floodplain habitat: connectivity (V3) and riparian cover (V4). Finally, channel capacity was measured using a flow capacity (V5) assessment metric. Three equations were used to estimate habitat quality indices based on the applicable limiting factors. A project that would address in-channel habitat only would be evaluated using the in-channel habitat assessment metrics for woody debris and pools. The bases address both in-channel habitat and channel capacity limiting factors. Figure 3-1 includes a flow diagram of which assessment metrics (labeled V1 to V5) are considered in the computation of HQI for a restoration action based on the assessment area limiting factor(s).

HQI is equal to one of three equations depending on the limiting factor(s) that apply to a given assessment area:

- $HQI = \frac{V1+V2+V5}{3}$ for assessment areas which evaluate both channel capacity and in-channel habitat limiting factors;
- $HQI = \frac{V1+V2}{2}$ for assessment areas which evaluate the in-channel habitat limiting factor only; and
- $HQI = \frac{V3+V4}{2}$ for assessment areas that evaluate the floodplain habitat limiting factor only.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

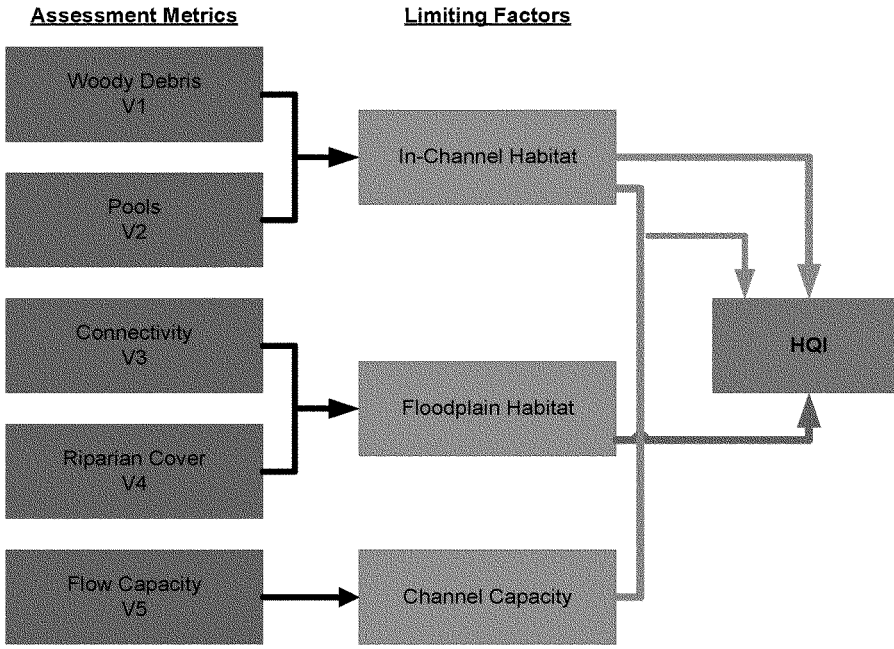


Figure 3-1. Flow Diagram of HQI Computation Based on Assessment Area Limiting Factor(s) and Assessment Metrics

Table 3-1 displays the evaluation of assessment areas by the limiting factor(s) the proposed project increments address. For each assessment area, three evaluations are presented. The first line is the evaluation of the without project condition for the assessment areas and is denoted by a letter followed by 0. It is scored based on the applicable limiting factor(s) and HQI is computed using the applicable HQI equation. The second line is for the project increment (with-project action) and is denoted with the same project letter followed by 1. It evaluates the habitat quality associated with the proposed action and is scored using the same assessment metrics used in the without project condition. Lastly, the third line presents the benefits of the proposed action. The benefits are taken as the change in HQI score multiplied by the affected area of the project.

$$Benefits\ (in\ AAHU) = Change\ in\ HQI\ Score\ (With\ Project - Without\ Project)\ x\ Affected\ Area$$

Table 3-1. EO Model Benefits for Assessment Areas with Channel Capacity and In-Channel Habitat Limiting Factors (Bases)

Quality Index Scores for Applicable Variables									
Project Number	Project ID	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
Bases: Limiting Factors for Assessment Area = Channel Capacity and In-Channel Habitat HQI = (V1 + V2 + V5)/3									
59	K0	219	0.1	0.21	N/A	N/A	0.03	0.11	24.5
59	K1	219	0.93	0.93	N/A	N/A	1	0.95	208.7
59	***K1***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***184.2***
50	L0	26	0.1	0.21	N/A	N/A	0.03	0.11	2.9
50	L1	26	0.93	0.93	N/A	N/A	0.5	0.79	20.4
50	***L1***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***17.5***
31	M0	68	0.1	0.21	N/A	N/A	0.03	0.11	7.6
31	M1	68	0.93	0.93	N/A	N/A	0.5	0.79	53.5
31	***M1***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***45.9***
62	N0	132	0.1	0.21	N/A	N/A	0.03	0.11	14.8
62	N1	132	0.93	0.93	N/A	N/A	1	0.95	125.8
62	***N1***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***111***
In-Channel Increments: Limiting Factors for Assessment Area = In-Channel Habitat HQI = (V1 + V2) / 2									
35	F0	107	0.1	0.21	N/A	N/A	N/A	0.16	16.6
35	F1	107	0.93	0.93	N/A	N/A	N/A	0.93	99.5
35	***F1***	***107***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***82.9***
43	J0	25	0.1	0.21	N/A	N/A	N/A	0.16	3.9
43	J1	25	0.93	0.93	N/A	N/A	N/A	0.93	23.2
43	***J1***	***25***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***19.4***
Floodplain Increments: Limiting Factors for Assessment Area = Floodplain Habitat HQI = (V3 + V4) / 2									
9	B0	45	N/A	N/A	-	0.68	N/A	0.34	15.3
9	B1	45	N/A	N/A	0.94	0.88	N/A	0.91	41
9	***B1***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
26	C0	17	N/A	N/A	-	0.4	N/A	0.2	3.4
26	C1	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
26	***C1***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
28	D0	23	N/A	N/A	-	0.55	N/A	0.28	6.3
28	D1	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
28	***D1***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
37	G0	34	N/A	N/A	-	0.61	N/A	0.31	10.4
37	G1	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
37	***G1***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
39	H0	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
39	H1	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
39	***H1***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
40	I0	29	N/A	N/A	-	0.1	N/A	0.05	1.5
40	I1	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
40	***I1***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***

With any attempt to quantify environmental benefits, the method will have inherent uncertainties and limitations. These model limitations and uncertainties are described in Appendix F, Ecosystem Benefits Model Documentation.

As the study team developed conceptual designs and cost estimates for the bases, a number of disposal options were identified for the riverbed excavation bases. Placement of dredged material in the estuary and nearshore area of the Skokomish River was identified as the most likely disposal option (other options included disposal in a nearby quarry or open-water disposal). Placement of dredged material in approximately 800 acres of the estuary would create high quality shellfish habitat (e.g., hard substrate for oyster attachment) and would significantly reduce costs associated with transportation and disposal of up to 2.5 million cubic yards of dredged material outside of the study area.

It should be noted that the environmental benefits model did not formally account for the benefits associated with placing dredged material in the estuary for shellfish attachment; the model only captures benefits related to channel habitat quality, floodplain habitat connectivity, and mainstem river channel capacity. To capture the approximate benefits associated with placement of hard substrate in the estuary for shellfish habitat, the study team developed a conservative estimate for the habitat quality change in the estuary and nearshore (0.25) that would result from placement of dredged material. This habitat quality score was multiplied by the affected area shown in Table 3-2 (511 acres for Base #5 and 843 acres for Base #1). These outputs are presented as "AAHU (Shellfish Substrate)" in Table 3-3.

Table 3-2. Base Benefits

Base	Affected Area Benefits (Channel Benefits)	Approximate Affected Area for Beneficial Use for Shellfish Substrate (Shellfish Benefits)	Improvement of Egg-to-Fry Survival (+/-%)
No Action	0 acres	0 acres	No Change
Base #2	26 acres	0 acres	No Change
Base #3	68 acres	0 acres	No Change
Base #5	132 acres	511 acres	+30%
Base #1	219 acres	843 acres	+52%

Average annual habitat units (AAHU's) calculated by the environmental benefits model (presented as "AAHU (EO Model)" in Table 3-3) were added to habitat units calculated outside of the EO model (shellfish substrate) to determine total habitat units. The total outputs are presented as "Total AAHU" in Table 3-3.

It should also be noted that the sediment excavation bases (Bases #1 and #5) improve egg-to-fry survival by reducing the frequency of flooding from four or more times annual to once every one to two years. Over the 50 year period of analysis, Base #1 and Base #5 are expected to show 52 percent and 30 percent improvement in egg-to-fry survival, respectively, as shown in Table 3-2. These benefits were not directly incorporated in to the cost effectiveness and incremental cost analyses. Rather, channel capacity improvements are included in the EO model which examines changes to flood flow capacity.

For the purposes of comparing and evaluating alternatives, the AAHU's presented in Table 3-3 will be used in IWR Planning Suite (USACE certified version 2.0.6.0) to evaluate the cost effectiveness and incremental cost of the bases in combinations with the additional incremental projects. Total AAHU's for incremental projects are equal to the difference in AAHU's for the without-project condition and the with-project condition for a given assessment area.

Table 3-3. Revised Environmental Outputs by Restoration Project

Project Number	Base Combinability	Project ID	Project Name	Total Acres Affected	AAHU (EO Model)	AAHU (Shellfish Substrate)	Total AAHU
59	1	K1	Base #1: Riverbed Excavation (RM 0-9)	219 + 843 shellfish = 1,062	184.2	210.8	395.0
50	2	L1	Base #2: Confluence Channel Excavation	26	17.5	n/a	17.5
31	3	M1	Base #3: Confluence Levee Removal	68	45.9	n/a	45.9
62	5	N1	Base #5: Riverbed Excavation (RM 3.5-9)	132 + 219 shellfish = 643	111.0	127.8	238.8
9	all	B1	Side Channel Reconnection	45	25.7	n/a	25.7
26	all	C1	Wetland Restoration at Dips Road	17	12.7	n/a	12.7
28	all	D1	Wetland Restoration at River Mile 9	23	13.6	n/a	13.6
35	all	F1	Upstream LWD Installation	107	82.9	n/a	82.9
37	all	G1	Wetland Restoration at Grange	34	18.5	n/a	18.5
39	2 and 3	H1	Hunter Creek Tributary Mouth Restoration	0.5	0.3	n/a	0.3
40	all	I1	Hunter Creek Tributary Reconnection	29	20.1	n/a	20.1
43	all	J1	Weaver Creek Tributary Reconnection	25	19.4	n/a	19.4

4. Evaluation of Project Costs

Table 4-1 shows the present value construction and real estate costs, computed interest during construction (IDC), periodic operations and maintenance (O&M) costs, and total investment costs and annualized costs for each base and increment at the October 2013 price level. O&M was assumed to be minimal for each of the increments, with exception of the excavation bases (Bases #1, #2, and #5). Periodic sediment excavation would be required to maintain channel capacity and is estimated to occur every 20 years for Bases #1 and #5, or for two cycles during the period of analysis (in years 20 and 40),

and every 10 years for Base #2, or five cycles during the period of analysis (in years 10, 20, 30, 40, and 50). Planning level cost estimates were developed for the purposes of alternative formulation and comparison using October 2013 prices. Additional cost information can be found in Appendix K, *Cost Estimate*. Costs were annualized using the IWR Planning Suite Annualization Tool (USACE certified version 2.0.6.0) using the construction cost, real estate cost, construction period (in months) for IDC computations, estimated O&M, the current discount rate (the fiscal year 2013 discount rate is 3.75 percent), and a 50 year period of analysis.

Table 4-1. Average Annual Cost of Bases and Increments (Oct 2013 price level, 3.75% discount rate)

Project Number	Project Name	Construction Cost (1,000s)	Real Estate Cost Estimate ($1,000s)	Interest During Construction ($1,000s)	Total Investment Cost ($1,000s)	Cost for periodic O&M / Frequency	Total Average Annual Cost ($1,000s)
59	Base #1: Riverbed Excavation (RM 0-9)	$141,391	$2	$7,173	$148,567	$43.4 M / Every 20 years (2x)	$8,035
50	Base #2: Confluence Channel Excavation	$14,017	$2	$65	$14,084	$6.2 M / Every 10 years (5x)	$1,153
31	Base #3: Confluence Levee Removal	$6,721	$741	$62	$7,525		$335
62	Base #5: Riverbed Excavation (RM 3.5-9)	$94,756	$2	$2,816	$97,575	$38.0 M / Every 20 years (2x)	$5,548
9	Side Channel Reconnection	$1,024	$2,069	$3	$3,096		$138
26	Wetland Restoration at Dips Road	$5,148	$97	$40	$5,285		$236,
28	Wetland Restoration at River Mile 9	$2,250	$101	$14	$2,365		$105
35	Upstream LWD Installation	$870	$2,357	$3	$3,229		$144
37	Wetland Restoration at Grange	$2,722	$538	$17	$3,277		$146
39	Hunter Creek Tributary Mouth	$11	$193	$0	$204		$9
40	Hunter Creek Tributary Reconnection	$4,190	$1,100	$13	$5,303		$236
43	Weaver Creek Tributary Reconnection	5,318	$2,261	$25	$7,603		$339

5. IWR Planning Suite Model Inputs for Cost Effectiveness and Incremental Cost Analyses

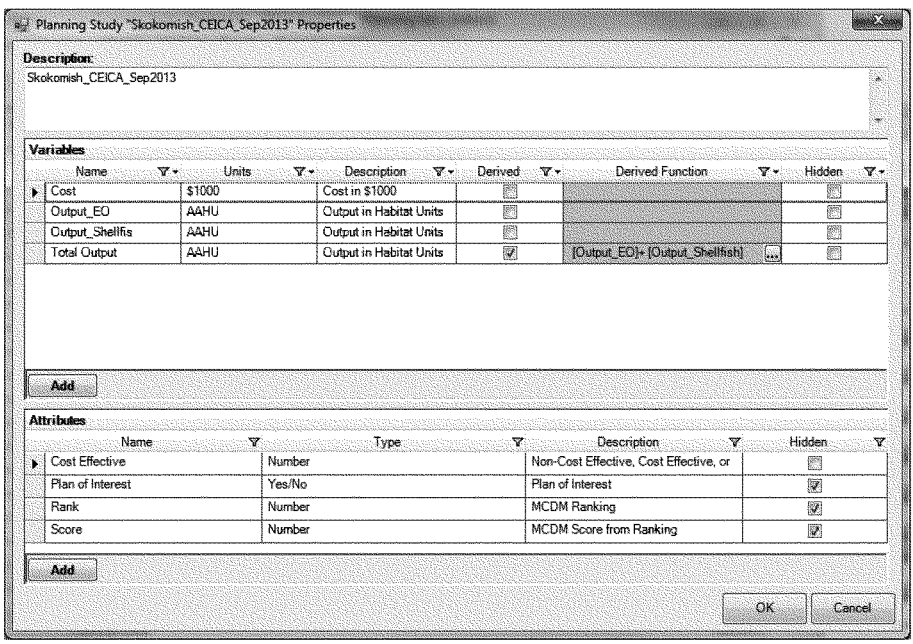
This section describes the model inputs for performing the cost effectiveness and incremental cost analyses using the IWR Planning Suite, version 2.0.6.0 (USACE certified model). The USACE Institute for Water Resources (IWR) developed this software to assist with the formulation and comparison of alternative plans. The software can assist with plan formulation by combining solutions to planning problems and calculating the additive effect of each combination, or "plan", by utilizing inputs on outputs (AAHU's), costs, and rules (combinability and dependency relationships) for combining solutions into plans. Plans are then compared in IWR Planning Suite by conducting cost effectiveness and incremental

cost analyses (CE/ICA), identifying the plans which are the best financial investments, and displaying the effects of each on a range of decision variables. The cost effectiveness and incremental cost analyses are presented in Section 6.

5.1 Planning Study Properties

Figure 5-1 displays the study variables for the cost effectiveness and incremental cost analysis. Cost is input as an annual cost in $1,000s. Two output scores are input Average Annual Habitat Units (AAHU), one for the Environmental Outputs Model AAHU's ("Output_EO") and one for shellfish substrate ("Output_Shellfis"). Total output ("Total Output") is derived by adding together two output scores ("[Output_EO] + [Output_Shellfish]"), and is also measured in AAHU's.

Figure 5-1. Planning Study Properties



5.2 Solutions and Scales

Four bases and eight project increments were input into IWR Planning Suite as shown in Figure 5-2. Along with the project name, other inputs for the bases and project increments include the average annual cost ("Cost" column, derived using the Annualizer in IWR Planning Suite), AAHU's derived from the Environmental Outputs Model ("Output_EO"), and AAHU's estimated for shellfish substrate associated with dredged material placement for Bases #1 and #5 ("Output_Shellfis"). Each unique project is assigned a code letter (i.e. Base #1 is code "K"). Each project has a No Action cost and output equal to

zero. The output for the action is gain in output (AAHU's) to be realized with implementation of the proposed project as compared to the No Action.

At the time that IWR Planning Suite was used to evaluate potential alternatives, the project team was using local site names to refer to each site where measures could be combined and evaluated as alternatives. During the project's feasibility-level design phase, site names were formalized in the Final Feasibility Report and Environmental Impact Statement; therefore, some site names presented in the figures below have changed, but no new sites were added to the analysis.

Figure 5-2. Solutions and Scales

Solutions and Scales

Solutions

Solution	Code	# Scales
Base Alternative #1: Riverbed Excavation (RM 0-9)	K	1
Base Alternative #5: Riverbed Excavation (RM 3.5-9	N	1
Base Alternative #2: Confluence Channel Excavation	L	1
Base Alternative #3: Car Body Levee Removal	M	1
Increment #9: Side Channel Reconnection	B	1
Increment #26: Dips Road Setback	C	1
Increment #28: River Mile 9 Levee Setback	D	1
Increment #35: Upstream LWD Installation	F	1
Increment #37: Grange Levee Setback	G	1
Increment #39: Hunter Creek Tributary Mouth	H	1
Increment #40: Hunter Creek Tributary Restoration	I	1

Add

Scaled Solution Effects on Variables

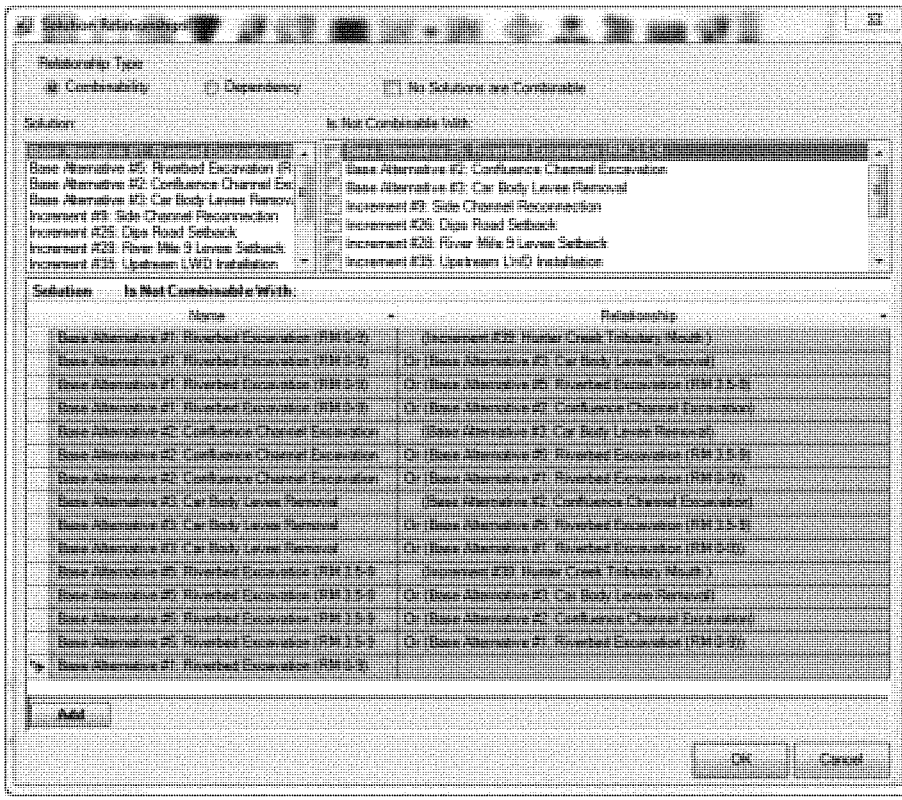
Cod		Name	Cost	Output_EO	Output_Shellfis
K	0	No Action	0	0	0
K	1	Base Alternative #1: Riverbed Excavation (RM 0-9)	8035	184.2	210.8
N	0	No Action	0	0	0
N	1	Base Alternative #5: Riverbed Excavation (RM 3.5-9	5548	111	127.8
L	0	No Action	0	0	0
L	1	Base Alternative #2: Confluence Channel Excavation	1153	17.5	0
M	0	No Action	0	0	0
M	1	Base Alternative #3: Car Body Levee Removal	335	45.9	0
B	0	No Action	0	0	0
B	1	Increment #9: Side Channel Reconnection	138	25.7	0
C	0	No Action	0	0	0
C	1	Increment #26: Dips Road Setback	236	12.7	0
D	0	No Action	0	0	0
D	1	Increment #28: River Mile 9 Levee Setback	105	13.6	0
F	0	No Action	0	0	0
F	1	Increment #35: Upstream LWD Installation	144	82.9	0
G	0	No Action	0	0	0
G	1	Increment #37: Grange Levee Setback	146	18.5	0
H	0	No Action	0	0	0
H	1	Increment #39: Hunter Creek Tributary Mouth	9	0.3	0
I	0	No Action	0	0	0
I	1	Increment #40: Hunter Creek Tributary Restoration	236	20.1	0
J	0	No Action	0	0	0
J	1	Increment #43: Weaver Creek Tributary Restoration	339	19.4	0

OK Cancel

5.3 Solution Relationships – Combinability

Combinability relationships were input in IWR Planning Suite as shown in Figure 5-3. Generally all solutions are combinable, with exception to the bases. No bases may be combined with any other base.

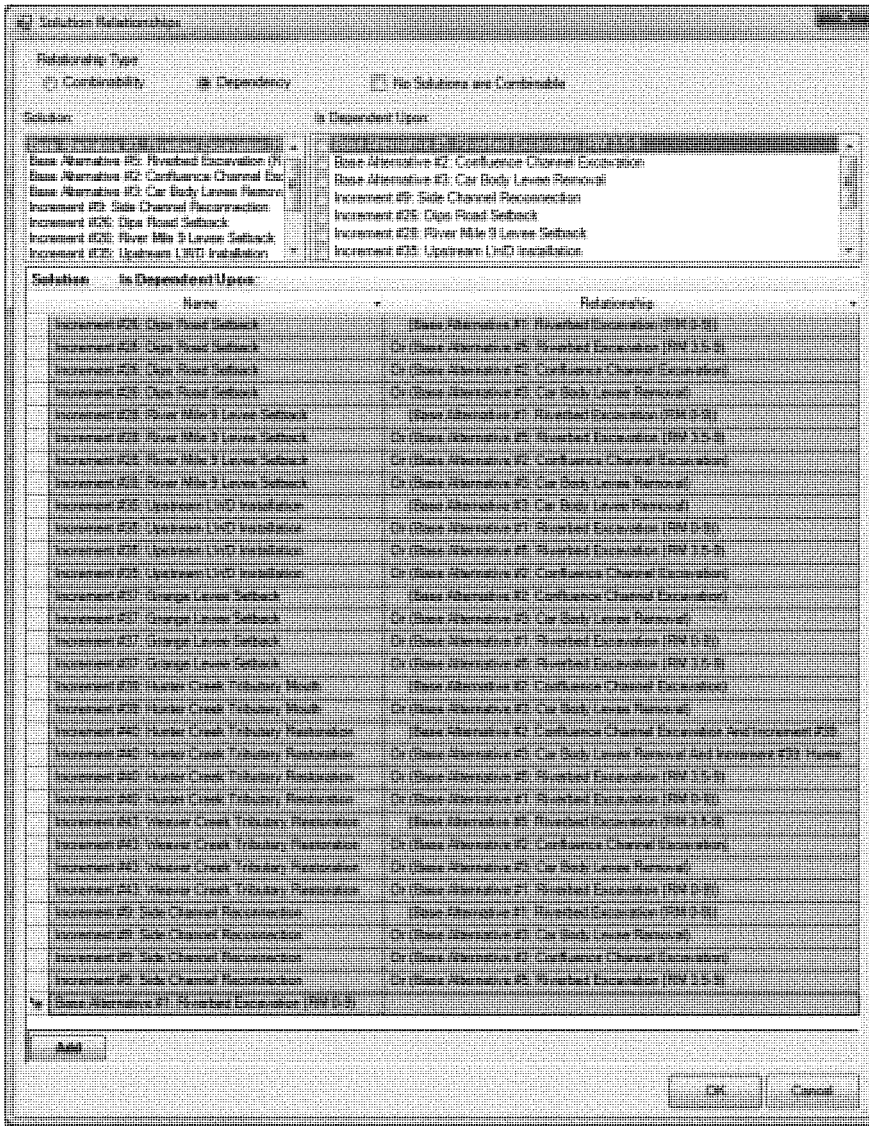
Figure 5-3. Solution Relationships – Combinability



5.4 Solution Relationships – Dependency

Dependency relationships were input in IWR Planning Suite as shown in Figure 5-4. Each incremental project is dependent on a base. Increment #40, Weaver Creek Tributary Restoration, is dependent on Increment #39, Hunter Creek Tributary Mouth, when combined with Base #2, Confluence Channel Excavation, and Base #3, Confluence Levee Removal. The mouth of Hunter Creek Tributary is assumed to be addressed by the excavation associated with Bases #1, Riverbed Excavation (River Mile 0-9), and #5, Riverbed Excavation (RM 3.5-9).

Figure 5-4. Solution Relationships – Dependency



6. Cost Effectiveness and Incremental Cost Analysis (CE/ICA) Alternatives Evaluation

Traditional benefit-cost analysis is not possible for this restoration study because costs and benefits are expressed in different units. Rather, cost effectiveness and incremental cost analysis (CE/ICA) was used to assist the process of determining what project features and design alternatives should be built based on comparison of quantified habitat benefits (outputs) and estimated costs of alternative feature designs. Cost effectiveness analysis is conducted to ensure that the least cost plan is identified for each possible level of environmental output; and that for any level of investment, the maximum level of output is identified. Subsequent incremental cost analysis of the cost effective plans is conducted to reveal changes in costs as output levels are increased.

Given the IWR Planning Suite inputs described in Section 5, a total of 705 plans were generated. Of these, 60 plans (including the No-Action Alternative) were identified as being cost effective using the cost effectiveness analysis. Cost effective plans are listed in Table 6-1 and all possible plans are displayed in Figure 6-1 as those plans which provide a given level of output at the lowest cost denoted by blue triangles and red squares. Those plans which are not cost effective are denoted by circles. Table 6-1 shows "best buy" plans in bold font, and plans that were carried forward into the final array of alternatives are highlighted in different colors. The process used to carry these plans forward is described in Section 7.

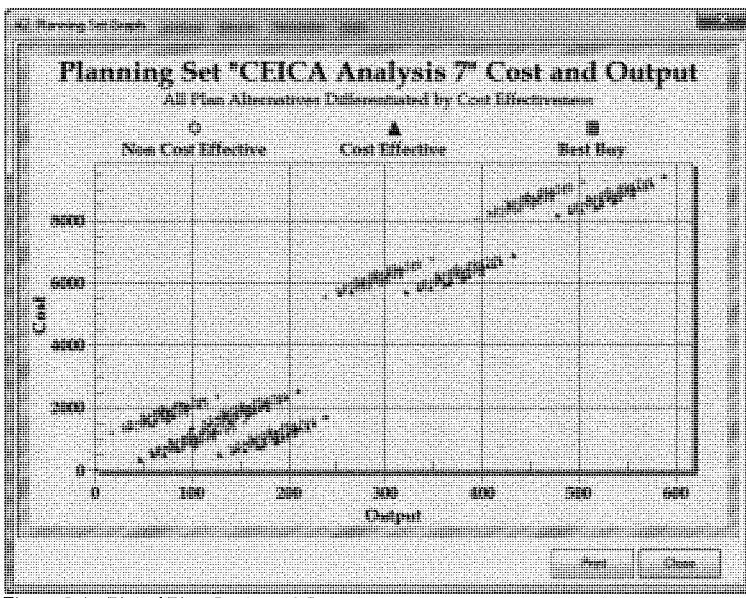


Figure 6-1. Plot of Plan Costs and Output

Table 6-1. Cost Effective Plans* (Oct 2013 price level, 3.75% discount rate)

Alternative # (Original #)	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
1	**No Action Plan**	**0.0**	**0.0**	**0.0**	**0**	
2	Base 3	45.9	0.0	45.9	335	7.30
3	Base 3+ Increment 39	46.2	0.0	46.2	344	7.45
4	Base 3+ Increment 28	59.5	0.0	59.5	440	7.39
5	Base 3+ Increments 28+39	59.8	0.0	59.8	449	7.51
6	Base 3+ Increment 9	71.6	0.0	71.6	473	6.61
7	**Base 3+ Increment 35**	**128.8**	**0.0**	**128.8**	**479**	**3.72**
8	Base 3+ Increments 35+39	129.1	0.0	129.1	488	3.78
9	Base 3+ Increments 35+28	142.4	0.0	142.4	584	4.10
10	Base 3+ Increments 35+28+39	142.7	0.0	142.7	593	4.16
11	Base 3+ Increments 35+9	154.5	0.0	154.5	617	3.99
12	Base 3+ Increments 35+9+39	154.8	0.0	154.8	626	4.04
13	**Base 3+ Increments 35+9+28**	**168.1**	**0.0**	**168.1**	**722**	**4.30**
14	Base 3+ Increments 35+9+28+39	168.4	0.0	168.4	731	4.34
15	Base 3+ Increments 35+9+37	173.0	0.0	173.0	763	4.41
16	Base 3+ Increments 35+9+37+39	173.3	0.0	173.3	772	4.45
17	Base 3+ Increments 35+9+39+40	174.9	0.0	174.9	862	4.93
18	Base 3+ Increments 35+9+28+37	186.6	0.0	186.6	868	4.65
19	Base 3+ Increments 35+9+28+37+39	186.9	0.0	186.9	877	4.69
20	Base 3+ Increments 35+9+39+40+28	188.5	0.0	188.5	967	5.13
21	Base 3+ Increments 35+9+37+39+40	193.4	0.0	193.4	1,008	5.21
22	Base 3+ Increments 35+9+28+37+26	199.3	0.0	199.3	1,104	5.54
23	**Base 3+ Increments 35+9+28+37+39+40**	**207.0**	**0.0**	**207.0**	**1,113**	**5.38**
24	Base 3+ Increments 35+9+28+39+40+43	207.9	0.0	207.9	1,306	6.28
25	Base 3+ Increments 35+9+37+39+40+43	212.8	0.0	212.8	1,347	6.33
26	Base 3+ Increments 35+9+28+37+39+40+26	219.7	0.0	219.7	1,349	6.14
27	Base 3+ Increments 35+9+37+39+40+43+28	226.4	0.0	226.4	1,452	6.41
28	**Base 3+ Increments 35+9+37+39+40+43+28+26**	**239.1**	**0.0**	**239.1**	**1,688**	**7.06**
29	Base 5+ Increment 28	124.6	127.8	252.4	5,653	22.40
30	Base 5+ Increment 9	136.7	127.8	264.5	5,686	21.50
31	Base 5+ Increment 35	193.9	127.8	321.7	5,692	17.69
32	Base 5+ Increments 35+28	207.5	127.8	335.3	5,797	17.29
33	Base 5+ Increments 35+9	219.6	127.8	347.4	5,830	16.78
34	Base 5+ Increments 35+9+28	233.2	127.8	361.0	5,935	16.44
35	Base 5+ Increments 35+9+37	238.1	127.8	365.9	5,976	16.33
36	Base 5+ Increments 35+9+40	239.7	127.8	367.5	6,066	16.51
37	Base 5+ Increments 35+9+28+37	251.7	127.8	379.5	6,081	16.02
38	Base 5+ Increments 35+9+28+40	253.3	127.8	381.1	6,171	16.19
39	Base 5+ Increments 35+9+40+37	258.2	127.8	386.0	6,212	16.09
40	Base 5+ Increments 35+9+40+37+28	271.8	127.8	399.6	6,317	15.81
41	Base 5+ Increments 35+9+28+40+43	272.7	127.8	400.5	6,510	16.25
42	Base 5+ Increments 35+9+28+40+43+37	277.6	127.8	405.4	6,551	16.16
43	Base 5+ Increments 35+9+40+37+28+26	284.5	127.8	412.3	6,553	15.89
44	Base 5+ Increments 35+9+40+37+28+43	291.2	127.8	419.0	6,656	15.89
45	Base 5+ Increments 35+9+40+37+28+43+26	303.9	127.8	431.7	6,892	15.96

Alternative # (Original #)	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
46	Base 1+ Increment 35	267.1	210.8	477.9	8,179	17.11
47	Base 1+ Increments 35+28	280.7	210.8	491.5	8,284	16.85
48	Base 1+ Increments 35+9	292.8	210.8	503.6	8,317	16.52
49	Base 1+ Increments 35+9+28	306.4	210.8	517.2	8,422	16.28
50	Base 1+ Increments 35+9+37	311.3	210.8	522.1	8,463	16.21
51	Base 1+ Increments 35+9+40	312.9	210.8	523.7	8,553	16.33
52	Base 1+ Increments 35+9+28+37	324.9	210.8	535.7	8,568	15.99
53	Base 1+ Increments 35+9+28+40	326.5	210.8	537.3	8,658	16.11
54	Base 1+ Increments 35+9+40+37	331.4	210.8	542.2	8,699	16.04
55	Base 1+ Increments 35+9+40+37+28	345.0	210.8	555.8	8,804	15.84
56	Base 1+ Increments 35+9+28+40+43	345.9	210.8	556.7	8,997	16.16
57	Base 1+ Increments 35+9+28+40+43+37	350.8	210.8	561.6	9,038	16.09
58	Base 1+ Increments 35+9+40+37+28+26	357.7	210.8	568.5	9,040	15.90
59	Base 1+ Increments 35+9+40+37+28+43	364.4	210.8	575.2	9,143	15.90
60	Base 1+ Increments 35+9+40+37+28+43+26	377.1	210.8	587.9	9,379	15.95

*Plans in bold represent "Best Buy" plans.

Incremental cost analysis identified nine of the cost effective plans as "Best Buy" plans, defined as those cost effective plans which provide the greatest incremental increase in output (benefits) for the lowest incremental increase in cost. These best buy plans are listed in Table 6-2 and include total output, total average annual cost, average cost per output, and incremental cost per incremental output. The incremental costs of the best buy plans are displayed as a bar graph in Figure 6-2. The first best buy plan is the No Action Plan. Seven of the remaining eight best buy plans are combinations of increments with Base #3 Confluence Levee Removal. The last best buy (Alternative #60/Best Buy 9) is Base #1 Riverbed Excavation RM 0-9 with all combinable increments. The incremental cost per output of the last best buy is $22,000 per AAHU, or an approximate $3,500 incremental cost per unit than the previous best buy (Alternative #28/Best Buy 8). The study team included a smaller scale sediment excavation plan (Base #5 Riverbed Excavation RM 3.5-9) in the final array of alternatives due to the high cost and scale of Base #1 Riverbed Excavation RM 0-9. The Base #5 plan carried forward is Alternative #45 from the cost effective plans. The incremental cost per output for this plan is estimated at $27,000 per AAHU, which has a higher incremental cost per output than the large scale riverbed excavation plan (Alternative #60/Best Buy 9).

Table 6-2. Best Buy Plans and Increment Cost per Incremental Output (Oct 2013 price level, 3.75% discount rate)

Alternative #	Plan Components	Total Output in AAHU's	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No Action Plan	0.0	0				Best Buy 1	No
7	Base #3: Confluence Levee Removal +35	128.8	479	$3.71	$3.71	$10,754	Best Buy 2	No
11	Base #3: Confluence Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy 3	No
13	Base #3: Confluence Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy 4	No
18	Base #3: Confluence Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy 5	No
23	Base #3: Confluence Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy 6	No
27	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43	226.4	1,452	$6.41	$17.47	$32,602	Best Buy 7	No
28	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43+26	239.1	1,688	$7.06	$18.58	$37,887	Best Buy 8	No
45	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	431.7	6,892	$15.96	$27.02	$154,623	Cost Effective	Yes
60	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	587.9	9,379	$16.00	$22.05	$210,434	Best Buy 9	Yes

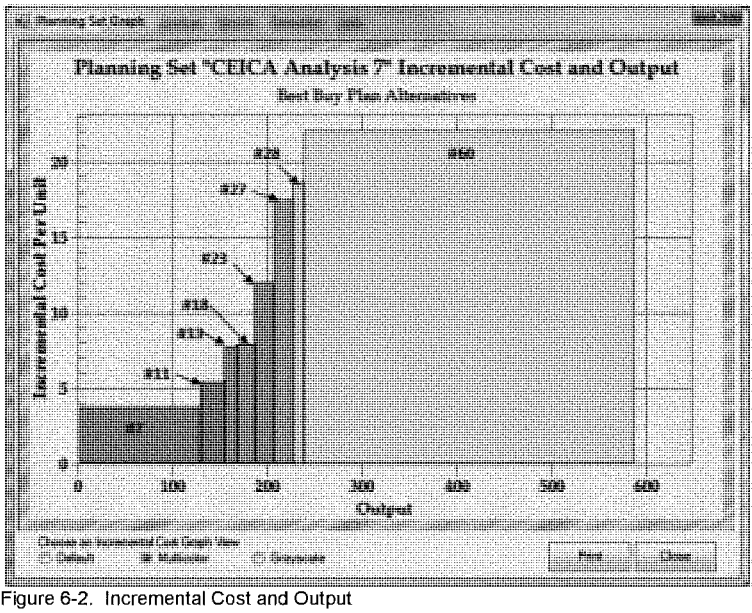


Figure 6-2. Incremental Cost and Output

7. Final Array of Alternatives

The alternatives carried forward for detailed evaluation in the final array were chosen based on CE/ICA results, total cost, incremental cost, and ecological value added between increments. This step resulted in carrying forward six alternatives into the final array of alternatives. The final array of alternatives includes the No-Action Alternative, three Confluence Levee Removal alternatives, and two Riverbed Excavation alternatives.

Logic for screening was based on habitat types restored by each alternative. Side channel or tributary increments provide rearing and refuge habitats in an active channel setting. In contrast, the wetland restoration increments (located at River Mile 9 and the Grange) reconnect floodplain and riparian zones but do not directly provide an active channel habitat in the reconnected zone. Both of these types of increments provide important but slightly different ecosystem restoration benefits.

Alternative #11 was carried forward because it is the first alternative that includes reconnection of a side channel, identified as critical rearing and refuge habitat in the study area. Alternative #18 was carried forward because it includes two wetland restoration increments at River Mile 9 and the Grange; these increments improve floodplain habitat connectivity in critical forested riparian zones of the study area, providing benefits to all riverine life stages of salmonids by increasing available spawning, incubation, rearing, and over-wintering habitats as well as high flow refuge for flood survival, and improving and

expanding wetlands. Alternative #27 was carried forward because it represents one of the largest-scale Confluence Levee Removal alternatives with all but one increment (a road relocation) included in the plan. While Alternative #45 is cost effective only, it was carried forward into the final array of alternatives because it meets the critical needs of the study area while requiring a smaller extent of dredging compared to Alternative #60. Alternative #60 was carried forward because it is the largest-scale Best Buy Plan and represents the most significant Federal investment for the study.

Alternatives #7, #13, #23, and #28 were not carried forward into the final array of alternatives. While Alternative #7 represents the least cost best buy plan, it was not carried forward because it does not include side channel reconnections, wetland restoration increments or tributary restorations, which are all critical habitat types requiring restoration in the study area. Although Alternative #13 includes a side channel reconnection, it was not carried forward because it only includes a single wetland restoration increment (Wetland Restoration at River Mile 9); restoration and reconnection of floodplain habitat in two riparian zone wetlands represents a more complete alternative. Similarly, Alternative #23 was not carried forward because it only includes one of two tributary restoration increments, significantly limiting the area of tributary restoration in the study area. Hunter Creek and Weaver Creek are the only two perennial groundwater-fed streams in the lower Skokomish Basin and restoration of fluvial and biological processes in both tributaries represents a more complete alternative.

Finally, Alternative #28 was not carried forward into the final array of alternatives. The only difference between Alternative #27 (carried forward into the final array) and Alternative #28 is the inclusion of wetland restoration at Dips Road, a road relocation increment which is not a feature that could be cost-shared as part of a proposed National Ecosystem Restoration Plan. This individual increment may be constructed by the non-Federal sponsors but was not carried forward as a best buy plan (Alternative #28) in the final array of alternatives. While the CE/ICA analysis presented in this report includes the Dips Road increment, Section 8.2 of the Economics Appendix (Appendix G) presents the results of a sensitivity analysis of CE/ICA that does not include the Dips Road increment. This sensitivity run removed the Dips Road increment and re-ran CE/ICA to determine whether the cost effective and incremental analysis results would change significantly without this feature. The analysis indicates that the final array of alternatives presented in this report are still considered to be cost effective and best buy plans.

Each alternative included in the final array meets the purpose and need for action. The best buy plans carried forward into the final array of alternatives is shown in Figure 7-1. As noted above, Alternative #45 is cost effective only and does not appear as a best buy plan in this figure. Descriptions of the final array of alternatives are included in the feasibility report.

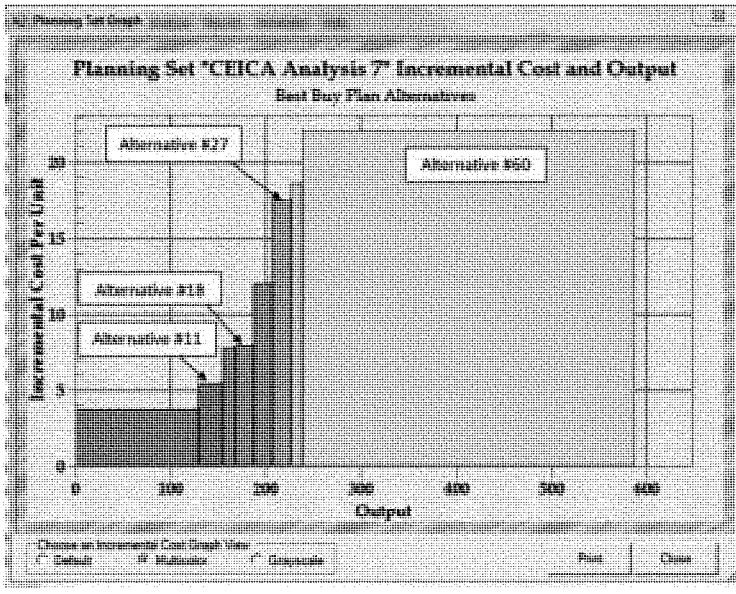


Figure 7-1. Best Buy Plans Carried Forward into Final Array of Alternatives

Table 7-1 summarizes the habitat benefit (AAHU's), acres restored, and average annual cost of the final array of alternatives. The total AAHU's and average annual cost of the alternatives are plotted in Figure 7-2. A plot of the incremental cost per output which includes cost effective Alternative #45 is shown in Figure 7-3. Alternative #45 is approximately $5,000 per incremental output greater than Alternative #60.

Table 7-1. Habitat Outputs and Costs of Final Array of Alternatives (Oct 2013 price level, 3.75% discount rate)

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Annual Cost ($1,000s)
No Action Alternative						
1	No Action Plan	0	n/a	0	0	$0
Confluence Levee Removal Alternatives						
11	Alternative #11 Confluence Levee Removal: *Base #3: Confluence Levee Removal* Increment 35 – Upstream LWD Increment 9 – Side Channel Reconnection	154.5	n/a	154.5	220 In-Channel and Floodplain	$617
18	Alternative #18 Confluence Levee Removal: Base #3: Confluence Levee Removal Increment 35 – Upstream LWD Increment 9 – Side Channel Reconnection Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9	186.6	n/a	186.6	277 In-Channel and Floodplain	$868
27	Alternative #27: Confluence Levee Removal: *Base #3: Confluence Levee Removal* Increment 35 – Upstream LWD Increment 9 – Side Channel Reconnection Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9 Increment 39 – Hunter Creek Tributary Mouth Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration	226.4	n/a	226.4	331.5 In-Channel and Floodplain	$1,452
Riverbed Excavation Alternatives						
45	Alternative #45 Riverbed Excavation: *Base #5: Riverbed Excavation (RM 3.5-9)* Increment 35 – Upstream LWD Increment 9 – Side Channel Reconnection Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9 Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration Increment 26 – Wetland Restoration at Dips Road	303.9	127.8	431.7	412 In-Channel & Floodplain + 511 Shellfish = 923 Total Acres Restored	$6,892

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Annual Cost ($1,000s)
60	Alternative #60 Riverbed Excavation: *Base #1: Riverbed Excavation (RM 0-9)* Increment 35 – Upstream LWD Increment 9 – Side Channel Reconnection Increment 37 – Wetland Restoration at Grange Increment 28 – Wetland Restoration at River Mile 9 Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration Increment 26 – Wetland Restoration at Dips Road	377.1	210.8	587.9	499 In-Channel & Floodplain + 843 Shellfish = 1,342 Total Acres Restored	$9,379

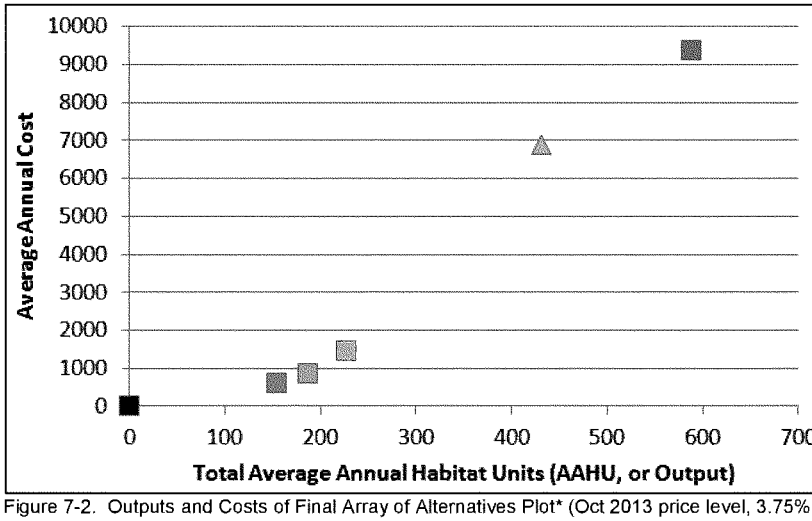


Figure 7-2. Outputs and Costs of Final Array of Alternatives Plot* (Oct 2013 price level, 3.75% discount rate)

*Square denotes "Best Buy" plan; triangle denotes "Cost Effective" plan

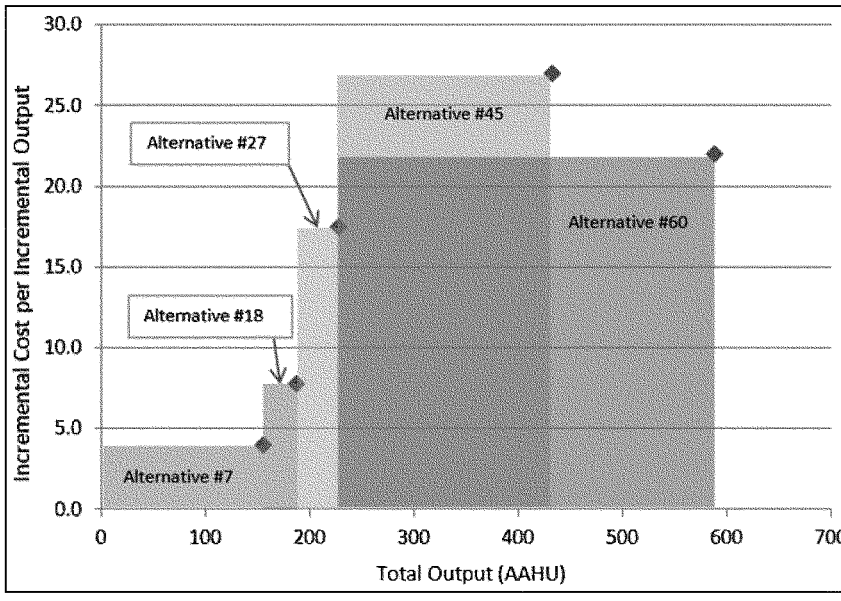


Figure 7-3. Incremental Costs for Final Array of Alternatives (Oct 2013 price level, 3.75% discount rate)

8. Sensitivity Analysis

8.1 CE/ICA With EO Model Outputs Only

A sensitivity run of the cost effectiveness and incremental analysis was performed on the EO Model outputs only, with benefits for shellfish substrate not included in this model. This sensitivity analysis was conducted once designs were refined for those increments carried forward. There were several disposal options considered for the large-scale riverbed excavation. The most feasible and cost effective disposal option was placement of material in the estuary. This placement of material would have benefits to shellfish. These incidental benefits were not accounted for in the development of the EO Model and were added after the fact assuming a moderate quality benefit for shellfish without use of an existing shellfish model. A sensitivity analysis was conducted to determine changes to the cost effectiveness and incremental cost analysis for not including these incidental shellfish benefits.

Costs for the base alternatives and increments did not change with changes to the benefits. Outputs for Bases #1 and #5 were reduced from 395.0 and 238.8 to 184.2 and 111.0, respectively. Figure 8-1 shows a plot of costs and outputs for each possible plan combination. There were 705 possible plan combinations, 50 of which were cost effective plans, and 9 of which were best buy plans. The best buy plans for this run of incremental cost analysis were the same as the best buy plans identified from the incremental cost

analysis that included the shellfish benefits. Incremental costs for Best Buy 9 (Base #1 with each combinable increment) increased from $22.05 to $55.73 per incremental output. The best buy incremental costs are displayed in Figure 8-2, and the incremental costs of the best buy plans are included in Table 8-1. The final array of alternatives is highlighted in Table 8-1. Without inclusion of the shellfish substrate benefits, total AAHU's are reduced from 587.9 to 377.1 which results in a steeper and narrower bar for the last best buy plan (Best Buy 9, green bar) as the bar graph shown in Figure 8-2.

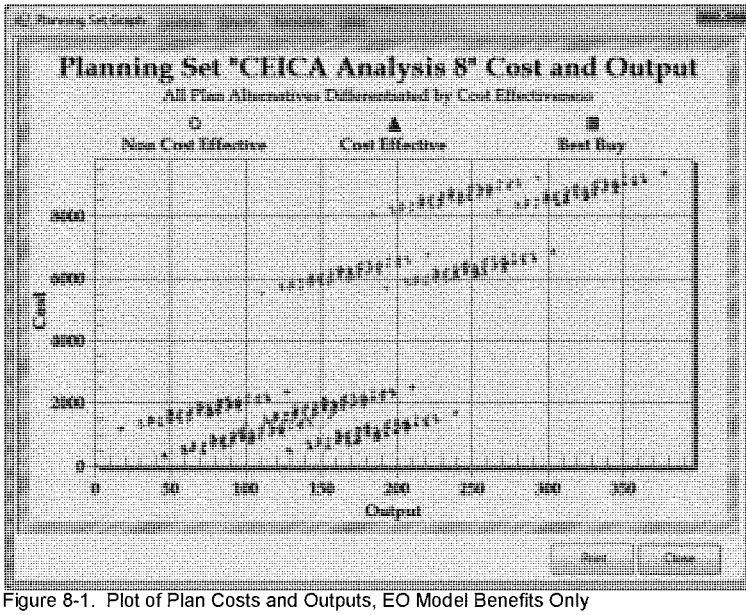


Figure 8-1. Plot of Plan Costs and Outputs, EO Model Benefits Only

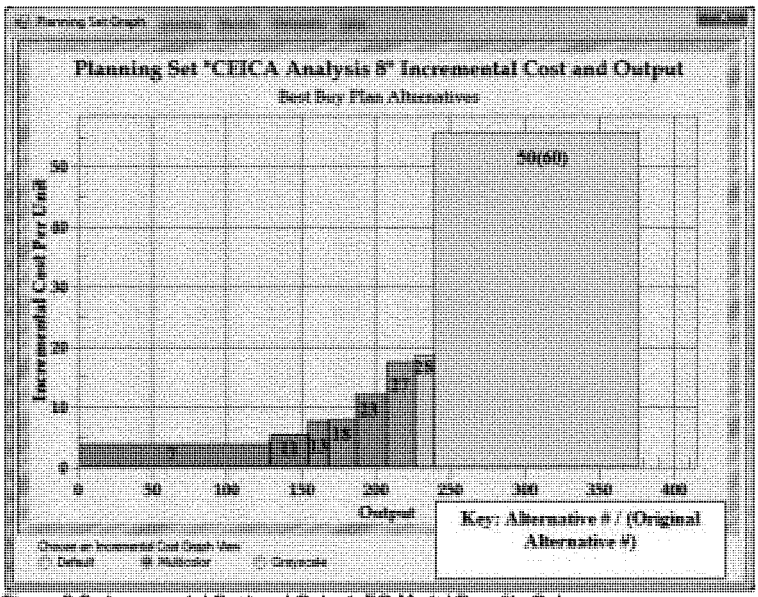


Figure 8-2. Incremental Cost and Output, EO Model Benefits Only

Table 8-1. Best Buy Plans, EO Model Benefits Only (Oct 2013 price level, 3.75% discount rate)

Alternative # (Original Alternative #)	Plan Components	Total Output in AAHU's (EO Model)	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No Action Plan	0.0	0				Best Buy	No
7	Base #3: Confluence Levee Removal +35	128.8	479	$3.72	$3.72	$10,754	Best Buy	No
11	Base #3: Confluence Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy	No
13	Base #3: Confluence Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy	No
18	Base #3: Confluence Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy	No
23	Base #3: Confluence Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy	No
27	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43	226.4	1,452	$6.41	$17.47	$32,602	Best Buy	No

Alternative # (Original Alternative #)	Plan Components	Total Output in AAHU's (EO Model)	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
28	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43 +26	239.1	1,688	$7.06	$18.58	$37,887	Best Buy	No
38(45)	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	303.9	6,892	$22.68	$71.09	$154,623	Cost Effective	Yes
50(60)	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	377.1	9,379	$24.87	$55.73	$210,434	Best Buy	Yes

8.2 CE/ICA without Increment #26 – Wetland Restoration at Dips Road

A sensitivity run of the cost effectiveness and incremental analysis was performed with removal of Increment #26, Wetland Restoration at Dips Road. Increment #26 is a road setback that is considered to be a relocation and would be funded solely by the non-Federal sponsor(s). The study team also identified this feature to be an increment that could only be included as a Locally Preferred Plan (LPP). The evaluation and comparison of alternatives led the study team to originally recommend Alternative #28 as the TSP which includes Increment #26. The next smallest best buy alternative, Alternative #27, includes the same project features as Alternative #28 with the exception of the Wetland Restoration at Dips Road, Increment #26. This alternative achieves similar benefits as the larger Alternative #28 without any large-scale relocations. Alternative #27 was identified as the tentatively selected plan (TSP). A sensitivity analysis was completed to confirm whether the proposed TSP is still a cost effective and best buy plan. The results of this analysis are below and indicate the proposed TSP is a cost effective, best buy plan.

Figure 8-3 shows a plot of costs and outputs for each possible plan combination. There were 321 possible plan combinations, 55 of which were cost effective plans, and 8 of which were best buy plans. The best buy plans for this run of incremental cost analysis were slightly different than the best buy plans identified from the incremental cost analysis that included Increment #26, with removal of Alternative #28, or the best buy plan for Base #3 which included all increments. The last best buy plan for Base #3 is now Alternative #27, which does not include Increment #26. The best buy which includes Base 1 and the cost effective plan which includes Base 5 did not include benefits and costs for Increment #26. Outputs for Bases #1 and #5 were reduced from 587.9 and 431.7 to 575.2 and 419, respectively. Incremental costs for the Base #1 best buy (original Alternative #59, now Alternative #55) and Base #5 cost effective plan (original Alternative #44, now Alternative #41) did not change from the evaluation presented in Chapter 6. The best buy incremental costs are displayed in Figure 8-4, and the incremental costs of the best buy

plans are included in Table 8-2.

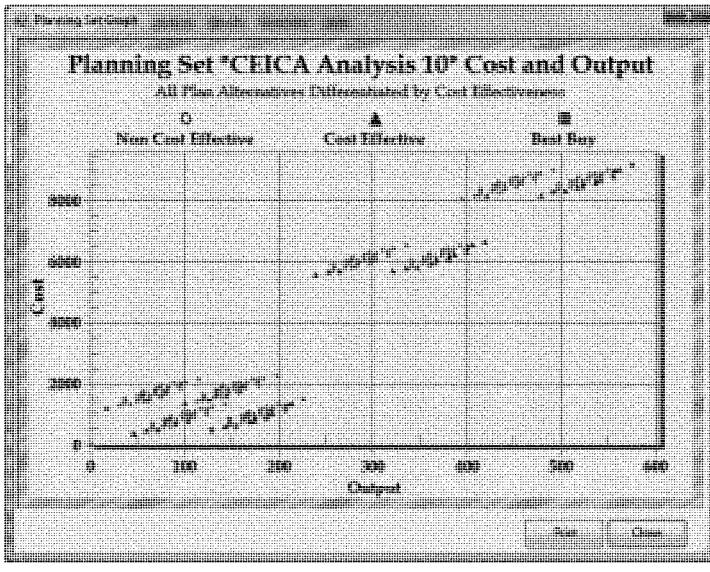


Figure 8-3. Plot of Alternative Costs and Outputs, Without Increment #26 – Dips Road

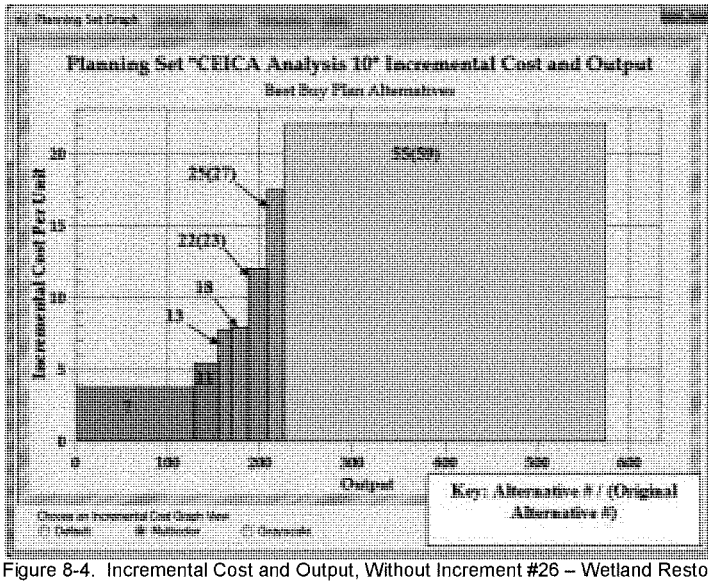


Figure 8-4. Incremental Cost and Output, Without Increment #26 – Wetland Restoration at Dips Road

Table 8-2. Best Buy Plans, Without Increment #26 – Wetland Restoration at Dips Road (Oct 2013 price level, 3.75% discount rate)

Alternative # (Original Alternative #)	Plan Components	Total Output in AAHU's (EO Model)	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No Action Plan	0.0	0				Best Buy	No
7	Base #3: Confluence Levee Removal +35	128.8	479	$3.72	$3.72	$10,754	Best Buy	No
11	Base #3: Confluence Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy	No
13	Base #3: Confluence Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy	No
18	Base #3: Confluence Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy	No
22(23)	Base #3: Confluence Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy	No
25(27)	Base #3: Confluence Levee Removal +35+9+37+28+39+40+43 +26	226.4	1,452	$6.41	$17.47	$32,602	Best Buy	No
41(44)	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	419.0	6,656	$15.89	$27.02	$154,623	Cost Effective	Yes
55(59)	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	575.2	9,143	$15.90	$22.05	$210,434	Best Buy	Yes

9. Recommended Plan

The Corps' objective in ecosystem restoration planning is to contribute to national ecosystem restoration (NER). Contributions to NER (outputs) are increases in the net quantity and/or quality of desired ecosystem resources. The NER Plan must reasonably maximize ecosystem restoration benefits compared to costs, consistent with the Federal objective. The selected plan must be shown to be cost effective and justified to achieve the desired level of output.

The evaluation and comparison of alternatives led the study team to initially recommend Alternative #27 as the Tentatively Selected Plan (TSP) as well as the environmentally preferable alternative. Alternative #27 is environmentally preferable because it has the greatest quantity of Average Annual Habitat Units

without the significant temporary construction impacts and environmental risk to salmon spawning habitat of Alternatives #45 and #60.

The TSP presented in the Draft FR/EIS (January 2014) included the removal of Confluence Levee, the installation of large woody debris, reconnection of a side channel, wetland restoration at two sites, and restoration of two tributaries. In subsequent coordination efforts between the Corps, the non-Federal sponsors, and local landowners in the study area, three increments that were originally included in the TSP are no longer being carried forward. The Hunter Creek Mouth (Increment #39), Hunter Creek Tributary Restoration (Increment #40), and Weaver Creek Tributary Restoration (Increment #43) are no longer included in the recommended plan due to a lack of landowner willingness. As the feasibility-level design phase was completed, these increments were determined to have insurmountable real estate and access issues that had not manifested earlier the analysis.

As described in the previous section, the TSP presented the Draft FR/EIS has been modified following agency, technical, and public review of the report as well as completion of feasibility-level design efforts. While the Draft FR/EIS presented the Corps' tentative proposal for a selected plan, this Final FR/EIS presents the Corps' recommended NER plan. Based on subsequent coordination efforts between the Corps, the non-Federal sponsors, and local landowners in the study area, Alternative #18 is presented as the recommended plan. This best buy plan includes the same increments as the original TSP (Confluence Levee removal, installation of large woody debris, reconnection of a side channel, and two wetland restoration increments) but does not include the Hunter and Weaver Creek tributary restorations. While less comprehensive than the original recommended plan, Alternative #18 is still considered complete, acceptable, efficient, and effective, and it restores the critical needs of the study area (restores year-round flow for fish passage). Alternative #18 is a best buy plan, is economically justified, and is more acceptable in terms of landowner willingness/support. Additionally, supplemental analyses of the two wetland embankments (RM 9 and Grange) were conducted to optimize these features for ecosystem benefit versus cost. This evaluation is presented as an addendum to this appendix. This analysis led to the reduced scale of embankments heights for each site, referred to as the small-scale scenarios. Costs have been revised to reflect the cost of the small scale wetland embankments. There were no changes to the benefits for these features.

The annual costs and benefits of the each of the components included in the recommended plan are shown in Table 9-1 based on feasibility-level costs developed following the cost effectiveness and incremental cost analyses. The recommended plan results in 277 acres of restoration with 186.6 average annual habitat units (AAHU's) with in-channel and floodplain benefits in the Lower Skokomish Watershed.

Table 9-1. Recommended Plan Components (Oct 2014 price level, 3.375% discount rate)

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Annual Cost ($1,000s)
18	Base #3: Confluence Levee Removal	45.9	0	45.9	68	$177
	Increment 35 – Upstream LWD	82.9	0	82.9	107	261
	Increment 9 – Side Channel Reconnection	25.7	0	25.7	45	79
	Increment 37 – Wetland Restoration at Grange	18.5	0	18.5	34	154
	Increment 28 – Wetland Restoration at River Mile 9	13.6	0	13.6	23	153
	Totals for Recommended Plan	**186.6**	**0**	**186.6**	**277**	**$824**

Project costs underwent a cost and schedule risk analysis to develop contingencies for the alternatives considered. Table 9-2 summarizes the refined project first costs at the October 2014 price level for the recommended plan. The estimated project first costs are $19,343,000, which includes monitoring costs of $374,000 and adaptive management costs of $127,000.

Table 9-2. Recommended Plan Cost Summary (October 2014 price level)

	Project First Cost (October 2014 price level)
Construction Item	
01 Lands & Damages (LERRD)	$1,687,000
Elements	
06 Fish & Wildlife Facilities	$12,806,000
06 Monitoring	$374,000
06 Adaptive Management	$127,000
Subtotal	***$14,994,000***
30 Planning, Engineering and Design (PED)	$2,545,000
31 Construction Management	$1,804,000
Total Estimated Cost	**$19,343,000**

Table 9-3 provides an economic summary of the recommended plan. Interest during construction was computed using project first costs at current price levels (Oetober 2014 price level), anticipated construction duration (construction duration ranges from three to 14 months for the three sites, with overall construction assumed over a 32-month period), and the current Federal discount rate (3.375% for fiscal year 2015), bringing total investment costs to $20,197,000. Minimal operations, maintenance, repair, rehabilitation or replacement (OMRR&R) expenses are estimated to be $10,000 per year. Monitoring for this alternative is estimated over a 10-year period with a cost of $374,000, and adaptive management is estimated at $137,000. Annual costs were updated using the feasibility-level first costs at

current price levels to include interest during construction. Average annual cost, included annual OMRR&R is estimated at $852,000, with an average annual cost of $4,600 per AAHU.

Table 9-3. Economic Summary for Recommended Plan (October 2014 price level)

	Cost and Benefit Summary of the Recommended Plan (October 2014 price level)
Interest Rate (Fiscal Year 2015)	3.375%
Interest Rate, Monthly	0.28%
Construction Period, Months	32
Period of Analysis, Years	50
Estimated Cost (Oct 2014 price level)	$19,343,000
Interest During Construction	$854,000
Investment Cost	$20,197,000
Average Annual Cost	
Amortized Cost	$842,000
OMRR&R	$10,000
Total Average Annual Cost	$852,000
Average Annual Benefits	
Average Annual Habitat Units (AAHUs)	186.6
Average Annual Cost/AAHU	$4,600
Average Annual Cost/Acre Restored	$3,100

Table 9-4 summarizes the cost sharing for the recommended plan. Lands, easements, right-of-ways, relocations, and disposals (LERRDs) are credited towards the non-Federal sponsor's 35 percent cost share responsibility. The Federal and non-Federal shares of the total estimated cost is $12,573,000 and $6,770,000, respectively.

Table 9-4. Project Cost Share of the Recommended Plan (October 2014 price level)

	Federal ($1,000s)	Non-Federal ($1,000s)	Total ($1,000s)
Ecosystem Restoration			
Lands & Damages		$1,687	$1,687
Fish & Wildlife Facilities	$12,806		12,806
Monitoring & Adaptive Management	501		501
Planning, Engineering & Design	2,545		2,545
Construction Management	1,804		1,804
Cash Contribution/Reimbursement	-5,083	5,083	0
Total Project Cost Share	**$12,573**	**$6,770**	**$19,343**
Total Project Cost Share (%)	***65%***	***35%***	***100%***

10. References

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Addendum

Skokomish Supplemental Analyses of Optimization of Wetland Embankment Sites

In July 2015, a supplemental analysis was conducted to provide additional evaluation and optimization of two wetland embankment sites included in the Skokomish recommended plan—Wetland Restoration at River Mile 9 and Wetland Restoration at Grange. These embankments were evaluated at two additional elevations (one lower and one higher which reasonably bracket the range of elevations to consider for optimization), as well as a "breach only" scenario (no embankment) for a total of 5 increments for each wetland site. For each site, a habitat model output score was derived using the methods outlined in Appendix F, Ecosystem Benefits Model Documentation. While the "breach only" scenario was evaluated for ecosystem outputs, these scenarios were not carried forward for cost effectiveness and incremental cost analysis (CE/ICA) because they did not meet the purpose and need, planning objectives. This rationale is described further in the evaluation of benefits below. For the remaining scenarios, costs were estimated and CE/ICA analyses were conducted to determine cost effective and best buy alternatives. The following scenarios were evaluated for each site:

- Without project
- With project original recommended plan scale scenario (original design, or average height of 5 ft for River Mile 9 and 6 ft for Grange)
- With project "breach only" scenario (evaluated for benefits only but not carried to CE/ICA)
- With project small scale scenario (based on 6,000 cfs flow containment at each embankment site; approximate 2-3ft reduction in average height for each embankment)
- With project large scale scenario (approximate 1 ft increase in average height for each embankment)

Benefit and Cost Inputs for the CE/ICA Sensitivity Analyses

Ecosystem Benefits

In order to conduct a cost effectiveness and incremental analysis, benefits for the three new scenarios were evaluated for habitat value using the same methodology as outlined in the approved for one-time use Skokomish environmental output model, specifically determining floodplain habitat values using average annual habitat units (AAHUs). The following summarizes the assumptions used to evaluate the three new scenarios for each of the wetland embankment sites. No changes were made to the analysis completed for the without project condition or the original recommended plans for each of the embankment sites.

- Acreage assumptions:

- Acreage for without project and wetland embankment scales is the same as for the original recommended plan.
- Greater acreage is associated with the "breach only" scenarios. Wetland Restoration at River Mile 9 acreage increased from 23 acres to 58 acres and Wetland Restoration at Grange acreage increased from 34 acres to 43 acres, rounded to the nearest acre. This assumption is based on GIS spatial analysis of hydraulic model results at the 6,000 cfs flow showing greater wetted area, where 6,000 cfs is the approximate capacity provided by the existing agriculture berms in the without project condition which is significantly less than the 50% annual chance of exceedance flow of approximately 17,000 cfs. Modeling results show that water would flow across a county road in the "breach only" scenario; however, for the purposes of estimating an acreage footprint, the boundary ends at the road alignment and does not extend beyond the road.

- Connectivity assumptions:
  - Connectivity HQI score assumed to be 0 for "breach only" scenario due to no reconnection to the mainstem (because flood flows would move south across the valley and there are no tributaries that feed back in to the main channel in the area flooded).
  - Connectivity HQI score for the larger scale wetland embankment scenarios assumed to be the same as for the original recommended plan scenario because they would provide year-round two-way connectivity of flood flows into the riparian zone and receding flows back into the river.
  - Connectivity HQI score for the smaller scale wetland embankments is the same as the original recommended plan due to uncertainty in comparable functionality. The approved EO Model states that an action gets 100% score if it provides a year-round connection. The smaller embankments would not contain a 1-year event; however, the EO model was not designed to be sensitive to various elevations of embankments because it was assumed the embankments would be designed to not overtop until greater than the 1-year flow event to achieve the needed two-way connectivity and therefore the 100% HQI.

- Riparian cover assumptions:
  - No additional riparian vegetation is gained with the "breach only" scenario. With the breaches, there is a bigger perimeter around the water and a less percent buffer around the riparian area. GIS analysis was conducted on the larger wetted areas to determine the proportion of perimeter with the buffer around the riparian area using the same methodology described in Appendix F, Ecosystem Benefits Model Documentation. The score for this scenario is assumed to be constant throughout the period of analysis. This results in a reduced score from the future without project condition of approximately 0.46 for Wetland Restoration at River Mile 9 and 0.46 for the Wetland Restoration at Grange. See Figures 2 and 3 for "breach only" riparian cover scores over a 50-year period of analysis.

- Small and large scale scenarios are assumed to have the same riparian cover HQI scores as the original recommended plan scenario given no expected change to the percent area of 150-foot buffer with continuous vegetation.

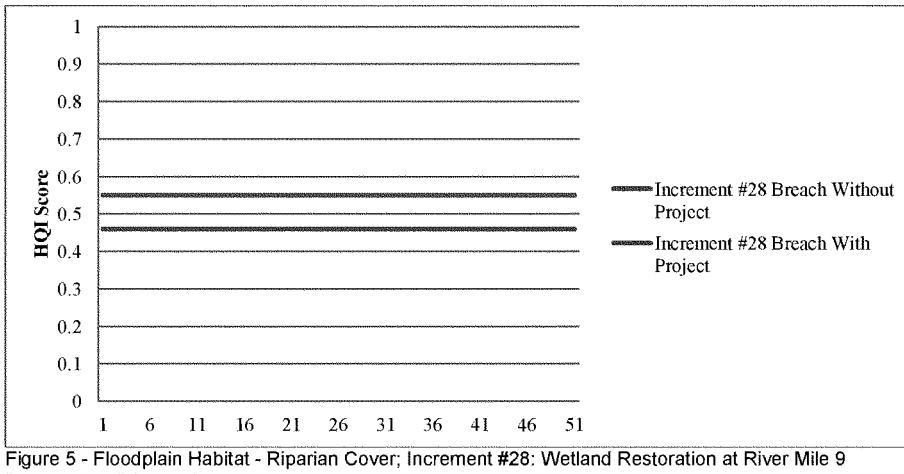

Figure 5 - Floodplain Habitat - Riparian Cover; Increment #28: Wetland Restoration at River Mile 9 "Breach Only" Scenario

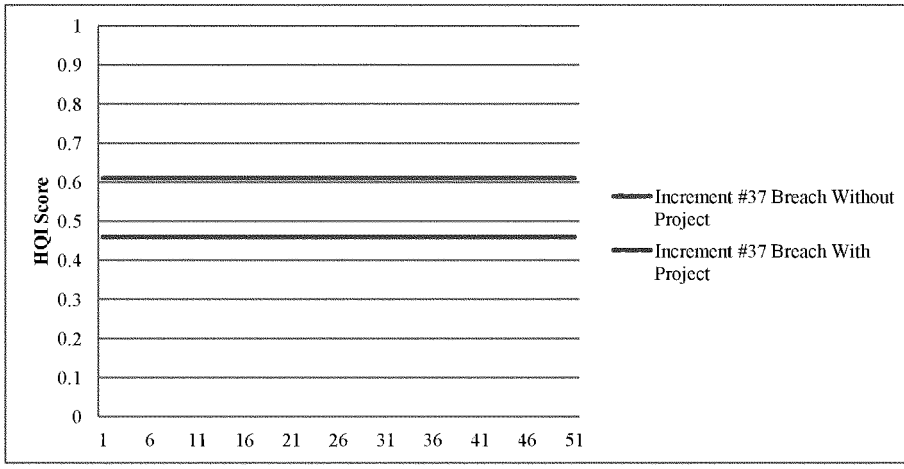

Figure 6 - Floodplain Habitat - Riparian Cover; Increment #38: Wetland Restoration at Grange "Breach Only" Scenario

The following tables summarize the benefit information that was used to evaluate River Mile 9 (Table 1) and Grange (Table 2) in CE/ICA analyses. It should be noted that while acreage increases for the "breach

only" scenario for each embankment, the riparian cover score is lower than the without project condition score and this scenario does not achieve floodplain connectivity as reflected in connectivity scores of 0. Therefore, the "breach only" scenarios provide an increase in acreage of low quality habitat that is not of a habitat type identified as a problem or in need of restoration in this area and does not achieve the project goals and objectives. While the breach only scenario shows a benefit for River Mile 9, this is due to the additional acreage that is gained but results in lower quality habitat than in the existing and future without project condition. The breach scenarios are problematic because in not achieving floodplain connectivity, ESA-listed fish would be stranded and killed in the floodplain more frequently than in the existing condition, resulting in "take" and a jeopardy opinion from the Services. The local sponsors and natural resource agencies would voice opposition to a breach-only design. Additionally, there would be a monetary cost associated with achieving this detrimental impact. If this site were designed to meet the purpose and need of the project, additional plantings and a side channel to achieve connectivity would be needed in addition to the breaches; however, no plantings could be established where the water meets the road, so it is not possible to achieve the same riparian buffer as existing conditions. Therefore, while benefits were quantified for the "breach only" scenarios, these scenarios were screened for reasons already described and were not carried forward in the cost effectiveness and incremental cost analysis for these 2 sites.

Table 5 – Increment 28 Wetland Restoration at River Mile 9 Benefits

Scale	Acres	Riparian Cover HQI	Connectivity HQI	HQI Score [(Riparian Cover + Connectivity) / 2]	AAHUs (Acres * HQI Score)	Benefits (With-Without AAHU)
Without Project	23	0.55	0	0.28	6.3	N/A
With Project – original scale scenario /original recommended plan	23	0.79	0.94	0.87	19.9	13.6
With Project – breach only scenario	58 (+)	0.46 (-)	0 (-)	0.23 (-)	13.3	7.0
With Project – small scale scenario	23	0.79	0.94	0.87	19.9	13.6
With Project – large scale scenario	23	0.79	0.94	0.87	19.9	13.6

Table 6 – Increment 37 Wetland Restoration at Grange Benefits

Scale	Acres	Riparian Cover HQI	Connectivity HQI	HQI Score [(Riparian Cover + Connectivity) / 2]	AAHUs (Acres * HQI Score)	Benefits (With-Without AAHU)
Without Project	34	0.61	0	0.31	10.4	N/A
With Project – original scale scenario / original recommended Plan	34	0.76	0.94	0.85	28.9	18.5
With Project – breach only scenario	43 (+)	0.46 (-)	0 (-)	0.23 (-)	9.9	-0.5
With Project – small scale scenario	34	0.76	0.94	0.85	28.9	18.5
With Project – large scale scenario	34	0.76	0.94	0.85	28.9	18.5

Costs

Parametric costs were developed for the two additional scales for each of the wetland embankment sites. The following summarizes the assumptions and methodology used to develop those additional cost estimates.

- Cost assumptions:
  - Construction costs at the October 2014 price level were developed for the small scale and large scale scenarios by computing new material quantities for those scales.
  - Construction management costs varied for each of the scales by applying the same percentages of construction cost to each scale.
  - PED costs are assumed to be the same regardless of scale.
  - Real estate costs are assumed to be the same regardless of scale.
  - Construction durations were approximated using estimated construction duration in days and assuming 22 working days per month for interest during construction (IDC) computation.
  - Annual operations and maintenance (O&M) estimates are assumed to be the same regardless of scale.
  - Average annual costs for each site and scale were computed using the certified cost annualizer and interest during construction spreadsheet tool in IWR PLAN suite using the total estimated cost, construction duration in months, and estimated annual O&M over a 50-year period of analysis. All costs shown in the analysis are at the October 2014 price level and utilize the current fiscal year 2015 Federal discount rate of 3.375 percent.

The following tables summarize the cost inputs to the CE/ICA analysis for River Mile 9 (Table 3) and Grange (Table 4).

Table 7 – Increment 28 Wetland Restoration at River Mile 9 Costs (Oct 2014 price level)

Scale	Construction Cost ($1,000s)	Total Cost ($1,000s)	Annual O&M ($1,000s)	Construction Duration (Months)	Average Annual Cost ($1,000s, including IDC and O&M, @3.375%)
Without Project	N/A	N/A	N/A	N/A	N/A
With Project – original scale scenario / original recommended plan	$3,049	$4,415	$5	3	$193
With Project – small scale scenario	$2,161	$3,333	$5	3	$144
With Project – large scale scenario	$4,349	$5,890	$5	4	$252

Table 8 – Increment 37 Wetland Restoration at Grange Costs (Oct 2014 price level)

Scale	Construction Cost ($1,000s)	Total Cost ($1,000s)	Annual O&M ($1,000s)	Construction Duration (Months)	Average Annual Cost ($1,000s, including IDC and O&M, @3.375%)
Without Project	N/A	N/A	N/A	N/A	N/A
With Project – original scale scenario / original recommended plan	$3,620	$5,143	$5	3	$223
With Project – small scale scenario	$2,196	$3,408	$5	3	$147
With Project – large scale scenario	$4,224	$5,871	$5	4	$251

Wetland Restoration at River Mile 9 Cost Effectiveness and Incremental Analysis Results

Cost and benefit information for Wetland Restoration at River Mile 9 was input into IWR Planning Suite and evaluated for cost effectiveness and incremental cost analysis. The results indicated two best buy plans (No Action/without project and small scale scenario). The original recommended plan and large scale scenarios are not cost effective as they provide the same benefits as the small scale scenario, but at an additional cost. Table 5 summarizes the results of the cost effectiveness and incremental cost analysis. Figure 3 displays the incremental costs and benefits of the best buy plans, and Figure 4 displays the costs and benefits for each of the scenarios evaluated for cost effectiveness and incremental cost.

There is still a degree of uncertainty in the scale of the wetland embankments as originally recommended. Existing terrain data was utilized to inform designs based on risk-informed SMART planning principles.

This data was evaluated to include greater uncertainty but was considered to be appropriate for this phase of study. This uncertainty exists due to use of multiple terrain data sets with accuracy ranging approximately 6 to 10 feet. The elevation change of 2 to 3 feet, on average, between the previously recommended embankment height and the lower scale embankment height is within the margin of error of this existing terrain data. Additional survey data obtained during PED phase, as well as additional hydraulic modeling, will help refine the optimum elevation. Cost schedule risk analysis performed on the project and resulting cost contingencies reflect the uncertainty in height and material needed for construction, and PED costs include additional survey and analysis to refine the elevation.

Table 9 – Increment 28 Wetland Restoration at River Mile 9 Cost Effectiveness and Incremental Analysis (Costs at Oct 2014 price level)

Scale	Output (AAHU)	Average Annual Cost ($1,000s, Oct 2014 price level)	Average Cost ($1,000s /AAHU)	Cost Effective and/or Best Buy Plan?	Incremental Cost ($1,000s)	Incremental Output (AAHU)	Inc Cost / Output ($1,000s)
Without Project	0	0		Best Buy			
With Project – original scale scenario / original recommended plan	13.6	$193	$14.2	Not Cost Effective			
With Project – large scale scenario	13.6	$252	$18.5	Not Cost Effective			
With Project – small scale scenario	13.6	$144	$10.6	Best Buy	$144	13.6	$10.6

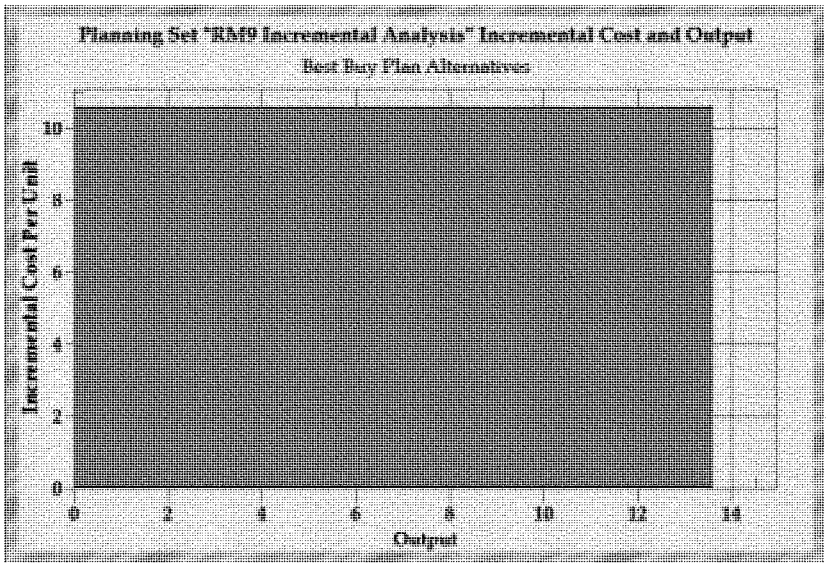

Figure 7 - River Mile 9 Incremental Costs and Incremental Benefits

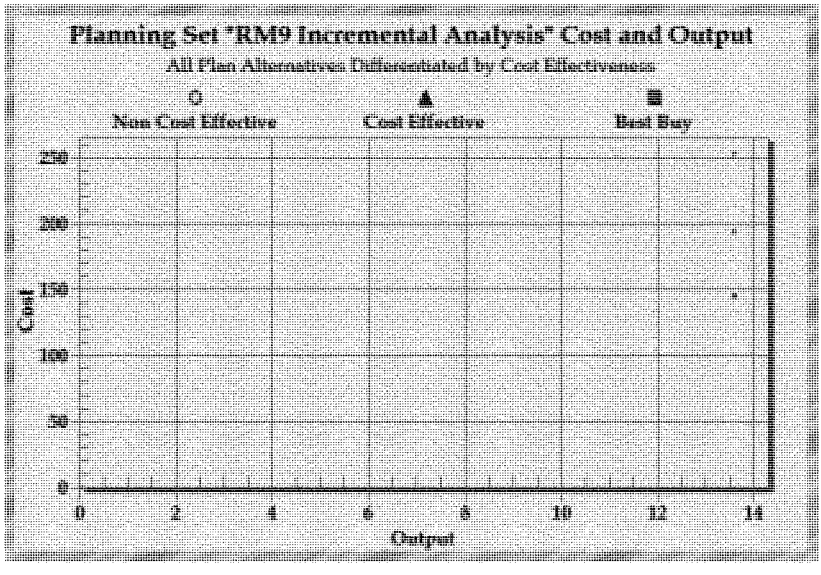

Figure 8 - River Mile 9 Plot of Costs and Benefits

Wetland Restoration at Grange Cost Effectiveness and Incremental Analysis Results

Cost and benefit information for Wetland Restoration at Grange was input into IWR Planning Suite and evaluated for cost effectiveness and incremental cost analysis. The results indicated two best buy plans (No Action/without project and small scale scenario). The original recommended plan and large scale scenarios are not cost effective as they provides the same benefits as the existing recommended plan, but at an additional cost. Table 6 summarizes the results of the cost effectiveness and incremental cost analysis. Figure 6 displays the incremental costs and benefits of the best buy plans, and Figure 7 displays the costs and benefits for each of the scenarios evaluated for cost effectiveness and incremental cost. Similar to the River Mile 9 wetland embankment, there are key uncertainties that will be addressed during PED phase to optimize and refine the wetland embankment height.

Table 10 – Increment 37 Wetland Restoration at Grange Cost Effectiveness and Incremental Analysis (Costs at Oct 2014 price level)

Scale	Output (AAHU)	Average Annual Cost ($1,000s)	Average Cost ($1,000s /AAHU)	Cost Effective and/or Best Buy Plan	Incremental Cost ($1,000s)	Incremental Output (AAHU)	Inc Cost / Output ($1,000s)
Without Project	0	0		Best Buy			
With Project – original scale scenario /original recommended plan	18.5	$223	$12.1	Not Cost Effective			
With Project – large scale scenario	18.5	$251	$13.6	Not Cost Effective			
With Project – small scale scenario	18.5	$147	$7.9	Best Buy	$147	18.5	$7.9

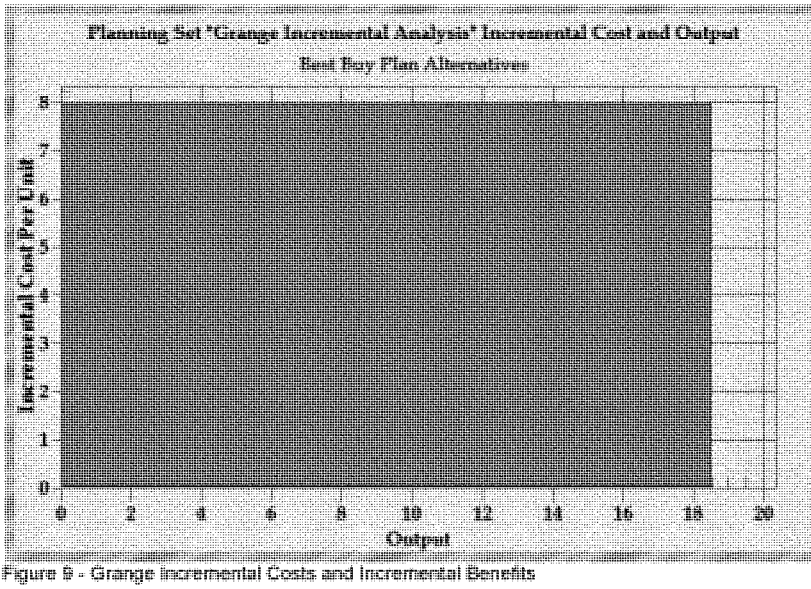

Figure 8 - Grange Incremental Costs and Incremental Benefits

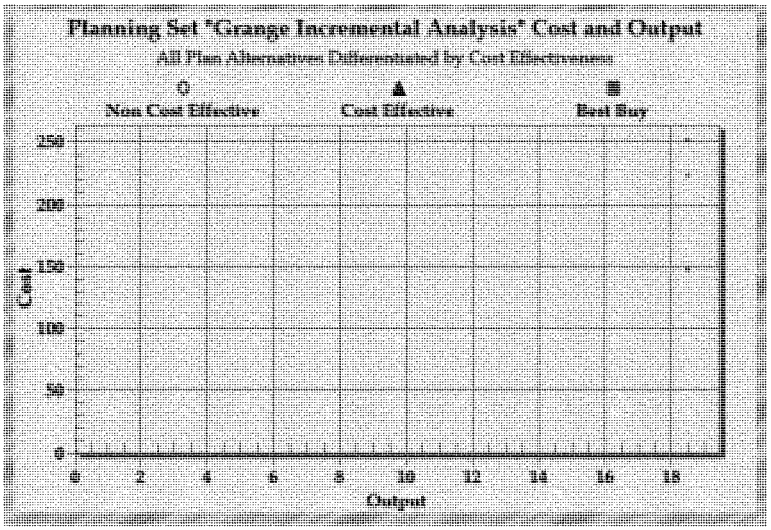

Figure 10 - Grange Plot of Costs and Benefits

Outstanding Risks and Uncertainties

The previously recommended plan for each site has been thoroughly evaluated and there is high confidence that they would perform as designed. There is less confidence in the performance and intended ecosystem benefits for the lower embankments given the frequency of overtopping during flows between 6,000 cfs and 12,500 cfs (approximately a 1-year event). Additionally, since the LiDAR and topography data have substantial uncertainty, it is not possible to tell whether the ecosystem benefit of 1-3 feet of water can be achieved across the entire length of the wetland embankments at the smaller scale elevation until more data is collected in PED. Smaller embankments will have a greater risk for allowing water and therefore fish to escape the riparian zone out toward the farm fields and county road compared to the original recommended plan and the existing conditions. Without additional survey work and engineering analysis, the benefits and costs for the lower embankments have greater associated risks and uncertainty than for the recommended plans. Cost contingencies for the smaller scale wetland embankments will be evaluated to reflect the degree of risk for these key uncertainties and the scope for PED phase will address these outstanding uncertainties to optimize embankment heights.

Outcome / Recommendation

An In-Progress Review was held with members of the Vertical Team on 29 July 2015. The results of the supplemental analysis were briefed by Seattle District and the Vertical Team recommended moving forward with the small scale wetland embankment scenario for both wetland restoration sites. The Final FR/EIS and PGM have been updated with the results of this analysis and continued coordination, and the final recommended plan reflects the smaller-scale embankments at the River Mile 9 and Grange sites.

Additionally, costs of the recommended plan presented in Section 9 of this appendix have been revised to reflect the costs of the smaller-scale wetland embankments.

SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION MASON COUNTY, WASHINGTON

APPENDIX H

ENGINEERING APPENDIX

August 2015

Integrated Feasibility Report and Environmental Impact Statement

US Army Corps of Engineers®
Seattle District

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1 INTRODUCTION

The integrated Feasibility Report and Environmental Impact Statement presents the results of a U.S. Army Corps of Engineers (Corps) Ecosystem Restoration feasibility study undertaken to identify and evaluate alternatives for restoring degraded structures, functions, and processes in the Skokomish River Basin, Washington. The Corps is undertaking this action in partnership with Mason County and the Skokomish Indian Tribe.

Engineering calculations and studies were undertaken in order to support the development and evaluation of alternatives; to inform cost estimates including schedules and evaluation of risk; to provide preliminary designs for HTRW, cultural resources, and real-estate work; and to document the intended project performance. This appendix documents the results of the engineering work in accordance with ER 1110-2-1150.

1.1 GENERAL PROJECT BACKGROUND

The Skokomish River Basin is located on Hood Canal, a natural fjord-like arm of the Puget Sound and water of national significance. The Skokomish River is the largest source of freshwater to Hood Canal as it flows into Annas Bay and of critical importance in the overall health of Hood Canal. Environmental degradation can be seen throughout the Skokomish River Basin including a loss of natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat. Four anadromous fish species (Chinook salmon, chum salmon, steelhead, and bull trout) that use the river as their primary habitat are listed under the Endangered Species Act (ESA) and have experienced population declines. The impaired ecosystem has adversely affected riverine, wetland, and estuarine habitats that are critical to these and other listed species. The underlying need for development of a plan for ecosystem restoration in the Basin has arisen from recognition and analysis of these problems.

1.2 SITE SELECTION AND PROJECT DEVELOPMENT

As part of the planning process for the study, the Project Delivery Team (PDT), in coordination with interested stakeholders and the public, developed a series of measures and alternatives to be considered as potential elements of the project solution. To guide alternatives formulation, the study team identified the planning objectives of the study. Based on the problems identified in the study area, planning objectives include the following:

- Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
- Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.

- Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

A recommended restoration plan was selected that includes a levee removal, a side channel reconnection, placement of large woody debris in the upstream reaches of the river, and wetland restoration at two sites. This Engineering Appendix outlines key design elements for the features included in the recommended plan.

The recommended plan includes five features: (Figure 1 below and Annex A; Sheet G-003)

- Confluence Levee Removal
- Wetland Restoration at River Mile 9
- Wetland Restoration at Grange
- Upstream Large Woody Debris
- Side Channel Reconnection

These features are described in more detail in the following sections.

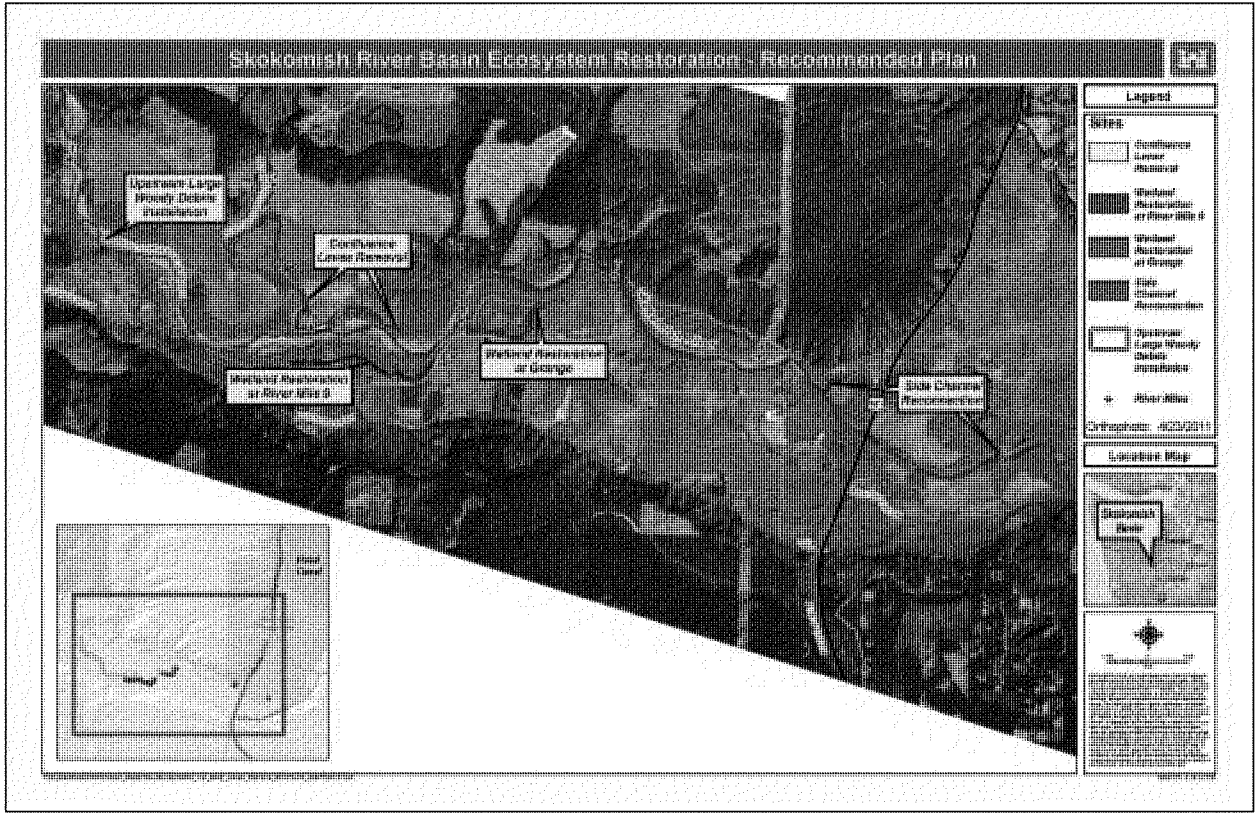

Figure 1-1. Recommended Plan

1.2.1 Confluence Levee Removal

In the vicinity of the North Fork/South Fork confluence, riverbed aggradation in the South Fork and the avulsion of the North Fork has lead to dry channel conditions developing in the South Fork during the late summer/early fall period. The dry channel stops the upstream migration of salmon returning to the South Fork. This feature addresses that problem by removing the Confluence Levee and diverting the South Fork into the North Fork near the pre-2003 confluence. The combined discharges would provide a continuous low flow channel in what is now the North Fork channel. The reach of the South Fork that goes dry in the late-summer/early-fall would be abandoned during those low flow periods.

This feature primarily addresses the study objective of restoring a continuous low flow channel near the confluence and to a lesser extent the objective of improving the quantity, quality, and complexity of pool habitat in the river. Mainstem flows would be diverted into the North Fork channel and reenter the mainstem at the present confluence location. This would bypass the subsurface flow reach and provide improved fish migration. A portion of flood flows would stay in the old channel. Installed LWD would direct flow in the new channel and improve fish habitat in the vicinity of the diversion.

1.2.1 Wetland Restoration at River Mile 9

The Wetland Restoration at River Mile 9 increment, located at RM 8.3-9.2, is intended to reconnect and restore high quality wetland habitat. An existing agricultural berm will be breached and a new wetland embankment will be constructed landward (south) varying distances, generally around 200-300 feet. Four strategically located sections of the existing agricultural berm would be removed. These breaches would allow flood waters to flow freely within the wetland restoration area, reconnecting the riparian zone to the aquatic habitat for the benefit of salmon and many other species. The wetland embankment will improve hydraulic conditions in the reconnected wetland area and is expected to hold water within the wetland at a greater depth and longer duration, thereby improving and expanding wetland conditions. This action would place about 24 acres of riparian habitat, forest, and floodplain ponds on the riverward side of the wetland embankment. The new wetland embankment would be approximately 4,370 feet long and would contain flow during moderate winter storm events up to approximately 6,000 cfs. The wetland embankment would also be designed for shallow overtopping. This feature includes planting of native vegetation.

1.2.2 Wetland Restoration at Grange

The Wetland Restoration at Grange, located at RM 7.5-8, is intended to reconnect and restore high quality wetland habitat. Similar to the Wetland Restoration at River Mile 9 described above, an existing agricultural berm will be breached and a new wetland embankment would be constructed landward (south). This action would place about 34 acres of riparian habitat, forest, and floodplain ponds on the riverward side of the Wetland Embankment. Two strategically selected sections of the existing agricultural berm would be breached. These breaches would allow flood waters to flow freely within the wetland restoration area, providing salmon access to the riparian habitat for refuge from high velocity and turbidity during high flows. The new wetland embankment would be approximately 2,740 feet long and would contain flow during moderate winter storm events up to approximately 6,000 cfs. This feature also includes planting of native vegetation.

1.2.3 Upstream Large Woody Debris

This feature, located from RM 9-11, would include placement and installation of anchored wood and Engineered Log Jams (ELJ). Small wood clusters, single logs, as well as larger ELJ would be installed in this reach to encourage low flow channel meandering and mid-channel bar formation and provide multiple types of habitat benefits for salmon.

1.2.4 Side Channel Reconnection

An abandoned channel that lies between RM 4 and 5.6 would be reconnected to the mainstem to provide high flow refuge and rearing habitat for fish. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would only be connected to the mainstem Skokomish River during high discharges and would not convey water year round. During high river discharges, the reconnected channel would provide low velocity refuge. During most of the year, the channel would provide pond habitat for fish rearing. Reconnecting the channel to the river could provide 45 acres of high quality, low velocity fish habitat. This feature would also include planting of native vegetation.

1.3 Design Features

Table 1-1 summarizes the project features developed in preparation of the conceptual design alternatives.

Table 1-1. Design Features

Project Feature	Description of Project Feature	Approx. Quantity
Confluence Levee Removal	Remove Existing Confluence Levee. For cost estimating purposes we are assuming the Confluence levee is comprised of earthen material and the possibilities that the levee is constructed with debris is included in the cost risk contingency	10,345 cubic yards (CY)
Existing Confluence Levee Breach	Enlarge an existing breach	7 ELJ, 26 single logs; 4,715 CY
Existing River Mile 9 Berm Breach	Breach four sections of the existing River Mile 9 Agricultural Berm to match existing grade	7,935 CY
Wetland Embankment at River Mile 9	Construct wetland embankment at River Mile 9, RM 8.3-9.2, to provide additional floodplain habitat	6,255 CY Planting Berm 2,050 CY
Existing Grange Berm Breach	Breach two sections of the existing Grange Agricultural Berm to match existing grade.	3,790 CY
Wetland Embankment at Grange	Construct wetland embankment at Grange, RM 7.5-8, to provide additional floodplain habitat	10,530 CY Planting Berm 1,500 CY
South Fork Large Woody Debris Installation	Bar Apex ELJ are designed with no net excavated material, 5-log channel cluster placements will create a total net excavation, single log placements are designed with no net excavated material	7 ELJ, 24 clusters, 56 single logs; 11,000 CY

Side Channel Reconnection Entrance	The abandoned channel that exists between RM's 4 and 5.6 would be reconnected to the main stem to provide high flow refuge and rearing habitat for fish. Placed wood may create a small net excavation	4 wood clusters; 3,600 CY channel; 930 CY wood excavation
Side Channel Reconnection Exit	Existing outlet will be used with no excavation planned at this stage of design. Placed wood may create a small net excavation	2 wood clusters; 460 CY wood excavation

1.4 Hydraulic Design

Two hydraulic models were utilized for this study to evaluate measures. River and floodplain hydraulics were modeled with a two-dimensional (2-D) SMS model. Bedload transport near the confluence of the north and south forks was modeled with a one-dimensional (1-D) HEC RAS model.

In 2014, the Bureau of Reclamation utilized SMS, a 2-D hydraulic model, to model floods and measures proposed in the project area of the Skokomish River Valley (USBR, 2014). The SMS software utilizes a dynamic wave solver to route flow through independent mesh cells and can, therefore, handle multiple water surface elevations and flow paths. Model outputs include the extent and depth of flood inundation, current velocities and directions, and flow distributions. The topographic data used for the Skokomish valley was developed from several sources from the best available data. A detailed description of the model and the results are presented in the Skokomish 2-D Modeling Report (Annex H-6).

Bedload transport modeling was completed by Seattle District using HEC-RAS 4.1, which incorporates bedload transport equations into a quasi-unsteady 1-D flow model of the Skokomish River. The bedload transport function used in this model was the Meyer-Peter Muller (MPM) equation. The model was calibrated to the stage/discharge and bedload measurements at the USGS mainstem gage (RM 4.8). The HEC-RAS model used in this analysis was originally developed by KCM in 1997. It was updated by CES (1999) and WEST (2006). For this bedload analysis USACE again updated the model with new channel cross-section surveys between RMs 2 and 11 in 2007 and RM 0-2 in 2011. Lateral weirs were used along the channel to simulate the diversion of flood waters from the main river channel. Active flow areas were limited to those along the river that influenced the amount of water in the main channel. The bed material gradation is an important model input for the bedload transport calculations. The bed material gradations used in the model were collected by Reclamation in 2009. The bedload transport results were compared to measurements collected at Highway 101 in 1994 by Simons and Associates and in 2010 by the USGS. A detailed description of the bedload transport model and the results are presented in the Skokomish River Basin Flooding and Sedimentation Baseline (Annex H-4).

The project area of the Skokomish River (roughly from RM 8-11) has changed significantly from the 1930's to present. The channel is presently much narrower and has a significantly reduced wood supply from what has existed historically. Previous reports have discussed the change in historic wood loadings (Annex H-6) and historic channel migration zone (Annex H-4). Few large jams are presently located mid channel, with the majority found pinned against banks in areas of secondary flow and blocking side channels. Estimates given for present wood loading are roughly 5-6 large jams per mile between RM 1-11 (Annex H-6). It is clear that

present wood loads are only a fraction of what has existed historically. Some estimates have suggested that this is 74-99% less wood than what has existed historically (TEAMS, 2009). The result of this is a channel that has significantly reduced hydraulic roughness and an absence of the complexity afforded by historic log jams. Significant opportunity exists to rehabilitate this reach with log placements, to include establishing stable scour pools and mid channel bars, re-activating historic side channels, and generally adding complexity to what is presently a stark gravel bed river. Use of mechanically placed wood in Northwest Rivers for these purposes has been widely documented (Collins 2011, Montgomery 2003, USACE 2009, USACE 2012, USACE 2014, and others). The South Fork reach of the project area is intended primarily for these rehabilitative efforts and was found to be suitable for the methods described here. Some wood is used to help direct flows through the diversion in the Confluence levee and to stabilize the side channel reconnection. The potential for reactivating side channels along the south fork depends largely on what the local sponsor is amenable to as later design phases are reached. Land along much of the historic channel migration zone is not presently available for restoration or has not yet been acquired by the sponsor. The potential exists to broaden the scope to activate historic side channels at future design phases. A similar project was undertaken much farther upstream on a steeper reach of the South Fork (TEAMS, 2009) with success. The present state of design with respect to wood placement is preliminary, with structure types, quantity, and locations selected to create localized effects within the present active channel footprint. Wood placements are planned for the South Fork between RMs 9 and 11, adjacent to the new Confluence Levee Removal channel, and at the side channel reconnection inlet and outlet. Species should mainly be conifers and Douglas Fir is specified in the design; however, Cedar can be used for increased longevity. The wood placements shall be anchored with boulders and/ or piles to prevent them from moving during bankfull discharges. Some LWD may be used to reduce the risk of harmful bank erosion and included in the design at later phases if deemed necessary from a channel migration risk perspective. Restoring historical wood loading is likely not entirely possible without bank protection. Areas of erosion risk/property loss will need to be identified and coordinated with the local sponsor. Areas that are potentially affected should have mitigation such as minimal placement of anchored wood or strategic placement of log jams to deflect flows. Several types of wood structures are presently included in the design:

- **Bar apex structure**: Located at meander crossings and at locations where minor geomorphic work is acceptable. Promote the formation of vegetated bars (existing and new) and development of deeper and narrower low flow channels to either side of the structure, increase low flow channel length, and scour pool formation. Will dissipate energy in floods, maintain large scour pools, and store woody material and gravel. This structure is anchored with piles, rootwads, and chained together. Seeding the structure and including plantings will help to provide replenishment as the structure decays.
- **5 log channel cluster:** Located along low flow channel margins and along braids formed by the bar apex structure to form low flow scour pools. Individual logs are chained to boulder anchors and interlocked. The root wad and trunk provide hydraulic shadows, feeding stations, and rearing and refuge habitat for juvenile salmonids. These structures also provide resting and refuge habitat for juvenile and adult salmonids, and aquatic insect colonization substrate and production.
- **5 log bank cluster:** Located in the channel banks to provide complex instream cover and bank protection. The elevation of the root wads off the bottom on the cover log base provides habitat partitioning that benefits salmonid rearing and refuge habitat. It also provides feeding stations in

hydraulic cover at the edge of flowing water that will provide drift feeding opportunities. The cover log base also affords easier construction to hold the top logs above the bottom during anchoring.

- **Single Anchored log:** Located along low flow channel margins and along braids formed by other structures to form low flow pool habitat. Each individual log is chained to a boulder anchor with the rootwad placed in a preformed scour pool and the trunk buried with excavated material. The root wad and trunk provide hydraulic shadows, feeding stations, rearing and refuge habitat for juvenile salmonids. These structures also provide resting and refuge habitat for adult salmonids, and aquatic insect colonization substrate and production.

The location of wood structures is preliminary at all sites and refinement is intended during the pre-construction, engineering, and design phase. Terrain used in modeling is generally poor resolution and was not significantly useful from a detailed design perspective (i.e. based hydraulic parameters). Modeling and analysis is expected to be updated at later design phases. New LiDAR when available is not expected to significantly change design concepts but will inform the location of wood. The location of wood structures will also depend upon how the river evolves (the location of the low flow channel and active channel margins) before the final designs are completed. Structure types and quantity were selected based upon preliminary guidance and may change at later phases. The overall quantity of wood is expected to allow sufficient flexibility with cost contingencies to meet project goals. The 50-year project life period may necessitate use of other wood types such a cedar or replenishment of wood as it decays and should be coordinated with the sponsor. It is desirable to use conifer species to maximize longevity of wood placements and to minimize the need to replace logs over the project life.

1.5 Civil Design

This section discusses the key elements of the civil design and determines the gross volumes associated with each feature included in the Feasibility report. The discussion includes the major components, construction, access and staging considerations.

1.5.1 Staging and Access

Based on evaluation of the site topography and predominant land use, approximately 3.7 acres of staging areas would be utilized. Staging would be anywhere within the project construction limits and the staging areas shown on the plans. Access will be at the locations shown on the plans.

1.5.2 General Construction Methodology

Specific timing restrictions will be required for in-water work to protect fish and wildlife and measures may be required under site-specific permit requirements to protect downstream infrastructure. Construction would be in the drier summer months to facilitate access and construction and to comply with regulated in-water work windows to protect sensitive fish species. Any excavated materials would be removed off-site. The erosion and water quality control plan and best management practices will be determined during Pre-construction Engineering and Design (PED). Generally the following are included:

- Existing roadways or travel paths will be used whenever possible and stream crossings minimized.

- The number of temporary access roads will be minimized and roads will be designed to avoid adverse effects like creating excessive erosion and avoiding crossing slopes greater than 30%.
- All temporary access-ways not needed for future access will be removed (including gravel surfaces) and planted by the end of the in-water work period and after project completion.
- As much as practicable, any large wood, native vegetation, weed-free topsoil, and native channel material displaced by construction will be stockpiled for use during site restoration.
- When construction is finished, the construction area will be cleaned up and rehabilitated (replanted and reseeded) as necessary.
- Prepare a Work Area Isolation Plan for all water crossing requiring flow diversion or isolation.
- Within seven calendar days of project completion, any disturbed bank and riparian areas shall be protected using native vegetation or other erosion control measures as appropriate.

1.5.3 Topography

Three different data sources were used to develop a topographic surface for 2-D mesh development:

- 1994 Photogrammetric 2-ft Contour Map
  - Horizontal Datum: Washington State Plane coordinate system South zone NAD 83/91.
  - Vertical Datum: NAVD 1988
  - Source: Bell Walker & Associates
  - Description: A Photogrammetric model was built with a stereoscopic drafting station using GPS registered aerial photography. Extends upstream to approximately RM 11 on Skokomish River.
- 2002 Bare-earth LIDAR
  - Horizontal Datum: Washington State Plane coordinate system South zone NAD 83/91.
  - Vertical Datum: NAVD 1988
  - Source: Puget Sound LIDAR Consortium
  - Description: Bare-earth LIDAR containing the X, Y, Z values of all the LIDAR returns classified as ground.
- 2014 field cross sections and utility information
  - Horizontal Datum: Washington State Plane coordinate system South zone NAD 83/91.
  - Vertical Datum: NAVD 1988
  - Source: Mason County
  - Description: May/June 2014 field topography at the Confluence Levee and Channel reconnection entrance area. Utility information collected in the River Mile 9 and Grange areas.

1.6 Geotechnical Design

This section presents background information for the geotechnical design and construction of the proposed environmental restoration features for the Skokomish General Investigation.

Proposed features of design include Confluence Levee degrade, wetland embankment at River Mile 9, wetland at Grange, large woody debris (LWD) structure anchors, and side channel reconnection.

Although the wetland embankment features are ecosystem restoration features, they were designed according to USACE levee design standards and text throughout this section references general design standards for levees. The Wetland Embankment elements of the wetland restoration projects will retain flood waters for a limited loading period and are designed to allow targeted reconnection to riparian wetlands during frequent, moderate storm events. The features are designed to be resilient for the 50-year study period assuming normal operations and maintenance. This standard protects the initial investment of the ecosystem restoration project.

> ***Errata Note***: The Geotechnical design of the wetland embankments described below and included in this Appendix and Annexes were based on a top of embankment profile for 17,000 cfs flow. The proposed project top of embankment elevation is now 6,000 cfs. The following design recommendations are still considered applicable for 35% level design. Due to the minimal impact the revisions would have on the overall design, it was decided that updates to the models and calculations would be completed in PED. The factor of safety against slope stability and seepage failure would be increased based on the lower embankment heights. The landside slope of the berm will be governed by overtopping flows and the waterside slope will be governed by the frictional strength of the embankment fill soil, which based on available sources, is not recommended to be steeper than 2H:1V. The levee geometry is not anticipated to change from the herein proposed based on the embankment height change. The settlement estimates will be reduced. Preliminary calculations based on the approximately 2 foot height reduction indicated that settlement will be reduced from 9" to 6" and 4.5" to 3". There is greater likelihood that the consolidation will happen during construction periods and not require overbuild. These points will need to be confirmed in PED. The following design analysis of these features proves the wetland embankment design concept is viable. Further refinement will occur in PED.

1.6.1 Geologic Setting

The Skokomish River Valley is located at the southeastern end of the Olympic Peninsula near the southernmost extent of Hood Canal. The Skokomish River flows east from its headwaters in the Olympic Mountains and descends through narrow steep gorges and cascading pools to the Skokomish Valley, which occupies the lower most 10 miles of the Skokomish drainage basin.

The Puget Lowlands have been impacted by multiple continental glaciations during Pleistocene time. The ice excavated the valley during the Vashon stade into the older Vashon advance outwash deposits (Great Lowland Fill) and pre-Vashon deposits (Booth, 1994). Holocene fluvial erosion has exerted minimal influence on the large-scale valley morphology.

The Skokomish catchment is underlain by thick deposits of glacial till and inter-glacial gravel, which is, in turn, underlain by basalt (Carson, 1970; Tabor, 1975). The lower portions of the basin consist of till deposited by the Vashon lobe of the Fraser Glaciation approximately 15,000 years ago. In the valley of the mainstem Skokomish, interglacial gravel interfingers with Holocene fluvial deposits of the Kitsap

Formation. Eocene basalt outcrops in upper portions of the basin, in the gorge. (Stover & Montgomery, 2000).

1.6.2 Local Geology

The site is located adjacent to the Skokomish River in a broad, (approximately ¾-mile wide) flat river valley about 5 miles southwest of the river's delta as it enters the Hood Canal. Geologic mapping for the site was obtained from the *Geologic Map of the Skokomish Valley and Union 7.5-minute Quadrangles, Mason County, Washington* (Polenz et al. 2010). Near-surface geology at the site is mapped as Quaternary age alluvium (Qa). Alluvium at the site typically consists of loose to medium dense, silty sand with gravel (Mason County 2014). Hills above the river valley (to the north and south) are generally mapped as glacial till (Qgt) with various ice contact deposits mapped between the upland glacial till and lowland alluvium. Occasional peat (Qp) zones are mapped in the valley, although not in the vicinity of the explorations for this study.

1.6.3 Subsurface Explorations

The subsurface exploration program for the project consisted of borings, test pits, and a hand auger along and near the proposed wetland embankment alignment. Additional explorations were performed in the area to inform a hazardous, toxic, and radioactive waste (HTRW) investigation. The subsurface explorations and testing for the Skokomish GI project site were performed in July of 2014 by Landau Associates, Olympia, Washington under contract to Mason County. The final geotechnical report can be found in Annex B-1. The Corps utilized the soil and geotechnical analytical laboratory analyses in these reports for the development of the new wetland embankment design.

1.6.4 Laboratory Testing

Geotechnical analytical laboratory testing performed on soil samples collected during the subsurface exploration program included visual classification, moisture content determinations, grain size analyses, hydrometer analyses, fines content determinations, Atterberg limits tests, organic content, and consolidation tests. The laboratory tests were conducted to evaluate index and engineering properties of the soils. Laboratory testing results can be found in Annex B-1: Geotechnical Exploration Report.

1.6.5 Soil Conditions

In general, subsurface conditions within the project area are consistent with the geologic history of the area. Based on site reconnaissance, review of information from previous geotechnical studies, and recent exploration and laboratory test programs, we conclude that to the depth of interest for the proposed work, the project sites are underlain varying layers of alluvium. Typically, for the wetland embankments, a layer of silt to silty sand overlies more coarse grained alluvial deposits of poorly graded sand or well graded gravels. Soil profiles can be inferred from sheets B-201 and B-202 in the plan set (Annex A).

The soil parameters were determined from exploration data, laboratory data, empirical relationships, and experience with similar soil types of the region. Soil design parameters listed in Table 1-2 were used for the Wetland Embankment design.

Table 1-2. Soil Parameters

Soil Type (USCS)	Unit Weight (γ, pcf)	Friction Angle (ϕ, degrees)	Cohesion (c, psf)	Hydraulic Conductivity (K, cm/s)
ML	110	30	0	5.00E-05
SM	115	32	0	1.00E-04
SP-SM	120	34	0	1.00E-02
SP	120	34	0	5.00E-02
GW/GP	120	34	0	5.00E-01

1.6.6 Proposed Wetland Embankment Fill

For wetland embankment fill, the following soil specifications are recommended as a typical levee gradation used for Northwest levee construction: USCS soil classification of SP-SM or SM, free of organics and debris, with LL<50, and a gradation meeting the following specifications in Table 1-3.

Table 1-3. Typical Wetland Embankment Fill Gradation

Sieve Designation	Percent Passing
3 inch	90-100
1 inch	70-95
½ inch	60-90
No. 4	50-85
No. 40	20-55
No. 200	10-20

Based on initial quantity calculations, the required fill for the wetland embankments will total approximately 42,500 CY. To account for losses and loose to compact soil state, these neat line quantities should be increased by 15 percent. Therefore, a total of approximately 50,000 loose CY are anticipated to be necessary to complete the construction of the wetland embankments.

Mason County has identified two nearby sources for potential borrow sources. First, approximately 40,000 loose CY of potential borrow material is stockpiled approximately 7 miles away from the proposed project sites. The source of the spoil is a roadside slope re-grade near US-101. Additional material from future WSDOT slope re-grades will be stockpiled for these purposes. The second source is a potential borrow source from the hill south of the Skokomish Valley. Site soils are of the Grove series classified as gravelly sandy loam (SM) by NRCS.

Samples from the boring logs also showed that soils in the vicinity of the project either exhibited too high of a fines content, exceeding 30 percent passing the number 200 sieve, or too coarse (<5% fines) for ideal levee construction. In addition, surface soils exhibit organic content and a high ground water table prevents deeper soils from being used because water content is much higher than expected optimum for proper compaction. Blending soil sources or creating a zoned embankment with adjacent borrow sources are considered to be less cost effective.

The degrade of the existing confluence levee may also provide a potential borrow source for material. The levee material is not overly saturated, but much of the surficial soil will need to be grubbed for

vegetation and organics. In addition, 5 grain size distribution tests were performed on hand auger samples recovered from the confluence levee. Only one of those samples exhibited desirable soil properties for levee fill.

Wetland embankment construction will consist of a maximum 8" lift of soil compacted to 95% of maximum with vibratory compaction methods consistent with the coarse grained fill. With the aforementioned soil type, gradation, and compaction assumptions, the constructed soil properties used for design analysis can be found in Table 1-4.

Table 1-4. Soil Parameters for Typical Wetland Embankment Fill

Soil Type (USCS)	Unit Weight (γ, pcf)	Friction Angle (φ, degrees)	Cohesion (c, psf)	Hydraulic Conductivity (K, cm/s)
Embankment Fill (SM)	120	35	0	5.00E-04

1.6.7 Disposal Sites

No specific disposal site has been identified at this stage in the design. For cost estimating purposes, all spoil is assumed to be disposed of off-site. However, some excess spoil may be found to have re-use potential on other projects. Spoil from the removal of the Confluence Levee may potentially be used for wetland embankment fill at the wetland restoration sites or for ballast of the bar apex LWD structures. Over excavation for foundation preparation of the wetland embankments may provide suitable material for top soil to cover wetland embankment slopes. Import material may need to be blended to provide suitable top soil mix.

1.6.8 Rock Sources for Erosion Protection

For wetland embankment locations requiring riprap armor, the following quarries are potential sources for materials. Potential quarries and the one-way haul distances to the project sites are listed in Table 1-5 below for cost estimating purposes only.

Table 1-5. Quarry Sites

Quarry	Haul Distance (Miles)
Little Creek Quarry	15
Kennedy Creek Quarry	17.5

Rock quality assessments have not been made on these potential sources. This is recommended during a later design phase.

1.6.9 Filter Blanket for Riprap Blankets

All instances of riprap protection for overtopping or riverward erosion protection will have a minimum 1-foot filter blanket beneath the riprap armor. This filter blanket will be designed in accordance with EM 1110-2-1901: Filter Design, Change 2 (USACE, 2005) based on the future selection of a levee fill material.

1.6.10 Groundwater Studies

A study entitled, "Miscellaneous Planning Studies: Skokomish River Diking Inventory" dated April 2001 and prepared by HDR Engineering, Inc. notes typical groundwater trends. "The groundwater table in the valley has been reported to be rising over the last thirty years. The groundwater level in the upper valley [upstream of Skokomish Community Church near RM 8.25] is typically 0.5 to 3.0 feet below grade." (12). During high water, the groundwater has been seen percolating from old river channels. The report continues, "current groundwater flows are away from the river and run with a light silty mud present in the water" (12).

Typical groundwater depths during the July 2014 geotechnical exploration were measured from 2.9 to 6.6 feet below ground surface. The groundwater surface was not encountered in a common water bearing stratum. Groundwater levels during these explorations can be found on the boring logs in Annex B-1.

1.6.11 Wetland Embankment Underseepage Analysis

Underseepage and seepage through the three representative wetland embankment cross sections were estimated using methods presented in USACE manuals (EM 1110-2-1913, April 30, 2000; EM 1110-2-1901, February, 2005). This analysis was accomplished using the finite element modeling program, Seep/W.

Much of the wetland embankment foundation is stratified with higher fines content soils (ML, SM) in the upper 5-10 feet with coarse grained soils (SP-SM, SP, GP, GW) in the lower foundation. Hydraulic conductivity estimates were attained through grain-size analyses using correlations and empirical equations, such as Hazen equation, as well as typical values based on soil classification. In-situ permeability testing was not completed during the reconnaissance geotechnical exploration. Prolonged seepage conditions could cause piping of the silty sand wetland embankment material. However, seepage analysis illustrates that the exit gradients experienced at the landward toe of the wetland embankment under design flood steady state seepage conditions are not conducive to seepage or piping. Maximum average exit gradients experienced at the landward toe of the wetland embankment were less than 0.3. Therefore, no seepage mitigation is recommended for the design. Foundation soils of minimal fines content such as the gravelly soils encountered beneath the upstream portion of the wetland embankment at River Mile 9 are anticipated to experience high underseepage quantities resulting in ponding landward of the wetland embankment structure similar to conditions that presently exist.

1.6.12 Wetland Embankment Slope Stability Analysis

Global stability analyses were performed for static and steady state seepage loading conditions. Slope stability of the proposed Wetland Embankment was evaluated at representative sections along the wetland embankment alignments in accordance with USACE Design and Construction of Levees, Section 6-5 (USACE, 2000). This analysis was accomplished using the limit equilibrium modeling program, Slope/W. The Factors of Safety reported are calculated using the Spencer method which satisfies both moment and force equilibrium, and considers both shear and normal interslice forces. The following loading conditions were analyzed:

1) **End of construction (Static).** End of construction analysis did not account for significant development of pore pressures in the shallow embankment soils. Foundation soils are relatively permeable and deposited in relatively thin strata. A static slope stability utilizing piezometric surface equivalent to the groundwater table at the time of the soil exploration and effective strengths of soils were used. This assumption can be confirmed in later design phases when time rate of consolidation is explored and construction phases are determined. The minimum required FS is 1.3 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).
2) **Steady-state**. This condition represents the long-term stability where the water level on the wetland embankment is at the design high water level. Effective soil strength parameters were used for the foundation soils. Pore pressures were imported from the steady state seepage model for use in this stability model. This condition is applicable to the landside slope, the minimum required FS is 1.4 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).
3) **Rapid drawdown.** The rapid drawdown loading condition was not analyzed. Based on indications of available wetland embankment fill sources and design permeability, the wetland embankment soils will be relatively permeable and not develop significant excess pore water pressures along the riverward slope. This assumption can be confirmed at a later design phase.

1.6.13 Wetland Embankment Settlement Analysis

For this level of design, one-dimensional consolidation theory was applied for the calculation of settlement. Consolidation settlement parameters are based on laboratory one-dimensional consolidation testing data. The consolidating layers are soft/loose layers of silt or silty sand with greater than 30 percent fine content by weight. Significant secondary compression is not anticipated due to the absence of highly organic or plastic soils. Atterberg limit testing of the soils indicated that the fines exhibited low plasticity or were non-plastic. Coefficient of consolidation and recompression were calculated based on the one-dimensional consolidation laboratory testing implementing typical Casagrande construction methods to determine the pre-consolidation stress. Five consolidation tests were completed with calculated coefficients in Table 1-6 below.

Table 1-6. One-Dimensional Consolidation Test Results

Boring	Sample	Depth (ft bgs.)	USCS	OCR	C_{CE}	C_{RE}
BH-02C	S-1	2.5	ML	5.0	.176	.008
BH-05R	S-4	12.5	SM	1.3	.116	-
BH-07R	S-1	2.5	ML	- Test Not Used -		
BH-08	S-3	7.5	ML	1.2	0.07	-
BH-10	S-3	6.5	SM	- Test Not Used -		

Normal pressure vs. strain curves from the one-dimensional consolidation tests for BH-07R and BH-10 exhibited significant sample disturbance and were not used for design. Over-consolidation ratios for soils ranged from 1.0 to 1.3; therefore, these alluvial deposits are classified as normally-consolidated. The sample from BH-02C taken at 2.5 feet exhibited over-consolidated behavior, but this can be

attributed to sample disturbance or from matric suction induced by fluctuating groundwater levels. Based on primary consolidation calculations, settlement was anticipated to range from 4-8 inches.

Due to the anticipated permeability of the silt and silty sand layers, much of this settlement may occur during the construction phase. Additional time rate of consolidation estimates will occur during subsequent design phases. For design, 6 inches of overbuild was prescribed to mitigate settlement with station 35+00 to 45+00 of the wetland embankment at River Mile 9 being increased by 9 inches due to the presence of a 10-foot thick layer of soft to very soft silt in the foundation.

1.6.14 Earthquake Studies

The Skokomish River Valley has a seismic site classification of D to E based on Washington State Department of Natural Resources Liquefaction Susceptibility and Site Class Maps of Washington State, by County (2004). The DNR maps also classified the liquefaction susceptibility of the river valley as moderate to high.

Earthquake loadings are not normally considered in analyzing the stability of levees because of the low risk associated with an earthquake coinciding with periods of high water. The severity of the expected earthquake and the consequences of levee failure are considered. The saturated loose silts and silty sands composing the levee foundation have liquefaction potential, but seismic design is not anticipated for this site based on low coincident loading probability and low expected consequences.

2 Confluence Levee Removal (Annex A, Sheets C-110 through C-115)

2.1 Site Description

The Confluence Levee removal removes approximately 5,400 lineal feet of levee including enlarging an existing breach to 300 lineal feet. The levee removal includes approximately 1,625 lineal feet on the left bank and 3,775 lineal feet on the right bank. This work requires 15,058 CY of material excavation. Estimates from satellite imagery include 61 trees (smaller than 12" DBH) and 57 trees (greater than 12" DBH) removed.

2.2 Hydraulic Design

In the vicinity of the North Fork/South Fork confluence, riverbed aggradation in the South Fork and the avulsion of the North Fork has led to dry channel conditions developing in the South Fork during the late summer/early fall time period. The dry channel stops the upstream migration of salmon returning to the South Fork. This measure addresses that problem by removing the Confluence levee and diverting the South Fork into the North Fork near the pre-2003 confluence. The combined discharges would provide a continuous low flow channel into what is now the North Fork channel. The reach of the South Fork that goes dry in the late-summer/early-fall would be abandoned during those low flow periods. This measure would have little effect on flooding since the existing South Fork channel would be available to convey flood discharges and both sides of the river frequently flood in this location already.

Since the 2003 North Fork avulsion, which shifted the confluence downstream about 1.5 miles, the Confluence levee has been a barrier between the North and South Fork channels. The Confluence levee is located at and downstream from the old confluence near RM 9. Aggradation in the South Fork channel has raised much of the riverbed to elevations above the North Fork at the old confluence, but the levee limits the flow diversions to the North Fork.

About 5,400 feet of the Confluence Levee, approximately 15,058 CY, would be removed. A small channel would be established to direct the South Fork flows into the current North Fork channel. The South Fork's bedload would be diverted to the combined channel after levee removal. Little deposition has been observed in the current North Fork channel. The river channels would then be permitted to naturally evolve over time. The new connection would allow upstream migrating salmon to bypass the reach of the channel that typically goes dry in the late summer. This action would have little impact on flooding, as the North Fork floodplain near the confluence is presently heavily inundated by the South Fork flood flows.

Deposition in the initial combined north/south forks channel is expected to be around 0.1 ft/year, which is similar to that in the existing south fork channel. Over time the channel is expected to aggrade and meander across the 1000-2000 ft wide northern floodplain. Spreading deposition across the northern floodplain would reduce the initial deposition rate, resulting in a long term deposition rate of about 0.02 ft/year (or about 1 ft during the 50 year project life). This would result in an active riverbed 2-4 ft lower than the existing south fork channel at the end of the 50 year period. Only minimal O&M is expected to be required because 1 foot, or even 2 feet, of sediment accumulation will not cause the river to move away from the northern floodplain as the existing South Fork riverbed will remain 2-4 ft above the new channel. Estimated sedimentation downstream of the diversion is further explained in the Skokomish River Car Body Sedimentation annex (H-5).

2.2.1 Design Considerations

The diversion through the old Confluence Levee into the North Fork was designed to pass all flow up to a typical winter flow of approximately 2,000 cubic feet per second (cfs). For greater flows than 2,000 cfs the historic south fork channel is reactivated. The diverted flows are expected to do geomorphic work downstream of the diversion for many years after the project as high flows will be split between the existing and new flow paths. The existing terrain will erode and existing vegetation will be altered as a new larger active channel forms there. This process will be allowed to occur naturally. A breach 300 ft wide with a bottom elevation of 53 ft NAVD88 was found to adequately pass the desired flows. This elevation requires excavation below the existing ground at the base of the levee. The area immediate vicinity of the breach will see an increase in water surface for the 0.01 ACE event (USBR, 2014) and is being included in the real estate takings analysis. Seven of the Bar Apex ELJ and twenty-six single logs were placed adjacent to the diversion to assist in keeping low flows in the diverted channel and to prevent the main channel from migrating around the diversion. This wood will encourage recruitment and aid in formation of the newly diverted channel. Concept graphics for placed wood are included in the annex to the Engineering Appendix (H-3). Local scour at log structures was estimated from scour holes at rootwads and logs observed at the site near the confluence. Observed scour ranged from 3-5 ft typically. A value of 5 ft was used in preliminary stability analysis for placed wood.

2.2.2 Risk, Next Steps, and Future Work

As better resolution terrain is acquired the SMS model can be updated and refined to allow better accuracy in modeling diverted flows and activation of the historic south fork channel. The Bar Apex ELJ placements adjacent to the diversion were roughly incorporated in the SMS model geometry as raised grid cells. However the locations and structure size were changed slightly from what was originally modeled to make better use of the structures. This should be corrected and refined to reflect actual placements and the model re-run to verify acceptable split of high flows. Number and placement of ELJ can then be further refined as necessary. The opportunity exists to move some of the ELJ's to the downstream side of the diversion to improve the habitat quality. This should be explored with the sponsor and is an opportunity to include persistent large wood in the area that otherwise would evolve into an unstable braided channel section with no large wood. The area presently does not have any large trees. Alternately loose wood could be introduced downstream of the diversion and allowed to migrate as the new channel area forms. Estimated local scour depths at placed wood will need further investigation based upon refined hydraulic modeling from better resolution terrain data, and anchoring methods updated to reflect estimations. No future sediment modeling is planned or suggested for this area unless the design changes significantly, in which case we will need to re-evaluate.

2.3 Civil Design

2.3.1 Breach

The work includes enlarging an existing breach to 200 LF long and 70 feet wide to elevation 53 feet NAVD 88 with 3 horizontal to 1 vertical side slopes. This work requires 4,715 CY of material excavation.

2.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans and will require crossing the South Fork Skokomish River. Temporary culverts and water diversion are necessary in these areas. The Confluence Levee Removal and wetland embankment at River Mile 9 share the staging area at the primary access point.

2.3.2 Construction Methodology

Construction would be in the drier summer months when the South Fork of the Skokomish River is low to facilitate access. The construction methodology is to field stake the excavation limits and walk the site with the project biologist to identify any trees to save, and any areas to modify. The area would then be cleared, and levee removed to the design profile. The excavated materials would be removed off-site. Construction of the breach may require a temporary cofferdam along the length of the north side of the breach north fork of Skokomish River.

2.3.3 Survey/GIS/Topography

The 2014 field cross section data was used for most of this evaluation. The first 1,000 feet of levee was not accessible because right-of-entry could not be obtained. This first 1,000 feet of levee removal was estimated using the 2002 Lidar information shown on the cross sections. This depicts a slightly more continuous levee than the 1994 photogrammetric topography, however, still indicates the levee may

not be continuous. For estimating purposes, the first 1,000 feet was estimated using averages from the remaining left bank work.

2.3.4 Risk, Next Steps, and Future Work

During PED, the design catch point will be field staked and the project walked to determine any modifications needed for final plans and specifications. Modifications may be a change in levee removal elevation, omitting areas where the removal of trees and habitat will be more disruptive than removing the levee.

2.4 Geotechnical Design

The Confluence Levee removal involves removal of approximately 15,058 CY of soil. Based on hand auger explorations and minimal grain size analysis, the USCS classification of the levee fill includes SM, SP-SM, SP, GP-GM, and GM. Excavation of slopes for the removal of the Confluence will not exceed a 2H:1V slope to ensure stability of the slopes during levee removal.

2.5 Planting Plan

A planting plan has been developed for the Confluence Levee Removal site. Approximately 3.6 acres will be cleared for the Confluence levee removal with a total work area limit of 7.7 acres. It is assumed that approximately 4 acres will need to be replanted with the following planting considerations:

- 100% of area will have conifers 15' on center (O.C.)
- 100% of area will have shrubs 6' O.C.
- 100% of area will have bark mulch 6" deep

For trees, a 1-gallon size is assumed with sourcing of bare-root plants for cost savings. Bare-root trees are planted in March/April versus potted trees that are planted in fall, so this would require a second, separate planting effort outside normal construction time, after main construction is complete. Finally, Because of the Japanese knotweed present, this site will need approx 10 years of invasive species removal and maintenance.

3 Wetland Restoration at River Mile 9 (Annex A, Sheets C-120 through C-124)

3.1 Site Description

The new wetland embankment at River Mile 9 from RM 8.3 to 9.2 is expected to be approximately 2 feet in height. The total length of the wetland embankment is approximately 4,370 linear feet. The wetland embankment crest width is 12 feet wide with 2H:1V riverward slopes and 6H:1V landward slopes to allow for overtopping flows. A planting berm will be placed at the riverward toe of the wetland embankment to allow for planting of native vegetation. The entire wetland embankment is designed for shallow overtopping similar to present conditions.

3.2 Hydraulic Design

The Wetland Restoration at River Mile 9, from RM 8.3-9.2, is intended to reconnect and restore high quality wetland habitat. The wetland embankment would be constructed landward (south) varying distances, generally around 200-300 ft, from the existing agricultural berm. This places more riparian forest and floodplain ponds on the riverward side of the wetland embankment. Four strategically located sections totaling approximately 950 ft section of the existing agricultural berm would be removed. These breaches would allow flood waters to flow freely within the wetland restoration area, providing salmon access to the riparian habitat. Breaches are located at existing ground elevations to allow the area to drain with receding flows to prevent stranding. From west to east the breaches were given elevations of 60, 57, 56, and 51 ft NAVD88 respectively. The new wetland embankment would generally be lower than the existing agricultural berm. There are a variety of reasons for this, including increasing the channel width significantly. The wetland embankment was designed for incipient overtopping at 6,000 cfs with a 6H:1V backslope.

3.2.1 Design Considerations

The wetland embankment was designed to improve hydraulic conditions in the reconnected wetland area. These structures will not significantly change the existing flooding conditions in the study area. While the system is aggrading in the area of the confluence between the North and South Forks of the Skokomish River, the majority of bedload is expected to pass through the diversion in the Confluence levee and bypass the wetland embankment setback area. Deposition in the section of the river adjacent to the wetland embankment at River Mile 9 will be reduced significantly and is expected to consist mostly of sediments finer than gravel, if any. Fine material makes up a small percentage of what has been observed in this area of the system. Material finer than 2 mm (very coarse sand) makes up 2% of the measured surface gradation at the confluence area, and the medium gravel component is less than 5%. Significant deposits of material smaller than medium gravel are typically not found in this area of the system (USACE, 2011). Preliminary sediment analysis using the 2d clear water SMS model indicated that hydraulic parameters typically exceed what is needed to transport sand and gravel. This analysis is presented in Annex H-2. The Shields number (i.e. critical transport parameter) was analyzed with hydraulic conditions from the model to predict transport for sand through medium gravel particles that are likely to reach the re-connected wetland areas. The full range of sand particles are transported and medium gravel is transported at depths over a foot. The small percentages of these sediments that do exist are likely to be transported farther downstream. As a result of this analysis, no overbuild for future deposition was specified for the embankments and is not expected to be needed. The risk of this affecting the cost contingency (which is 35% for each embankment) was found to be low. No significant change in the 0.01 ACE water surface is expected at the site. Rip rap was necessary at 3 locations on the wetland embankment face due to proximity and orientation to the main channel and estimated velocity of 4-6 ft/s at the wetland embankment face. Class 2 rock was found to be adequate from the methods provided in EM 1110-2-1601 for sizing rip rap. These methods are employed in the software application SAMwin 1.0 which was used for analysis. Results are presented in Annex H-2. The remainder of the wetland embankment is vegetated on the riverward and landward sides.

3.2.2 Risk, Next Steps, and Future Work

Due to the preliminary nature of the location of the wetland embankment, it may be reconfigured at later design phases. The 2D hydraulic modeling (SMS 11.1) would need to be reconfigured for any significant changes and re-run to estimate overtopping characteristics. The existing agricultural berm overtops between 6,000 cfs and a 0.5 ACE event (likely toward the lower end). The difference between these events is in the 0.5-2 ft range along the new embankment. Annual flows should be developed and run in the SMS model to refine overtopping estimates and flood extents. High performance turf reinforcement mats (HPTRM's) or biorevetments can be investigated during future engineering and design as a viable alternative to rip rap. The wetland embankment design will need to be finalized for adequate superiority for controlled overtopping consistent with ETL 1110-2-299. The sedimentation analysis described above will need to be checked for adequate transport of sand and gravel once the 2D clear water model is improved with better terrain. The improved accuracy will support the level of analysis.

3.3 Civil Design

The area includes approximately 4,370 lineal feet of new wetland embankment with a planting berm. This work requires 6,255 CY of wetland embankment material, 2,050 CY of planting berm material, 705 CY of topsoil, 2,125 CY of stripping, 662 CY of wearing course, 115 CY of riprap and 85 CY of filter material.

3.3.1 Breach

The work includes 4 breaches, 70 feet wide (totaling 935 lineal feet) of the existing agricultural berm, totaling 7,935 CY of excavation. Two areas adjacent to the proposed breaches of the agricultural berm will require erosion protection on the riverside. These are shown on the plans.

- 100' long x 70' wide, elevation 60 NAVD 88
- 180' long x 70' wide, elevation 57 NAVD 88
- 290' long x 70' wide, elevation 56 NAVD 88
- 365' long x 70' wide, elevation 51 NAVD 88

3.3.2 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans. The Confluence Levee Removal and Wetland Restoration at River Mile 9 share the staging area at the primary access point.

3.3.3 Construction Methodology

Construction would be in the drier summer months to facilitate access and construction. The area would then be cleared, and the Wetland Embankment constructed to the design profile. Some excavated materials would be used to construct the planting berm, with any excess material removed off-site.

3.3.4 Survey/GIS/Topography

The 1994 photogrammetric topography was used here, supplemented by 2014 utility information.

3.3.5 Risk, Next Steps, and Future Work

There are two areas close to the breaches that are treated with riprap for erosion protection. These areas and the tie-in require additional refinements during PED.

3.4 Geotechnical Design

The wetland embankment at River Mile 9 is approximately 4,370 linear feet in length and varies in height along its alignment from 4-6 feet in height. The wetland embankment was designed for overtopping and incorporates a sod covered 6H:1V landside slope to protect against shallow overtopping for short durations.

3.4.1 Subsurface Explorations and Soil Classification

Subsurface explorations were completed at approximately 1000 linear foot intervals along the proposed wetland embankment setback alignment except where significant vegetation removal would be required. The upstream portion of this wetland embankment was defined by boring BH-01, which indicated a coarse grained foundation consisting of well graded gravel for nearly the entire depth of the boring. The remaining portion of the wetland embankment portrayed a low plasticity silt (ML) confining layer underlain by varying layers of more coarse grained alluvial deposits. No specific depositional layering was evident in these random alluvial deposits. The wetland embankment foundation consists of three distinct layers of varying thickness. First, the upper confining layer is a silty sand (SM) to silt (ML) confining layer ranging from 5-10 feet in thickness. Atterberg limit testing indicates low plasiticity with a maximum PI of 11 (BH-09R). The underlying layer includes 10-20 feet of poorly graded sands (SP or SP-SM) with varying percentages of fines. The final layer evident in borings BH-09, BH-10, and BH-07R at the downstream end of the wetland embankment is a permeable well graded gravel layer of 7-15 foot thickness.

3.4.2 Design Considerations

Wetland embankment design indicates that a typical section with 2H:1V riverside and 6H:1V landside slopes and 12-foot crown width would be sufficient to meet seepage and stability design criteria. Additional design criteria details are listed in the following sections. The landside slope was developed to allow for shallow and short duration overtopping.

3.4.3 Seepage

Seepage results for the typical 2H:1V riverside and 6H:1V landside computed for the wetland embankment at River Mile 9 were attained for two varying foundations at the upstream end and downstream end of the wetland embankment. First, a typical wetland embankment section at station 2+00 was used to represent the upstream coarse grained foundation conditions. (See Figure B-3 of Annex B-3). Second, a typical wetland embankment section at station 25+00 was selected to represent the critically thin silt confining layer and represent the critical condition for underseepage and piping for the downstream portion of the wetland embankment. (See Figure B-6 of Annex B-3). For the gravel foundation section, the average vertical exit gradient taken over two feet below the landward toe of the wetland embankment is equal to 0.05. Assuming a unit weight of 120 pcf for the gravel layer, the factor of safety against seepage is equal to 18.5. For the silt foundation section, the average vertical exit

gradient taken over two feet below the landward toe of the wetland embankment is equal to 0.27. Assuming a unit weight of 110 pcf for the confining silt layer, the factor of safety against seepage is equal to 2.8. No additional seepage mitigation measures are recommended at this design phase. However, gravelly soils with limited fines content encountered beneath the upstream portion of the wetland embankment at River Mile 9 are anticipated to experience high underseepage quantities resulting in ponding landward of the wetland embankment structure similar to conditions that presently exist.

3.4.4 Slope Stability

Slope Stability results for the typical 2H:1V riverside and 6H:1V landside slope indicate the wetland embankment design meets required factors of safety for loading conditions. The stability analysis of the landward slope was designed to meet a 1.4 factor of safety for long term steady state seepage and 1.3 for static loading. (See Figures B-1, B-2, B-4, and B-5 of Annex B-3).

3.4.5 Settlement

Based on available soil information and one-dimensional consolidation test data, settlement for the wetland embankment at River Mile 9 is estimated to be less than 6 inches except at the upstream and downstream ends of the wetland embankment. At the upstream end of the wetland embankment, only coarse grained soils exist that would experience negligible settlement during construction. A consolidation test for the very soft silt layer in BH-02 (Station 10+00) indicated a steep modified compression index (C_{CE}). Although the laboratory testing of the sample indicates a significant degree of overconsolidation, the recent alluvial deposit was conservatively estimated to be normally consolidated. When this compression index is applied to a thick layer of soft silt near station 35+00, computed settlement increased to approximately 9 inches. Settlement predictions for the wetland embankment at River Mile 9 are listed by project station in Table 3-1 below.

Table 3-1. Predicted Total Primary Settlement

Station	Expected Settlement (inches)
0+00	0
10+00	4.5
24+00	4.5
35+00	9
45+00	9

Time rate of consolidation analysis will be performed at a later time. Initial correlations based on liquid limit (LL) indicate that 90% settlement would be reached within 75 days of the full load being applied.

3.4.6 Transition to Existing Agricultural Berms

The wetland embankment will need to tie in to the existing agricultural berms at the upstream and downstream end of the proposed alignment. The existing agricultural berm is of unknown construction and materials and has a significantly narrower section that is not designed for overtopping. The existing agricultural berms will not be improved because the project goal is for environmental restoration. The agricultural berms are currently at risk of overtopping breach and potentially other geotechnical failure

modes prior to breach. A goal of this project is to not increase the likelihood of overtopping upstream or downstream. The wetland embankment is expected to have no change to performance and level of protection.

3.4.7 Wet Weather Considerations

In the Puget Sound region, wet weather generally begins about mid-October and continues through about May, although rainy periods could occur at any time of the year. Thus, it would be advisable to schedule earthwork during the drier weather months of June through September. Soil with fines contents higher than 5 to 8 percent is highly susceptible to changes in water content and tends to become unstable and difficult or impossible to compact if the moisture content significantly exceeds the optimum. During wet weather months, the groundwater levels could increase, resulting in seepage into site excavations. Performing earthwork during dry weather would reduce these problems and costs associated with rainwater, trafficability, and handling of wet soil. Placing and compacting fill for the new Wetland Embankment may not be practicable during wet weather.

3.4.8 Wetland Embankment Planting Plan

The wetland embankment is designed with a vegetation planting plan. The minimum wetland embankment prism as described above will be planted with only sod cover. For ecological benefits, the riverside slope of the wetland embankment will be overbuilt with agricultural berm breach spoils to form a planting berm of approximate dimensions of 7 feet wide and 3.5 feet in height. (See Annex B-6). This berm will be planted with tree species with mature heights of 10 – 20 feet. Assumptions were made that trees would be planted a maximum of 2 feet from the hinge point of the planting berm (5 feet from the catch point of the wetland embankment section). If plantings can be placed within the slope of the planting berm or closer to the hinge point on the berm crest, the amount of spoil required for construction could be reduced.

3.4.9 Risk, Next Steps, and Future Work

Time rate of consolidation analysis is planned for the next engineering design phase. In addition, further exploration into end of construction slope stability loading conditions is recommended. Finally, continued coordination and analysis is required to finalize the preliminary embankment planting plan requirements and the planting berm dimensions.

3.5 Operations and Maintenance

The proposed wetland embankments were designed in accordance with applicable USACE engineering manuals. Operation and maintenance of these structures will be necessary to ensure proper functioning of the wetland embankment structures to maintain ecological benefits at the site. Maintenance zones should extend 15 feet from both the riverward and landward wetland embankment toe. This maintenance zone is visible on the feasibility-level design plan set and should remain free of unwanted vegetation and unauthorized encroachments. Sod cover and riprap maintenance will be necessary to ensure proper functioning of erosion protection; especially at overtopping locations.

At the completion of the Wetland Restoration projects, an operation manual detailing proper maintenance practices will be provided to the local sponsor. The wetland embankment will not be eligible for rehabilitation assistance under the PL84-99 program due to inability to meet the minimum level of protection guidelines.

3.6 Planting Plan

A planting plan has been developed for the Wetland Restoration at River Mile 9 site. The new wetland embankment area will have approximately 5 acres planted with only grass. A planting berm will be constructed from materials excavated from the breached sections of existing agricultural berm at River Mile 9 and potentially from the Confluence Levee. This berm will be approximately 4' to 6' wide and 2' to 3' tall. The berm will be planted with grass and will be planted with one row of short willow species 6' O.C. In addition, the staging area (approximately 14,000 square feet) will be replanted with grass. The breach areas (approximately 2 acres) will also be replanted with grass.

4 Wetland Embankment at Grange (Annex A, Sheets C-130 through C-133)

4.1 Site Description

The new wetland embankment at Grange from RM 7.5 to 8 is expected to be approximately 4 feet in height. The total length of the wetland embankment is approximately 2,750 linear feet. The wetland embankment crest width is 12 feet wide with 2H:1V riverward slopes and 6H:1V landward slopes to allow for overtopping flows. A planting berm will be placed at the riverward toe of the wetland embankment to allow for planting of native vegetation. The entire wetland embankment is designed for shallow overtopping similar to present conditions.

4.2 Hydraulic Design

The wetland restoration at Grange, RM 7.5-8, is intended to reconnect and restore high quality wetland habitat. The wetland embankment would be constructed landward (south) up to 1,200 ft from the existing agricultural berm. This would place about 40 acres of riparian habitat, forest and floodplain ponds, on the riverward side of the wetland embankment. Two strategically selected sections of the existing agricultural berm summing to approximately 800 ft would be breached. These breaches would allow flood waters to flow freely within the restored wetland area, providing salmon access to the riparian habitat. Breaches are located at existing ground elevations to allow the area to drain with receding flows. From west to east the breaches were given elevations of 49 and 44 ft NAVD88 respectively. The new wetland embankment would generally be lower than the existing agricultural berm. There are a variety of reasons for this, including increasing the channel width significantly. The wetland embankment was generally designed for incipient overtopping at 6,000 cfs with a 6H:1V backslope. The exception is a length of wetland embankment between stations 15+00 to 18+00 which was designed with a slightly higher crest in the vicinity of homes.

4.2.1 Design Considerations

The wetland embankment was designed to improve hydraulic conditions in the reconnected wetland area. These structures will not change the existing flooding conditions in the study area. While the system is aggrading in the area of the confluence between the North and South Forks of the Skokomish River, the majority of bedload is expected to pass through the diversion in the Confluence Levee and bypass the wetland embankment setback area. Deposition in the section of the river adjacent to the wetland embankment at Grange will be reduced significantly and is expected to consist mostly of sediments finer than gravel, if any. Fine material makes up a small percentage of what has been observed in this area of the system. Material finer than 2 mm (very coarse sand) makes up 2% of the measured surface gradation at the confluence area, and the medium gravel component is less than 5%. Significant deposits of material smaller than medium gravel are typically not found in this area of the system (USACE, 2011). Preliminary sediment analysis using the 2d clear water SMS model indicated that hydraulic parameters typically exceed what is needed to transport sand and gravel. This analysis is presented in Annex H-2. The Shields number (i.e., critical transport parameter) was analyzed with hydraulic conditions from the model to predict transport for sand through medium gravel particles that are likely to reach the re-connected wetland areas. The full range of sand particles are transported and medium gravel is transported at depths over 2 feet. The small percentages of these sediments that do exist are likely to be transported farther downstream. As a result of this analysis, no overbuild for future deposition was specified for the embankments and is not expected to be needed. The risk of this affecting the cost contingency was found to be low. No significant change in the 0.01 ACE water surface is expected at the site. Rip rap was necessary near the west end due to proximity to the main channel and estimated velocity of 4-6 ft/s at the wetland embankment face. Class 2 rock was found to be adequate from the methods provided in EM 1110-2-1601 for sizing rip rap. These methods are employed in the software application SAMwin 1.0 which was used for analysis. Results are presented in Annex H-2. Rip rap is used from STA 21-26 on the face, and on both sides where overtopping occurs from STA 15-18 on a 3H:1V slope. The remainder of the wetland embankment is vegetated with a 6H:1V backslope.

4.2.2 Risk, Next Steps, and Future Work

Due to the preliminary nature of the location the wetland embankment may be reconfigured at later design phases. The hydraulic modeling (SMS 11.1) would need to be reconfigured for any significant changes and re-run to estimate overtopping characteristics. The existing agricultural berm overtops between 6,000 cfs and a 0.5 ACE event (likely toward the lower end). The difference between these events is in the 1-2.5 ft range along the new embankment. Annual flows should be developed and run in the SMS model during PED to refine overtopping estimates and flood extents. High performance turf reinforcement mats (HPTRM's) or biorevetments can be investigated during future engineering and design phases as a viable alternative to rip rap. The wetland embankment design will need to be finalized for adequate superiority for controlled overtopping consistent with ETL 1110-2-299. The sedimentation analysis described above will need to be checked for adequate transport of sand and gravel once the 2D clear water model is improved with better terrain. The improved accuracy will support the level of analysis.

4.3 Civil Design

The area includes approximately 2,750 lineal feet of new wetland embankment with a planting berm. This work requires 10,530 CY of wetland embankment material, 1,500 CY of planting berm material, 550 CY of topsoil and 1,955 CY of stripping, 440 CY of wearing course, 1,130 CY riprap and 785 CY filter material.

4.3.1 Breach

The work includes 2 breaches, 40 feet wide (totaling 880 lineal feet) of the existing agricultural berm, totaling 3,789 CY of excavation.

- 280' long x 40' wide, elevation 49 NAVD 88
- 600' long x 40' wide, elevation 44 NAVD 88

4.3.2 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans. The staging area is sited near beginning and the end of the Wetland Embankment at Grange. These will be refined during final plans and specifications.

4.3.3 Construction Methodology

Construction would be in the drier summer months to facilitate access and construction. The area would then be cleared, and Wetland Embankment constructed to the design profile. Some excavated materials would be used to construct the planting berm, with any excess material removed off-site.

4.3.4 Survey/GIS/Topography

The 1994 photogrametric topography was used here, supplemented by 2014 utility information.

4.3.5 Risk, Next Steps, and Future Work

Portions of the alignment are in dense brush resulting in inaccurate survey information. Comparison with the 2002 LIDAR indicates the 1994 photogrametric information is probably more reliable. Rights of entry could not be obtained to update the topographic information. Should this feature be carried into PED updated topographic data is required.

4.4 Geotechnical Design

The wetland embankment at Grange is approximately 2,750 linear foot long with a height ranging from 5 to 10 feet in height. The wetland embankment was designed for overtopping and incorporates a sod covered 6H:1V landside slope to protect against shallow overtopping for short durations. The wetland embankment section adjacent to homes was overbuilt 1.5 feet to provide structure superiority and encourage incipient overtopping in uninhabited areas. This design consideration is intended to minimize life safety concerns associated with embankment construction near adjacent homes.

4.4.1 Subsurface Explorations and Soil Classification

Due to right of entry issues, the upstream portion of this wetland embankment was not accessible for subsurface explorations. The explorations completed for this design phase began near station 15+00 and

continued downstream. The wetland embankment foundation consists of three distinct layers of varying thickness. First, the upper confining layer is a silty sand (SM) to silt (ML) confining layer ranging from 5-10 feet in thickness. Atterberg limit testing indicates low plasiticity with a maximum PI of 11 (BH-09R). The underlying layer includes 10-20 feet of poorly graded sands (SP or SP-SM) with varying percentages of fines. The final layer evident in borings BH-09, BH-10, and BH-07R at the downstream end of the Wetland Embankment is a permeable well graded gravel layer of 7-15 foot thickness.

4.4.2 Design Considerations

Wetland embankment design indicates that a typical wetland embankment section with 2H:1V riverside and 6H:1V landside slopes and 12-foot crown width would be sufficient to meet seepage and stability design criteria. Additional design criteria details are listed in the following sections. The landside slope was developed to allow for shallow and short duration overtopping.

4.4.3 Seepage

Seepage results for the typical 2H:1V riverside and 6H:1V computed for wetland embankment at River Mile 9 are considered applicable for foundation conditions present at the wetland embankment at Grange. (See Figure B-6 of Annex B-3). The atypical overtopping section with a 3H:1V landside slope and riprap armor was analyzed. The average vertical exit gradient taken over two feet below the landward toe of the wetland embankment was equal to 0.17. (See Figure B-9 of Annex B-3). Assuming a unit weight of 115 pcf for the confining silty sand layer, the factor of safety against seepage is equal to 5.0.

4.4.4 Slope Stability

Slope stability results for the typical 2H:1V riverside and 6H:1V landside slope computed for the wetland embankment at River Mile 9 are considered applicable for foundation conditions present at the wetland embankment at Grange. (See Figures B-4 and B-5 of Annex B-3). The atypical overtopping section with a 3H:1V landside slope and riprap armor was analyzed. (See Figures B-7 and B-8 of Annex B-3). Overtopping sections of the wetland embankment at Grange were designed with a 1 foot granular filter blanket and 1.5 foot layer of class II riprap to prevent overtopping erosion and scour damages. The stability analysis of the landward slope was designed to meet a 1.4 factor of safety for long term steady state seepage prior to the addition of the riprap. The riprap erosion protection may be replaced with another overtopping protection measure in later design phases. Therefore, the wetland embankment section was flattened to a 3H:1V slope to remain stable should another method be utilized.

The downstream approximately 1000 linear feet of wetland embankment is overlying very soft silts and very loose silty sands with blow counts of 0 for the upper 5-10 feet below ground surface elevation. If the current alignment is taken forward into preliminary engineering design, this section will need to be evaluated for during and end of construction slope stability. During the next geotechnical exploration phase, a combination of in-situ testing and laboratory testing is recommended to determine undrained shear strengths. Field tests such as vane shear and laboratory undrained triaxial tests on relatively undisturbed samples can be performed. Time rate of consolidation will also be necessary to determine rate of consolidation and impacts to construction sequencing. At this time, significant cost inflation for end of construction slope stability mitigation measures is considered unlikely.

4.4.5 Settlement

Based on available soil information and one-dimensional consolidation test data, settlement for the wetland embankment at Grange is estimated to be less than 6 inches. Time rate of consolidation analysis will be performed at a later time. Initial correlations based on liquid limit (LL) indicate that 90% settlement would be reached within 75 days of the full load being applied. Pore pressure monitoring using piezometers and settlement plates may be required during construction if a staged construction is determined to be necessary. Pore pressure dissipation may control the construction staging intervals.

4.4.6 Transition to Existing Agricultural Berms

The wetland embankment will need to tie in to the existing agricultural berms at the upstream and downstream end of the proposed setback alignment. The existing agricultural berm is of unknown construction and materials and has a significantly narrower section that is not designed for overtopping. The existing agricultural berms will not be improved because the project goal is for environmental restoration. The existing agricultural berms are currently at risk of overtopping breach and potentially other geotechnical failure modes prior to breach. This project is designed to have no change in the flooding conditions in the study area.

4.4.7 Wet Weather Considerations

In the Puget Sound region, wet weather generally begins about mid-October and continues through about May, although rainy periods could occur at any time of the year. Thus, it would be advisable to schedule earthwork during the drier weather months of June through September. Soil with fines contents higher than 5 to 8 percent is highly susceptible to changes in water content and tends to become unstable and difficult or impossible to compact if the moisture content significantly exceeds the optimum. During wet weather months, the groundwater levels could increase, resulting in seepage into site excavations. Performing earthwork during dry weather would reduce these problems and costs associated with rainwater, trafficability, and handling of wet soil. Placing and compacting fill for the new Wetland embankment may not be practicable during wet weather.

4.4.8 Wetland Embankment Planting Plan

The wetland embankment is designed with a vegetation planning plan. The minimum wetland embankment prism as described above will be planted with only sod cover. For ecological benefits, the riverside slope of the wetland embankment will be overbuilt with agricultural berm breach spoils to form a planting berm of approximate dimensions of 7 feet wide and 3.5 feet in height. (See Annex B-6). This berm will be planted with tree species with mature heights of 10 – 20 feet. Assumptions were made that trees would be planted a maximum of 2 feet from the hinge point of the planting berm (5 feet from the catch point of the wetland embankment section). If plantings can be placed within the slope of the planting berm or closer to the hinge point on the berm crest, the amount of spoil required for construction could be reduced.

4.4.9 Risk, Next Steps, and Future Work

A significant portion of the proposed wetland embankment alignment subsurface was not able to be explored due to inability to acquire rights of entry. Additional subsurface exploration will be required to characterize the foundation soils along the proposed alignment, especially in locations where the

wetland embankment section will be constructed within existing saturated low land areas. These locations may require additional stability or settlement mitigation due to the presence of soft soils.

Additional soil information, time rate of consolidation analysis, and end of construction slope stability analysis is required for the downstream end of the Wetland Embankment proposed to be constructed on soft foundation soils. This information will inform the construction schedule of the wetland embankment. Finally, further analysis and coordination is required to finalize the preliminary embankment planting plan requirements and the planting berm dimensions.

4.5 Operations and Maintenance

The proposed wetland embankments were designed in accordance with applicable USACE engineering manuals. Operation and maintenance of these structures will be necessary to ensure proper functioning of the wetland embankment structures to maintain ecological benefits at the site. Maintenance zones should extend 15 feet from both the riverward and landward wetland embankment toe. This maintenance zone is visible on the feasibility-level design plan set and should remain free of unwanted vegetation and unauthorized encroachments. Sod cover and riprap maintenance will be necessary to ensure proper functioning of erosion protection; especially at overtopping locations.

At the completion of the wetland restoration projects, an operation manual detailing proper maintenance practices will be provided to the local sponsor. The wetland embankments will not be eligible for rehabilitation assistance under the PL84-99 program due to inability to meet the minimum level of protection guidelines.

4.6 Planting Plan

A planting plan has been developed for the Wetland Restoration at Grange site. The new wetland embankment area will have approximately 4 acres planted with only grass. A planting berm will be constructed from materials excavated from the breached sections of existing wetland embankment at Grange and potentially from the Confluence Levee. This berm will be 4′ to 6′ wide and 2′ to 3′ tall. The berm will be planted with grass and will be planted with one row of short willow species 6′ O.C. Breach areas (approximately 1 acre) will be replanted with grass. Staging areas will have the following planting plan:

- 100% of area will have conifers 10′ O.C.
- 100% of area will have shrubs 6′ O.C.
- 100% of area will have bark mulch 6″ deep

5 Upstream LWD (Annex A, Sheets C-140 through C-1410)

5.1 Site Description

This increment, located from RM 9-11, would include placement and installation of large woody debris. Small wood clusters as well as larger ELJ's would be installed in this reach to increase low flow channel

meandering, encourage mid channel bar formation, and provide multiple types of habitat benefits for salmon. The volume of added wood will improve the quantity, quality, and complexity of pools in the Skokomish River to promote rearing success and provide year round fish passage. Formation of mid channel bars will Improve the quantity, quality, and complexity of native riparian and floodplain habitats. Existing natural log jams are primarily located on the outside of bends with loose wood parked upon gravel bars and located in areas where it can persist without being swept away at higher flows. The river crosses from one side of the active channel width to the other frequently (perhaps decadal) and there is little wood in the channel to create long term stability. The existing wood load has reduced significantly from historic images dating back to the 1930's.

5.2 Hydraulic Design

The South Fork of the Skokomish River presently has a significantly reduced supply of the wood load from what has existed historically. Three of the wood structure types discussed in section 1.4 are included in the design: Bar apex ELJ, 5 log channel cluster, and single log placements. These are intended to restore much of the missing habitat and channel complexity afforded by the historical wood load. The function of each type was discussed in section 1.4, with the general purpose being to encourage low flow channel braiding and complexity, and to form scour pools and provide in-stream cover along low flow channel margins. A target of 64 LWD pieces and clusters per mile was selected for the South Fork, with a minimum of 21 per mile being acceptable (Fox and Bolton, 2007). Individual logs should be 2-3 ft diameter and 15-30 ft long, and should have a rootwad. The individual logs and clusters would be placed parallel to flow, with larger ELJ's placed along the center of the active channel to minimize the hydraulic disturbance to the overall channel footprint. All placed wood has the potential to recruit additional wood from upstream sources and grow in size and impact, however because the diminished upstream wood load has not been well quantified recruitment is difficult to predict. The potential exists for the active channel width to change with any wood placement. Existing log jams were located in orthographic photos and their formed mid-channel bars were measured to characterize the potential for this geomorphic work. Bars were found to be between 200-300 ft long behind log jams of similar size to the bar apex ELJ. This footprint was used as a template for preliminarily locating the structure in areas away from bends to minimize the impact to the active channel width.

5.2.1 Design Considerations

All placed wood is designed to be stable through bankfull flows with safety factors between 1.3 and 2. Only the largest structure (bar apex ELJ) required the use of piles and was preliminarily designed with a safety factor of 2. The Bar apex structure is anchored with 10 piles driven to a depth of 12-20 ft, two large logs buried with rootwads inverted and angled in the downstream direction for lateral bracing, and excavated material replaced as ballast. Twenty-seven logs of varying length and 36 CY of logging slash are specified for this ELJ at a total of 7 locations. The Bar Apex ELJ is expected to be planted with Conifers to provide stability as mid channel bars form behind it and to supplement future wood supplies to the reach. The 5 log channel cluster and the single log placements are anchored with 4-5 ft boulder anchors buried directly under the log trunk with a total of 24 clusters used. Single logs are placed at a total of 56 locations. This total number of placements (80) is slightly greater than the approximately 64 pieces and clusters estimated to be needed at earlier design phases. This "buffer" of approximately 20%

was used to allow some flexibility in placement at later phases of design due to the poor resolution of terrain data used for feasibility. Additionally, in application the low flow channel will migrate with time and it will likely not continually contact all wood placements. As the channel changes before later design phases there is sufficient quantity accounted for to place wood across the active channel width. As the low flow channel moves some existing habitat may be altered or degraded while new habitat forms. The process will likely be evolving for some time as the river adjusts to the new wood placements. Wood placements were reflected in the 2d SMS model geometry by global roughness increase and raised grid cells (Annex H-6). Local scour at log structures was estimated from scour holes at rootwads and logs observed at the site near the confluence. Observed scour ranged from 3-5 ft typically. A value of 5 ft was used in preliminary stability analysis for placed wood.

5.2.2 Risk, Next Steps, and Future Work

All wood included in the South Fork has been preliminarily located and designed with stable anchoring. SMS Modeling for the south fork channel area was developed from poor resolution terrain data and was not generally suitable for use in quantifying the potential for geomorphic work resulting from wood placement. Once better LIDAR and channel surveys are collected the results can be improved. Further analysis is suggested using the depth-velocity product for evaluating and refining specific locations based upon the potential for desired scour pools to form at structures and wood clusters. Similar projects on the White River have been successful at locations with values ranging from 60-80 (USACE, 2012). The model geometry should be updated with grid cells modified for wood specific ELJ placements and refined roughness. This will allow for more accurate estimation of changes in the 0.01 ACE water surface over the reach. The locations of the Bar Apex ELJ, 5 log channel cluster, and single log placements will need to be refined based upon the location of the low flow channel at later design phases. Specific locations of wood needs to be based on the location of the low flow channel (i.e. 2000 to 4000 cfs on the south fork) and its elevations, rather than on bars where it could be undercut. Designs need to be further evaluated for flow attack from all directions. Stability calculations for the Bar Apex ELJ were preliminary and assume pre-drilled piles which are likely conservative. Greater pull out strength can be realized if piles are driven and only pre-drilled if necessary. Simplified methods of estimating the maximum pile working load were used (Broms and EM 1110-2-2906) and needs to be refined using more advanced methods such CLM for final design. The only available boring at RM 9 indicates that conditions are favorable for driving piles and piles have been widely used in similar rivers in the district. If bank protection is authorized at later design phases the Bar apex ELJ can be added to either of the two large bends in the reach to take advantage of bend hydraulics to create scour pools against a hardened bank. Additionally, estimated local scour depths at placed wood will need further investigation based upon refined hydraulic modeling from better resolution terrain data, and anchoring methods updated to reflect estimations. As mentioned earlier, the potential for reactivating side channels along the South Fork depends largely on what the local sponsor is amenable to as later design phases are reached. A supplemental approach to be considered at later design phases may be to introduce loose logs at the upstream end of the reach and allow for migration and tracking. This would help to replenish deteriorated anchored wood and augment the reduced upstream wood supply.

5.3 Civil Design

5.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans and will require crossing the South Fork Skokomish River. Three water crossings are anticipated; the size and location is dependent on the river flows and location. Temporary culverts and water diversion are necessary in these areas.

5.3.2 Construction Methodology

Construction would be in the drier summer months when the South Fork of the Skokomish River is low to facilitate access. The majority of excavated material for wood placement is reused as fill for ballast.

5.3.3 Survey/GIS/Topography

1994 photogrammetry topography was used.

5.3.4 Risk, Next Steps, and Future Work

This covers a 2 mile stretch of the south fork, and will require crossing the river in a few places. The river access and refined placement of the LWD structures will be refined in PED.

5.4 Geotechnical Design

Based on initial hydrology and hydraulic pile design for lateral loads and scour depth, the pile depth is anticipated at approximately 20 feet below ground surface.

5.4.1 Subsurface Explorations and Soil Classification

Boring log BH-15 through the in-channel deposits along the left bank of the South Fork of the Skokomish River was used to develop pile design criteria. The log of BH-15 generally indicates a 20 foot layer of medium dense gravel. Visual classification of the bed substrate indicates a significant cobble fraction. The boring layer between approximately 20 and 30 feet below ground surface indicates a very dense poorly graded sand layer. Both soil conditions, gravels and cobbles as well as very dense soils, present a risk to successfully driving piles to the target depth.

Bedrock has not been observed in the main channel within the project limits based on the existing geotechnical explorations and knowledge of geologic process. Bedrock conditions are not expected to constrain the construction and function of the ELJs. Log pile embedment depths are not expected to reach bedrock throughout the project site.

5.4.2 Design Considerations

The existence of boulders or cobbles within foundation layers can present driving problems and hinder determination of ultimate axial capacity of a single pile. (EM 1110-2-2906, 2-8). The Seattle District has successfully driven timber piles in similar gravel and cobble substrates on past ecosystem restoration projects. Methods utilized diesel powered hammers to drive piles. Based on the alluvial deposits encountered in BH-15, there is confidence that driving timber piles in this environment will also be successful. Piles should have steel driving shoes as well as steel bands to protect the timber pile during driving.

Without additional site specific boring logs to provide additional data points on the substrate conditions, pre-drilling should be considered as a contingency plan. Pile installation could be accomplished by pre-drilling within 2 feet of the planned tip elevation. The diameter of the pre-drill should be approximately the diameter of the timber pile tip or slightly larger. Additional explorations into site specific pile locations during later engineering and design phases can confirm that traditional pile driving is possible, but planning should anticipate utilizing a contractor that should be prepared to pre-drill. The geotechnical explorations for this design phase did not encounter significant heave, but this condition is likely given the coarse grained soils and high groundwater table. A slurry mix can be used to resist caving in the hole prior to pile driving.

If the piles cannot be driven to their design embedment, the Government Engineer on site will be required to adjust deign in the field to add additional pilings or increase ballast/rock anchors. The number of additional piles needed would be determined during construction on a case-by-case basis and would depend on how many piles do not reach the intended embedment and by how much. The construction budget for pile installation should have a contingency to account for additional piles installed. The contract plans and/or specifications should also include language stating that additional piles may be required if the intended embedment is not reached.

For the pile design, the soil blow counts were corrected to a $(N1)_{60}$ corrected blow count depending on the effective stress at the SPT elevation below ground surface. The normalized blow counts for each layer were translated to relative density. Correlation of the relative density for USCS soil classifications to dry unit weight and angle of internal friction (U.S. Navy) provided information for pile design. Geotechnical parameters for medium dense gravel and very dense sand are tabulated below in Table 5-1.

Table 5-1. In-Channel Deposit Soil Parameters

Soil Unit (USCS Classification)	Depth (Feet)	Dry Unit Weight (γ_{dry})	Friction Angle (°)
Medium Dense Gravel (GW)	0-20	125	33
Very dense Sand (SP)	20-30	115	38

Single pile pull-out capacity was calculated for use in hydrology and hydraulics ELJ superstructure calculations. The pull-out capacity is tabulated by depth in Annex B-5. For this design phase, only 25% of the available pull-out capacity was assessed due to the possibility of installing piles using pre-drilling methods. Based on the above assumptions, the single load pile capacity is estimated to be approximately 3,000 lbf.

Ballast for engineered log jam design can likely be taken from excavation required to install some anchored logs and boulders. The gravelly channel deposits are anticipated to provide sufficient unit weight and relative erosion resistance. Given the width of the alluvial valley, overtopping of the ELJ structures is not a significant concern.

5.4.3 Risk, Next Steps, and Future Work

Site specific subsurface analysis at the proposed locations of the apex bars should be accomplished to determine the suitability of wood pile design.

A wave equation analysis for pile driving was not completed for this phase of engineering and design, but is recommended for the next preliminary engineering and design (PED) phase. This analysis is used to assess which pile driving methods and equipment can be used without overstressing the piles.

5.5 Operations and Maintenance

Placed ELJ are expected to be stable at design conditions, however attrition is possible for single log placements due to estimated local scour depths possibly exceeding the actual size of the boulder anchor. The same applies to the 5 log channel cluster, although to a lesser degree because the logs are chained together into a rigid structure. In the event that logs break free of anchoring they would likely imbed elsewhere in the channel. A contingency of 20% was added to the total placed wood volume to account for some potential loss. Future modifications to the design may include introduction of loose tagged wood into the South Fork, in which the maintenance plan would need to be modified. There are no bridges or other structures in the channel where migration is possible that could be harmed, and no additional effort is required to account for loose wood beyond the monitoring plan.

6 Side Channel Reconnection (Annex A, Sheets C-150, C-151 and C-157)

6.1 Site Description

An abandoned channel that exists between RM's 4 and 5.6 would be reconnected to the main stem to provide high flow refuge and rearing habitat for fish. The 1935 Skokomish River Valley map shows this channel was an overflow channel, connected to a downstream meander that was later cutoff from the river. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would only be connected to the river during moderate discharges and would not convey water year round. Reconnecting the channel to the river could provide 45 acres of high quality, low velocity fish habitat.

6.2 Hydraulic Design

The existing channel is narrow and sinuous, with plentiful riparian vegetation and adjacent wetlands. The existing highway 101 bridge is estimated to be adequate in width and height to convey flows. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The area presently floods heavily from several locations along the main river for a 0.5 ACE event and larger. So no significant change is expected in the 0.01 ACE water surface at the site. The channel would be reconnected to the river for lower flows than what is presently able to enter. The inlet elevation would be located to allow discharges greater than a moderate winter storm (approximately 4000-6000 cfs) to enter. The channel would not convey

water year round, however the interior wetland would be wet year round from backwater at the outlet and groundwater. During high river discharges the reconnected channel would provide a low velocity refuge. The entrance will be placed too high for bedload to enter from the main river, however fines are expected to continue to enter the side channel at high flows as they presently do. There may be some suspended sediment deposition near the side-channel entrance, but this should require only infrequent O&M action, which is accounted for in the existing O&M estimate. During most of the year the channel would provide ponded habitat for fish rearing. Reconnecting the channel to the river would provide 45 acres of high quality, low velocity fish habitat.

Improving the hydraulic connection of the channel to make it more accessible for fish would involve improvements to both the inlet and outlet. The inlet would be designed with buried wood to create hardened banks and located to prevent the river from "capturing" (permanently diverting into) the channel. At the downstream end, the channel would be reconnected to the old meander through an existing outlet that presently backwaters at the lowest flow. Use of this outlet will preserve existing water levels and prevent the wetland from dewatering.

6.2.1 Design Considerations

The inlet location was placed to provide for a stable connection to the main river that is not likely to accumulate significant wood. However prediction of recruitment is not entirely possible given the dynamic nature of the river. The inlet was located a few hundred feet directly downstream from a large natural log jam at RM 5.7 that is located in a depositional zone for wood and sediment. If this existing jam remains stable the inlet should remain clear of loose wood and stable as well. The excavated channel sections have a 50 ft bottom width, with 2H:1V side slopes. The depth of cut would vary from 0-5 ft and be a few hundred ft long. The constructed inlet bottom elevation would be roughly 31 ft NAVD88 to activate at the desired flow. The existing outlet bottom elevation is estimated to be about 23 ft NAVD88. Six of the 5-log bank clusters were placed at the inlet and outlet to provide for stable banks and refuge for salmonids. Individual logs can be either anchored with boulders or chained to existing trees on the bank for stability. Concept graphics for placed wood are included in Annex H-3 to the Engineering Appendix.

6.2.2 Risk, Next Steps, and Future Work

The side channel reconnection measure needs to be ultimately modeled as a separate reach incorporating better resolution LIDAR and field survey. One-dimensional modeling such as HEC RAS is suitable for this due to the low gradient and extent of ponded water. Terrain data used for feasibility design was very poor quality in this area. Better resolution terrain data for the inlet and outlet is needed for later design phases. This will enable fine tuning of inlet elevation (and outlet if necessary) and estimating interior stages at design flows. The capacity of the existing highway 101 bridge was discussed with the sponsor and estimated to be of adequate size to convey side channel flows. This bridge would need to be incorporated into modeling to verify that its capacity and design is adequate.

6.3 Civil Design

The entrance requires approximately 550 lineal feet of channel, 50 feet wide requires 3,600 CY excavation with 2 horizontal to 1 vertical side slopes 3 to 4 foot in depth.

6.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans.

The entrance channel reconnection area will require a temporary road through a treed area, and crosses the old channel. The old channel is fed by the Skokomish River and runoff from the hillside. While the inlet elevation at the Skokomish River inlet is not known, observation of water from the hillside from a culvert just upstream of the project area, and the flow in the old channel would indicate most of the flow is from the culvert during the drier summer months or when the Skokomish River elevation is low.

The exit channel reconnection area is accessed via an abandoned gravel road which was covered with water in numerous locations in early October as shown on the plans. At this time the source of the water is unknown; culverts and road raises are anticipated for access. The remainder of the access is via another abandoned trail overgrown with trees and brush. The work area crosses a secondary channel and the primary channel.

Access will be in the locations shown on the plans and will require crossing the mainstem Skokomish River. Three water crossings are anticipated the size and location is dependent on the river flows and location. Temporary culverts and water diversion are necessary in these areas.

6.3.2 Construction Methodology

Construction would be in the drier summer months when the South Fork of the Skokomish River is low to facilitate access. The construction methodology is to provide a temporary crossing across the existing channel. Working from the river landward, excavate the new channel. The final connection would be at the existing channel. The excavated materials would be disposed of off-site.

The exit channel work could divert the main channel through a culvert to the secondary channel to facilitate crossing the main channel. The main river may require some cofferdam technique depending on final the location and elevation of the LWD structures.

6.3.3 Survey/GIS/Topography

A combination of 1994 photogrametric topgraphy, 2002 bare-earth LIDAR information, and 2014 field cross-sections was used to site and obtain the excavation quantities for the proposed entrance channel. The topographic information at the exit is not useful. Field reconnaissance indicates the topography does not indicate the channel at the exit. The channel is well pronounced in this location and little or no channel work is required.

6.3.4 Risk, Next Steps, and Future Work

The location of the LWD structures at both the entrance and exit structures may require fish exclusion and temporary cofferdams. This may require additional detailed survey in these areas. Additional survey may be required in areas adjacent to and along the channel.

6.4 Geotechnical Design

No subsurface explorations were performed in the vicinity of the side channel reconnection. All channel slopes were designed to mimic naturally occurring slopes of the existing channels. Site specific exploration and confirmation of channel design slopes shall occur at a later design phase.

Proposed large woody debris shall be installed and anchored within the design recommendations and constraints previously described in Section 5.

6.5 Operations and Maintenance

The inlet and outlet should both be monitored for wood accumulation, and removal of trapped wood may be necessary to sustain desired connectivity to the main river. It is not possible to predict the occurrence of this, and judgment will be required to evaluate how much wood accumulation is tolerable.

6.6 Planting Plan

A planting plan has been developed for the Side Channel Reconnection site. The channel inlet area is approximately 1 acre and will have the following planting plan:

- Conifers planted in 1 row, 10-15' O.C. for 550' length both banks
- Shrubs planted in 1 row, 6' O.C. for 550' length both banks
- Stakes planted 2' O.C. for 550' length that is approx 4' wide, both banks

The access route to inlet channel is approximately 10' wide X 200' long and will have the following planting plan:

- 100% of area will have conifers 10-15' O.C.
- 100% of area will have shrubs 6' O.C.

The outlet channel will have the following planting plan:

- Conifers planted in 1 row, 10-15' O.C. for full length both banks
- Shrubs planted in 1 row, 6' O.C. for full length both banks
- Stakes planted 2' O.C. for full length that is approx 4' wide, both banks

The access route to the outlet channel is approximately 10' wide X 1,000' long and will have the following planting plan:

- 100% of area will have shrubs 6' O.C.
- 100% of area will have bark mulch 6" deep
- During PED, the study team will consider creating hummocks with high spots for conifers; this planting approach would require slightly more soil material and additional conifers to add to project cost.

7 Hazardous, Toxic and Radioactive Waste (HTRW)

A Phase II HTRW investigation was complete in July 2014. There were no sampling results that warranted further evaluation or investigation within the footprint of the recommended plan, including the Confluence levee site. Please refer to Appendix I – HTRW, for additional information.

8 Planting Plan

A feasibility-level planting plan has been developed for cost estimating purposes as well as Endangered Species Act (ESA) consultation requirements. A summary of the planting plan for each site included in throughout the Engineering Appendix. The following plant species will likely be used based on site-specific considerations:

- Grass species mix
  - 40% creeping red fescue
  - 40% perennial ryegrass
  - 10% white clover
  - 10% highland colonial bentgrass
- Stake species
  - Willow
  - Red osier dogwood
- Shrub species
  - Snowberry
  - Serviceberry
  - Twinberry
  - Pacific Ninebark
- Conifer species
  - Western Red Cedar
  - Hemlock
  - Sitka Spruce

9 Cost Considerations

Cost estimates have been developed for the recommended plan. Please refer to Appendix K – Cost Engineering, for additional information.

10 Schedule for Design and Construction

The pre-construction, engineering and design (PED) phase will include additional refinements of design (65%, 95%, 100%) and associated analysis (e.g., additional survey data, LiDAR, etc.) for features included in the recommended plan. It is anticipated that this phase will last approximately 2 years.

Construction will likely be completed in two phases over two to three years:

- Phase I: Wetland Restoration at Grange, Wetland Restoration at River Mile 9, Confluence Levee Removal and diversion, and Side Channel Reconnection
- Phase II: Upstream LWD and Confluence Levee diversion LWD

11 Outline Of Specifications

The following information outlines the specifications that will be included in the contract documents during PED:

DIVISION 0 PROCURMENT AND CONTRACTING

00 01 15 List of Drawings
00 41 00 Bid Schedules

DIVISION 1 GENERAL REQUIRMENTS

01 11 00 Summary of Work
01 14 00 Work Restrictions
01 00 10 Supplementary Requirements
01 00 50 Site Specific Supplementary Requirements
01 02 50 Measurement and Payment
01 03 50 Modification Procedures
01 06 00 Water Quality Standards
01 06 10 Environmental Protection
01 35 26 Government Safety Requirements
01 35 40 Environmental Management
01 45 00 Quality Control Systems (QCS)
01 32 00 Project Schedule
01 33 00 Submittal Procedures
01 57 20 Environmental Protection
013 56A Storm Water Pollution Prevention Measures
01 45 10 Contractor Quality Control
01 50 00 Construction Facilities and Temporary Controls
01 56 00 Diversion and Care of Water
01 57 23 Temporary Storm Water Pollution Control
01 56 10 Dust Control
01 56 50 Construction Spoils Handling
01 74 19 Construction and Demolition Waste Management
01 62 35 Recycled/Recovered Materials
01 7 0 20 As Built Records and Drawings
01 70 30 Warranty of Construction
01 78 00 Closeout Submittals

DIVISION 31 EARTHWORK

31 00 00 Earthwork
31 05 19 Geotextile
31 05 21 Geogrid Soil Reinforcement
31 11 00 Clearing and Grubbing
31 32 11 Soil Surface Erosion Control
31 32 39 Bioengineering Practices for Stream Bank Stabilization
31 62 19 Timber Piles

DIVISION 32 EXTERIOR IMPROVEMENTS

32 92 19 Seeding
32 92 23 Sodding
32 92 26 Sprigging
32 93 00 Exterior Plants
32 96 00 Transplanting Exterior Plants

DIVISION 35 WATERWAYS AND MARINE CONSTRUCTION

35 41 19 Stone, Channel Protection for Structures
35 41 00 Levee Construction
35 44 00 In-stream and Floodplain Habitat Construction

Note: Annexes are available electronically and are not included in printed versions of Appendix H.

Annex A

Engineering Design Drawing Annex

Naming conventions for some features included in the recommended plan have evolved over time. The Confluence Levee is locally referred to as the Car Body Levee. The existing agricultural berms, as well as the proposed wetland embankments, near River Mile 9 and the Grange are referred to as "River Mile 9 Levee" and "Grange Levee."

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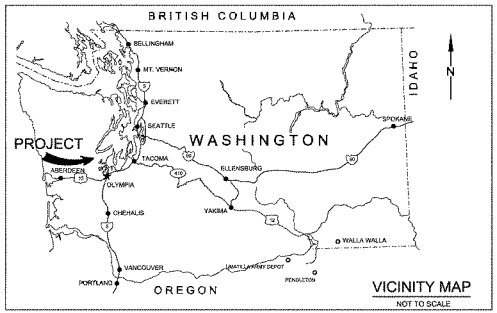
SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION DRAFT FEASIBILITY JANUARY 2015

SKOKOMISH WA



VICINITY MAP
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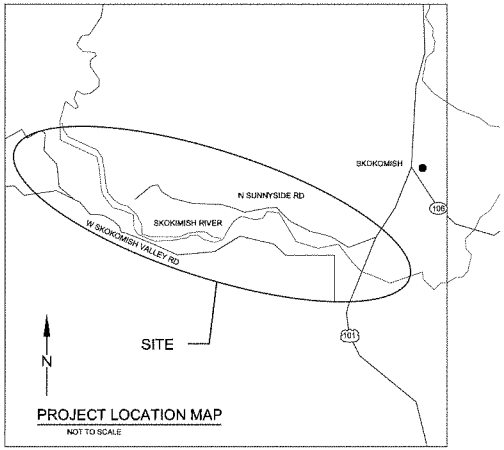

PROJECT LOCATION MAP
NOT TO SCALE

FY15

SAFETY PAYS

IF SHEET MEASURES LESS THAN 22" X 34" IT IS A REDUCED PRINT. REDUCE SCALE ACCORDINGLY.

US Army Corps of Engineers • Seattle District

File No: E-25-1-22
Date: JANUARY 2015
Solicitation No.:

Recommended by: GUY GREEN, P.E. Chief, Design Branch — Date 01/20/15
Approved by: JOANN T. WALLS, P.E. Chief, Engineering Div. — Date 01/20/15

Submitted by: JAY MICHEL MESKO Project Manager — Date 01/20/15
Reviewed by: ANIL NISARGAND, P.E. Chief, Spec. and Tech Review — Date 01/20/15

U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT SEATTLE, WASHINGTON
Prepared by: JEN WEST, P.E. Chief, Civil Section — Date 01/20/15

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PROMAGS
TITLE AREA AND VICINITY MAPS

SHEET IDENTIFICATION
G-001
Sheet 1 of 10

DESIGN FILE: pw:\\NWS-ADSTP-AP.nwd.usace.army.mil:nwsadstp01\Documents\Civil Works\Skokomish River, WA\FY15 PROMAGS SKOK\Current\PlanetCad_Drawings\G-001 COVER SHEET

DATE AND TIME PLOTTED: 04/09/15

PLATE NO.	TITLE
GENERAL	
G-001	COVER SHEET
G-002	INDEX SHEET
G-003	VICINITY MAP
GEOTECHNICAL	
B-201	WETLAND RESTORATION AT RIVER MILE 9 EXPLORATION PLAN AND SOIL PROFILE
B-202	WETLAND RESTORATION AT GRANGE EXPLORATION PLAN AND SOIL PROFILE
CIVIL	
C-001	LEGEND AND ABBREVIATIONS
C-101	SITE ACCESS AND STAGING UPSTREAM LWD
C-102	SITE ACCESS AND STAGING RIVER MILE 9
C-103	SITE ACCESS AND STAGING CHANNEL RECONNECTION
C-110	CONFLUENCE LEVEE REMOVAL OVERALL SITE PLAN
C-111	CONFLUENCE LEVEE REMOVAL SITE PLAN 1
C-112	CONFLUENCE LEVEE REMOVAL SITE PLAN 2
C-113	CONFLUENCE LEVEE REMOVAL SITE PLAN 3
C-114	CONFLUENCE LEVEE REMOVAL SITE PLAN 4
C-115	CONFLUENCE LEVEE REMOVAL SITE PLAN 5
C-210	CONFLUENCE LEVEE REMOVAL PLAN & PROFILE
C-310	CONFLUENCE LEVEEE REMOVAL TYPICAL SECTIONS
C-610	CONFLUENCE LEVEE REMOVAL CURVE DATA
C-120	WETLAND RESTORATION AT RIVER MILE 9 OVERALL SITE PLAN
C-121	WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 1
C-122	WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 2
C-123	WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 3
C-124	WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 4
C-220	WETLAND RESTORATION AT RIVER MILE 9 PLAN & PROFILE
C-320	WETLAND RESTORATION AT RIVER MILE 9 TYPICAL SECTIONS
C-620	WETLAND RESTORATION AT RIVER MILE 9 CURVE DATA
C-130	WETLAND RESTORATION AT GRANGE OVERALL SITE PLAN
C-131	WETLAND RESTORATION AT GRANGE SITE PLAN 1
C-132	WETLAND RESTORATION AT GRANGE SITE PLAN 2
C-133	WETLAND RESTORATION AT GRANGE SITE PLAN 3
C-230	WETLAND RESTORATION AT GRANGE PLAN & PROFILE
C-330	WETLAND RESTORATION AT GRANGE TYPICAL SECTIONS
C-630	WETLAND RESTORATION AT GRANGE CURVE DATA
C-140	UPSTREAM LWD OVERALL SITE PLAN
C-141	UPSTREAM LWD SITE PLAN 1
C-142	UPSTREAM LWD SITE PLAN 2
C-143	UPSTREAM LWD SITE PLAN 3
C-144	UPSTREAM LWD SITE PLAN 4
C-145	UPSTREAM LWD SITE PLAN 5
C-146	UPSTREAM LWD SITE PLAN 6
C-147	UPSTREAM LWD SITE PLAN 7
C-148	UPSTREAM LWD SITE PLAN 8
C-149	UPSTREAM LWD SITE PLAN 9
C-1410	UPSTREAM LWD SITE PLAN 10
C-540	UPSTREAM DETAILS 1
C-541	UPSTREAM DETAILS 2
C-150	CHANNEL RECONNECTION OVERALL SHEET
C-151	CHANNEL RECONNECTION ENTRANCE SITE PLAN
C-152	CHANNEL RECONNECTION SITE PLAN 2 THRU 6 NOT USED
C-157	CHANNEL RECONNECTION EXIT SITE PLAN
C-350	CHANNEL RECONNECTION TYPICAL SECTIONS
C-650	CHANNEL RECONNECTION ENTRANCE CURVE DATA

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: CADD MANAGER
DRAWN BY: CADD TECH
CHECKED BY: SUPERVISOR
PLOT DATE: 7/31/14
DATE: 7/31/14
SIZE: 24 X 36
SCALE: AS NOTED
FILE NAME: G-002 INDEX SHEET.dgn

SOLICITATION NO.
CONTRACT NO.
FILE NUMBER
DACW67-

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SNOQUALMIE RIVER, WASHINGTON
PHASE 1
INDEX SHEET

SHEET IDENTIFICATION
G-002
SHEET 2 OF 10

DATE AND TIME PLOTTED: 8/4/2015

RESIDEN FILE: per:\NWS-ASP1P-PN:\m.m.oates.army.mil\users\f10\documents\Civil Models\Snoqualmie River, WA\P116\PN3NEW\SNOQ\Current Plates\Civil_Plates\Civil\G_Sheets\General\G-002 DRAWING INDEX SHEET 1

VICINITY MAP
1"=1000'

N

0 1,000' 2,000'
1"= 1,000'

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SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	CHKD.	DESIGNER	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY
DRAWN BY
CHECKED BY
SUPERVISED BY
PROJ. MGR.
PLOT DATE
PLOT SCALE
FILE NAME
PROJECT NO.

DATE
SOLICITATION NO.
CONTRACT NO.
FILE NUMBER
DACW67-
FILE NAME
F:\Projects\Snoqualmie\Snoqualmie_Design\Snoqualmie_Design.dgn

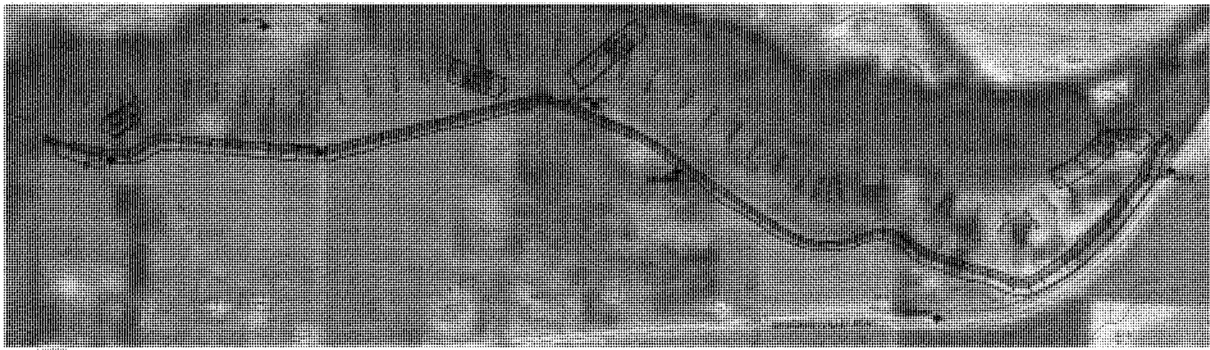
SNOHOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SNOHOMISH COUNTY, WASHINGTON
PH3948M2

VICINITY MAP

SHEET IDENTIFICATION
G-003
SHEET 3 OF 90

DESIGN FILE: per WWW-ABOV/ftp://ftp.nwd-mil.usace.army.mil:/cmsdrf/Documents/Civil Works/Snohomish River/ PH3948 TO 16-PH3948 SNOHOCurrent Project/Cad_Data/CAD_Drawings/General/G-003 VICINITY MAP

DATE AND TIME PLOTTED: 5/4/2015



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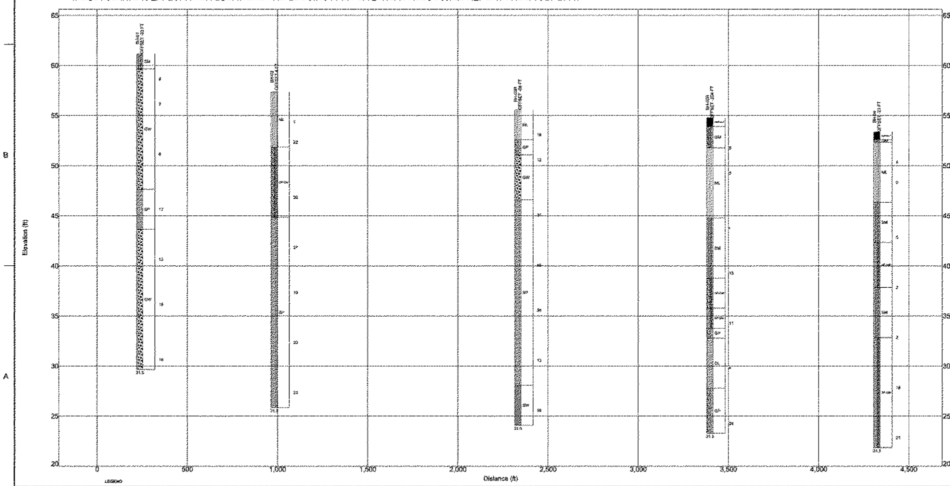
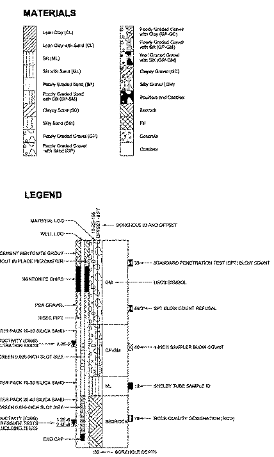
3. MAP COMPILED FROM FIELD SURVEY PEFORMED BY MASON COUNTY MAY/JUNE 2014 AND AERIAL PHOTOGRAPHY DATED 3-MAR-1994
4. GEOTECHNICAL EXPLORATION LOCATIONS AND LOGGING ARE PER LANDAU ASSOCIATES REPORT FROM JULY 2014.





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SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: GONIA | DATE:
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PLOT DATE: 5/4/2015 | PLOT TIME: 11:11:50 AM | FILE NUMBER: E-29-1-22
SIZE: ANSI D | FILE NAME: PN394832 GM B MILE 9_EXPLORATION PLAN & SOIL

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

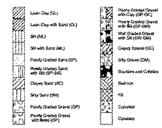
WETLAND RESTORATION AT RIVER MILE 9
EXPLORATION PLAN AND SOIL PROFILE

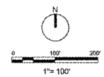
SHEET IDENTIFICATION
B-201
SHEET 6 OF 51

DATE AND TIME PLOTTED: 5/4/2015
DESIGN FILE: pw:\\NWS-AS01PJW.nws.ds.usace.army.mil:bentws01\Documents\Civil Works\Skokomish River, WA\FY16 PN394832 SKOKO\...\B-201 WETLAND RESTORATION AT RIVER MILE 9 EXPLORATION PLAN & SOIL P

NOTES:
1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.
2. VERTICAL DATUM BASED ON NAVD 1988
3. MAP COMPILED FROM FIELD SURVEY PEFORMED BY MASON COUNTY MAY/JUNE 2014 AND AERIAL PHOTOGRAPHY DATED 3-MAR-1994
4. GEOTECHNICAL EXPLORATION LOCATIONS AND LOGGING ARE PER LANDAU ASSOCIATES REPORT FROM JULY 2014.

MATERIALS





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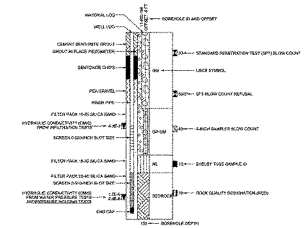

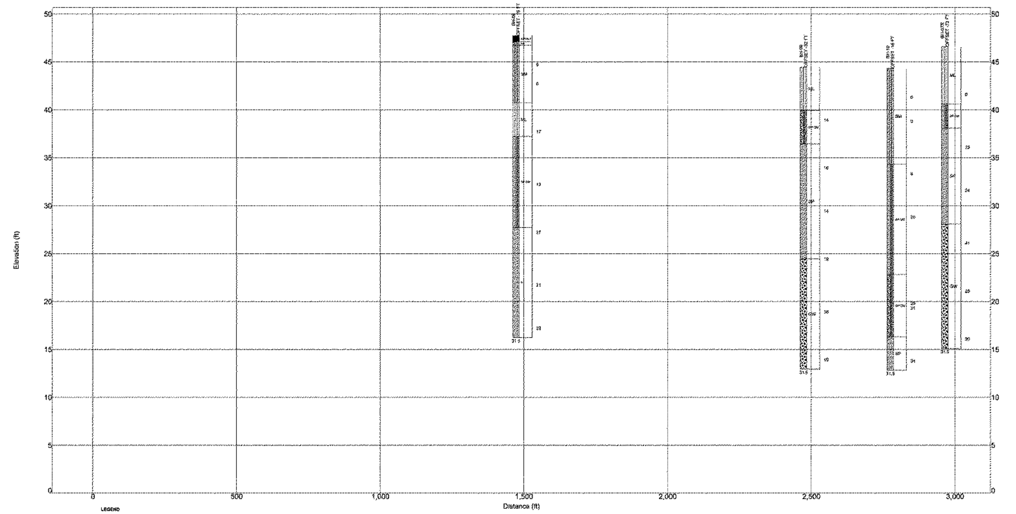

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SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

WETLAND RESTORATION AT GRANGE
EXPLORATION PLAN AND SOIL PROFILE

SHEET IDENTIFICATION
B-202

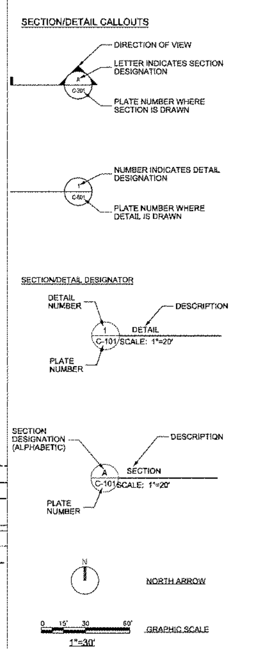
US Army Corps of Engineers
SEATTLE DISTRICT

DATE AND TIME PLOTTED: 5/4/2015

CIVIL LEGEND

EXISTING / DESIGN	DESCRIPTION
	CONTROL POINT AND ELEVATION
	MAJOR CONTOUR
	MAJOR CONTOUR OBSCURED BY VEGETATION
	MINOR CONTOUR
	MINOR CONTOUR OBSCURED BY VEGETATION
	GROUND SHOT AND ELEVATION
	GROUND SHOT NUMBER AND ELEVATION
	COMMUNICATION NUMBER AND ELEVATION
	POWER POLE NUMBER AND ELEVATION
	POWER POLE NUMBER AND ELEVATION
	POWER POLE GUY NUMBER AND ELEVATION
	UNDERGROUND COMMUNICATION NUMBER AND ELEVATION
	BUILDING
	EDGE OF WATER
	EDGE OF VEGETATION
	GRAVEL ROAD
	ASPHALT ROAD
	LEVEE
	BRIDGE
	CULVERT
	IN-SITU GROUND
O	POINT OF CURVATURE/POINT OF TANGENCY
Δ	POINT OF INTERSECTION
	ACCESS ROUTE
	CONSTRUCTION LIMIT
C/L	TEMPORARY EASEMENT
	PROPERTY LINE
	EMBANKMENT TOP
	BREACH
	EMBANKMENT TOE
ELEV 40	FINISH GRADE ELEVATION
	FILL GRADING SYMBOL
	CUT GRADING SYMBOL
	APEX ENGINEERED LOG JAM
	5 LOG ENGINEERED LOG JAM
	SINGLE LOG LARGE WOODY DEBRIS

DRAFTING



GENERAL NOTES

1. ALL NATIVE ORGANIC MATERIAL THAT HAS TO BE CLEARED FOR ACCESS WILL REMAIN ON SITE. TREES THAT ARE REMOVED MAY BE PLACED IN-STREAM AS DEEMED APPROPRIATE BY COR AND PROJECT BIOLOGIST.

2. BOUNDARIES OF CLEARING LIMITS ASSOCIATED WITH SITE ACCESS AND CONSTRUCTION WILL BE MARKED TO AVOID OR MINIMIZE DISTURBANCE OF RIPARIAN VEGETATION, WETLANDS AND OTHER SENSITIVE SITES.

3. PROJECT OPERATIONS MAY CEASE AT REQUEST OF THE COR UNDER HIGH FLOW CONDITIONS THAT MAY INUNDATE THE PROJECT AREA.

4. A POLLUTION AND EROSION CONTROL PLAN, COMMENSURATE WITH THE SIZE OF THE PROJECT, MUST BE PREPARED AND CARRIED OUT TO PREVENT POLLUTION CAUSED BY SURVEYING OR CONSTRUCTION OPERATIONS.

5. A SPILL PREVENTION PLAN WILL BE PREPARED AND SUBMITTED TO THE CORPS.

CIVIL ABBREVIATIONS

AC	ASPHALTIC CONCRETE
BOT	BOTTOM
COE	CORPS OF ENGINEERS
COR	USACE CONTRACTING OFFICER REPRESENTATIVE
CY	CUBIC YARDS
DBH	DIAMETER AT BREAST HEIGHT
DIA	DIAMETER
E	EAST
EL, ELEV	ELEVATION
ELJ	ENGINEERED LOG JAM
EXIST	EXISTING
FT	FEET/FOOT
GPS	GLOBAL POSITIONING SATELLITE
H, HORIZ	HORIZONTAL
IE	INVERT ELEVATION
IN	INCH/INCHES
L	LENGTH
LF	LINEAL FOOT/FEET
LWD	LARGE WOOD DEBRIS
MIN	MINIMUM
N	NORTH
NAD	NORTH AMERICA DATUM
NAVD	NORTH AMERICA VERTICAL DATUM
NO.	NUMBER
NTS	NOT TO SCALE
OC	ON-CENTER
OHWM	ORDINARY HIGH WATER MARK
PC	POINT OF CURVATURE
PI	POINT OF INTERSECTION
PVI	POINT OF VERTICAL INTERSECTION
PT	POINT OF TANGENCY
R	RADIUS
R/W	RIGHT OF WAY
SE	SOUTHEAST
SECT	SECTION
SF	SQUARE FEET
STA	STATION
STD	STANDARD
T	TANGENT
TEMP	TEMPORARY
TESC	TEMPORARY EROSION AND SEDIMENT CONTROL
TYP	TYPICAL
VAR	VARIES
V, VERT	VERTICAL
VOL	VOLUME
W/	WITH
WS	WATER SURFACE

GENERAL NOTES CONTINUED

6. THE SITE WILL BE STABILIZED DURING ANY SIGNIFICANT BREAK IN WORK.

7. A SUPPLY OF EMERGENCY EROSION CONTROL MATERIALS WILL BE ON HAND AND TEMPORARY EROSION CONTROLS WILL BE INSTALLED AND MAINTAINED IN PLACE UNTIL SITE RESTORATION IS COMPLETE.

8. STRAW BALES, FILTER FABRIC, TEMPORARY SEDIMENT PONDS, CHECK DAMS OF PEA GRAVEL FILLED BURLAP BAGS OR OTHER MATERIAL, AND/OR IMMEDIATE MULCHING OF EXPOSED AREAS SHALL BE USED TO PREVENT SILT-LADEN WATER FROM ENTERING WATERS OF THE U.S

9. ALL DISCHARGE WATER CREATED BY CONSTRUCTION (E.G., CONCRETE WASHOUT, PUMPING FOR WORK AREA ISOLATION, VEHICLE WASH WATER, DRILLING FLUIDS) WILL BE TREATED TO AVOID NEGATIVE WATER QUALITY AND QUANTITY IMPACTS. REMOVAL OF FINES MAY BE ACCOMPLISHED WITH BIOSWALES; CONCRETE WASHOUT WITH ALTERED PH, MAY BE INFILTRATED.

10. TO THE EXTENT FEASIBLE, WORK REQUIRING USE OF HEAVY EQUIPMENT WILL BE COMPLETED BY WORKING FROM THE TOP OF THE BANK.

11. ALL IN-WATER WORK WILL OCCUR DURING THE WDFW DESIGNATED IN-WATER WORK WINDOW FOR THE SKOKOMISH RIVER (CURRENTLY JULY 15-SEPTEMBER 15).

12. TURBIDITY MONITORING WILL OCCUR DURING ALL IN-WATER WORK ACCORDING TO THE CONDITIONS ISSUED IN THE 401 WATER QUALITY CERTIFICATION FROM THE WASHINGTON DEPARTMENT OF ECOLOGY.

GENERAL NOTES CONTINUED

13. WHEN CONSTRUCTION IS FINISHED, THE DISTURBED AREAS AREA WILL BE CLEANED UP AND REPLANTED AND RESEEDED WITH NATIVE VEGETATION AND CONIFERS 15' OC OR AS INDICATED ON THE PLANS. WITHIN SEVEN CALENDAR DAYS OF PROJECT COMPLETION, ANY DISTURBED BANK AND RIPARIAN AREAS SHALL BE PROTECTED USING NATIVE VEGETATION OR OTHER EROSION CONTROL MEASURES AS APPROPRIATE. FOR EROSION CONTROL, STERILE GRASSES MAY BE USED IN LIEU OF NATIVE SEED MIXES.

14. PLANTING OF SHRUBS AND TREES WILL BE COMPLETED BETWEEN OCTOBER 1 AND APRIL 15 OF THE YEAR FOLLOWING CONSTRUCTION.

15. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL WORK IN ACCORDANCE TO THE SPECIFICATION AND DRAWINGS.

16. THE CONTRACTOR SHALL COORDINATE WITH USACE COR PRIOR TO AND DURING CONSTRUCTION TO ADDRESS CONCERNS.

17. THE CONTRACTOR SHALL ENSURE THE WORK CREW HAS ALL APPLICABLE SAFETY TRAINING PRIOR TO CONSTRUCTION.

WASTE DISPOSAL AND MANAGEMENT:

1. THE CONTRACTOR SHALL COMPLY WITH ALL RELEVANT WASHINGTON STATE STORM WATER AND CONSTRUCTION SITE EROSION CONTROL MEASURES AT THE WORK SITE. SEE SPECIFICATION SECTION 01 57 23

2. THE CONSTRUCTION STORMWATER POLLUTION PREVENTION PLAN SHALL BE SUBMITTED BY CONTRACTOR AND REVIEWED BY USACE. APPROVED MEASURES SHALL BE INSTALLED BY THE CONTRACTOR PRIOR TO ANY SITE WORK.

3. THE CONTRACTOR SHALL PROVIDE PORTABLE SANITARY ACCOMMODATIONS FOR EMPLOYEES AND USACE PERSONNEL ASSIGNED TO THE WORK SITE AS MAY BE NECESSARY BASED ON NUMBER AN USE. ACCOMMODATION IN A NEAT AND SANITARY CONDITION. SEE SPECIFICATION SECTION 01 50 00. THE ACCOMMODATIONS SHALL COMPLY WITH REQUIREMENTS AND REGULATIONS OF EM 385-1-1 AND STATE HEALTH DEPARTMENT LOCAL ORDINANCES.

4. THE CONTRACTOR SHALL PROVIDE TRASH RECEPTACLES. RUBBISH, DEBRIS, GARBAGE AND OTHER REFUSE SHALL BE REMOVED FROM ALL WORK SITES AT THE END OF EACH SHIFT AND DISPOSED OF IN THE TRASH RECEPTACLES. TRASH SHALL BE REMOVED FROM THE JOB SITE AT LEAST ONCE A WEEK AND DISPOSED OF LEGALLY, OFF SITE.

OTHER REQUIREMENTS:

1. WORKING WITH THE PROJECT ECOLOGIST, IDENTIFY AND FLAG THE GRADING LIMIT EVERY 100' AND IN ADDITIONAL LOCATIONS AS PRACTICAL FOR SURVEY IDENTIFICATION AND REFERENCE DURING CONSTRUCTION. THE PROJECT BIOLOGIST WILL WALK THE SITE AND MARK ANY TREES TO PROTECT WITH THE CONTRACTOR AND CONTRACTING OFFICER.

2. DUST CONTROL SHALL BE PERFORMED IN ACCORDANCE WITH CONTRACT SPECIFICATION SECTION 01 57 17 DUST CONTROL.

3. DO NOT EXCAVATE OR DISTURB BEYOND THE PROJECT LIMITS UNLESS NOTED OTHERWISE. THE CONTRACTING OFFICER WILL BE NOTIFIED IMMEDIATELY IF THESE CONDITIONS ARE ANTICIPATED.

4. DO NOT FILL EXISTING DITCHES OR CHANNELS UNLESS OTHERWISE SHOWN ON PLANS

5. ALL AREAS OF THE JOB SITE TEMPORARILY DISTURBED BY CONSTRUCTION SHALL BE GRADED TO THE PRE- CONSTRUCTION GRADE AND PROTECTED AND/OR REVEGETATED AS NECESSARY WITHIN SEVEN CALENDAR DAYS OF PROJECT COMPLETION. PLANTING OF SHRUBS AND TREES WILL BE COMPLETED BETWEEN OCTOBER 1 AND APRIL 15 OF THE YEAR FOLLOWING CONSTRUCTION.

6. ALL MATERIALS USED FOR CONSTRUCTION SHALL BE NEW AND UNDAMAGED UNLESS OTHERWISE APPROVED BY USACE. THE SAME MANUFACTURER OF EACH ITEM SHALL BE USED THROUGHOUT THE WORK UNLESS OTHERWISE APPROVED BY USACE.

7. TRAFFIC CONTROL SUBMITTAL. TEMPORARY STORAGE OF CONSTRUCTION EQUIPMENT IS ALLOWED ANYWHERE WITHIN THE CONSTRUCTION LIMITS SHOWN ON THE PLANS. HOWEVER TRAFFIC OR STORAGE OF EQUIPMENT IS NOT ALLOWED IN THE FOLLOWING AREAS OR AS INDICATED ON THE PLANS: THE EXISTING DEPRESSION AREAS AND AREAS TO BE PLANTED. SEE SPECIFICATION SECTION 01 50 00.

8. PROTECT EXISTING UTILITIES AND PAVEMENT, ALL DAMAGED AC WILL BE REPAIRED AS PART OF THE CONTRACT.

9. ALL PAVED TRAFFIC AREAS WILL BE KEPT FREE FORM SEDIMENT ACCUMULATIONS BY DAILY SWEEPING OR WASHING. CONSTRUCTION ACCESS SHALL BE STABILIZED SURFACES. VEHICLES WASH/RINSE STATION PRIOR TO LEAVING SITES.

10. ALL DISTURBED AREAS OTHER THAN SPECIFIED CONTRACT WORK AREAS SHALL BE RETURNED TO THEIR PRE-CONSTRUCTION CONDITION AT PROJECT COMPLETION TO THE SATISFACTORY OF THE CONTRACTING OFFICER

11. INITIAL AND POST AC PAYMENT CONSTRUCTION SURVEYS WILL BE PERFORMED TO DETERMINE AC TO BE REPAIRED SEE SPECIFICATION SECTION 02 41 00.

12. ESTABLISH TRAFFIC CONTROL BARRIERS AND FLAGGERS AS NEEDED TO ISOLATE TRAFFIC.

13. THE EXISTING GRAVEL ROADS/TRAILS MAY BE USED AS HEAVY EQUIPMENT CONSTRUCTION ACCESS AND MAY REQUIRE ADDITIONAL STABILIZED CONSTRUCTION ACCESS.

14. AFTER COMPLETION OF THE WORK, TOOLS, SURPLUS MATERIALS, TEMPORARY DRAINAGE, RUBBISH, AND DEBRIS INCIDENTAL TO THE WORK SHALL BE REMOVED AND DISPOSED OF BY THE CONTRACTOR. ALL ROADS OR ANY OTHER PRE-EXISTING ITEMS THAT ARE DAMAGED DUE TO THE CONTRACTORS ACTIONS SHALL BE REPAIRED OR REPLACED PRIOR TO COMPLETION OF THIS CONTRACT AT NO COST TO THE GOVERNMENT.

15. AREAS TO BE LANDSCAPED WHICH ARE COMPACTED OR TREATED FOR STABILIZED ACCESS WILL BE RENOVATED BY REMOVING ALL FOREIGN MATERIAL. THE SUBGRADE MATERIAL SHALL BE SCARIFIED AND BLENDED AT LEAST 18 INCHES IN DEPTH. THE FOREIGN MATERIAL REMOVED SHALL BE REPLACED WITH AT LEAST 6 INCHES OF TOPSOIL TO THE ELEVATION OF THE SURROUNDING AREA AND BLENDED TO MEET THE ADJACENT SLOPES. SEE SPECIFICATION SECTION 01 50 00.

16. STREAM CROSSING SHALL BE MINIMIZED, A WORK AREA ISOLATION PLAN SHALL BE SUBMITTED FOR ALL WATER CROSSINGS REQUIRING FLOW DIVERSION OR ISOLATION.

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DORSEY | DATE: 5/4/2015
DWN BY: KATO | CKD BY: MAY | SOLICITATION NO.:
SUBMITTED BY: WEST | CONTRACT NO.:
PLOT DATE: 5/4/2015 | PLOT TIME: 11:07:07 AM | FILE NUMBER: 8-25-1-22
SIZE: ANSI D | FILE NAME: PN364832-CIVC-001.dgn

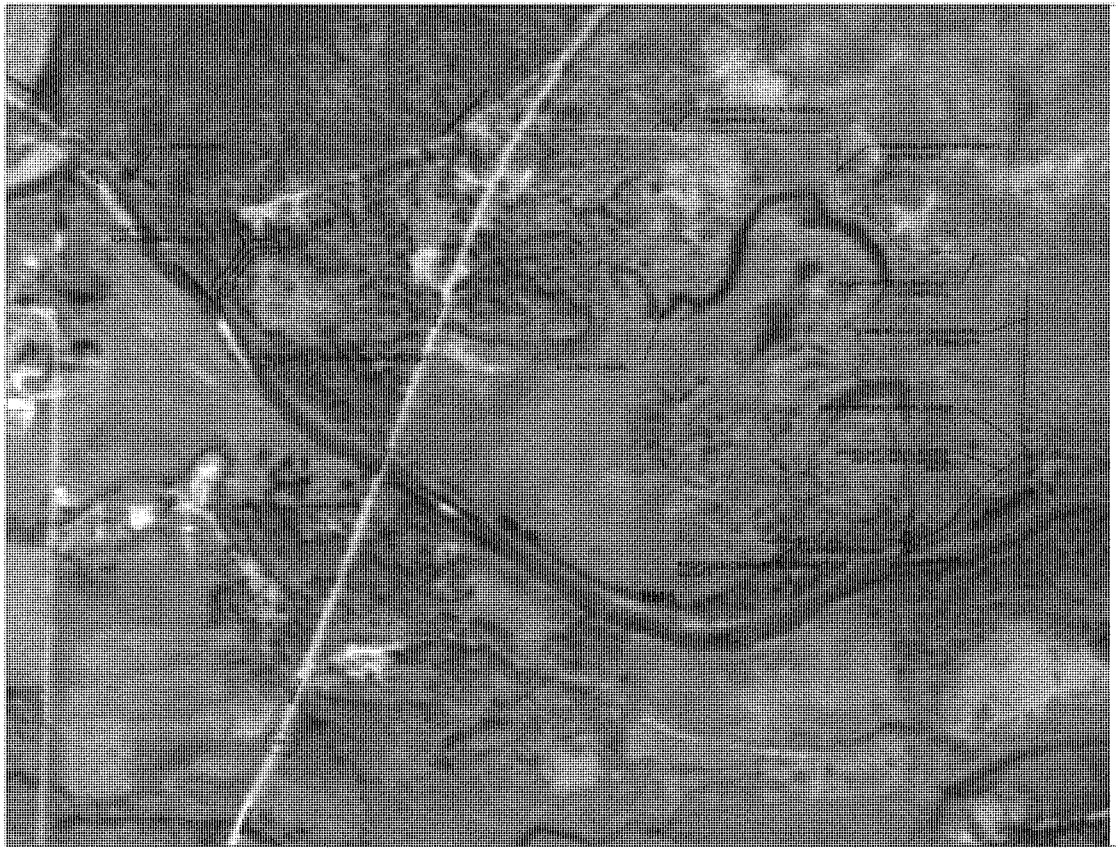
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN364832
LEGEND AND ABBREVIATIONS

SHEET IDENTIFICATION
C-001
SHEET 6 OF 52

DATE AND TIME PLOTTED: 5/4/2015 DESIGN FILE: pw:\\NWS-ASO1P.W.nwt.ds.usace.army.mil:conws01\Documents\Civil Works\Skokomish River, WA\FY16 PN364832 SKOKCurrent Phase\Con_Docs\CAD_Sheets\Civil\C-001 LEGEND AND ABBREVIATIONS

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
SITE ACCESS AND STAGING
UPSTREAM LWD
SHEET IDENTIFICATION
C-101
N
1"= 300'
1 SITE ACCESS AND STAGING UPSTREAM LWD
1"=300'

1 SITE ACCESS AND STAGING RIVER MILE 9
1"=300'
0 300' 600'
1"= 300'
N
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PREMIMIZ
SITE ACCESS AND STAGING
RIVER MILE 9
SHEET IDENTIFICATION
C-102
U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON
DESIGNED BY
DATE
DRAWN BY
DATE
SOLICITATION NO.:
CONTRACT NO.:
SUBMITTED BY
PLOT DATE
PLOT TIME
FILE NAME
DESIGN FILE
DATE AND TIME PLOTTED



1 SITE ACCESS AND STAGING CHANNEL RECONNECTION
1"=300'

N

0 300 600
1"= 300'

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUPERVISED BY:
PLOT DATE:
PLOT TIME:
FILE NAME:
FILE NUMBER:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DATA FILE NAME:
DATA FILE NUMBER:
DESIGN AGENCY:

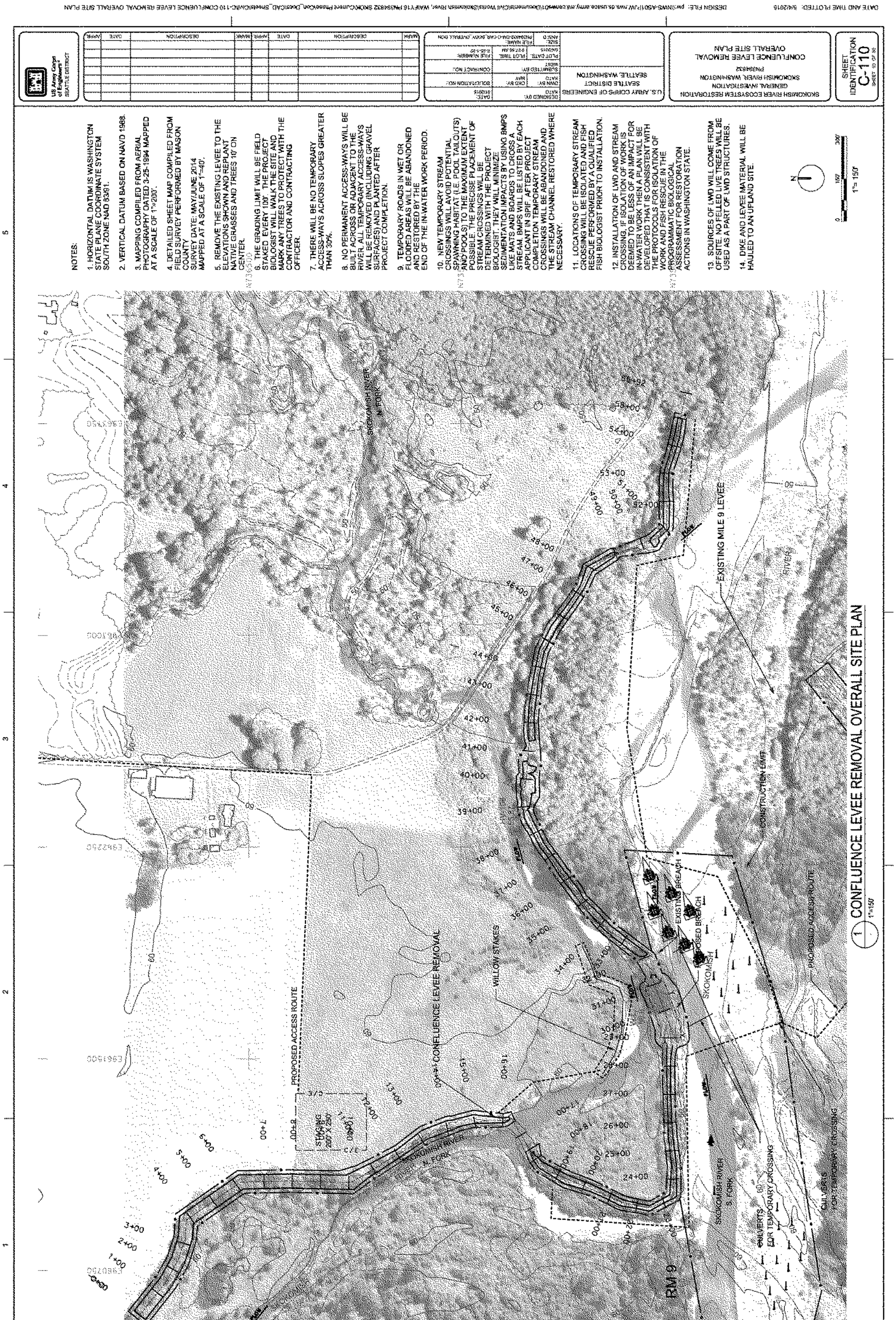
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GRAVEL & FINES TRAP
SKOKOMISH TRIBAL NATION
PROBHA32

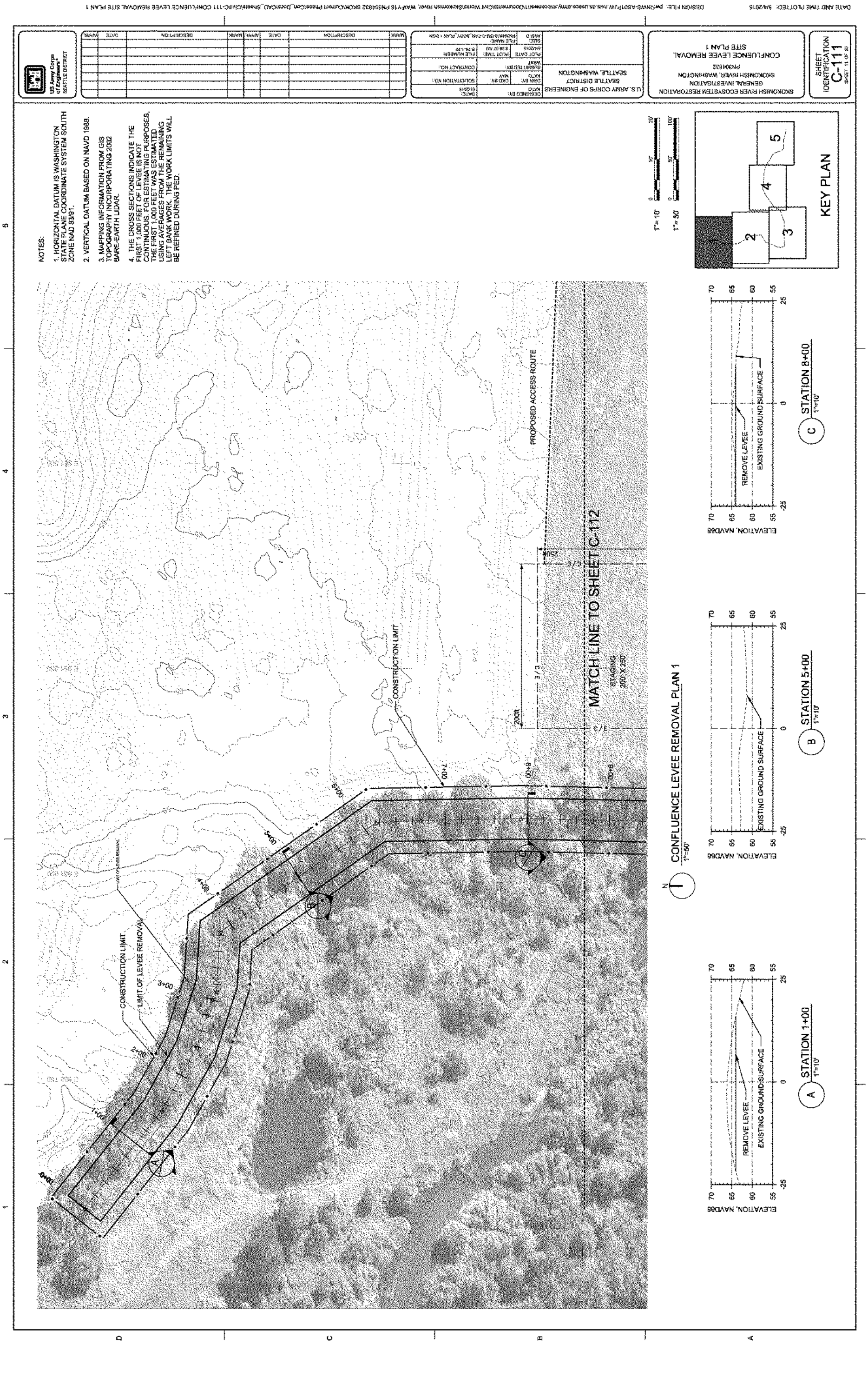
SITE ACCESS AND STAGING CHANNEL RECONNECTION

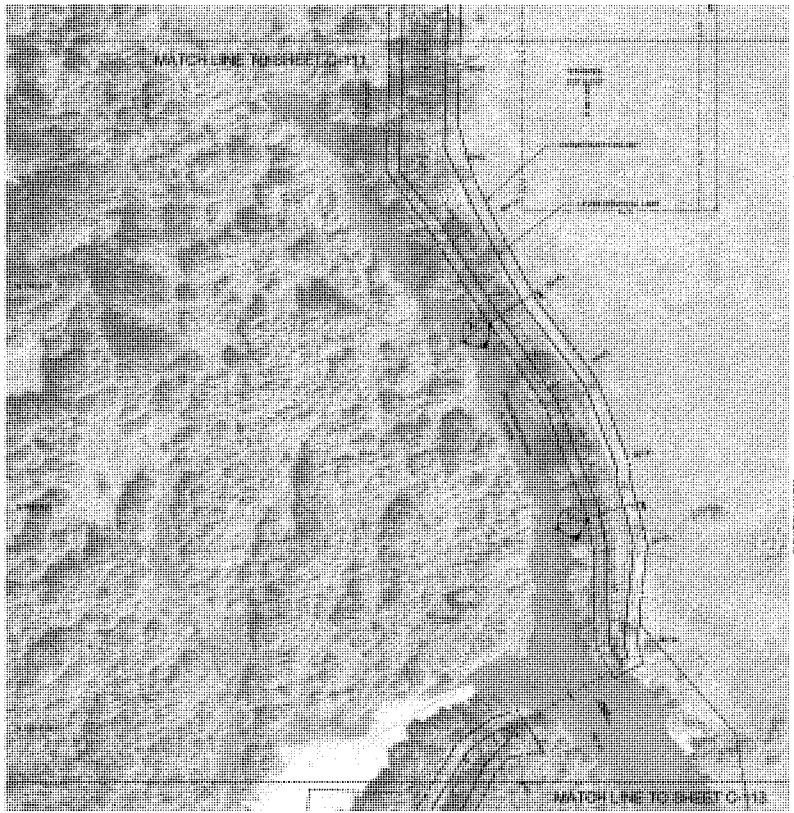
SHEET IDENTIFICATION
C-103
SHEET 3 OF 92

DESIGN FILE: pw:\\NWS-ABDTI-PW-net.ds.usace.army.mil:sewer\h\Documents\Civil Works\Backstream\Rivers\HHAP\10 PROBHA32 SkoKoCounce\ProjectCon_Sheet\Grant-C-103 SITE ACCESS AND STAGING CHANNEL RECONNECTION

DATE AND TIME PLOTTED: 5/4/2015


DATE AND TIME PLOTTED: 5/4/2015
DESIGN FILE: pw:\\NWS-AS01PJW.nws.ds.usace.army.mil:cenws01\Documents\Civil Works\Skokomish River, WA\FY16 PN394832 SKOK\Current Phase\Con_Docs\CAD_Sheets\Civil\C-110 CONFLUENCE LEVEE REMOVAL OVERALL SITE PLAN
US Army Corps of Engineers® SEATTLE DISTRICT
MARK
DESCRIPTION
DATE
APPR.
U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832
CONFLUENCE LEVEE REMOVAL
OVERALL SITE PLAN
SHEET IDENTIFICATION
C-110
NOTES:
1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.
2. VERTICAL DATUM BASED ON NAVD 1988.
3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.
4. DETAILED SHEET MAP COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014 MAPPED AT A SCALE OF 1"=40'.
5. REMOVE THE EXISTING LEVEE TO THE ELEVATIONS SHOWN AND REPLANT NATIVE GRASSES AND TREES 10' ON CENTER.
6. THE GRADING LIMIT WILL BE FIELD STAKED EVERY 100'. THE PROJECT BIOLOGIST WILL WALK THE SITE AND MARK ANY TREES TO PROTECT WITH THE CONTRACTOR AND CONTRACTING OFFICER.
7. THERE WILL BE NO TEMPORARY ACCESS-WAYS ACROSS SLOPES GREATER THAN 30%.
8. NO PERMANENT ACCESS-WAYS WILL BE BUILT ACROSS OR ADJACENT TO THE RIVER. ALL TEMPORARY ACCESS-WAYS WILL BE REMOVED (INCLUDING GRAVEL SURFACES) AND PLANTED AFTER PROJECT COMPLETION.
9. TEMPORARY ROADS IN WET OR FLOODED AREAS WILL BE ABANDONED AND RESTORED BY THE END OF THE IN-WATER WORK PERIOD.
10. NEW TEMPORARY STREAM CROSSINGS WILL AVOID POTENTIAL SPAWNING HABITAT (I.E. POOL TAILOUTS) AND POOLS) TO THE MAXIMUM EXTENT POSSIBLE. THE PRECISE PLACEMENT OF STREAM CROSSINGS WILL BE DETERMINED WITH THE PROJECT BIOLOGIST. THEY WILL MINIMIZE SEDIMENTATION IMPACTS BY USING BMPS LIKE MATS AND BOARDS TO CROSS A STREAM. BMPS WILL BE LISTED BY EACH APPLICANT IN SPIF. AFTER PROJECT COMPLETION TEMPORARY STREAM CROSSINGS WILL BE ABANDONED AND THE STREAM CHANNEL RESTORED WHERE NECESSARY.
11. LOCATIONS OF TEMPORARY STREAM CROSSING WILL BE ISOLATED AND FISH RESCUE PERFORMED BY A QUALIFIED FISH BIOLOGIST PRIOR TO INSTALLATION.
12. INSTALLATION OF LWD AND STREAM CROSSING, IF ISOLATION OF WORK IS DEEMED TO BE LESS OF AN IMPACT FOR IN-WATER WORK THEN A PLAN WILL BE DEVELOPED THAT IS CONSISTENT WITH THE PROTOCOLS FOR ISOLATION OF WORK AND FISH RESCUE IN THE PROGRAMMATIC BIOLOGICAL ASSESSMENT FOR RESTORATION ACTIONS IN WASHINGTON STATE.
13. SOURCES OF LWD WILL COME FROM OFFSITE. NO FELLED LIVE TREES WILL BE USED AS A PART OF LWD STRUCTURES.
14. DIKE AND LEVEE MATERIAL WILL BE HAULED TO AN UPLAND SITE.
N
0 150' 300'
1"= 150'
SKOKOMISH RIVER N. FORK
EXISTING MILE 9 LEVEE
RIVER
CONSTRUCTION LIMIT
EXISTING BREACH
PROPOSED BREACH
SKOKOMISH
PROPOSED ACCESS ROUTE
CONFLUENCE LEVEE REMOVAL
WILLOW STAKES
STAGING 200' X 250'
SKOKOMISH RIVER S. FORK
CULVERTS FOR TEMPORARY CROSSING
RM 9
CONFLUENCE LEVEE REMOVAL OVERALL SITE PLAN
1"=150'


US Army Corps of Engineers
SEATTLE DISTRICT
U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
CONFLUENCE LEVEE REMOVAL
SITE PLAN 1
SHEET IDENTIFICATION
C-111
NOTES:
1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.
2. VERTICAL DATUM BASED ON NAVD 1988.
3. MAPPING INFORMATION FROM GIS TOPOGRAPHY INCORPORATING 2012 BARE-EARTH LIDAR.
4. THE CROSS SECTIONS INDICATE THE FIRST 1,000 FEET OF LEVEE IS NOT CONTINUOUS. FOR ESTIMATING PURPOSES, THE FIRST 1,000 FEET WAS ESTIMATED USING AVERAGES FROM THE REMAINING LEFT BANK WORK. THE WORK LIMITS WILL BE REFINED DURING PED.
1"= 10'
1"= 50'
KEY PLAN
1
2
3
4
5
CONSTRUCTION LIMIT
LIMIT OF LEVEE REMOVAL
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
PROPOSED ACCESS ROUTE
MATCH LINE TO SHEET C-112
STAGING
200' X 250'
200ft
250ft
CONFLUENCE LEVEE REMOVAL PLAN 1
1"=50'
N
ELEVATION, NAVD88
REMOVE LEVEE
EXISTING GROUND SURFACE
A STATION 1+00
1"=10'
B STATION 5+00
1"=10'
C STATION 8+00
1"=10'



CONFLUENCE LEVEE REMOVAL PLAN 2
1"=50'

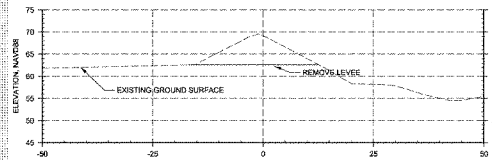
NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

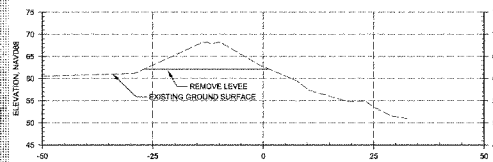
2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAP COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY, SURVEY DATE: MAY/JUNE 2014.

4. THE FIRST 1,000 FEET OF LEVEE REMOVAL IS ESTIMATED USING MAPPING INFORMATION FROM GIS TOPOGRAPY INCORPORATING 2002 BARE-EARTH LIDAR.

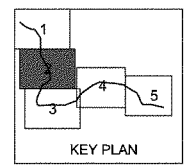


A STATION 12+00
1"=10'



B STATION 14+50
1"=10'

1"= 10' 0 10' 30'
1"= 50' 0 50' 100'



KEY PLAN

U.S. Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPD

DESIGNED BY: DATE
DRAWN BY: SOLICITATION NO.
CHKD BY: CONTRACT NO.
SUBMITTED BY: FILE NUMBER
PLOT DATE: PLOT FILE: DACW67-2-14-0000
PLOT SCALE: PAGE SIZE: 24 X 36
REV. FILE NAME: C112_CONFLUENCE_LEVEE_REMOVAL_PLAN_2.DWG

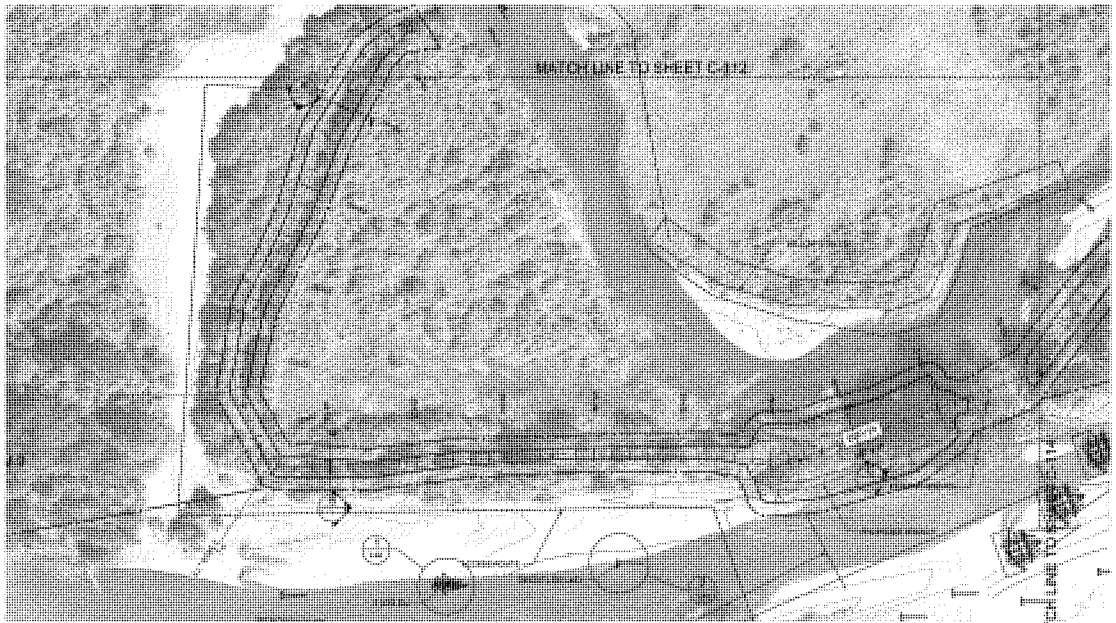
U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PHASE2

CONFLUENCE LEVEE REMOVAL
SITE PLAN 2

SHEET IDENTIFICATION
C-112
SHEET 12 OF 90

DATE AND TIME PLOTTED: 9/3/2015 DESIGN FILE: per:///WRA-fs8/P:/Civil Wks/Documents/Civil Works/Skokomish/Phase1/Phase2/Confluence_Levee/CAD_Drawings/C112 CONFLUENCE LEVEE REMOVAL SITE PLAN 2



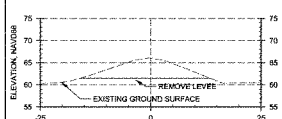
1 CONFLUENCE LEVEE REMOVAL PLAN
1"=10'

NOTES:

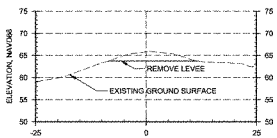
1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

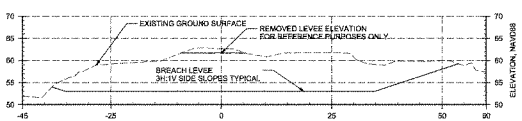
3. DETAILED SHEET MAP COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY
SURVEY DATE: MAY/JUNE 2014
MAPPED AT A SCALE OF 1"=40'.



A STATION 19+00
1"=10'

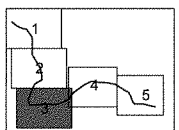


B STATION 24+00
1"=10'



C STATION 30+00
1"=10'

1"= 10' 0 10' 20'
1"= 50' 0 50' 100'



KEY PLAN

U.S. Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

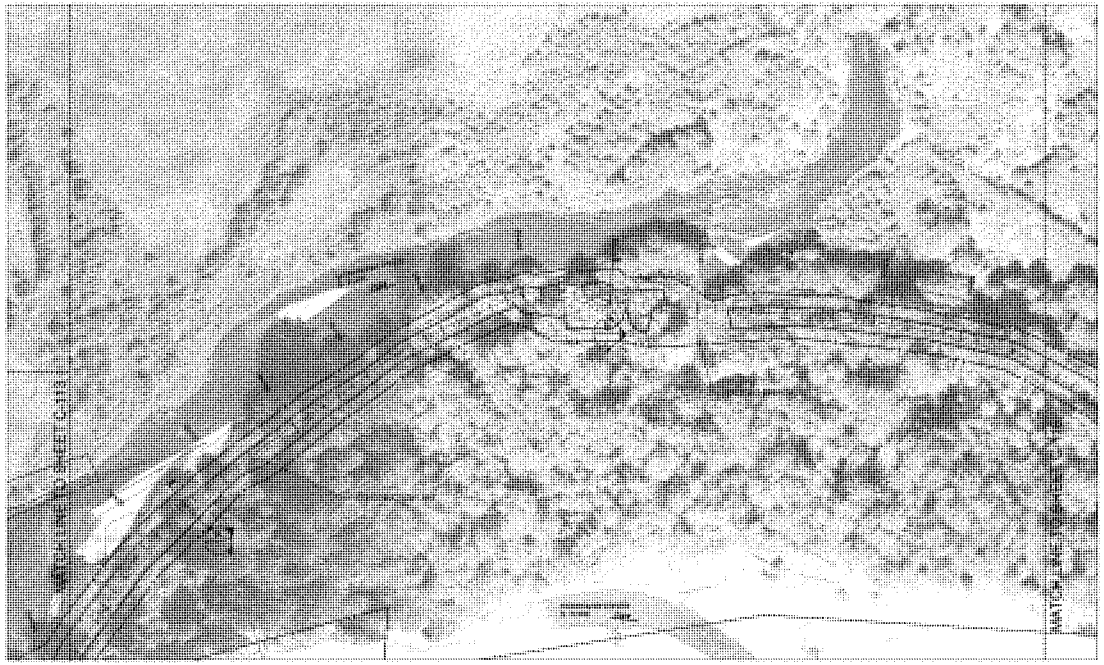
DESIGNED BY
DRAWN BY
CHECKED BY
SUPERVISED BY
PLOT DATE
PLOT SCALE
PLOT TIME
FILE NAME
DESIGN FILE NO.
SCALE
SOLICITATION NO.
CONTRACT NO.
FWP NUMBER
DACW67-01-B-0001
FILE NAME
C:\PROJECT\MASON CLAM_BKWT_PLAN 1.DGN

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH, MASON COUNTY, WASHINGTON
PROJ#0432
CONFLUENCE LEVEE REMOVAL
SITE PLAN 3

SHEET IDENTIFICATION
C-113
SHEET 13 OF 50

DESIGN FILE: pw:\\WWO-ASDWP-P1\wo_ds\data_eng_ed\projects\Documents\Cor Works\Documents\Cor Works\Skokomish River, WA\P115 (PN0432) SKOKOMISH\Current Phase\Con_Plans\CAD_Drawings\CNC113 CONFLUENCE LEVEE REMOVAL SITE PLAN 3

DATE AND TIME PLOTTED: 5/4/2015



NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

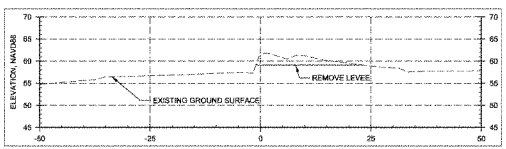
2. VERTICAL DATUM BASED ON NAVD 1988.

3. DETAILED SHEET MAP COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY
SURVEY DATE: MAY/JUNE 2014
MAPPED AT A SCALE OF 1"=40'.

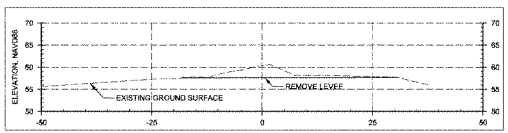
1"= 10' 0 10' 20'

1"= 50' 0 50' 100'

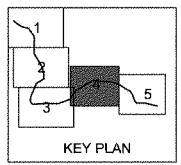
1 CONFLUENCE LEVEE REMOVAL PLAN 4
1"=50'



A STATION 34+50
1"=10'



B STATION 40+00
1"=10'



KEY PLAN

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	DWN.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT DATE:
PLOT SCALE:
PLOT MODE:
FILE NAME:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DATE:

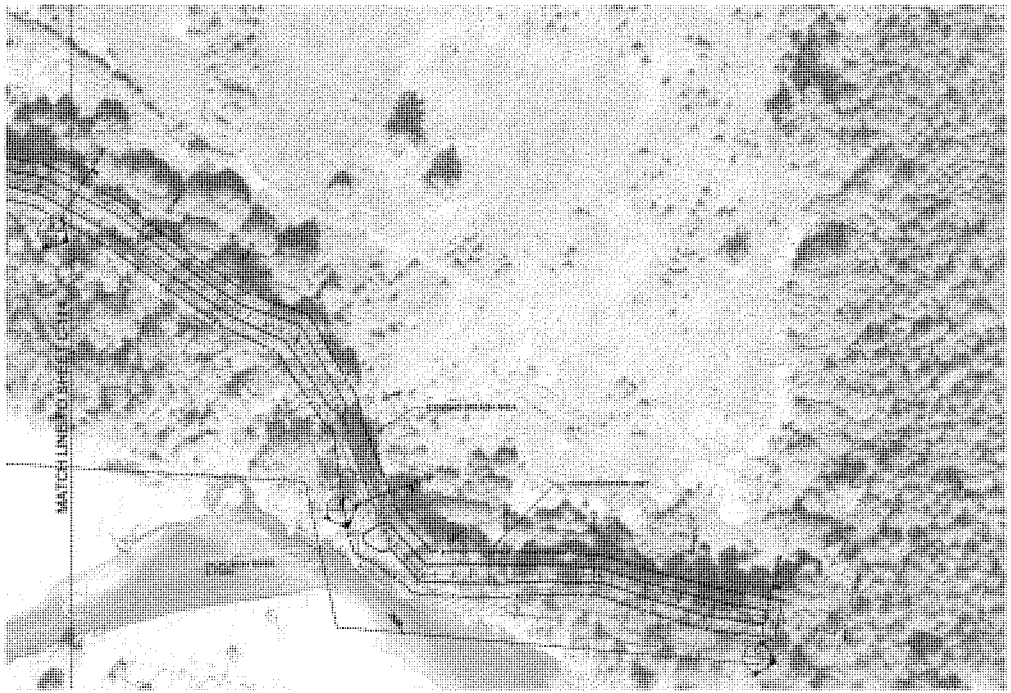
SKOKOMISH RIVER ECOSYSTEM RESTORATION
REMOVAL WYPES FROM NOT
STORM DAMAGED FLOOD WALL
PH3H1002

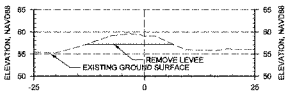
CONFLUENCE LEVEE REMOVAL
SITE PLAN 4

SHEET IDENTIFICATION
C-114
SHEET 14 OF 34

DATE AND TIME PLOTTED: 6/23/2015

DESIGN FILE: per N:\NS-ABS\PVAR mas.ds.usace.army.mil domain\Projects\Documents\Civil Works\Backwaters\Hood River, WA\P1167\P3H1002 SKOKOMISH\Contract Plans\Civil_Drawings\C-114 CONFLUENCE LEVEE REMOVAL SITE PLAN 4





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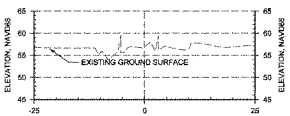

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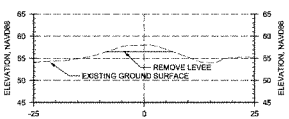
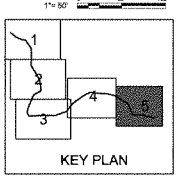


C STATION 55+00
1"=10'

1"= 10' 0 10' 20'
1"= 50' 0 50' 100'



KEY PLAN

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. DETAILED SHEET MAP COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY
SURVEY DATE: MAY/JUNE 2014
MAPPED AT A SCALE OF 1"=40'.

N
CONFLUENCE LEVEE REMOVAL PLAN 5
1"=50'

U.S. Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT DATE:
FILE NAME:
SIZE:
SCALE:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
CAD NUMBER:
FILE NAME:
DESIGN AGENCY: JUAN SON

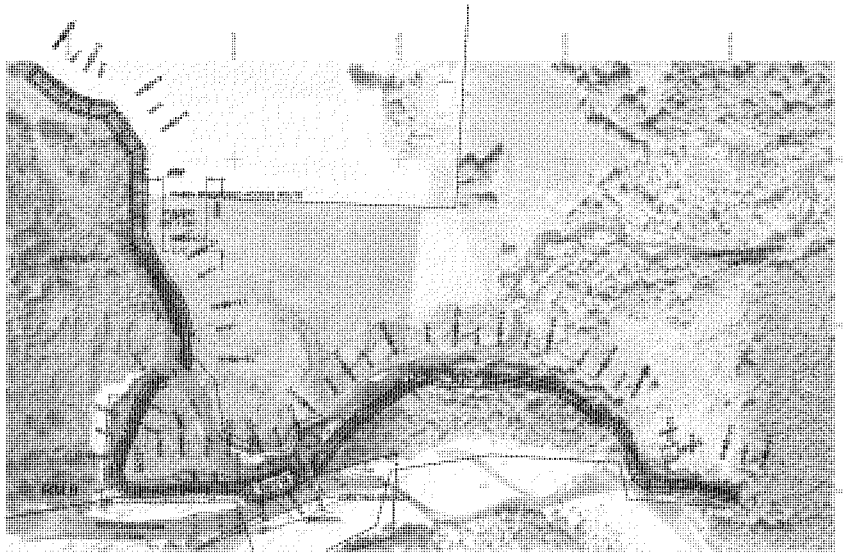
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PHASE 1
CONFLUENCE LEVEE REMOVAL
SITE PLAN 5

SHEET IDENTIFICATION
C-115
SHEET 15 OF 36

DESIGN FILE: jpw:W:\PROJ\SDP\PJR mod dis sdata emrg dtl Crowder\Documents\Civil Works\Backbone Files\ WA\715 RIVER\B2 BIOPC\Current\ PhaseCad_Plans\CAD_Sheets\CN\C-115 CONFLUENCE LEVEE REMOVAL SITE PLAN 5

DATE AND TIME PLOTTED: 5/4/2015

746



CONFLUENCE LEVEE REMOVAL PLAN
1"=200'

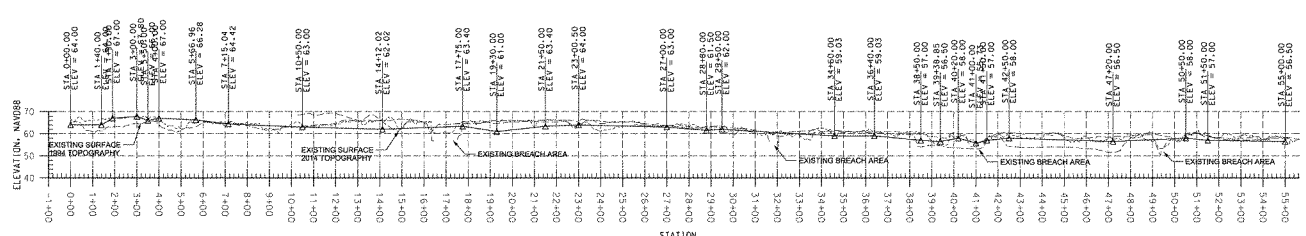
NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. DETAILED SHEET MAP COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY
SURVEY DATE: MAY/JUNE 2014
MAPPED AT A SCALE OF 1"=40'.

4. UPSTREAM OF THIS POINT MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994
MAPPED AT A SCALE OF 1"=200'.



CONFLUENCE LEVEE REMOVAL PROFILE
1"=200' H
1"=20' V

1"= 200' H 1"= 20' V

N

1"= 200'

US Army Corps of Engineers
SEATTLE DISTRICT

DATE	DRWN	DESCRIPTION	REVISIONS	DRWN	DATE

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

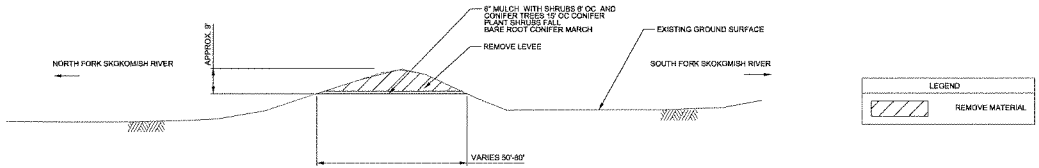
DESIGNED BY: DRAWN BY: CHECKED BY: SUBMITTED BY: PLOT DATE: FILE NAME: SIZE: FILE NAME: PLOT SCALE: 1"=20' H AND 1"=20' V
ORIGINAL SIGN: SIGNATURE HERE
CONTRACT NO.: CONTRACT NAME: FILE NUMBER: SHEET NUMBER:

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SNOQUALMIE, WASHINGTON
FRIDAY

CONFLUENCE LEVEE REMOVAL
PLAN AND PROFILE

SHEET IDENTIFICATION
C-210
SHEET 18 OF 34

DATE AND TIME PLOTTED 9/9/2015 DESIGN FILE: pw://WRD-ABIQV1.ar.nwp.ds.usace.army.mil:usace01/Documents/Civil Works/Shared Projects/Snoqualmie Rivers NWP/TIB PROGRAM SNOQUALmmel Rivers NWP/Civil/Plans/Con_Dwg/CAD_Sheets/Con/C-210 CONFLUENCE LEVEE REMOVAL PLAN & PROFILE



A C-310 CONFLUENCE LEVEE REMOVAL
NOT TO SCALE

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: [illegible]
DRAWN BY: [illegible]
CHECKED BY: [illegible]
SUBMITTED BY: [illegible]
PLOT DATE: [illegible]
FILE NAME: [illegible]
SIZE: [illegible]
FILE NUMBER: [illegible]
PLOT SCALE: [illegible]
PLOT TIME: [illegible]
DATA: [illegible]
SOLICITATION NO.: [illegible]
CONTRACT NO.: [illegible]
FILE NUMBER: [illegible]
PLOT SCALE: [illegible]
PLOT TIME: [illegible]
DESIGN AGENCY: [illegible]

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH, MASON COUNTY, WASHINGTON
PROJ#5432

CONFLUENCE LEVEE REMOVAL

SHEET IDENTIFICATION
C-310
SHEET 17 OF 30

DATE AND TIME PLOTTED: 5/4/2015

DISPLAY FILE: pw:\\NWS-ASOT2.BA.nwd.ds.usace.army.mil:cwnwd1\Documents\SkoKoi Skokomish River_WWFY15 PROJMAKE (BKOK)\Current Plans\Con_Dsign\CAD_Sheets\Civil\C-310 CONFLUENCE LEVEE REMOVAL TYPICAL SECTION

CONFLUENCE REMOVAL HORIZONTAL CURVE DATA

Point	Station	Northing	Easting	Tangential Direction	Tangential Length
POB	-0+60.713	736,885.717	960,592.757	S 51°40'00.5" E	150.882
PI #1	1+50.169	736,792.136	960,711.111	S 61°02'53.0" E	88.699
PI #2	2+38.868	736,749.198	960,788.725	S 72°49'22.6" E	41.283
PI #3	2+80.151	736,737.006	960,828.167	S 72°10'52.2" E	19.927
PI #4	3+00.078	736,730.909	960,847.138	S 59°03'14.2" E	10.704
PI #5	3+10.783	736,725.404	960,856.319	S 86°18'08.3" E	73.003
PI #6	3+83.786	736,720.696	960,929.170	S 35°03'37.9" E	232.048
PI #7	6+15.834	736,530.754	961,062.468	S 2°54'47.2" E	54.475
PI #8	6+70.309	736,476.349	961,065.236	S 1°02'52.1" E	121.837
PI #9	7+92.146	736,354.533	961,067.464	S 1°19'10.3" W	216.389
PI #10	10+08.535	736,138.201	961,062.481	S 31°02'58.9" E	356.373
PI #11	13+64.908	735,832.889	961,246.292	S 11°39'26.1" E	180.081
PI #12	15+44.989	735,656.523	961,282.680	S 1°28'46.1" W	65.047
PI #13	16+10.036	735,591.497	961,281.001	S 24°28'37.1" E	21.286
PI #14	16+31.323	735,572.124	961,289.820	S 59°27'42.9" W	140.710
PI #15	17+72.033	735,500.627	961,168.628	S 56°41'03.8" W	66.467
PI #16	18+38.499	735,464.121	961,113.085	S 23°07'15.4" W	310.401
PI #17	21+48.901	735,178.651	960,991.198	S 11°32'58.8" W	78.010
PI #18	22+44.216	735,085.266	960,972.114	S 20°37'39.0" E	48.901
PI #19	23+38.734	734,995.951	961,005.735	N 87°03'52.2" E	292.619
PI #20	26+52.607	735,012.433	961,327.157	S 89°00'08.5" E	280.987
PI #21	29+33.604	735,007.541	961,608.111	N 69°47'56.2" E	288.992
PI #22	32+22.596	735,107.334	961,879.326	N 31°34'49.3" E	143.253
PI #23	33+65.849	735,229.372	961,954.347	N 42°16'17.4" E	81.312
PI #24	34+47.161	735,289.541	962,009.041	N 54°52'22.7" E	298.940
PI #25	37+46.101	735,461.548	962,253.538	N 64°00'50.5" E	99.282
PI #26	38+45.383	735,505.049	962,342.783	N 65°20'35.5" E	53.053
PI #27	38+98.436	735,527.181	962,390.998	N 85°36'06.6" E	48.578
PI #28	39+47.014	735,530.907	962,439.434	S 76°06'54.2" E	52.732
PI #29	39+99.746	735,518.252	962,490.625	S 85°48'54.9" E	298.528
PI #30	42+98.275	735,496.468	962,788.357	S 78°17'47.6" E	162.033
PI #31	44+60.308	735,463.600	962,947.022	S 57°54'09.4" E	266.197
PI #32	47+26.505	735,322.154	963,172.529	S 63°48'10.8" E	73.906
PI #33	48+00.411	735,289.527	963,238.844	S 31°06'37.0" E	89.116
PI #34	48+89.527	735,213.229	963,284.889	S 20°57'48.6" E	161.974
PI #35	50+51.501	735,061.976	963,342.839	S 44°06'30.3" E	54.981
PI #36	51+06.482	735,022.535	963,381.116	S 89°54'35.3" E	199.419
PI #37	53+05.880	735,022.221	963,580.534	S 74°53'16.2" E	122.820
PI #38	54+28.700	734,990.201	963,699.107	S 77°03'56.0" E	163.679
POE	55+92.380	734,953.563	963,858.633		

Curve	Radius	Length	Tangent	Delta	Degree of Curvature (Arc)
PI #18	60.000	33.606	17.305	32°10'37.85" LEFT	95°29'34.68"
PI #19	40.000	50.480	29.226	72°18'28.71" LEFT	143°14'22.02"

CONFLUENCE REMOVAL VERTICAL CURVE DATA

Element	Point	Station	Elevation	Point	Station	Elevation	Tangent Grade	Tangent Length
LINEAR	POB	0+00.000	64.000	PVI	1+40.000	64.000	0.000%	140.000
LINEAR	PVI	1+40.000	64.000	PVI	1+90.000	67.000	6.000%	50.000
LINEAR	PVI	1+90.000	67.000	PVI	3+00.000	67.800	0.727%	110.000
LINEAR	PVI	3+00.000	67.800	PVI	3+50.000	66.000	-3.600%	50.000
LINEAR	PVI	3+50.000	66.000	PVI	4+00.000	67.000	2.000%	50.000
LINEAR	PVI	4+00.000	67.000	PVI	5+66.984	66.279	-0.432%	166.984
LINEAR	PVI	5+66.984	66.279	PVI	7+15.043	64.415	-1.259%	148.079
LINEAR	PVI	7+15.043	64.415	PVI	10+50.000	63.000	-0.422%	334.957
LINEAR	PVI	10+50.000	63.000	PVI	14+12.021	62.023	-0.270%	362.021
LINEAR	PVI	14+12.021	62.023	PVI	17+75.000	63.400	0.379%	362.979
LINEAR	PVI	17+75.000	63.400	PVI	19+30.000	61.000	-1.548%	155.000
LINEAR	PVI	19+30.000	61.000	PVI	21+50.000	63.400	1.091%	220.000
LINEAR	PVI	21+50.000	63.400	PVI	23+00.505	64.000	0.399%	150.505
LINEAR	PVI	23+00.505	64.000	PVI	27+00.000	63.000	-0.250%	399.495
LINEAR	PVI	27+00.000	63.000	PVI	28+80.000	61.500	-0.833%	180.000
LINEAR	PVI	28+80.000	61.500	PVI	29+50.000	62.000	0.714%	70.000
LINEAR	PVI	29+50.000	62.000	PVI	34+60.000	59.032	-0.582%	510.000
LINEAR	PVI	34+60.000	59.032	PVI	36+40.000	59.032	0.000%	180.000
LINEAR	PVI	36+40.000	59.032	PVI	38+50.000	57.000	-0.968%	210.000
LINEAR	PVI	38+50.000	57.000	PVI	39+38.847	56.500	-0.563%	88.847
LINEAR	PVI	39+38.847	56.500	PVI	40+20.000	58.000	1.848%	81.153
LINEAR	PVI	40+20.000	58.000	PVI	41+00.000	55.728	-2.840%	80.000
LINEAR	PVI	41+00.000	55.728	PVI	41+50.000	57.000	2.543%	50.000
LINEAR	PVI	41+50.000	57.000	PVI	42+50.000	58.000	1.000%	100.000
LINEAR	PVI	42+50.000	58.000	PVI	47+20.000	56.500	-0.319%	470.000
LINEAR	PVI	47+20.000	56.500	PVI	50+50.000	58.000	0.455%	330.000
LINEAR	PVI	50+50.000	58.000	PVI	51+50.000	57.000	-1.000%	100.000
LINEAR	PVI	51+50.000	57.000	POE	55+00.000	56.500	-0.143%	350.000

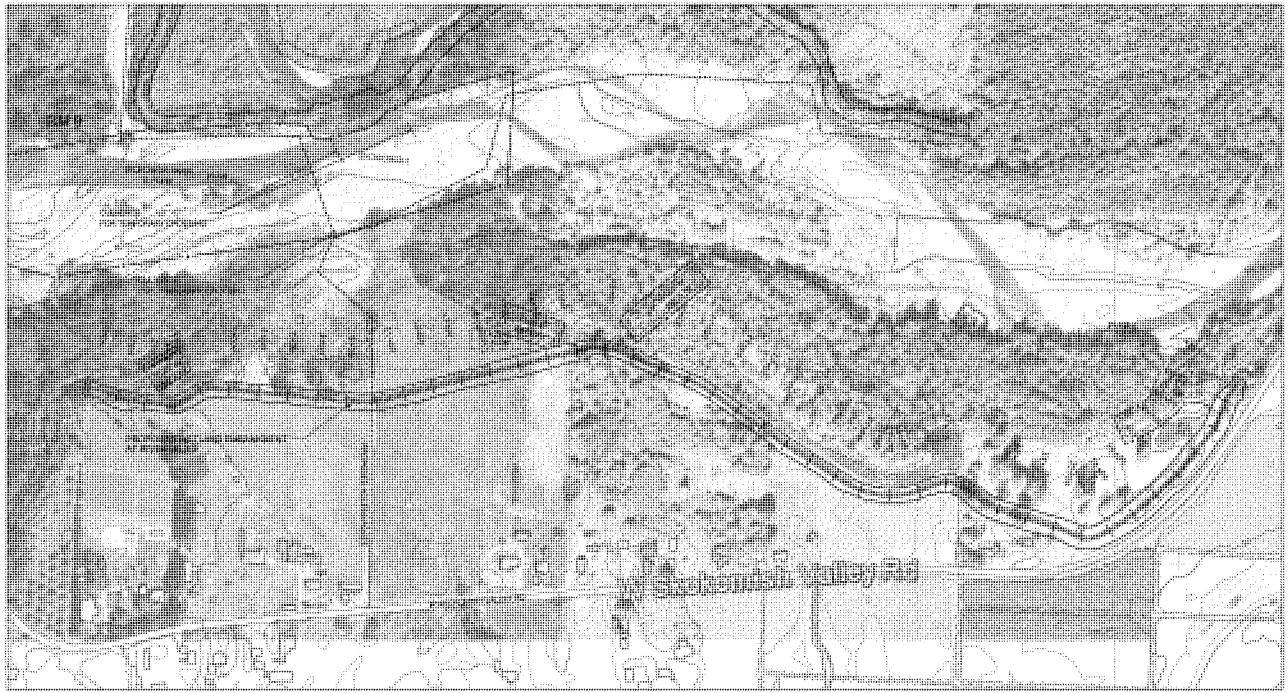
US Army Corps of Engineers
SEATTLE DISTRICT

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832
CONFLUENCE LEVEE REMOVAL
CURVE DATA

SHEET IDENTIFICATION
C-610

DATE AND TIME PLOTTED: 6/4/2015



WETLAND EMBANKMENT AT RIVER MILE 9 OVERALL SITE PLAN
1"=150'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

N

0 150' 300'
1"= 150'

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DWN BY:
CKD BY:
SUPV BY:
MANAGER BY:
DATE:
REGISTRATION NO.:
CONTRACT NO.:
FILE NUMBER:
DACW67-94-D-0016
PLOT DATE: 8/5/2015
PLOT TIME: 14:00
FILE NAME: C120.DWG
PAGE SIZE: 24 X 36 (ANSI-D)
SCALE: 1"=150' (ANSI-D)

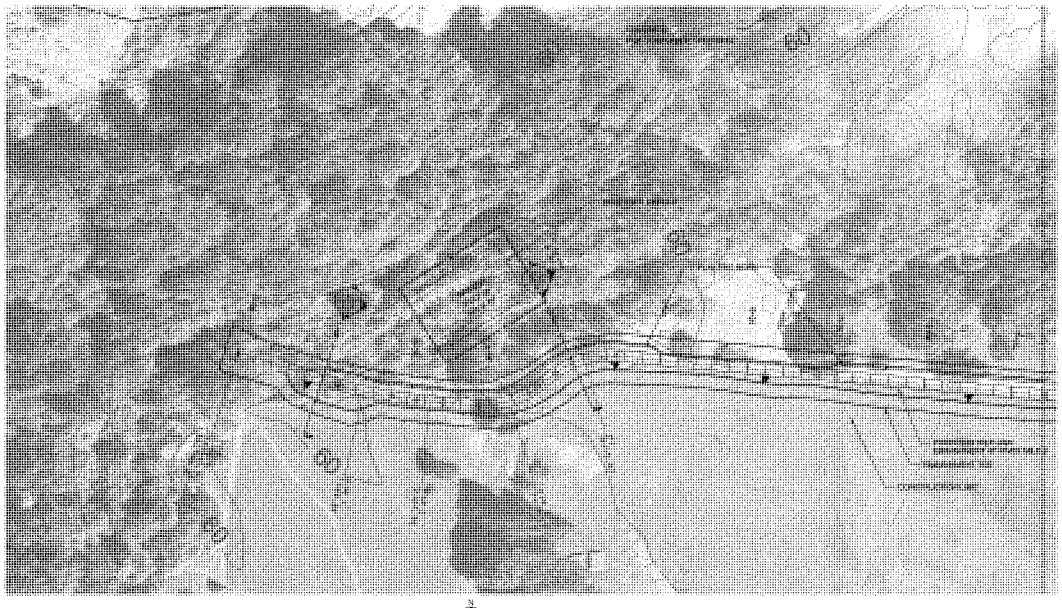
SKOKOMISH RIVER ECOSYSTEM RESTORATION
SKOKOMISH TRIBE OF WASHINGTON
SHELTON, MASON COUNTY, WASHINGTON
PROJ#1632

WETLAND RESTORATION AT
RIVER MILE 9
OVERALL SITE PLAN

SHEET IDENTIFICATION
C-120
SHEET 19 OF 36

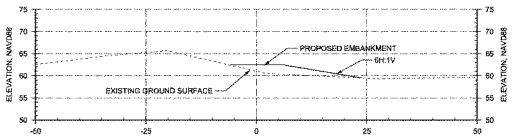
DESIGN FILE: pw:\\CDC3-WSDPWP001\SBA-wa.fs.usace.army.mil.sbawa01\Documents\Civil Works\Skokomish River_WA\PTN\INCRMAP2 BRON\Current Plans\Civil_Drawings\C-30 WETLAND RESTORATION AT RIVER MILE 9 OVERALL SITE PLAN

DATE AND TIME PLOTTED: 8/5/2015

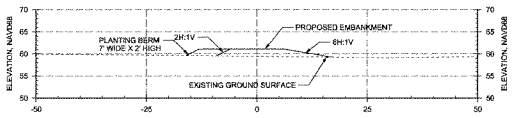


MATCH LINE SEE PLATE C-122

WETLAND EMBANKMENT AT RIVER MILE 9 PLAN 1
1"=50'



A STATION 1+00
1"=10'



B STATION 4+00
1"=10'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

5. THE GRADING LIMIT WILL BE FIELD STAKED EVERY 100'. THE PROJECT BIOLOGIST WILL WALK THE SITE AND MARK ANY TREES TO PROTECT WITH THE CONTRACTOR AND CONTRACTING OFFICER.

6. THERE WILL BE NO TEMPORARY ACCESS-WAYS ACROSS SLOPES GREATER THAN 30%.

7. NO PERMANENT ACCESS-WAYS WILL BE BUILT ACROSS OR DJACENT TO THE RIVER. ALL TEMPORARY ACCESS-WAYS WILL BE REMOVED (INCLUDING GRAVEL SURFACES) AND PLANTED AFTER PROJECT COMPLETION.

8. TEMPORARY ROADS IN WET OR FLOODED AREAS WILL BE ABANDONED AND RESTORED BY THE END OF THE IN-WATER WORK PERIOD.

9. NEW TEMPORARY STREAM CROSSINGS WILL AVOID POTENTIAL SPAWNING HABITAT (I.E. POOL TAILOUTS) AND POOLS) TO THE MAXIMUM EXTENT POSSIBLE. THE PRECISE PLACEMENT OF STREAM CROSSINGS WILL BE DETERMINED WITH THE PROJECT BIOLOGIST. THEY WILL MINIMIZE SEDIMENTATION IMPACTS BY USING BMPS LIKE MATS AND BOARDS TO CROSS A STREAM. BMPS WILL BE LISTED BY EACH APPLICANT IN SPIF. AFTER PROJECT COMPLETION TEMPORARY STREAM CROSSINGS WILL BE ABANDONED AND THE STREAM CHANNEL RESTORED WHERE NECESSARY.

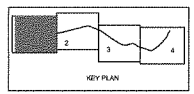
10. LOCATIONS OF TEMPORARY STREAM CROSSING WILL BE ISOLATED AND FISH RESCUE PERFORMED BY A QUALIFIED FISH BIOLOGIST PRIOR TO INSTALLATION.

11. INSTALLATION OF LWD AND STREAM CROSSING, IF ISOLATION OF WORK IS DEEMED TO BE LESS OF AN IMPACT FOR IN-WATER WORK THEN A PLAN WILL BE DEVELOPED THAT IS CONSISTENT WITH THE PROTOCOLS FOR ISOLATION OF WORK AND FISH RESCUE IN THE PROGRAMMATIC BIOLOGICAL ASSESSMENT FOR RESTORATION ACTIONS IN WASHINGTON STATE.

12. SOURCES OF LWD WILL COME FROM OFFSITE. NO FELLED LIVE TREES WILL BE USED AS A PART OF LWD STRUCTURES.

13. DIKE AND BERM MATERIAL WILL BE HAULED TO AN UPLAND SITE. IF MATERIAL MEETS THE SPECIFICATIONS, WILL BE INCORPORATED INTO THE SETBACK EMBANKMENT.

1"= 10' 0 10' 20'
1"= 50' 0 50' 100'



KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DRAWN BY: CHECKED BY: SUPERVISED BY: PLOT DATE: PLOT TIME: FILE NAME: SIZE: FILE NUMBER: SCALE: AS SHOWN

SHELL: SOLICITATION NO.: CONTRACT NO.: FILE NUMBER: SCALE: AS SHOWN

SKOKOMISH RIVER ECOSYSTEM RESTORATION
CHUM AND WATERSHED RESTORATION
SKOKOMISH INDIAN TRIBE
MASON COUNTY, WASHINGTON
PROHMSQ

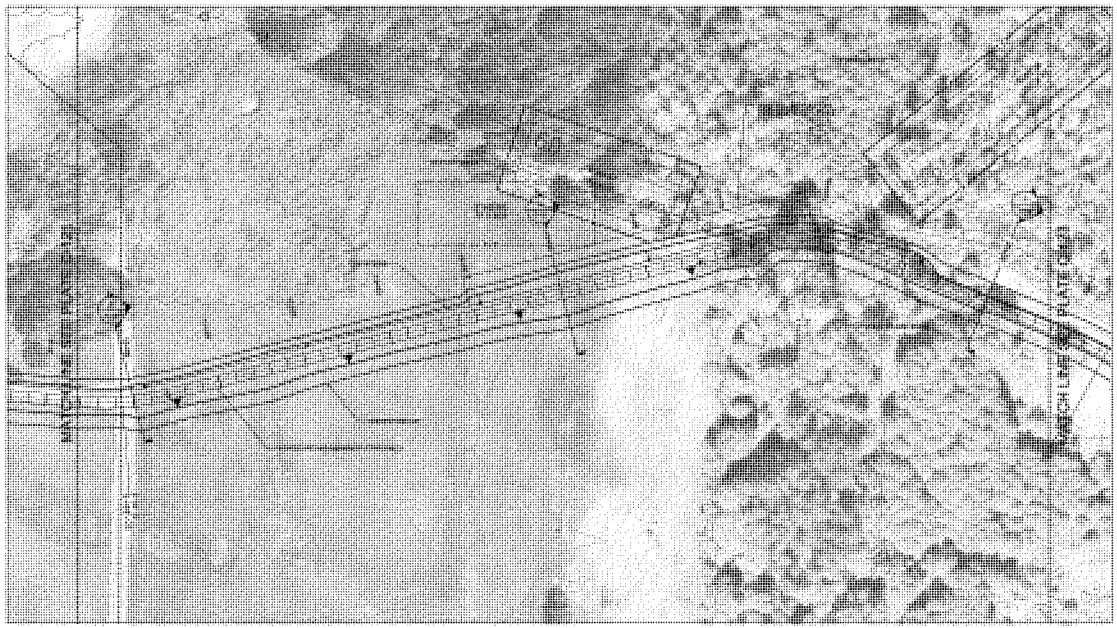
WETLAND RESTORATION AT
RIVER MILE 9
SITE PLAN 1

SHEET IDENTIFICATION
C-121
SHEET 20 OF 90

DATE AND TIME PLOTTED: 9/5/2015

DESIGN FILE: C:\users\jbridge\documents\revit\fpm\73320\7420\420\420-C-MILE_9_PLAN_1_0000 CFS.DGN

751



NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

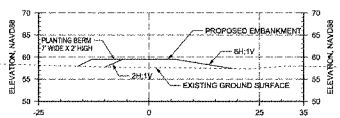
2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

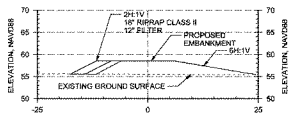
4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

N

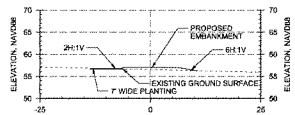
WETLAND EMBANKMENT AT RIVER MILE 9 PLAN 2
1"=50'



A STATION 10+00
1"=10'

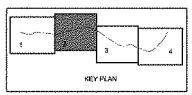


B STATION 15+00
1"=10'



C STATION 20+00
1"=10'

1"= 10' 0 10' 20'
1"= 50' 0 50' 100'



KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

SYMBOL	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS SEATTLE DISTRICT SEATTLE, WASHINGTON	DESIGNED BY: DRAWN BY: CHECKED BY: SUBMITTED BY: PLOT DATE: PLOT SCALE: PLOT STYLE: FILE NAME:	12/16/97 1"=50'	DATE: SOLICITATION NO.: CONTRACT NO.: FOR OFFICIAL USE ONLY:

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SNOQUALMIE, WASHINGTON
FN3H4532

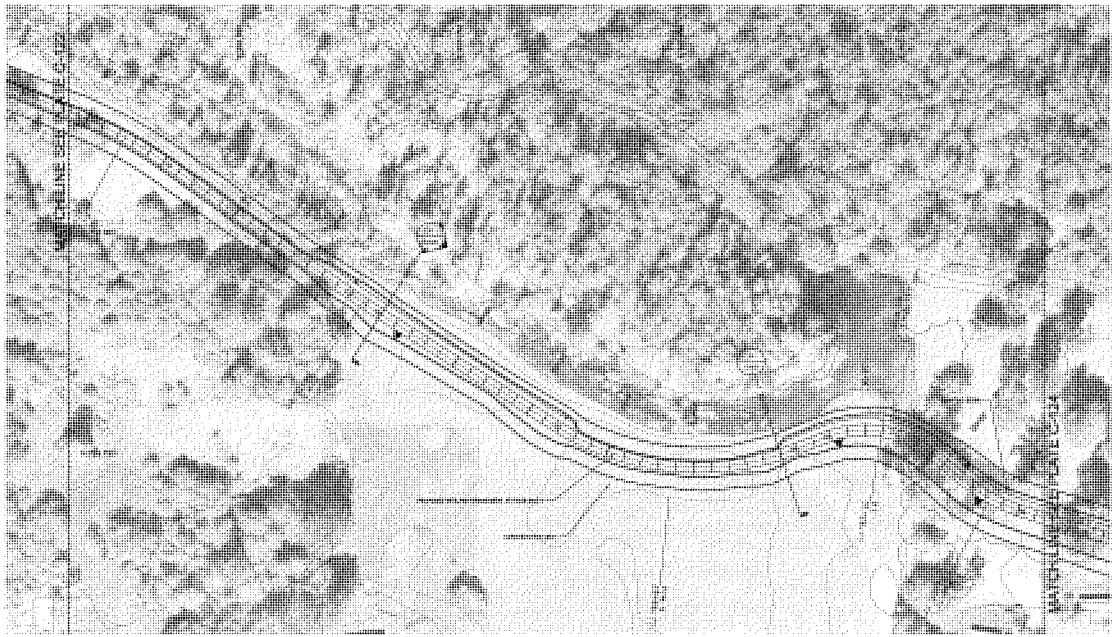
WETLAND RESTORATION AT RIVER MILE 9 SITE
SITE PLAN 2

SHEET IDENTIFICATION
C-122
SHEET 21 OF 30

DESIGN FILE pw:\\SCE-WWDPWWP0106A.nwd\ne.army.mil\dana\PCDocuments\Civil Works\Snoqualmie\Wetland Restoration, River Mile 9 Site Plan 2

DATE AND TIME PLOTTED: 6/5/2015

752



NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

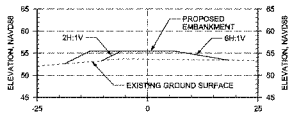
2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

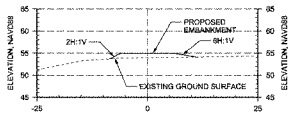
4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

N

WETLAND EMBANKMENT AT RIVER MILE 9 PLAN 3
1"=50'

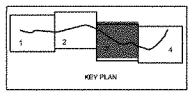


A STATION 25+00
1"=10'



B STATION 30+00
1"=10'

1"= 10' 0 10' 20'
1"= 50' 0 50' 100'



KEY PLAN

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
RENTON, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT DATE: 7/1/2015
FILE NAME: C-123.DWG
REF: 1994 AERIAL PHOTOGRAPHY, MAY/JUNE 2014, & SURVEY, MAY/JUNE 2014

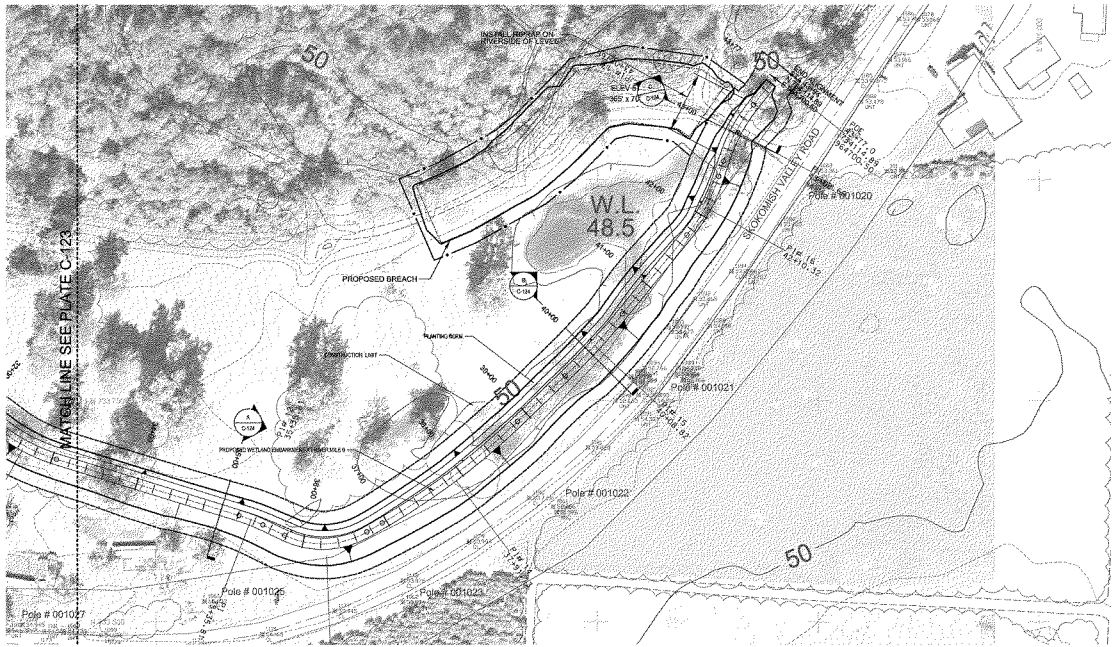
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DACW67-1-15-0001

DUWAMISH RIVER ECOSYSTEM RESTORATION
CENTRAL WATERWAY
SHORELINE RESTORATION
PH3H4802

WETLAND RESTORATION AT
RIVER MILE 9
SITE PLAN 3

SHEET IDENTIFICATION
C-123
SHEET 22 OF 54

DATE AND TIME PLOTTED: 9/23/2015 DESIGN FILE: pw:\\CDE-NWP\PWO\SEA-fwd.ds.usace.army.mil:sewad\Documents\Civil Works\Duwamish\Civil Works\Duwamish River, MN\TYPE PROJ\H4802 SHORE\Central Plant\Civil_Drawings\CAD_Sheets\C-123 WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 3



1 WETLAND EMBANKMENT AT RIVER MILE 9 PLAN 4
1"=50'

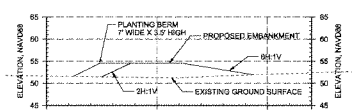
NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

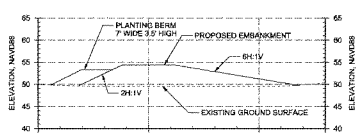
2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

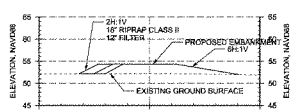
4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.



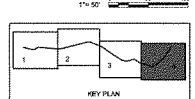
A STATION 35+00
1"=10'



B STATION 40+00
1"=10'



C STATION 43+00
1"=10'



U.S. Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

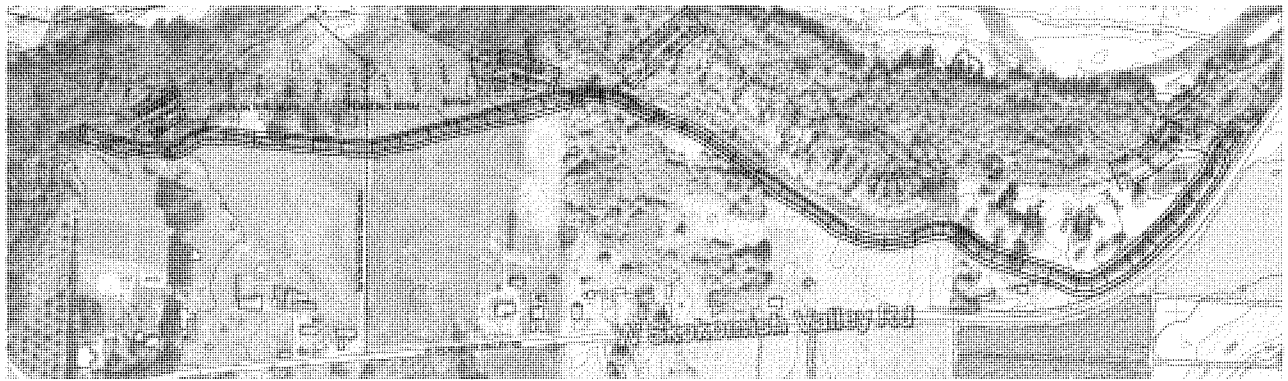
DESIGNED BY
DRAWN BY
CHECKED BY
SUBMITTED BY
PLOT DATE
PLOT SCALE
PLOT BY
DATE
REGISTRATION NO.
CONTRACT NO.
FILE NUMBER
SHEET SIZE
PROJECT TITLE
SKOKOMISH RIVER ECOSYSTEM RESTORATION GENERAL INVESTIGATION SKOKOMISH RIVER, MASON COUNTY, WASHINGTON
PROJ#3432
WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 4

SHEET IDENTIFICATION
C-124
SHEET 22 OF 40

DESIGN FILE: pw:\\COE-NWS\PROJECTS\A Ports and Waterways\Skokomish River, WA\PT16 PROJ\BIS SKOK\Current Plans\Skok_GENERAL\Sheets\NWS-124 WETLAND RESTORATION AT RIVER MILE 9 SITE PLAN 4

DATE AND TIME PLOTTED: 6/5/2015

754



NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

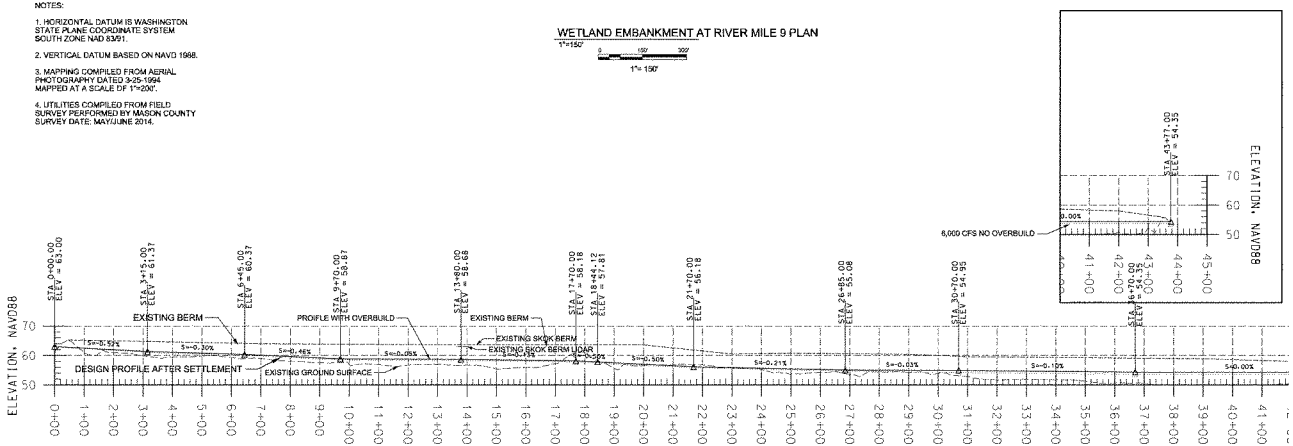
4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

WETLAND EMBANKMENT AT RIVER MILE 9 PLAN

1"=150'

0 150' 300'

1"= 150'



WETLAND EMBANKMENT AT RIVER MILE 9 PROFILE

1"=150'

0 150' 300'

1"= 150' H

0 15' 30'

1"= 15' V

US Army Corps of Engineers®
SEATTLE DISTRICT

SYMBOL	DESCRIPTION	DATE	APPR.	DRAWN	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DRAWN BY: | DATE:
DWN BY: | CKD BY: | SIGNATURE NO.
SUBMITTED BY: | CONTRACT NO.
PLOT DATE: 9/25/2015 | PLOT TIME: 11:57 AM | FILE NAME: 01-WETLAND RESTORATION PLAN & PROFILE_JOB25.dgn
SIZE: D | FILE NAME: 01-WETLAND RESTORATION PLAN & PROFILE_JOB25.dgn

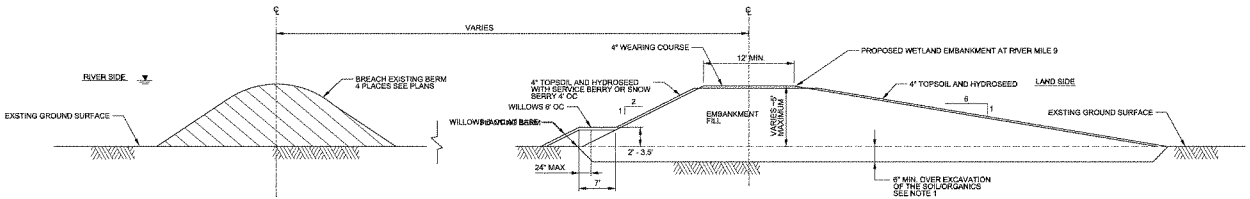
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, MASON COUNTY, WA
FHQM633

WETLAND RESTORATION AT
RIVER MILE 9
PLAN AND PROFILE

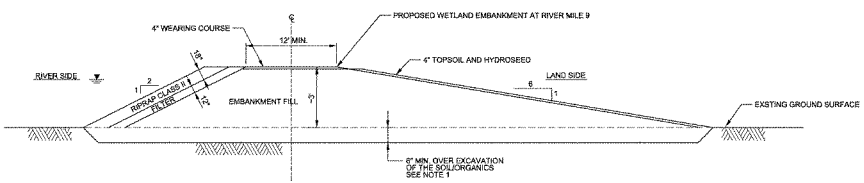
SHEET IDENTIFICATION
C-220
SHEET 25 OF 44

DATE AND TIME PLOTTED: 9/25/2015

DESIGN FILE: pw:\\COE-LWO\PWWW\SEA.nwd.sea.army.mil:admin01\Documents\Civil Works\Skokomish River, WA\377\PROJMGD SKOK\Current Phase\Civil_Drawings\Civil\PROMGD SKK-MILE_9_PLAN & PROFILE_JOB25.dgn



A C-320 TYPICAL WETLAND EMBANKMENT AT RIVER MILE 9 SECTION
NOT TO SCALE



B C-320 TYPICAL WETLAND EMBANKMENT AT RIVER MILE 9 WITH RIPRAP SECTION
NOT TO SCALE

NOTES:

1. RIPRAP (CLASS II) SHALL BE GRADED AS FOLLOWS (ASSUMES SPHERICAL DIAMETER, 165 PCF):

100 % SMALLER THAN 18" (120-290 POUNDS)
80 % SMALLER THAN 15" (85-170 POUNDS)
50 % SIZE EQUAL TO OR GREATER THAN 12" (35-85 POUNDS)
30 % SMALLER THAN 9" (15-35 POUNDS)

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DATE:
DRAWN BY: SOLICITATION NO.:
CHECKED BY: CONTRACT NO.:
SUBMITTED BY: FILE NUMBER:
PLOT DATE: 15 OCT 2002 PLOT SCALE: 1:1
PLOT TIME: PLOT DRIVER: PDF
CADD: PROJECTION: SPCS NAD 83 WA SOUTH, US FT, INTERNATIONAL ARCS (FT)

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GRAVEL & VINE VILLAGE
SHORELINE, WASHINGTON
PN:34832

WETLAND RESTORATION AT TYPICAL SECTIONS

SHEET IDENTIFICATION
C-320
SHEET 20 OF 40

DESIGN FILE: pw:\\COE-NWSEPMWORSA.nwd.usace.army.mil:bmw007\Documents\Civil Works\Skokomish Nwk, WA\PTN 1\NWA\02 SHORE\Current Project\C-_Lines\CAD_Drawings\C\C-320 WETLAND RESTORATION AT RIVER MILE 9 TYPICAL SECTIONS

DATE AND TIME PLOTTED: 10/22/15

WETLAND RESTORATION EMBANKMENT AT RIVER MILE 9 HORIZONTAL CURVE DATA

POB 0+00.000
NORTHING: 734,099.719
EASTING: 960,794.213

Tangential Direction: S 72°41'01.7" E
Tangential Length: 117.640

PI #1 1+49.839
NORTHING: 734,055.120
EASTING: 960,937.260
Radius: 400.000
Length: 64.259
Tangent: 32.186
Delta: 9°12'16.03" Left
Degree of Curvature(Arc): 14°19'26.20"

Tangential Direction: S 81°53'17.7" E
Tangential Length: 27.579

PI #2 2+24.751
NORTHING: 734,044.530
EASTING: 961,011.580
Radius: 400.000
Length: 30.531
Tangent: 15.273
Delta: 4°22'23.82" Left
Degree of Curvature(Arc): 14°19'26.20"

Tangential Direction: S 86°15'41.5" E
Tangential Length: 39.560

PI #3 3+17.132
NORTHING: 734,038.506
EASTING: 961,103.759
Radius: 100.000
Length: 71.864
Tangent: 37.563
Delta: 41°10'30.64" Left
Degree of Curvature(Arc): 57°17'44.81"

Tangential Direction: N 52°33'47.8" E
Tangential Length: 24.537

PI #4 4+15.032
NORTHING: 734,100.000
EASTING: 961,184.083
Radius: 100.000
Length: 74.477
Tangent: 39.061
Delta: 42°40'25.54" Right
Degree of Curvature(Arc): 57°17'44.81"

Tangential Direction: S 84°45'51.6" E
Tangential Length: 485.772

PI #5 9+88.025
NORTHING: 734,047.380
EASTING: 961,758.320
Radius: 300.000
Length: 102.607
Tangent: 51.909
Delta: 19°36'47.22" Left
Degree of Curvature(Arc): 19°05'54.94"

Tangential Direction: N 75°38'21.2" E
Tangential Length: 653.873

PI #6 17+65.139
NORTHING: 734,246.680
EASTING: 962,534.410
Radius: 200.000
Length: 126.489
Tangent: 65.440
Delta: 36°14'10.81" Right
Degree of Curvature(Arc): 28°38'52.40"

Tangential Direction: S 68°07'28.0" E
Tangential Length: 240.197

PI #7 21+48.546
NORTHING: 734,110.189
EASTING: 962,872.941
Radius: 500.000
Length: 117.774
Tangent: 59.161
Delta: 13°29'45.49" Right
Degree of Curvature(Arc): 11°27'32.96"

Tangential Direction: S 54°37'42.6" E
Tangential Length: 248.569

PI #8 24+75.891
NORTHING: 733,920.350
EASTING: 963,140.310
Radius: 800.000
Length: 40.317
Tangent: 20.163
Delta: 2°52'14.91" Left
Degree of Curvature(Arc): 7°09'43.10"

Tangential Direction: S 57°36'57.5" E
Tangential Length: 236.457

PI #9 28+86.775
NORTHING: 733,699.674
EASTING: 963,486.915
Radius: 300.000
Length: 260.208
Tangent: 151.283
Delta: 59°35'55.86" Left
Degree of Curvature(Arc): 19°05'54.94"

Tangential Direction: N 68°58'06.8" E
Tangential Length: 40.149

PI #10 31+26.107
NORTHING: 733,793.576
EASTING: 963,731.137
Radius: 120.000
Length: 127.096
Tangent: 70.240
Delta: 60°41'02.45" Right
Degree of Curvature(Arc): 47°44'47.34"

Tangential Direction: S 50°20'50.7" E
Tangential Length: 43.404

PI #11 32+86.173
NORTHING: 733,895.665
EASTING: 963,949.282
Radius: 200.000
Length: 78.564
Tangent: 39.806
Delta: 22°29'45.91" Left
Degree of Curvature(Arc): 28°38'52.40"

Tangential Direction: S 72°50'36.8" E
Tangential Length: 216.318

PI #12 35+55.806
NORTHING: 733,615.990
EASTING: 964,107.922
Radius: 200.000
Length: 29.022
Tangent: 14.535
Delta: 8°18'50.88" Right
Degree of Curvature(Arc): 28°38'52.40"

Tangential Direction: S 64°32'45.7" E
Tangential Length: 27.342

PI #13 38+30.250
NORTHING: 733,575.277
EASTING: 964,193.244
Radius: 100.000
Length: 96.871
Tangent: 52.616
Delta: 55°30'11.36" Left
Degree of Curvature(Arc): 57°17'44.81"

Tangential Direction: N 59°57'02.0" E
Tangential Length: 26.236

PI #14 37+91.133
NORTHING: 733,850.025
EASTING: 964,339.741
Radius: 800.000
Length: 191.858
Tangent: 96.392
Delta: 13°44'27.31" Left
Degree of Curvature(Arc): 7°09'43.10"

Tangential Direction: N 46°12'35.6" E
Tangential Length: 74.387

PI #15 40+08.817
NORTHING: 733,811.307
EASTING: 964,497.951
Radius: 800.000
Length: 95.945
Tangent: 47.829
Delta: 6°90'34.48" Left
Degree of Curvature(Arc): 7°09'43.10"

Tangential Direction: N 39°22'01.1" E
Tangential Length: 115.476

PI #16 42+10.324
NORTHING: 733,967.179
EASTING: 964,625.435
Radius: 200.000
Length: 73.714
Tangent: 38.315
Delta: 21°41'25.21" Left
Degree of Curvature(Arc): 28°38'52.40"

Tangential Direction: N 17°40'35.9" E
Tangential Length: 18.261

PI #17 43+02.659
NORTHING: 734,056.030
EASTING: 964,663.751
Radius: 200.000
Length: 72.547
Tangent: 36.676
Delta: 20°46'58.98" Right
Degree of Curvature(Arc): 28°38'52.40"

Tangential Direction: N 38°27'34.9" E
Tangential Length: 36.487

POE 43+77.017
NORTHING: 734,114.686
EASTING: 964,700.500

WETLAND RESTORATION EMBANKMENT AT RIVER MILE 9 VERTICAL CURVE DATA

VERTICAL ALIGNMENT NAME: MILE 9 VERT DESIGN

		STATION	ELEVATION
ELEMENT: LINEAR			
	POB	0+00.000	61.500
	PVI	0+50.775	65.097
	TANGENT GRADE:		7.064%
	TANGENT LENGTH:		50.775
ELEMENT: LINEAR			
	PVI	0+50.775	65.097
	PVI	6+43.544	62.798
	TANGENT GRADE:		-0.368%
	TANGENT LENGTH:		592.769
ELEMENT: LINEAR			
	PVI	6+43.544	62.798
	PVI	9+91.952	61.008
	TANGENT GRADE:		-0.514%
	TANGENT LENGTH:		348.408
ELEMENT: LINEAR			
	PVI	9+91.952	61.008
	PVI	11+96.484	59.493
	TANGENT GRADE:		-0.740%
	TANGENT LENGTH:		204.512
ELEMENT: LINEAR			
	PVI	11+96.484	59.493
	PVI	19+93.727	58.504
	TANGENT GRADE:		-0.199%
	TANGENT LENGTH:		497.283
ELEMENT: LINEAR			
	PVI	16+93.727	58.504
	PVI	17+93.121	59.000
	TANGENT GRADE:		0.499%
	TANGENT LENGTH:		99.394
ELEMENT: LINEAR			
	PVI	17+93.121	59.000
	PVI	18+44.124	58.898
	TANGENT GRADE:		-0.200%
	TANGENT LENGTH:		51.003
ELEMENT: LINEAR			
	PVI	18+44.124	58.898
	PVI	25+00.000	57.386
	TANGENT GRADE:		-0.231%
	TANGENT LENGTH:		655.876
ELEMENT: LINEAR			
	PVI	25+00.000	57.386
	PVI	30+42.229	56.100
	TANGENT GRADE:		-0.237%
	TANGENT LENGTH:		542.229
ELEMENT: LINEAR			
	PVI	30+42.229	56.100
	PVI	35+00.000	56.000
	TANGENT GRADE:		-0.022%
	TANGENT LENGTH:		457.771
ELEMENT: LINEAR			
	PVI	35+00.000	56.000
	POE	44+36.408	56.000
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		936.408

VERTICAL ALIGNMENT NAME: MILE 9 VERT DESIGN WITH OVERBUILD

		STATION	ELEVATION
ELEMENT: LINEAR			
	POB	0+00.000	56.950
	PVI	0+50.775	65.097
	TANGENT GRADE:		16.242%
	TANGENT LENGTH:		50.775
ELEMENT: LINEAR			
	PVI	0+50.775	65.097
	PVI	6+43.544	63.175
	TANGENT GRADE:		-0.324%
	TANGENT LENGTH:		592.769
ELEMENT: LINEAR			
	PVI	6+43.544	63.175
	PVI	10+00.000	61.365
	TANGENT GRADE:		-0.509%
	TANGENT LENGTH:		356.456
ELEMENT: LINEAR			
	PVI	10+00.000	61.365
	PVI	11+96.484	59.865
	TANGENT GRADE:		-0.774%
	TANGENT LENGTH:		196.484
ELEMENT: LINEAR			
	PVI	11+96.484	59.865
	PVI	19+93.727	58.875
	TANGENT GRADE:		-0.199%
	TANGENT LENGTH:		497.283
ELEMENT: LINEAR			
	PVI	18+93.727	58.875
	PVI	17+93.121	59.375
	TANGENT GRADE:		0.503%
	TANGENT LENGTH:		99.394
ELEMENT: LINEAR			
	PVI	17+93.121	59.375
	PVI	18+44.124	58.898
	TANGENT GRADE:		-0.935%
	TANGENT LENGTH:		51.003
ELEMENT: LINEAR			
	PVI	18+44.124	58.898
	PVI	25+00.000	57.755
	TANGENT GRADE:		-0.173%
	TANGENT LENGTH:		655.876
ELEMENT: LINEAR			
	PVI	25+00.000	57.755
	PVI	30+42.229	56.850
	TANGENT GRADE:		-0.169%
	TANGENT LENGTH:		542.229
ELEMENT: LINEAR			
	PVI	30+42.229	56.850
	PVI	35+00.000	56.750
	TANGENT GRADE:		-0.022%
	TANGENT LENGTH:		457.771
ELEMENT: LINEAR			
	PVI	35+00.000	56.750
	POE	44+36.408	56.750
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		936.408

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: JAMES
DRAWN BY: JAMES
CHKD BY: SCOTT
SUBMITTED BY: SCOTT
PLOT DATE: 7/27/2015
SIZE: 22X34
FILE NAME: C-620 WETLAND RESTORATION AT RIVER MILE 9 CURVE DATA.DWG

SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DACW67-
DRAWING NO.
C-620
SHEET 20 OF 40

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH, MASON COUNTY, WA
PH94402

WETLAND RESTORATION AT
RIVER MILE 9
CURVE DATA

SHEET IDENTIFICATION
C-620
SHEET 20 OF 40

757

DESIGN FILE: per WWB-A&E17\PN rivers de ceem army mil\ceem\FCDocuments\Civil\Documents\Civil Work\Skokomish\Plans\ WA\PTN PROJECTS SKOKOMISH\Current Plans\Cov_Sheets\C-620 WETLAND RESTORATION AT RIVER MILE 9 CURVE DATA.

DATE AND TIME PLOTTED: 9/4/2015

WETLAND RESTORATION AT GRANGE OVERALL SITE PLAN
1"= 100'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

N

0 100' 200'
1"= 100'

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	DESIGNED/DR.	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

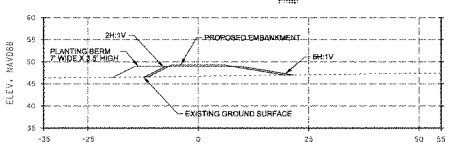
DESIGNED BY:
DRAWN BY:
CHKD BY:
REVIEW BY:
SUPV BY:
APPR BY:
PLOT DATE:
PLOT TIME:
FILE NAME:
LAYER:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
FILE TITLE:
DWG NAME: C:\DRAWINGS\GRANGE_OVERALL_0000-C130.DGN

MACKAMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SHORELINE, MASON COUNTY, WASHINGTON
PH34632
WETLAND RESTORATION AT GRANGE
OVERALL SITE PLAN

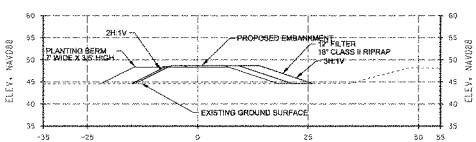
SHEET IDENTIFICATION
C-130
SHEET 27 OF 36

DATE AND TIME PLOTTED: 8/5/2015 DESIGN FILE: pw:\\COE-NWS\PWSD\185A-ows-ib.usace.army.mil:ewsd\Obermeier\Grant Wetlands\Mackamish River, WA\PY34 PROMASS DRONK\Grant Preservation_DRONKAD_Shoreline\C-130 WETLAND RESTORATION AT GRANGE OVERALL SITE PLAN 0000.DGN

WETLAND EMBANKMENT AT GRANGE PLANT
1"=40'



A 5+00
1"=10'



B 7+00
1"=10'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAP COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-MAR-1994.

4. UTILITIES COMPILED FROM FIELD SURVEY PERFORMED BY MASON COUNTY SURVEY DATE: MAY/JUNE 2014.

5. THERE WILL BE NO TEMPORARY ACCESS-WAYS ACROSS SLOPES GREATER THAN 30%.

6. NO PERMANENT ACCESS-WAYS WILL BE BUILT ACROSS OR ADJACENT TO THE RIVER. ALL TEMPORARY ACCESS-WAYS WILL BE REMOVED (INCLUDING GRAVEL SURFACES) AND PLANTED AFTER PROJECT COMPLETION.

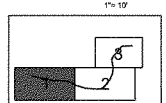
7. TEMPORARY ROADS IN WET OR FLOODED AREAS WILL BE ABANDONED AND RESTORED BY THE END OF THE IN-WATER WORK PERIOD.

8. DIKE AND BERM MATERIAL WILL BE HAULED TO AN UPLAND SITE. IF MATERIAL MEETS THE SPECIFICATIONS, WILL BE INCORPORATED INTO THE SETBACK EMBANKMENT.

N

0 50 100
1"= 50'

0 10 20
1"= 10'



KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DWR
DRAWN BY: CRD/BF/DWR
CHECKED BY: DWR
SUBMITTED BY: DWR
PLOT DATE: 13-OCT-2015
PLOT SCALE: 1:1
FILE NAME: C131_WETLAND RESTORATION AT GRANGE PLANT.DWG

SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
PROJECT NO.:

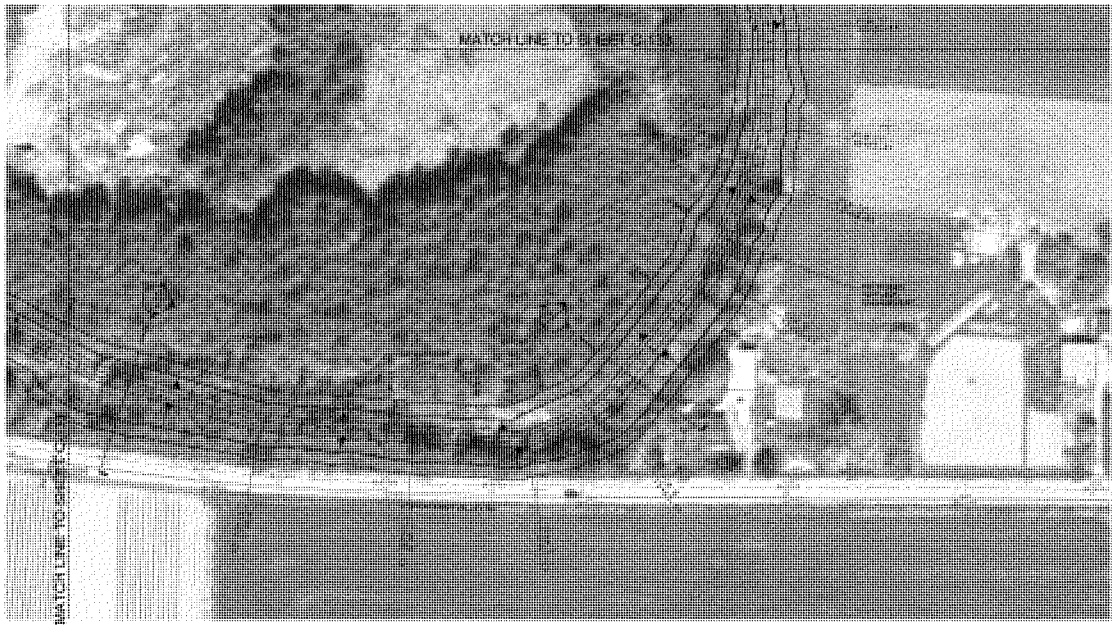
SKOKOMISH RIVER ECOSYSTEM RESTORATION
FEASIBILITY INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PHASE2

WETLAND RESTORATION AT GRANGE
SITE PLAN 1

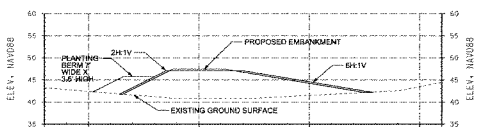
SHEET IDENTIFICATION
C-131
SHEET 29 OF 40

DATE AND TIME PLOTTED: 9/5/2019 RELEASE FILE: P:\PROJECTS\SKOKOMISH\DRAWINGS\SKOKOMISH_FEASIBILITY\WETLAND RESTORATION AT GRANGE SITE PLAN 1

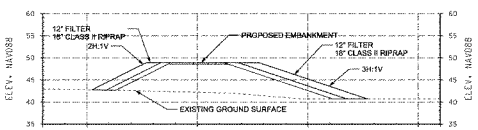
759



WETLAND EMBANKMENT AT GRANGE PLAN 2
1"=50'



A 10+00
1"=10'



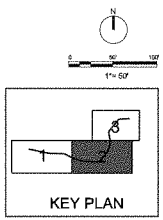
B 16+00
1"=10'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988

3. MAP COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-MAR-1994



KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	CHKD.	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHKD BY:
SUPV BY:
APPR BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DACW67-73-C-0077
PLOT DATE: 7-OCT-1994
PLOT SCALE: 1:1
PLOT UNITS: INCHES
USER NAME: STEVEBAUER
DESIGN FILE: J:\PROJDATA\WRIA9\SNOKOMISH\Grange\Grange Wetland\Snohomish River_WRIA9_Grange Wetland Site Plan 2.dgn

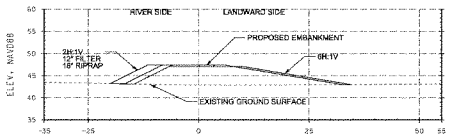
SNOHOMISH RIVER ECOSYSTEM RESTORATION
GRANGE WETLANDS PLAN
SNOHOMISH COUNTY, WASHINGTON
PH.0H132

WETLAND RESTORATION AT GRANGE
SITE PLAN 2

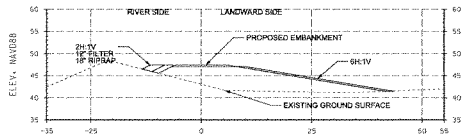
SHEET IDENTIFICATION
C-132
SHEET 22 OF 56

DATE AND TIME PLOTTED: 6/13/2015

DESIGN FILE: J:\PROJDATA\WRIA9\SNOKOMISH\Grange\Grange Wetland\Snohomish River_WRIA9_Grange Wetland Site Plan 2.dgn



A 25+00
1"=10'



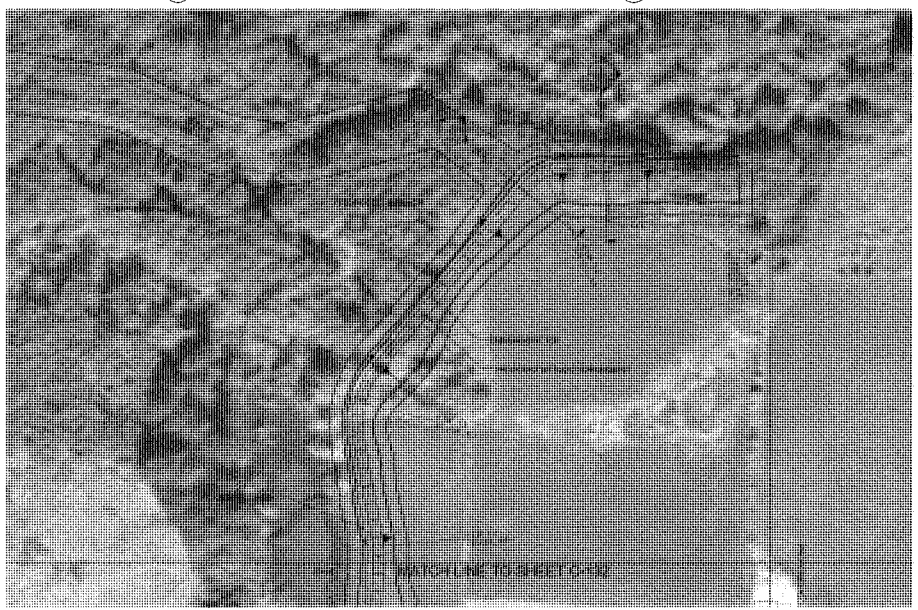
B 26+00
1"=10'

NOTES:

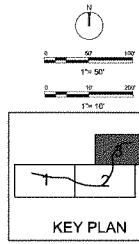
1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAP COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-MAR-1994.



WETLAND EMBANKMENT AT GRANGE PLAN 3
1"=50'



KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT DATE: FLOT FILE:
PLOT SCALE: PLOT TYPE:
PROJ. ENGINEER:
PROJ. MANAGER:
FILE NAME: C:\DOCUMENTS AND SETTINGS\ADMINISTRATOR\DESKTOP\CONTRACT PLAN 3_WRK-133.DWG

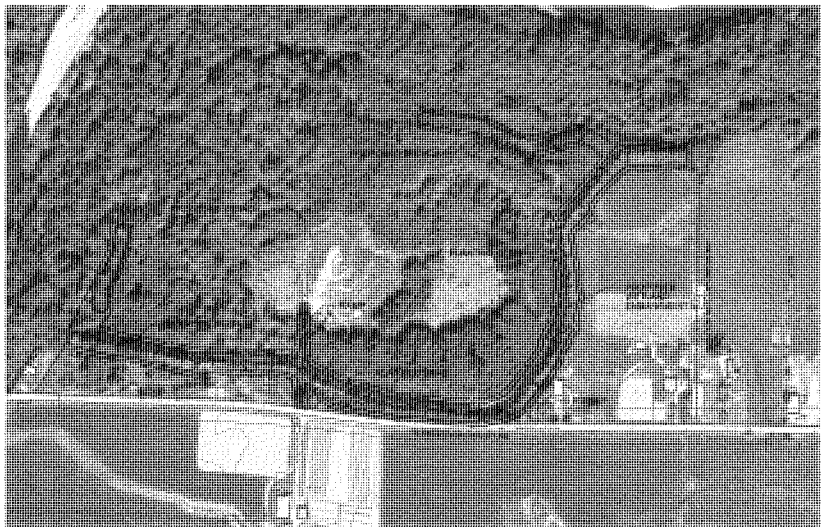
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, MASON COUNTY, WA.
PH3M02

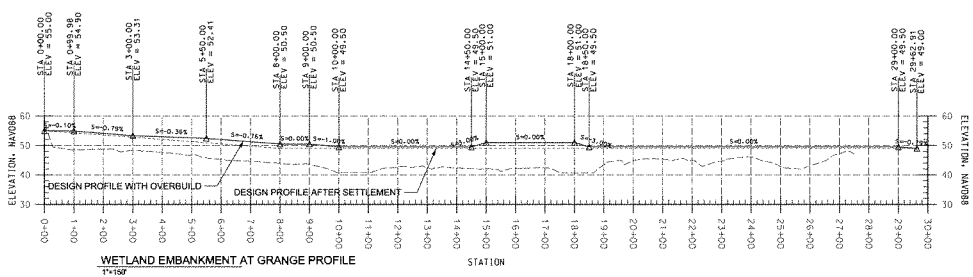
WETLAND RESTORATION AT GRANGE
SITE PLAN 3

SHEET IDENTIFICATION
C-133
SHEET 33 OF 40

DATE AND TIME PLOTTED: 6/23/2015 DESIGN FILE: per:\DOE-NW\DPW\WSM-new.ds.usace.army.mil:cwnw07\Documents\ROJ\Documents\ROJ\Project\Skokomish River, WA\WYTE PH3M02 SKOKOCurrent Phase\Civil_Drawings\C-133 WETLAND RESTORATION AT GRANGE SITE PLAN 3



WETLAND EMBANKMENT AT GRANGE PLAN
1"=150'



WETLAND EMBANKMENT AT GRANGE PROFILE
1"=150'

0 150' 300'
1"= 150' H

0 15' 30'
1"= 15' V

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988

3. MAP COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-MAR-1994

N

0 150' 300'
1"= 150'

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

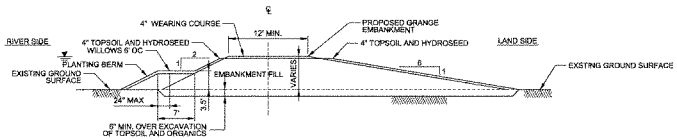
DESIGNED BY:
DRAWN BY:
CHKD BY:
APPR BY:
DATE:
SCALE:
PLOT DATE:
DWG. NAME:
SIZE:
FILE NAME:
SOLICITATION NO.:
CONTRACT NO.:
IDENT. NO.:
PLOT SCALE:
PLOT TIME:
FILE NAME:
C:\PROJECT\SNOQUALMIE_PLAN_&_PROFILE.DGN

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GRANGE, KING COUNTY, WASHINGTON
SNOQUALMIE RIVER, WRIA 7
PN:P94832
WETLAND RESTORATION AT GRANGE
PLAN AND PROFILE

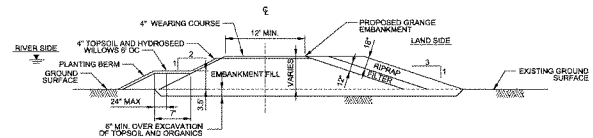
SHEET IDENTIFICATION
C-230
SHEET 31 OF 36

DESIGN FILE: pw:\\nwk-ASD01.srf.nwk.ds.usace.army.mil:sthesh10\Documents\Civil Works\Backgrounds\Plan Sheet_WA\PT16-PN\NASB_ENVIRO\Grange\PN-C230 WETLAND RESTORATION AT GRANGE PLAN & PROFILE

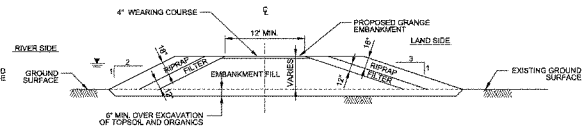
DATE AND TIME PLOTTED: 5/4/2015



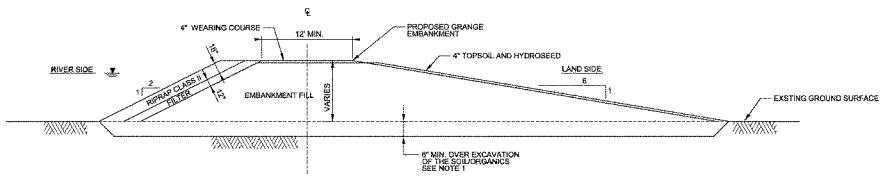
A C-330 WETLAND EMBANKMENT AT GRANGE TYPICAL SECTION 6H:1V LANDSIDE
NOT TO SCALE



B C-330 WETLAND EMBANKMENT AT GRANGE TYPICAL SECTION
3H:1V LANDSIDE
NOT TO SCALE



D C-330 WETLAND EMBANKMENT AT GRANGE TYPICAL SECTION
2H:1V RIVERSIDE 3H:1V LANDSIDE W/RIPRAP
NOT TO SCALE



C C-330 WETLAND EMBANKMENT AT GRANGE TYPICAL SECTION 2H:1V RIVERSIDE WITH RIPRAP
NOT TO SCALE

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
DATE BY:
SUBMITTED BY:
PLOT DATE:
PLOT SCALE:
FILE NAME:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
SHEET NO.:
SHEET TITLE: WETLAND RESTORATION AT GRANGE

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SNOQUALMIE, WASHINGTON
PN34832

SHEET IDENTIFICATION
C-330
SHEET 33 OF 58

DATE AND TIME PLOTTED: 9/4/2015

DESIGN FILE: per:N:\HS-AS\19\dh\ms.dh.usace.army.mil\stamsd1\Documents\Civil Works\Snoqualmie\Flood\Fish_Land\CAD_Shared\Civil\C-300 WETLAND RESTORATION AT GRANGE TYPICAL SECTION

WETLAND RESTORATION AT GRANGE HORIZONTAL CURVE DATA

POB 0+00.000
NORTHING: 736,024.039
EASTING: 968,965.882

TANGENTIAL DIRECTION: S 77°57'15.4" E
TANGENTIAL LENGTH: 435.407

PI #1 4+44.748
NORTHING: 734,931.224
EASTING: 969,192.816
RADIUS: 100.000
LENGTH: 16.604
TANGENT: 9.339
DELTA: 10°40'14.28" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 88°37'29.7" E
TANGENTIAL LENGTH: 182.004

PI #2 6+06.352
NORTHING: 734,927.365
EASTING: 969,282.429
RADIUS: 100.000
LENGTH: 1.694
TANGENT: 0.317
DELTA: 0°57'47.65" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 88°59'17.4" E
TANGENTIAL LENGTH: 125.059

PI #3 7+56.373
NORTHING: 734,924.713
EASTING: 969,411.428
RADIUS: 100.000
LENGTH: 46.438
TANGENT: 23.645
DELTA: 26°36'21.84" RIGHT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 62°22'55.7" E
TANGENTIAL LENGTH: 170.276

PI #4 9+57.846
NORTHING: 734,850.460
EASTING: 969,591.580
RADIUS: 100.000
LENGTH: 18.744
TANGENT: 9.399
DELTA: 10°44'21.84" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 73°07'17.3" E
TANGENTIAL LENGTH: 179.423

PI #5 11+57.688
NORTHING: 734,772.420
EASTING: 969,782.870
RADIUS: 100.000
LENGTH: 22.087
TANGENT: 11.079
DELTA: 12°38'36.93" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 85°45'54.3" E
TANGENTIAL LENGTH: 160.249

PI #6 13+30.117
NORTHING: 734,759.680
EASTING: 969,934.920
RADIUS: 100.000
LENGTH: 2.361
TANGENT: 1.194
DELTA: 1°23'52.70" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 87°07'58.0" E
TANGENTIAL LENGTH: 102.583

PI #7 14+57.574
NORTHING: 734,753.304
EASTING: 967,062.217
RADIUS: 100.000
LENGTH: 46.543
TANGENT: 23.701
DELTA: 26°40'01.13" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 66°12'00.9" E
TANGENTIAL LENGTH: 47.510

PI #8 15+53.581
NORTHING: 734,792.394
EASTING: 967,170.849
RADIUS: 100.000
LENGTH: 50.228
TANGENT: 26.658
DELTA: 28°46'42.19" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 37°25'18.7" E
TANGENTIAL LENGTH: 157.953

PI #9 17+48.856
NORTHING: 734,946.594
EASTING: 967,288.834
RADIUS: 100.000
LENGTH: 21.628
TANGENT: 10.553
DELTA: 12°02'53.36" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 25°22'25.4" E
TANGENTIAL LENGTH: 101.453

PI #10 19+68.663
NORTHING: 735,056.589
EASTING: 967,341.144
RADIUS: 100.000
LENGTH: 20.063
TANGENT: 10.065
DELTA: 11°29'42.73" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 13°52'42.6" E
TANGENTIAL LENGTH: 34.816

PI #11 19+23.908
NORTHING: 735,110.590
EASTING: 967,354.390
RADIUS: 100.000
LENGTH: 20.611
TANGENT: 10.342
DELTA: 11°46'38.02" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 2°04'08.6" E
TANGENTIAL LENGTH: 85.053

PI #12 29+30.438
NORTHING: 735,217.134
EASTING: 967,388.242
RADIUS: 100.000
LENGTH: 22.521
TANGENT: 11.308
DELTA: 12°54'11.99" LEFT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 10°50'03.4" W
TANGENTIAL LENGTH: 108.711

PI #13 21+98.300
NORTHING: 735,382.097
EASTING: 967,326.872
RADIUS: 100.000
LENGTH: 87.771
TANGENT: 46.938
DELTA: 50°17'20.12" RIGHT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: N 39°27'16.7" E
TANGENTIAL LENGTH: 269.545

PI #14 25+31.300
NORTHING: 735,643.590
EASTING: 967,542.162
RADIUS: 50.000
LENGTH: 42.489
TANGENT: 22.622
DELTA: 48°41'21.62" RIGHT
DEGREE OF CURVATURE(ARC): 114°35'29.61"

TANGENTIAL DIRECTION: N 88°18'38.3" E
TANGENTIAL LENGTH: 200.248

POE 27+51.413
NORTHING: 735,651.148
EASTING: 967,754.914

WETLAND RESTORATION AT GRANGE VERTICAL CURVE DATA

VERTICAL ALIGNMENT NAME: GRANGE VERTICAL DESIGN

		STATION	ELEVATION
ELEMENT: LINEAR	POB	0+00.000	55.000
	PVI	0+99.975	54.300
	TANGENT GRADE:		-0.700%
	TANGENT LENGTH:		99.975
ELEMENT: LINEAR	PVI	0+99.975	54.300
	PVI	3+00.000	52.807
	TANGENT GRADE:		-0.747%
	TANGENT LENGTH:		200.025
ELEMENT: LINEAR	PVI	3+00.000	52.807
	PVI	7+99.597	49.000
	TANGENT GRADE:		-0.762%
	TANGENT LENGTH:		499.597
ELEMENT: LINEAR	PVI	7+99.597	49.000
	POE	29+62.913	49.000
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		2163.316

VERTICAL ALIGNMENT NAME: GRANGE VERTICAL DESIGN WITH OVERBUILD

		STATION	ELEVATION
ELEMENT: LINEAR	POB	0+00.000	55.000
	PVI	0+99.975	54.300
	TANGENT GRADE:		-0.100%
	TANGENT LENGTH:		99.975
ELEMENT: LINEAR	PVI	0+99.975	54.300
	PVI	3+00.000	53.310
	TANGENT GRADE:		-0.785%
	TANGENT LENGTH:		200.025
ELEMENT: LINEAR	PVI	3+00.000	53.310
	PVI	5+50.000	52.405
	TANGENT GRADE:		-0.362%
	TANGENT LENGTH:		250.000
ELEMENT: LINEAR	PVI	5+50.000	52.405
	PVI	8+00.000	50.500
	TANGENT GRADE:		-0.762%
	TANGENT LENGTH:		250.000
ELEMENT: LINEAR	PVI	8+00.000	50.500
	PVI	9+00.000	50.500
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		100.000
ELEMENT: LINEAR	PVI	9+00.000	50.500
	PVI	10+00.000	49.500
	TANGENT GRADE:		-1.000%
	TANGENT LENGTH:		100.000
ELEMENT: LINEAR	PVI	10+00.000	49.500
	PVI	14+50.000	49.500
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		450.000
ELEMENT: LINEAR	PVI	14+50.000	49.500
	PVI	15+00.000	51.000
	TANGENT GRADE:		3.000%
	TANGENT LENGTH:		50.000
ELEMENT: LINEAR	PVI	15+00.000	51.000
	PVI	18+00.000	51.000
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		300.000
ELEMENT: LINEAR	PVI	18+00.000	51.000
	PVI	19+50.000	49.500
	TANGENT GRADE:		-3.000%
	TANGENT LENGTH:		50.000
ELEMENT: LINEAR	PVI	18+50.000	49.500
	PVI	29+00.000	49.500
	TANGENT GRADE:		0.000%
	TANGENT LENGTH:		1050.000
ELEMENT: LINEAR	PVI	29+00.000	49.500
	POE	29+62.913	49.000
	TANGENT GRADE:		-0.795%
	TANGENT LENGTH:		62.913

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DATE:
DWN BY: DATE:
CKD BY: DATE:
SUBMITTED BY:
SIZE: FSA NUMBER:
PROJECT NO: PROJ TASK:
DATE: 5/4/2015 TYPE: PLOT DATE
SCALE: 1:1 FILE NAME: C-630.DGN

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GRANGE AT KIRKLAND
SKOKOMISH, KITSAP COUNTY, WASHINGTON
PROJ#5432
WETLAND RESTORATION AT GRANGE
CURVE DATA

SHEET IDENTIFICATION
C-630
SHEET 33 OF 46

764

DGN FILE: pw:\\WWA-ADPW-PR:\wa.ab.usace.army.mil:wwadpw01\Documents\In-Out Work\Biological\Hydro_Design\Civil\C-630 WETLAND RESTORATION AT GRANGE CURVE DATA

DATE AND TIME PLOTTED: 5/4/2015

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

N

0 300' 600'

1"= 300'

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SCALE: 1"=300'
PLOT DATE: 11-17-1995
PLOT TIME: 14:00
FILE NAME: PROM8402.DWG
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DATUM: NAVD 88
SHEET 34 OF 40

SKAGIT/SAUK RIVER ECOSYSTEM RESTORATION
MINERAL WATER BLOCK
SKAGIT COUNTY, WASHINGTON
PROM8402

UPSTREAM I/WO
OVERALL SITE PLAN

SHEET IDENTIFICATION
C-140
SHEET 34 OF 40

DATE AND TIME PLOTTED: 11/13/2015 DESIGN FILE: jar:\WWS-SBOT\JW Wes.fs.secret.army.mil.sesedd1\Documents\Cad Works\Skagiman\Plan\WATER\TRONDHEIM BRONC\current\Plotted\Cpc_Dwg\CAD_Sheets\C140 AD UPSTREAM WO OVERALL SITE PLAN

UPSTREAM LWD PLAN 1
1"=50'

MATCH LINE TO PLATE C-142

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

4. THE GRADING LIMIT WILL BE FIELD STAKED EVERY 100'. THE PROJECT BIOLOGIST WILL WALK THE SITE AND MARK ANY TREES TO PROTECT WITH THE CONTRACTOR AND CONTRACTING OFFICER.

5. THERE WILL BE NO TEMPORARY ACCESS-WAYS ACROSS SLOPES GREATER THAN 30%.

6. NO PERMANENT ACCESS-WAYS WILL BE BUILT ACROSS OR ADJACENT TO THE RIVER. ALL TEMPORARY ACCESS-WAYS WILL BE REMOVED (INCLUDING GRAVEL SURFACES) AND PLANTED AFTER PROJECT COMPLETION.

7. TEMPORARY ROADS IN WET OR FLOODED AREAS WILL BE ABANDONED AND RESTORED BY THE END OF THE IN-WATER WORK PERIOD.

8. NEW TEMPORARY STREAM CROSSINGS WILL AVOID POTENTIAL SPAWNING HABITAT (I.E. POOL TAILOUTS) AND POOLS) TO THE MAXIMUM EXTENT POSSIBLE. THE PRECISE PLACEMENT OF STREAM CROSSINGS WILL BE DETERMINED WITH THE PROJECT BIOLOGIST. THEY WILL MINIMIZE SEDIMENTATION IMPACTS BY USING BMPS LIKE MATS AND BOARDS TO CROSS A STREAM. BMPS WILL BE LISTED BY EACH APPLICANT IN SPIF. AFTER PROJECT COMPLETION TEMPORARY STREAM CROSSINGS WILL BE ABANDONED AND THE STREAM CHANNEL RESTORED WHERE NECESSARY.

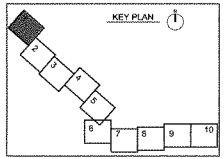
9. LOCATIONS OF TEMPORARY STREAM CROSSING WILL BE ISOLATED AND FISH RESCUE PERFORMED BY A QUALIFIED FISH BIOLOGIST PRIOR TO INSTALLATION.

10. INSTALLATION OF LWD AND STREAM CROSSING. IF ISOLATION OF WORK IS DEEMED TO BE LESS OF AN IMPACT FOR IN-WATER WORK THEN A PLAN WILL BE DEVELOPED THAT IS CONSISTENT WITH THE PROTOCOLS FOR ISOLATION OF WORK AND FISH RESCUE IN THE PROGRAMMATIC BIOLOGICAL ASSESSMENT FOR RESTORATION ACTIONS IN WASHINGTON STATE.

11. SOURCES OF LWD WILL COME FROM OFFSITE. NO FELLED LIVE TREES WILL BE USED AS A PART OF LWD STRUCTURES.

N
0 50' 100'
1"= 50'

KEY PLAN



US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DRAWN BY: REVIEWED BY: SUPERVISED BY: DATE: SOLICITATION NO.: CONTRACT NO.: FILE NUMBER: FACILITY CODE: FACILITY NAME: PROJECT NAME: SKOKOMISH RIVER

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN2H8132

UPSTREAM LWD
SITE PLAN 1

SHEET IDENTIFICATION
C-141
SHEET 35 OF 96

DATE AND TIME PLOTTED: 5/6/2015 DESIGN FILE: pw://WRSASDFP.AF.usace.army.mil:Seattle01/Documents/Civil Works/Skokomish River/ARCurrent/PlansCue_Check/CAD_Sheets/SHEET-141 UPSTREAM LWD SITE PLAN 1

UPSTREAM LWD PLAN 2
1"=50'

NOTES:

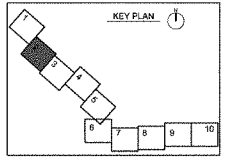
1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

0 50 100'
1"= 50'

KEY PLAN



US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	CHKD.	DRWN.	DATE	DESCRIPTION	MARK

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHKD BY:
SUBMITTED BY:
PLOT DATE: 15-01-1996
PLOT SCALE: 1:1
PLOT MODE: PAPER
FILE: PAPER
FILE NAME: C:\PROJECT\SKAGIT\SKAGIT\PRIME\UPSTREAM PLAN 2.DWG

SOLICITATION NO.:
CONTRACT NO.:
FAC. NUMBER:
PROJECT NO.:

SKOKOMISH RIVER ECOSYSTEM RESTORATION
ORIGINAL WYE-FRITCHIE
SKOKOMISH RIVER, MASON COUNTY, WA
PRIME02

UPSTREAM LWD
SITE PLAN 2

SHEET IDENTIFICATION
C-142
SHEET 38 OF 42

DESIGN FILE: pw:\\NWS-ABSFTVR:nws.es.sscor.army.mil:sseattl\Documents\Civil Works\Skokomish River, WA\PTE PN\SHEETS SKOKC\Current Plans\Civil_Direct\CAD_Drawings\C-142 UPSTREAM LWD SITE PLAN 2

DATE AND TIME PLOTTED: 10/3/2015

UPSTREAM LWD PLAN 3
1"=50'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

0 50' 100'
1"= 50'

KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED
DRAWN
SUBSTITUTION NO.
CONTRACT NO.
FILE NUMBER
DATE
PLOT DATE 7/12/95
PLOT SCALE 1:1
PLOT UNITS inches
FILE NAME C:\PROJECT\SNOHOMISH\PHASE1\UPSTREAM PLAN 3.DWG

SNOHOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SNOHOMISH COUNTY, WASHINGTON
PHASE1

UPSTREAM LWD
SITE A,A-3

SHEET IDENTIFICATION
C-143
SHEET 37 OF 50

DESIGN FILE: jim:/mnt/d:/d0/17/JP/JP.run/ds.dsc/usr/army/ed/pnwsd/h/Documents/Civil Work/Documents/Civil Work/Documents/Phase1/Cad_Data/Cad_Drawings/Civil/C-143 UPSTREAM LWD SITE A PLAN 3

DATE AND TIME PLOTTED 5/12/2015

UPSTREAM LWD PLAN 4
1"=50'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

0 50 100'
1"= 50'

KEY PLAN

1 2 3 4 5 6 7 8 9 10

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DATE
DRAWN BY: DATE
CHECKED BY: DATE
SUBMITTED BY: DATE
PLOT DATE: FILE NAME:
PLOT SCALE: FILE NUMBER:
SIZE: A1 CONTRACT NO.:
SHEET: 144 OF 144 SHEETS

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PHSM002

UPSTREAM LWD
SITE PLAN 4

SHEET IDENTIFICATION
C-144
SHEET 38 OF 38

DATE AND TIME PLOTTED: 9/6/2016 DESIGN FILE: per:\\WWS-ABS01\Pdrive\data.army.pd.seattle\Documents\Civil Works\Skokomish\Reach 4\WP\TIE PROGRESS SKOKOMISH\Current Plans\Civil_Sheets\Civil\C-144 UPSTREAM LWD SITE PLAN 4

UPSTREAM LWD PLAN 5
1"=50'

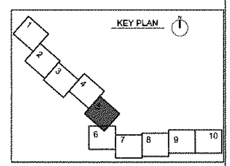
NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

0 50' 100'
1"= 50'



US Army Corps of Engineers
SEATTLE DISTRICT

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

UPSTREAM LWD
SITE PLAN 5

SHEET IDENTIFICATION
C-145

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

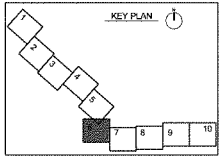
3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994. MAPPED AT A SCALE OF 1"=200'.

N

0 50' 100'

1"= 50'

KEY PLAN



US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: DATE: DRAWN BY: DATE: CHECKED BY: DATE: SUBMITTED BY: DATE: PLOT DATE: 15-01-NOV SCALE: AS NOTED FILE NAME: 01-146.DWG SIZE: 24X36 DESIGN FILE: PW:\\NWS-ABSFTP-SRV.nws.ds.usace.army.mil (secure)\Documents\Civil Works\Documents\Plans_WARFIELD PROGRAM\SNOKO\Current Plans\Cons_Class\CAD_Drawings\Civil\C-146 UPSTREAM LAND SITE PLAN.dwg

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
REMOVAL WITH RESTORATION
SNOQUALMIE, WASHINGTON
PROGRAM

UPSTREAM LAND SITE PLAN

SHEET IDENTIFICATION
C-146
SHEET 46 OF 50

DATE AND TIME PLOTTED: 10/3/2015

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

N

0 50' 100'

1"= 50'

KEY PLAN

1 2 3 4 5 6 7 8 9 10

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: CAD
DRAWN BY: CAD
CHECKED BY: SOUSTOWNHAL
DATE: 12/12/97
SCALE: 1"=50'
COORDINATE NO.:
PROJECT NO.: 2148 number
FILE NO.: 2148 number
PLOT DATE: PLOT TIME: 2148 number
FILE NAME: 2148 number
PLAN NAME: Upstream Conceptual Plan 7.DWG

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GRANDY CREEK TO HWY 101
SKOKOMISH TRIBE, JEFFERSON COUNTY, WASHINGTON
PN:094032

UPSTREAM LWD
SITE PLAN 7

SHEET IDENTIFICATION
C-147
SHEET #1 OF 4E

DATE AND TIME PLOTTED: 5/12/2015

DESIGN FILE: jar:\\WWW-ADD\H:\Jar\data\army dist\Cleanup\Documents\Civil Works\Skokomish River_\PN\PN118_PN094032_SR\PNDocuments\PlanningCon_Docs\CAD_Sheets\Grandy\C147 UPSTREAM LWD SITE PLAN 7

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

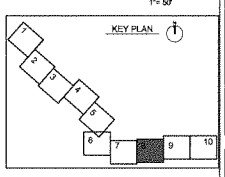
3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

N

0 50' 100'

1"= 50'

KEY PLAN



US Army Corps of Engineers® SEATTLE DISTRICT

MARK	REVISION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUPERVISED BY:
PLOT DATE: 11-07-1996
PLOT SCALE: 1:1
FILE NAME: 148-UPSTREAM.DWG

DWG. STATUS:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
APPROVED BY:
CONSTRUCTION-OPERATIONAL PLAN FORM

SKOKOMISH RIVER ECOSYSTEM RESTORATION
DOMESTIC WATER INTAKE
SKOKOMISH INDIAN RESERVATION
PRISM/IQ

UPSTREAM LAND SITE PLAN 8

SHEET IDENTIFICATION
C-148
SHEET 12 OF 34

DATE AND TIME PLOTTED 6/5/2015

DESIGN FILE: jar:\\WWB-ASSP\JAR\ver.6.0.cscad.dmp.jar.zarnell\Documents\Civil Works\Skokomish Rivet. WWP\THE PROGRAM SKOKOMIsh\Current Plans\Civil_Land\CAD_Drawings\civil\C-148 UPSTREAM LAND SITE PLAN 8

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

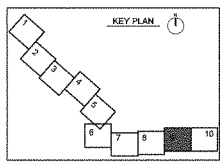
3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

N

0 50' 150'

1"= 50'

KEY PLAN



US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	CHKD.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: SWS
DRAWN BY: SWS
CHECKED BY: REGISTRATION NO.
APPROVED BY: CONTRACT NO.
SUBMITTED BY:
PLOT DATE: 7/13/2015 FILE NUMBER
PLOT SCALE: 1:1 FILE TITLE
PROJ. FILE: FILE NAME: C:\Users\swsmith\Documents\Civil Works\Skokomish River_project\Lyd Plan 9.dwg

SKOKOMISH RIVER ECOSYSTEM RESTORATION
LOWER LYNDER RIVER
SKOKOMISH INDIAN TRIBE, WASHINGTON
PROJ#5432

UPSTREAM LWD
SITE PLAN 9

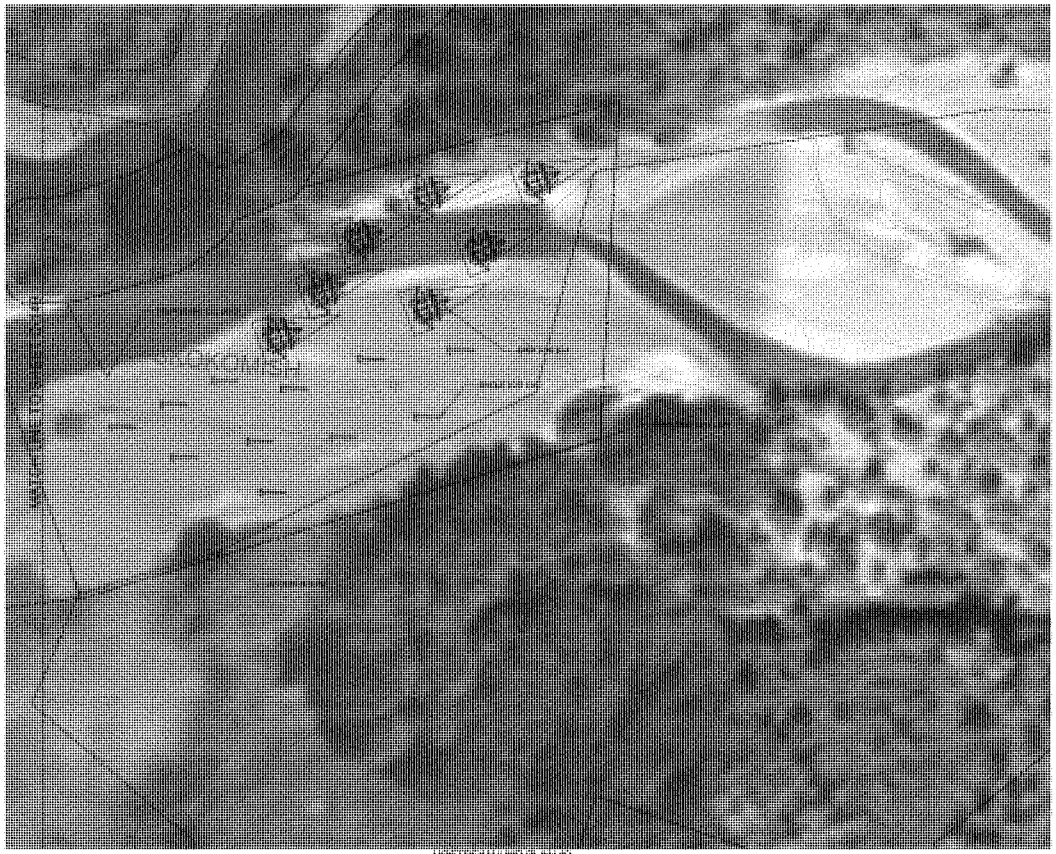
SHEET IDENTIFICATION
C-149
SHEET 43 OF 90

DESIGN FILE: pw:\\WRKGABDV1.net.usace.army.mil:server04\Documents\Civil Works\Skokomish River_WorkFiles\Lower Lynder\Lyd_Plan9.dwg

DATE AND TIME PLOTTED: 9/4/2015

UPSTREAM LWD SITE PLAN 9

774



NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

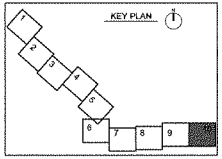
3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

N

0 50' 100'

1"= 50'

KEY PLAN



US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT DATE: 11-07-94
PLOT SCALE: 1"=50'
PLOT NAME: C1410.DWG
FILE NAME: J:\PROJECT\SKOKOMISH\PLAN\C1410.DWG

DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
DACW67-94-B-0015

SKOKOMISH RIVER ECOSYSTEM RESTORATION
SKOKOMISH WATERSHED
SKOKOMISH INDIAN RESERVATION
PNW1682

UPSTREAM LWD
UPSTREAM LWD SITE PLAN 10

SHEET IDENTIFICATION
C-1410
SHEET 48 OF 90

DATE AND TIME PLOTTED: 11/7/2015

DESIGN FILE: pw:\\nwd-sdpn1\jlw:\wes.army.mil.cenwd\bldsuccessor\Civil Works\Skokomish River, WA\PW16\PROGRESS SKOKOMISH\Current Phase\Con_Docs\CAD_Drawings\Civil\C-1410 UPSTREAM LWD SITE PLAN 10

5 LOG CHANNEL CLUSTER MATERIAL SCHEDULE

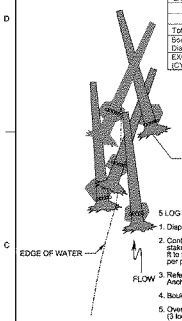
All logs Douglas fir log 24-36 in DBH with root wad

ELJ LAYER	30'
1	3
2	2
Total	5

Boulders 4-5 ft Nominal Diameter	5
EXCAVATION (CY)	456

5 LOG CHANNEL CLUSTER CONTROL POINT TABLE

NORTHING	EASTING



5 LOG CHANNEL STRUCTURE NOTES:

1. Dispose of excavated material into bend timber crib structure
2. Contractor to use ELJ control point table to locate ELJ control point stakes. Prior to layout COR designee may reposition stake within 100 ft to fit field conditions. Contractor to complete layout and installation per plans once engineer approves control point locations.
3. Refer to "Typical log to log chain connection" and "Typical Log to Boulder Anchor Connection" notes and details.
4. Boulder anchors to be excavated and placed prior to log placement.
5. Overlapping log to log connections shown on plans shall be chained (3 locations per structure) in addition to chained boulder anchors.

1 5 LOG CHANNEL CLUSTER
NTS

GENERAL NOTES FOR ELJ AND WOOD CLUSTERS ANCHORING:

Typical boulder anchor connection:

1. Use 0.75 inch shackle to fasten chain ends to eye bolts
2. Use 0.5 inch galvanized marine chain.
3. Use 4-5 ft nominal diameter boulder (as measured at intermediate axis) unless otherwise specified, placed as shown on plans.
4. All logs Douglas Fir 24-36 inch DBH without splits or cracks unless approved by engineer.
5. Use 7/8 inch OD, 12inch long, galvanized, threaded, round, eye bolt, embed thread end 8 inches into boulder
6. Notch logs 2-4 inches deep around circumference at chained connections with chainsaw to get secure fit
7. Drill and clean 1.0 inch OD holes in boulders, depth not to exceed 9 inches.
8. Fill holes with Hilti type HIT RE 500 epoxy and insert galvanized threaded eye bolts into boulder. Let epoxy set up per manufacturer guidelines.
9. Shackle one end of chain to eye, place log and wrap chain tightly, and shackle free end to remaining eye.
10. Staple chain 3 times to log to tension.

CHAIN LENGTH CONNECTION SCHEDULE

Log diameter (ft)	Chain length (ft)
1	7
2	14
3	21
4	27

Typical log to log chain connection and log to pile chain connection:

1. Use 0.75 inch shackle to fasten chain ends together minimizing slack.
2. Use 0.5 inch galvanized marine chain to securely lash.
3. All logs Douglas Fir 24-36 inch DBH without splits or cracks unless approved by engineer.
4. Notch logs 2-4 inches deep around circumference at chained connections with chainsaw to get secure fit.
5. Chain length (ft)= 10x(d1+d2)/2, where d=diameter of log to be chained.

SINGLE ANCHORED LOG MATERIAL SCHEDULE

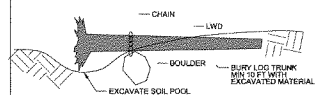
All logs Douglas fir log 24-36 in DBH with root wad

ELJ LAYER	30'
1	1
Total	1

Boulders 4-5 ft Nom Dia	1
EXCAVATION AND BACKFILL (CY)	91

SINGLE ANCHORED LOG NOTES:

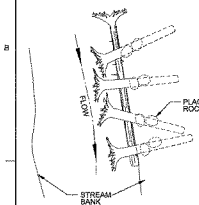
1. Dispose of excess excavated material
2. Contractor to use ELJ control point table to locate ELJ control point stakes. Prior to layout COR designee may reposition stake within 100 ft to fit field conditions. Contractor to complete layout and installation per plans once engineer approves control point locations.
3. Refer to "Typical Boulder Anchor Connection" notes.
4. Boulder anchors to be excavated and placed prior to log placement.



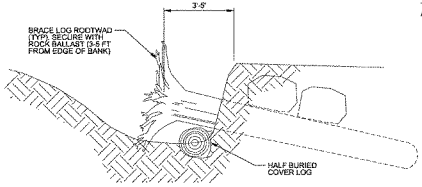
2 SINGLE ANCHORED LOG
NTS

SINGLE LOG ELJ CONTROL POINT TABLE

NORTHING	EASTING



PLAN
NTS



ELEVATION
NTS

3 5 LOG BANK CLUSTER
NTS

NOTE:

1. STANDING TREES MAY BE USED FOR ANCHORING WHEN AVAILABLE, AND BOULDERS RE-POSITIONED, AS APPROVED BY ENGINEER

5 LOG BANK CLUSTER MATERIAL SCHEDULE

All logs Douglas fir log 24-36 in DBH with root wad

ELJ LAYER	30'
1	1
2	4
Total	5

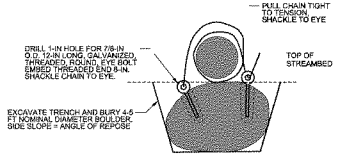
Boulders 3-4 ft Nom Dia	8
EXCAVATION (CY)	377
BACKFILL (CY)	49

5 LOG BANK CLUSTER CONTROL POINT TABLE

Easting	Northing
975394	733361
975441	733323
975411	733281
975368	733311
980056	731513
980006	731539

5 LOG BANK CLUSTER NOTES:

1. Dispose of excess excavated material into bend timber crib structure.
2. Contractor to use ELJ control point table to locate ELJ control point stakes. Prior to layout COR designee may reposition stake within 100 ft to fit field conditions. Contractor to complete layout and installation per plans once engineer approves control point locations.
3. Shackle mechanical soil anchor tether to chain as shown
4. Refer to "Typical Boulder Anchor Connection" detail.
5. Boulder anchors to be placed on top of layer 2
6. As log layers are placed, place backfill using care to fill voids.
7. Grade and bucket tamp conserved coarse streambed material as ELJ ballast.



4 TYPICAL LOG TO BOULDER ANCHOR CONNECTION
NTS

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

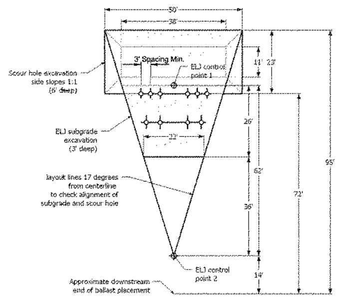
DESIGNED BY: DWR
DWN BY: DWR
CKD BY: CEB
SIZE: ANSI D
FSA NUMBER: N/A
CONTRACT NO.:
PLOT DATE: 7/15/2015
PLOT TIME: 11:00
FILE NAME: 01-540-DETAILS.DGN
SHEET: 41 OF 42
FILE NUMBER: N/A
DESIGN FILE: pw:\\WVAS-ASD1P.sfr.net.de.usace.army.mil:Document\Duwamish\Duwamish\Duwamish River_WA\PT16-PROJECT 2\DWG\current\Plans\Civil_Details\540-C-540 UPSTREAM LWD DETAILS 1

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GENERAL, PARTS 1 AND 2
SNOQUALMIE, WASHINGTON
PROJ#5432

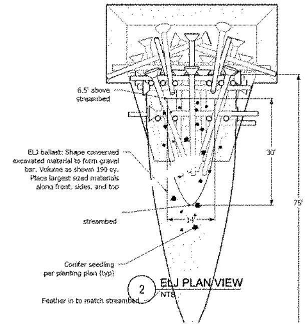
UPSTREAM LWD
DETAILS 1

SHEET IDENTIFICATION
C-540
SHEET 41 OF 42

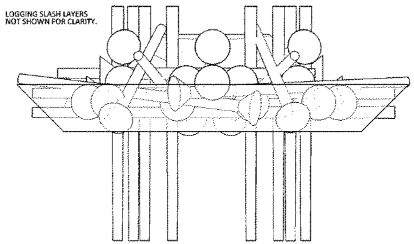
DATE AND TIME PLOTTED: 9/4/2015



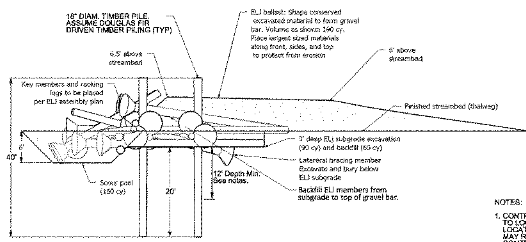
1 ELJ LAYOUT
NTS



2 ELJ PLAN VIEW
NTS



3 ELJ FRONT VIEW
NTS



4 ELJ ELEVATION VIEW
NTS

ELJ MATERIAL SCHEDULE

All logs Douglas fir log 18-22 in DBH with rootwad unless otherwise specified

ELJ LAYER	45' NO ROOTWAD	30'	25'	20'
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
TOTAL				
TIMBER PILES (18" DIA, 30' LONG)				
EXCAVATION & BACKFILL (CY)				
LOGGING SLASH (CY)				

ELJ CONTROL POINT TABLE

NORTHING	EASTING

NOTES:

1. CONTRACTOR TO USE ELJ CONTROL POINT TABLE (CONTROL POINT 1) TO LOCATE ELJ CONTROL POINT STAKES. CONTROL POINT 2 TO BE LOCATED IN DOWNSTREAM DIRECTION. PRIOR TO LAYOUT COR DESIGNEE MAY REPOSITION STAKES WITHIN 100 FT TO FIT FIELD CONDITIONS. CONTRACTOR TO COMPLETE LAYOUT AND INSTALLATION PER PLANS ONCE ENGINEER APPROVES CONTROL POINT LOCATIONS.
2. REFER TO "TYPICAL LOG TO LOG CHAIN CONNECTION AND LOG TO PILE CHAIN CONNECTION" NOTES.
3. CONTRACTOR WILL LAY OUT PILE LOCATIONS PER PLANS. COR WILL APPROVE PLAN BEFORE PILE DRIVING COMMENCES.
4. USE TIMBER PILE WITH STEEL DRIVING POINT AND TWO STEEL DRIVING BANDS PER PILE.
5. ADDITIONAL STABILIZATION MEASURES SUCH AS PILES, BOULDERS, AND STREAMBED BALLAST CAN BE ADDED PER COR APPROVAL TO MEET STABILITY REQUIREMENTS IN EVENT THAT MINIMUM DESIGN PILE DEPTH IS NOT REACHED.
6. ALL LOG PLACEMENTS PER ELJ ASSEMBLY PLAN.
7. AS LOG LAYERS ARE PLACED, PLACE BACKFILL USING CARE TO FILL VOIDS.
8. GRADE AND BUCKET TAMP CONSERVED COARSE STREAMBED MATERIAL AS ELJ BALLAST TO LINES AND GRADES AS SHOWN.
9. PLANT TOP OF ELJ BALLAST (APPROXIMATELY 20' X 40') WITH CONIFERS 8' ON-CENTER.

BAR APEX STRUCTURE DETAILS

US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: COMPORT | DATE: 5/18/15
DWN BY: JT | CKD BY: MAY | SOLICITATION NO.:
SUBMITTED BY: WEST | CONTRACT NO.:
PLOT DATE: 5/4/2015 | PLOT TIME: 11:59:47 AM | FILE NUMBER: E-78-1-57
SIZE: ANSI D | FILE NAME: PN34832-DM-UPSTREAM_DETAILS 2.DGN

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN334832
UPSTREAM LWD
DETAILS 2

SHEET IDENTIFICATION
C-541
SHEET 46 OF 92

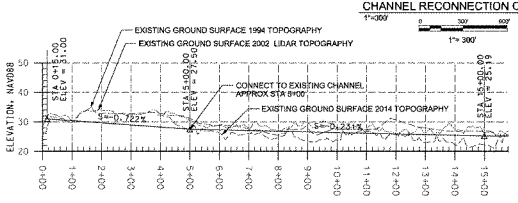
DATE AND TIME PLOTTED: 5/4/2015
DESIGN FILE: pw:\\NWS-AS01PJW.nws.ds.usace.army.mil:orrows01\Documents\Civil Works\Skokomish River, WA\FY18 PN364832 SKOK\Current Phase\Con_Docs\CAD_Sheets\Civil\C-541 UPSTREAM LWD DETAILS 2

CHANNEL RECONNECTION OVERALL PLAN

1"=300'

0 300' 600'

1"= 300'



CHANNEL RECONNECTION INLET PROFILE

1"=150' H
1"=15' V

0 150' 300'

1"= 150' H

0 15' 30'

1"= 15' V

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-23-1994 MAPPED AT A SCALE OF 1"=200'.

4. UPSTREAM MAPPING SUPPLEMENTED BY GIS TOPOGRAPHY INCORPORATING 2002 BARE-EARTH LIDAR.

5. UPSTREAM MAPPING SUPPLEMENTED BY FIELD SURVEY PERFORMED BY MASON COUNTY
SURVEY DATE: MAY/JUNE 2014.

6. DOWNSTREAM MAP COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-MAR-1994.

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	MARK	DESCRIPTION	DATE	MARK

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUPERVISED BY:
DATE:
SCALE: 1"=300'
PLOT DATE: 7-OCT-2015
FILE NAME: C150.DGN
DESIGN FILE: pw:\\nwk-sdc01-pr.nwk.ds.usace.army.mil:nwkwd01\Documents\Chris Reed\Sickbrook\Part 1\NWP 116 PROGRESS WORK\Current\Phase\Cpt_Chris\CAD_Sheets\CHRC-150 CHANNEL RECONNECT OVERALL SITE PLAN

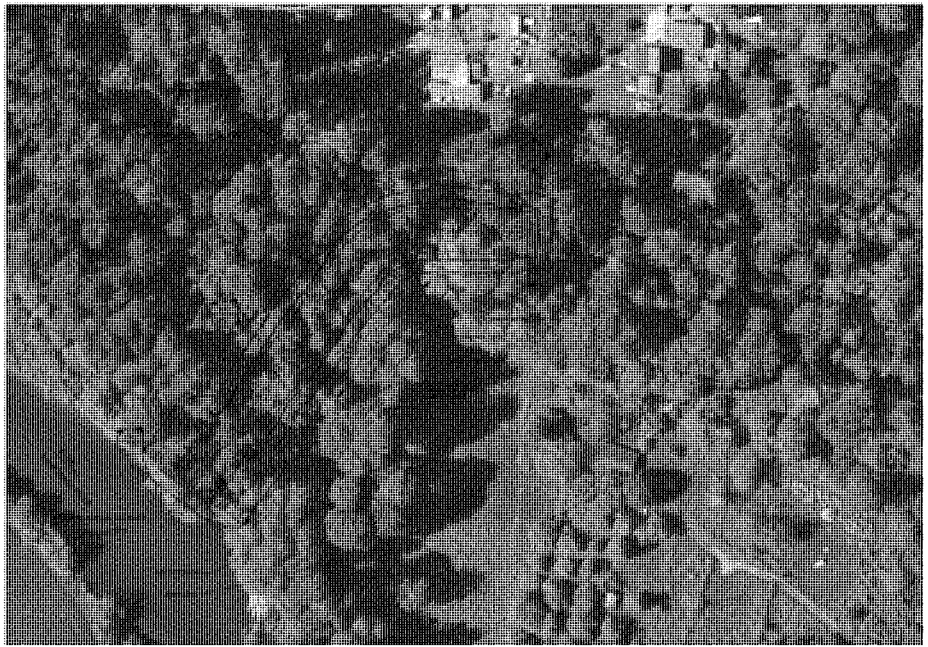
SICKOMISH RIVER ECOSYSTEM RESTORATION
CAMPBELL LAKE, WASHINGTON
BOTHELL, KING COUNTY, WASHINGTON
PHASE 1B

CHANNEL RECONNECT
OVERALL SITE PLAN

SHEET IDENTIFICATION
C-150
SHEET 47 OF 56

DATE AND TIME PLOTTED: 5/6/2015

778



CHANNEL RECONNECTION ENTRANCE SITE PLAN
1"=50'

NOTES:

1. HORIZONTAL DATUM IS WASHINGTON STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83/91.

2. VERTICAL DATUM BASED ON NAVD 1988.

3. MAPPING COMPILED FROM AERIAL PHOTOGRAPHY DATED 3-25-1994 MAPPED AT A SCALE OF 1"=200'.

4. UPSTREAM MAPPING SUPPLEMENTED BY GIS TOPOGRAPHY INCORPORATING 2002 BARE-EARTH LIDAR.

5. UPSTREAM MAPPING SUPPLEMENTED BY FIELD SURVEY PERFORMED BY MASON COUNTY
SURVEY DATE: MAY/JUNE 2014.

6. THERE WILL BE NO TEMPORARY ACCESS-WAYS ACROSS SLOPES GREATER THAN 30%.

7. NO PERMANENT ACCESS-WAYS WILL BE BUILT ACROSS OR ADJACENT TO THE RIVER. ALL TEMPORARY ACCESS-WAYS WILL BE REMOVED (INCLUDING GRAVEL SURFACES) AND PLANTED AFTER PROJECT COMPLETION.

8. TEMPORARY ROADS IN WET OR FLOODED AREAS WILL BE ABANDONED AND RESTORED BY THE END OF THE IN-WATER WORK PERIOD.

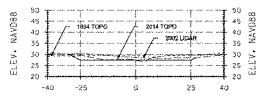
9. NEW TEMPORARY STREAM CROSSINGS WILL AVOID POTENTIAL SPAWNING HABITAT (I.E. POOL TAILOUTS) AND POOLS) TO THE MAXIMUM EXTENT POSSIBLE. THE PRECISE PLACEMENT OF STREAM CROSSINGS WILL BE DETERMINED WITH THE PROJECT BIOLOGIST. THEY WILL MINIMIZE SEDIMENTATION IMPACTS BY USING BMPS LIKE MATS AND BOARDS TO CROSS A STREAM. BMPS WILL BE LISTED BY EACH APPLICANT IN SPIF. AFTER PROJECT COMPLETION TEMPORARY STREAM CROSSINGS WILL BE ABANDONED AND THE STREAM CHANNEL RESTORED WHERE NECESSARY.

10. LOCATIONS OF TEMPORARY STREAM CROSSING WILL BE ISOLATED AND FISH RESCUE PERFORMED BY A QUALIFIED FISH BIOLOGIST PRIOR TO INSTALLATION.

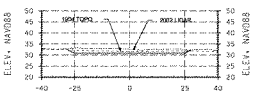
11. INSTALLATION OF LWD AND STREAM CROSSING, IF ISOLATION OF WORK IS DEEMED TO BE LESS OF AN IMPACT FOR IN-WATER WORK THEN A PLAN WILL BE DEVELOPED THAT IS CONSISTENT WITH THE PROTOCOLS FOR ISOLATION OF WORK AND FISH RESCUE IN THE PROGRAMMATIC BIOLOGICAL ASSESSMENT FOR RESTORATION ACTIONS IN WASHINGTON STATE.

12. SIDE CHANNEL HABITAT WILL BE CONSTRUCTED TO PREVENT FISH STRANDING BY PROVIDING A POSITIVE GRADE TO THE EXISTING CHANNEL.

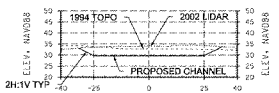
13. EXCAVATION AND GRADING WILL OCCUR BEGINNING AT THE UPSTREAM END AND WORK ITS WAY DOWNSTREAM. THE DOWNSTREAM PLUG WILL BE REMOVAL WILL BE THE LAST STEP AND WILL OCCUR DURING THE FISH WINDOW BEHIND A FLOATING SILT CURTAIN.



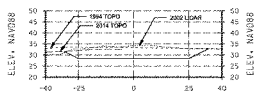
D 5+40
1"=20'



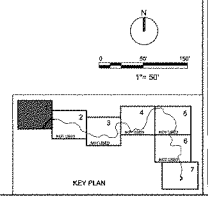
A 0+40
1"=20'



B 2+00
1"=20'



B 3+80
1"=20'



US Army Corps of Engineers
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT DATE: 11-07-2014
FILE NAME: 151_CHANNEL RECONNECTION ENTRANCE SITE PLAN.DWG
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
PROJECT NO.:

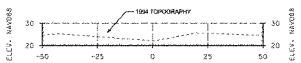
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PHASE2

CHANNEL RECONNECTION
ENTRANCE SITE PLAN

SHEET IDENTIFICATION
C-151
SHEET 45 OF 90

DATE AND TIME PLOTTED: 11/6/2015 DESIGN FILE: per://nwd-ab-s01p1.ar.nwd.usace.army.mil:/nwd/1/Documents/Civil Works/Skokomish/Phase 2/WP1/15-PR/PHASE2 SKOKOMISH/Current Plans/Con_Drawings/CAD_Drawings/CAD-151 CHANNEL RECONNECTION ENTRANCE SITE PLAN

A 95+40
1"=20'



B 95+10
1"=20'

0 20' 40'
1"= 20'

CHANNEL RECONNECTION EXIT PLAN
1"=50'

1. HORIZONTAL DATUM
[illegible] ZONE

2. VERTICAL DATUM [illegible] ON NAVD [illegible]

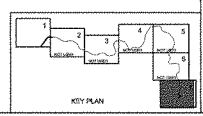
3. [illegible] VERTICAL [illegible] 1994.

4. [illegible] RIVER [illegible] 360

PHOTO 1

PHOTO 2

0 50' 100'
1"= 50'



KEY PLAN

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	CHKD.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGN
CONSULT
DWG. CHK.
DWG. REV.
SUPV. REVIEW
PROJ. MGR.
SUBSTITUTION NO.
CONTRACT NO.
SPK NUMBER
SPK FILE NO.
DATE
SCALE
PROJECT NO.
DWG. NO.
DATA FILE NAME
(Project_Name_Drawing_Number_Current_Revision_Number_Sheet_Number_Current_Revision_Form)

SACRAMENTO RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SACRAMENTO, CALIFORNIA
PROPHUB
CHANNEL RECONNECTION
EXIT SITE PLAN

SHEET IDENTIFICATION
C-157
SHEET 43 OF 46

DESIGN FILE: per WWW-ASDV1/P:/net as dated array.mil.sthesh/Documents/Civil Works/Sacramento River / WWY-16-PROPHUB BRONCo/current/Project/Cpn_Cleanup/CAD_Drawings/Civil/C-157 CHANNEL RECONNECTION EXIT SITE PLAN

DATE AND TIME PLOTTED: 5/4/2015

CHANNEL RECONNECTION ENTRANCE HORIZONTAL CURVE DATA

POB -0+17.669
NORTHING: 733,266.891
EASTING: 975,368.599

TANGENTIAL DIRECTION: N 36°18'41.8" E
TANGENTIAL LENGTH: 349.948

PI #1 3+84.760
NORTHING: 733,591.172
EASTING: 975,607.275
RADIUS: 100.000
LENGTH: 86.816
TANGENT: 92.561
DELTA: 55°28'17.02" RIGHT
DEGREE OF CURVATURE(ARC): 57°17'44.81"

TANGENTIAL DIRECTION: S 86°13'01.2" E
TANGENTIAL LENGTH: 94.774

PI #2 5+23.769
NORTHING: 733,588.587
EASTING: 975,754.558

TANGENTIAL DIRECTION: S 87°58'34.4" E
TANGENTIAL LENGTH: 140.830

PI #3 6+64.589
NORTHING: 733,581.614
EASTING: 975,895.251

TANGENTIAL DIRECTION: S 72°04'28.7" E
TANGENTIAL LENGTH: 100.149

CHANNEL RECONNECTION ENTRANCE VERTICAL CURVE DATA

		STATION	ELEVATION
ELEMENT: LINEAR			
	POB	0+15.000	31.000
	PVI	5+00.000	27.500
	TANGENT GRADE:	-0.722%	
	TANGENT LENGTH:	485.000	
ELEMENT: LINEAR			
	PVI	5+00.000	27.500
	PVI	15+00.000	25.195
	TANGENT GRADE:	-0.231%	
	TANGENT LENGTH:	1000.000	
ELEMENT: LINEAR			
	PVI	15+00.000	25.195
	POE	27+00.000	24.860
	TANGENT GRADE:	-0.043%	
	TANGENT LENGTH:	1200.000	

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DATE	DESCRIPTION	APPR	MARK	DATE	DESCRIPTION	APPR	MARK	DATE	DESCRIPTION	APPR

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:
DATE:
DRAWN BY:
DATE:
CHKD BY:
DATE:
SUBMITTED BY:
DATE:
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
PROJECT NO.:
PLOT DATE: 7/27/2015
PLOT TIME: 11:14:00
REF. FILE(S): PROJECT-COMMON, ARCHITECTURE, CONNECTION, CONTROL

SNOQUALMIE RIVER ECOSYSTEM RESTORATION
GENERAL WORK BY OTHERS
SNOQUALMIE, WASHINGTON
PN94803

CHANNEL RECONNECTION ENTRANCE
CURVE DATA

SHEET IDENTIFICATION
C-650
SHEET 52 OF 90

DATE AND TIME PLOTTED: 8/4/2015 DESIGN FILE: per:\\N19-AS1\PWN-nas.ds.usace.army.mil\cenwd\C3\Common\Civil Works\Snoqualmie\Flood Risk_MAP\TIF\PN94803 SNOQCurrent Phase\Civil_Sheets\Civil\C-650 CHANNEL RECONNECTION ENTRANCE CURVE DATA

Annex B

Geotechnical Annex

B-1: Geotechnical Exploration Report B-1

B-2: Borrow Source Report B-499

B-3: Seepage & Slope Stability Levee Modeling Results B-515

B-4: Settlement Calculations B-524

B-5: Engineered Log Jam Pile Calculations B-533

B-6: Vegetation Variance Exhibit B-537

Naming conventions for some features included in the recommended plan have evolved over time. The Confluence Levee is locally referred to as the Car Body Levee. The existing agricultural berms, as well as the proposed wetland embankments, near River Mile 9 and the Grange are referred to as "River Mile 9 Levee" and "Grange Levee."

Final Geotechnical Data Report
Geotechnical and HTRW Investigation
Skokomish General Investigation
Skokomish, Washington

August 21, 2014

Prepared for

Mason County
Department of Public Works

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1.0 INTRODUCTION

This Final Geotechnical Data Report (GDR) presents the results of our geotechnical subsurface investigation and hazardous, toxic, and radioactive waste (HTRW) soil investigation located in the lower Skokomish River Valley in Skokomish, Washington (site). The overall project location is shown on the Vicinity Map, Figure 1. The Site and Exploration Plan, Figure 2, and the HTRW Site and Exploration Plan, Figure 3, show the approximate locations of the subsurface explorations completed for this study. Appendix A presents summary logs of conditions observed in our explorations. Results of the laboratory geotechnical testing program are summarized in Appendix B. The complete laboratory result reports are presented in appendix C. Summary results of the analytical testing for the HTRW are presented in a tabular format in Appendix D. Complete analytical testing results are provided in Appendix E. The surveyed location of the geotechnical investigations are presented in a tabular format in Appendix F. Copies of the driller logs completed by the subcontracted driller during exploration are included as Appendix G. Photographs of all exploration locations, excavated soil, well-lit walls (test pits only), and samples are provided in Appendix H. Copies of the Daily Field Reports are presented in Appendix I.

2.0 GEOLOGIC SETTING

The site is located adjacent to the Skokomish River in a broad, (approximately ¾-mile wide) flat river valley about 5 miles southwest of the river's delta as it enters the Hood Canal. Geologic mapping for the site was obtained from the *Geologic Map of the Skokomish Valley and Union 7.5-minute Quadrangles, Mason County, Washington* (Polenz et al. 2010). Near-surface geology at the site is mapped as Quaternary age alluvium (Qa). Alluvium at the site typically consists of loose to medium dense, silty sand with gravel (Mason County 2014). Hills above the river valley (to the north and south) are generally mapped as glacial till (Qgt) with various ice contact deposits mapped between the upland glacial till and lowland alluvium. Occasional peat (Qp) zones are mapped in the valley, although not in the vicinity of the explorations for this study.

3.0 GEOTECHNICAL AND HTRW INVESTIGATIONS

Field and laboratory testing activities associated with the geotechnical and HTRW investigations are discussed in this section. Field activities included performing public and private utility locates, hollow-stem auger drilling, test pit excavation, hand-auger drilling, and surveying. Soil samples were collected during all subsurface exploration activities. Geotechnical laboratory testing was completed on samples obtained during the geotechnical investigation, which included hollow-stem auger drilling, test pit excavation, and hand-auger borings. Geotechnical and analytical laboratory testing was also completed on samples obtained during the HTRW investigation, which included hand-auger borings.

The exploratory program was coordinated and monitored by a Landau Associates' licensed professional engineer who also obtained representative soil samples, maintained a detailed record of the observed subsurface soil and groundwater conditions, described the soil encountered by visual and textural examination, and photographed each sample and exploration location. Each representative soil type observed in our exploratory borings was described using the soil classification system shown on Figure A-1, in general accordance with ASTM International (ASTM) D2488, *Standard Recommended Practice for Description of Soils (Visual-Manual Procedure).* Logs of the explorations are presented on Figures A-2 through A-40. A tabulated summary of the explorations is presented in Table 1. These logs represent our interpretation of subsurface conditions identified during the field exploration program. The stratigraphic contacts shown on the individual logs represent the approximate boundaries between soil types; actual transitions may be more gradual. The soil and groundwater conditions depicted are only for the specific date and locations reported, and therefore, are not necessarily representative of other locations and times.

3.1 UTILITY LOCATE

Prior to drilling, the public "call before you dig" underground utility locate service was contacted to locate public utilities that could overlap with our exploration areas. A Landau Associates' representative visited the site prior to calling in the locate request to mark all boring and test pit locations. A private locating company (Applied Professional Services, Inc.) was also subcontracted to identify subsurface conductible utilities at the site. We met with the private locating company to walk the site once the public locate was complete.

3.2 GEOTECHNICAL INVESTIGATION

Subsurface conditions at the proposed site were explored between July 9 and July 17, 2014. The exploration program consisted of advancing 6 test pits (TP-02R, TP-12R, TP-17R, TP-19R, TP-23R, and

TP-27); 1 hand auger (HA-01X); and 11 hollow-stem auger borings (BH-01, BH-02, BH-03R, BH-04, BH-05R, BH-07R, BH-08, BH-09R, BH-10, BH-14R, and BH-15) at the approximate locations illustrated on the Site and Exploration Plan (Figure 2).

3.2.1 TEST PIT EXCAVATION AND HAND-AUGER DRILLING

Six test pits (TP-02R, TP-12R, TP-17R, TP-19R, TP-23R, and TP-27) where excavated on June 16 and 17, 2014 to depths between 7 and 9.5 feet (ft) below ground surface (BGS). Excavation of the test pits were completed by Howard's Construction & Excavating of Olympia, Washington under subcontract to Landau Associates. A Caterpillar 305C CR Mini-Tracked excavator was used to excavate the test pits. Hand-auger drilling of HA-01X was completed by a Landau Associates' licensed professional engineer on June 16, 2014.

Disturbed soil samples were collected from depths indicated on the test pit logs (Figure A-2 through A-7) and hand-auger log (A-8). Samples were logged and collected in sample jars soon after they were collected from the test pit or hand auger. Upon completion of excavation and sampling, the test pits and hand-auger borings were backfilled with soil cuttings excavated from the exploration.

3.2.2 HOLLOW-STEM AUGER DRILLING

Eleven hollow-stem auger borings (BH-01, BH-02, BH-03R, BH-04, BH-05R, BH-07R, BH-08, BH-09R, BH-10, BH-14R, and BH-15) where explored between June 9 and June 13, 2014. Drilling was completed by Holocene Drilling, Inc. of Puyallup, Washington under subcontract to Landau Associates. The drillers used both a track-mounted Diedrich D-50 drill rig and a truck-mounted BK-81 to advance a hollow-stem auger to depths ranging from 31.5 to 41.5 ft BGS.

Disturbed soil samples were collected during drilling at frequent intervals using a 1.5-inch inside-diameter Standard Penetration Test split-spoon sampler. The samplers were driven up to 18 inches (or a portion thereof) into the undisturbed soil ahead of the auger bit with a 140-pound automatic hammer falling a distance of approximately 30 inches, performed in accordance with ASTM D1586. The number of blows required to drive the sampler for the final 12 inches (or portion thereof) of soil penetration is noted on the boring logs adjacent to the appropriate sample notation. A 2.375-inch inside-diameter modified California sampler was used to "chase" the standard split-spoon barrel if fractured rock or inadequate sample for testing was recovered in the standard split-spoon barrel. Blow counts in order to drive the modified California sampler were not recorded. Relatively undisturbed samples of fine-grained soil encountered in the borings were obtained by advancing a 3-inch outside-diameter, thin-walled Shelby tube into the undisturbed soil ahead of the drill bit. The tube was advanced approximately 30 inches

using drill-rig hydraulics. After removal of the tube from the borehole, the ends of the tube were capped, sealed, labeled, and transported to the testing lab in an upright position.

Upon completion of drilling and sampling, the boreholes were decommissioned in general accordance with the requirements of Washington State Department of Ecology and Washington Administrative Code Chapter 173-160.

3.2.3 GEOTECHNICAL LABORATORY TESTING

Geotechnical laboratory testing consisted of moisture content determinations (ASTM D2216), particle size analyses (ASTM C136/C117, ASTM D422), Atterberg limits (ASTM D4318), consolidation testing (ASTM D2435) and organic content testing (ASTM D2974) described below. All geotechnical laboratory testing was completed by U.S. Army Corps of Engineers (USACE) approved laboratories under subcontract to Landau Associates. Consolidation testing was completed by Northwest Geotech, Inc. of Wilsonville, Oregon. Moisture content determinations, particle size analyses, and organic content testing were completed by Northwest Geotech, Inc. of Wilsonville, Oregon and Krazan & Associates, Inc. of Puyallup, Washington under subcontract to Landau Associates. Moisture content determinations, particle size analyses, and organic content testing are summarized in Appendix B. Geotechnical Laboratory Reports provided by the subcontracted laboratories are provided in Appendix C.

The samples were checked against the field log descriptions, which were updated where appropriate in general accordance with ASTM D2487, *Standard Test Method for Classification of Soils for Engineering Purposes*.

3.3 HTRW INVESTIGATION

The HTRW investigation focused on the Car Body Levee in the northwest portion of the site. The existing levee is about 4,600 ft long and covered in dense vegetation. The primary purpose of the investigation was to gain information regarding the level and extent of possible contamination due to the car bodies located within the levee. Activities associated with the HTRW investigation included brush clearing, physical evaluation of the car bodies and levee, hand-auger borings, and background soil and sediment sampling.

3.3.1 CAR BODY LEVEE SURFACE CONDITIONS

The Car Body Levee was heavily vegetated with brush, young trees, and a few large trees during our May 8, 2014 pre-exploration site visits. As part of this project, the brush and young trees were cleared from the crest and sides of the levee to observe the physical condition. The northern portion of

the levee between about hand auger HA-21 and HA-33 appears to have been more recently modified or repaired, as evident by younger vegetation, a higher levee elevation, and better condition of the levee itself. At the time of our explorations there were two locations where the levee had been breached and water was flowing through the levee. There were also multiple locations where the levee had been breached; however, water would only flow through the levee at these locations during high water events. During our exploration we observed common indications of surface raveling of the levee sides and toe erosion throughout the levee.

3.3.2 HAND-AUGER BORINGS

Landau Associates' field representatives advanced shallow hand-auger borings along the crest of the levee (HA-01 through HA-23 and HA-33), at the location of every identified car body (HA-24 through HA-27), and at the location of a downed telephone pole (HA-28). The hand augers at the location of the car bodies and telephone pole were selected in an attempt to sample the soil with the highest likelihood of containing contamination.

One sample from each hand-auger boring was collected in appropriate sampling containers provided by TestAmerica and photographed. Volatile organic compound readings for all samples were measured and reported using a photo-ionization detector. Each sample collected was tested by TestAmerica of Tacoma, Washington under subcontract to Landau Associates for a suite of three analytical tests: lead [U.S. Environmental Protection Agency (EPA) Method 6010C], total petroleum hydrocarbons – gasoline range organics (NWTPH-Gx), and total petroleum hydrocarbons – diesel range organics (NWTPH-Dx).

In addition to the tests above, five representative geotechnical soil samples were collected from different hand-auger borings along the levee crest and submitted to Krazan & Associates for moisture content determinations and grain size analyses.

3.3.3 PHYSICAL EVALUATION OF CAR BODIES

Four partially buried car bodies and one downed telephone pole were observed during our exploration of the Car Body Levee. The locations of the car bodies and telephone pole are shown on Figure 3. Photos of the car bodies and telephone pole are presented in Appendix H. Specific descriptions of each of the car bodies can be found in the corresponding hand-auger log in Appendix A.

In general, the car bodies appeared to have been buried for a number of years as the rusty condition and era of car indicates. We did not observe any batteries or free petroleum product in the vehicles. At least one of the vehicles had a fuel tank; however, the tank appeared to be empty.

We also observed a downed telephone pole along the levee alignment which did not appear to have a power transformer. We sampled the soil beneath the downed telephone pole where the transformer would have been located for contaminants. Additional details of the downed telephone pole can be found in hand-auger log HA-28 in Appendix A.

3.3.4 BACKGROUND SOIL AND SEDIMENT SAMPLING

Landau Associates collected samples from locations upstream and downstream of the Car Body Levee to determine background concentrations of contaminants. One soil sample and one sediment sample from the top 6 inches of ground surface was collected at locations approximately 200 ft upstream (HA-29 and HA-30) of the Car Body Levee and 200 ft downstream (HA-31 and HA-32) of the Car Body Levee.

Each background sample collected was submitted to TestAmerica for a suite of three analytical tests: lead (EPA Method 6010C), total petroleum hydrocarbons – gasoline range organics (NWTPH-Gx), and total petroleum hydrocarbons – diesel range organics (NWTPH-Dx). The two sediment samples were analyzed for total organic content using method EPA Method 9060A and grain size distribution using the method described in *Recommended Protocols for Measuring Conventional Sediment Variables in Puget Sound*, Puget Sound Estuarine Program, 1986. Analytical Test results are summarized in Table D1. Analytical Laboratory Reports provided by the TestAmerica are provided in Appendix E.

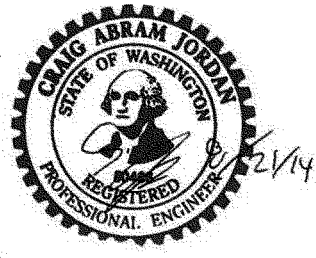
3.4 SURVEYING

MTN2COAST, LLC of Olympia, Washington under subcontract to Landau Associates, surveyed the locations of all completed borings and test pits for this study, outside of the HTRW investigation site. A chart listing the surveyed exploration locations is provided in Appendix F.

4.0 USE OF THIS REPORT

This Final GDR summarizes the results from our field exploration and laboratory testing program completed for the exclusive use of Mason County and USACE for specific application to the Geotechnical and HTRW Investigations, Skokomish General Investigation in Skokomish, Washington. Within the limitations of scope, schedule, and budget, our services have been provided in accordance with generally accepted geotechnical engineering principles and practices in the area at the time the report was prepared. We make no other warranty, either express or implied.

LANDAU ASSOCIATES, INC.



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Project Geotechnical Engineer

Calvin A. McCaughan, P.E.
Associate Geotechnical Engineer

CAJ/CAM/bar

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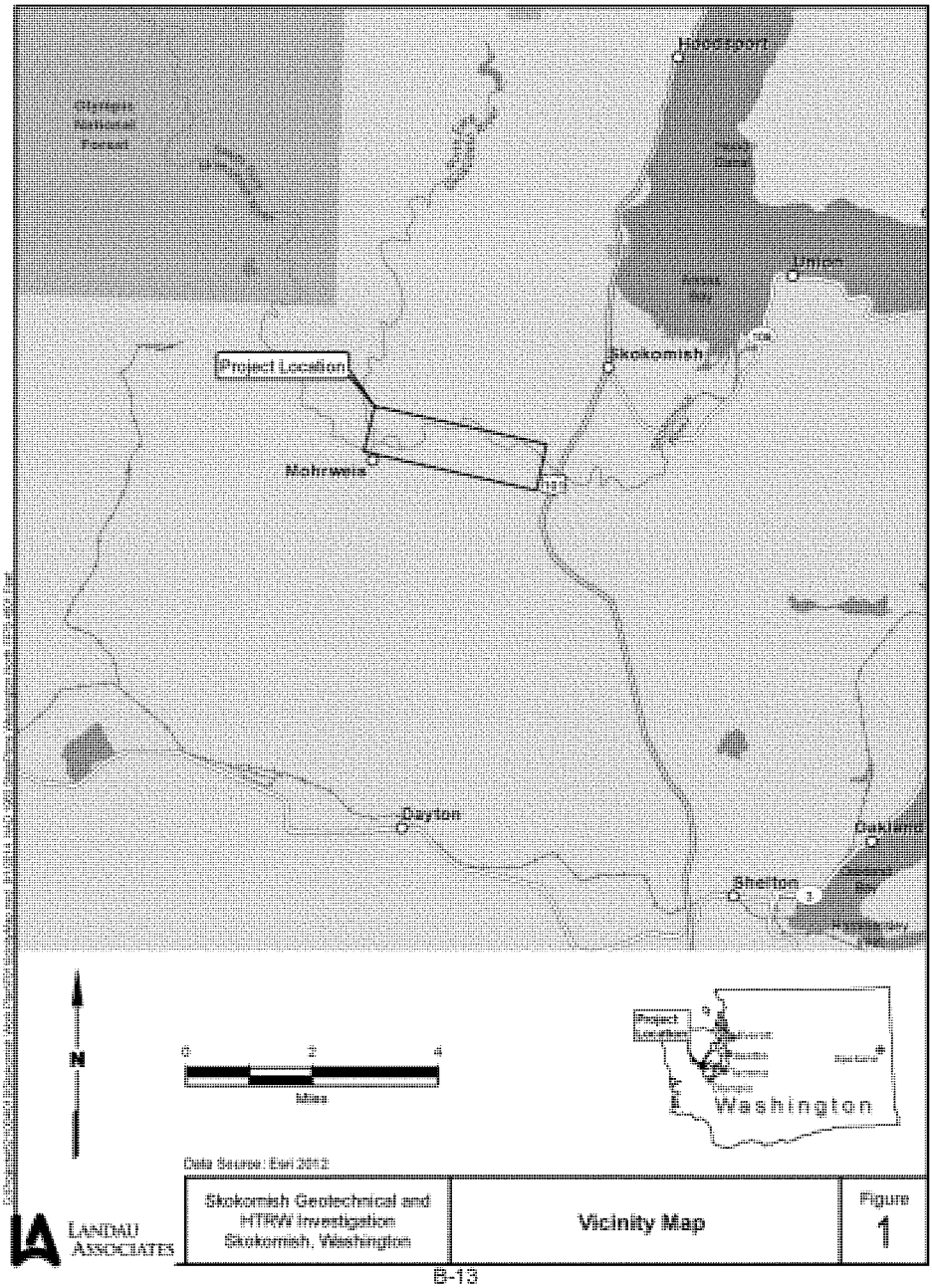
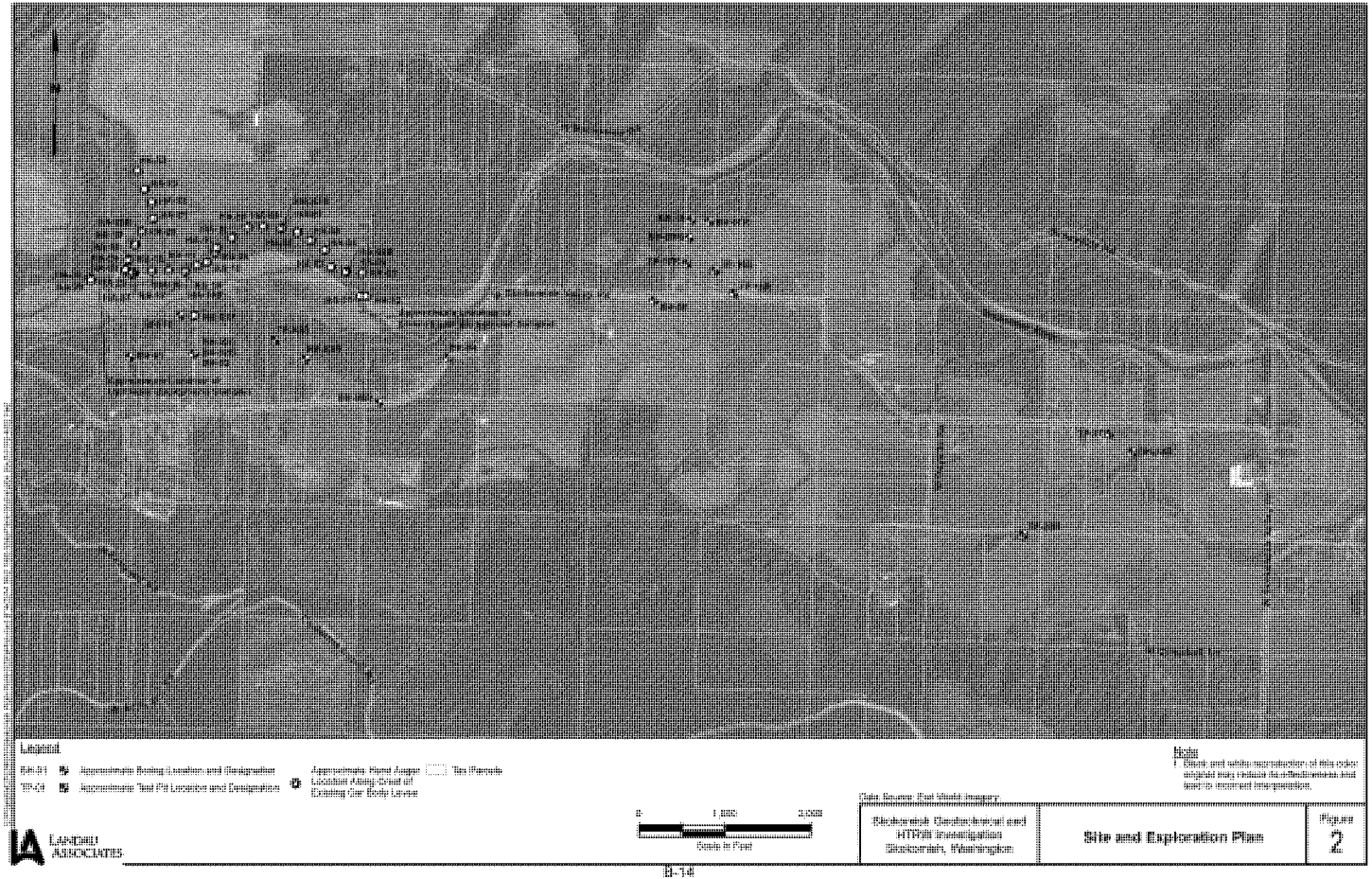
Mason County. 2014. *Skokomish General Investigation Geotechnical Statement of Work*. January 31.

Polenz, M., et. al. 2010. *Geologic Map of the Skokomish Valley and Union 7.5-Minute Quadrangles, Mason County, Washington*. Washington Division of Geology and Earth Resources, Open File Report 2010-3, scale 1:24,000. June.


Olympic National Forest
Hoodsport
Union
Skokomish
Project Location
Mahrwalis
Dayton
Oakland
Shelton
N
0
2
4
Miles
Project Location
Washington
Data Source: Esri 2012
LANDAU ASSOCIATES
Skokomish Geotechnical and HTRW Investigation
Skokomish, Washington
Vicinity Map
Figure
1


Legend
Approximate Boring Location and Designation
Approximate Test Pit Location and Designation
Approximate Point Auger Location Along Crest of Existing Dike Body Levee
Tax Parcels
Note
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
Data Source: Fall World Imagery
0
1,000
2,000
Scale in Feet
LANDAU ASSOCIATES
Richland Geotechnical and HTRW Investigation
Richland, Washington
Site and Exploration Plan
Figure
2

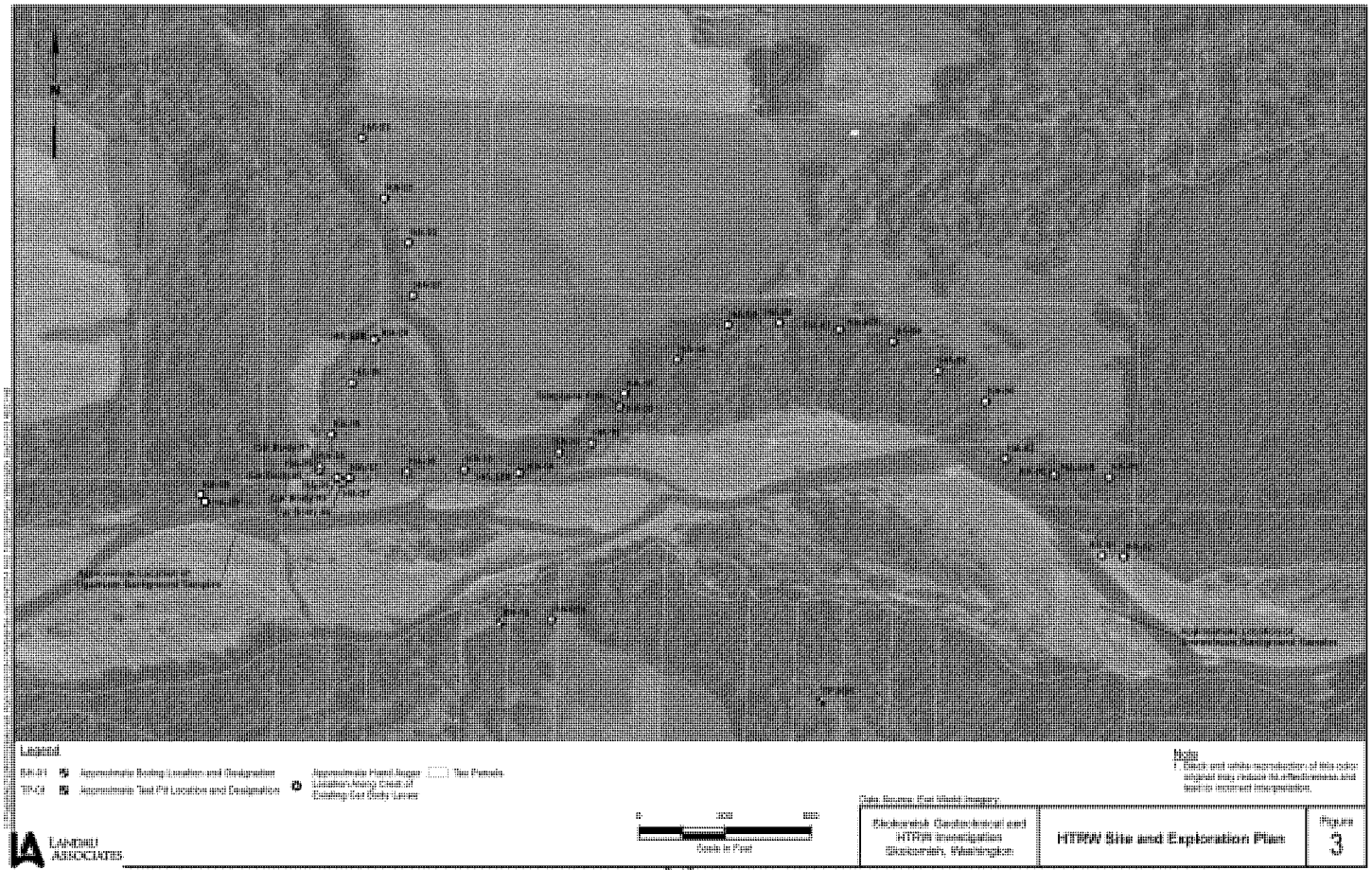

Legend
Approximate Boring Location and Designation
Approximate Test Pit Location and Designation
Approximate Hand Auger
Tax Parcels
Location Along Crest of Existing Ear Body Levee
Note
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
Site Survey Per Shell Imagery
0
100
200
Scale in Feet
LANDAU ASSOCIATES
Geotech Geotechnical and HTRW Investigation
Bellevue, Washington
HTRW Site and Exploration Plan
Figure
3

TABLE 1
TABULATED SUMMARY OF EXPLORATIONS
SKOKOMISH GEOTECHNICAL AND HTRW INVESTIGATION
MASON COUNTY, WASHINGTON

Exploration ID	Ground Surface Elevation	Depth of Exploration	Approximate Groundwater Depth at Time of Drilling	Figure
TP-02R	56.8	7	5	A-2
TP-13R	41.2	9	4	A-3
TP-17R	44.0	9	5	A-4
TP-19R	42.3	8	4	A-5
TP-23R	31.4	9.5	3	A-6
TP-27	33.6	9	5	A-7
HA-01X	60.0	5.5	4	A-8
BH-01	61.2	31.5	4.1	A-9
BH-02	57.4	31.5	2.9	A-10
BH-02B	62.5	3.5	No Groundwater Observed	A-11
BH-02C	62.5	5	No Groundwater Observed	A-12
BH-03R	55.6	31.5	3.7	A-13
BH-04	53.4	31.5	8.1	A-14
BH-05R	54.8	31.5	6.6	A-15
BH-07R	46.6	31.5	6.2	A-16
BH-08	47.7	31.5	6.2	A-17
BH-09R	44.4	31.5	3.9	A-18
BH-10	44.3	31.5	4	A-19
BH-14R	32.0	31.5	3.5	A-20
BH-15	62.9	41.5	6.2	A-21
HA-01	TBD	3.5	Groundwater not encountered	A-22
HA-02	TBD	3	Groundwater not encountered	A-22
HA-02B	TBD	1.8	Groundwater not encountered	A-23
HA-03	TBD	3.3	Groundwater not encountered	A-23
HA-04	TBD	3	Groundwater not encountered	A-24
HA-05	TBD	3	Groundwater not encountered	A-24
HA-06	TBD	3.3	Groundwater not encountered	A-25
HA-07	TBD	3	Groundwater not encountered	A-25
HA-07B	TBD	1.3	Groundwater not encountered	A-26
HA-08	TBD	3	Groundwater not encountered	A-26
HA-09	TBD	3	Groundwater not encountered	A-27
HA-10	TBD	3	Groundwater not encountered	A-27
HA-11	TBD	3	Groundwater not encountered	A-28
HA-12	TBD	3	Groundwater not encountered	A-28
HA-13	TBD	3	Groundwater not encountered	A-29
HA-14	TBD	3	Groundwater not encountered	A-29
HA-14B	TBD	1	Groundwater not encountered	A-30
HA-15	TBD	3	Groundwater not encountered	A-30
HA-16	TBD	3	Groundwater not encountered	A-31

TABLE 1
TABULATED SUMMARY OF EXPLORATIONS
SKOKOMISH GEOTECHNICAL AND HTRW INVESTIGATION
MASON COUNTY, WASHINGTON

Exploration ID	Ground Surface Elevation	Depth of Exploration	Approximate Groundwater Depth at Time of Drilling	Figure
HA-17	TBD	3	Groundwater not encountered	A-31
HA-18	TBD	3	Groundwater not encountered	A-32
HA-19	TBD	3	Groundwater not encountered	A-32
HA-20	TBD	3	Groundwater not encountered	A-33
HA-20B	TBD	1	Groundwater not encountered	A-33
HA-21	TBD	3.3	Groundwater not encountered	A-34
HA-22	TBD	3	Groundwater not encountered	A-34
HA-23	TBD	3	Groundwater not encountered	A-35
HA-24	TBD	1	Groundwater not encountered	A-35
HA-25	TBD	1	Groundwater not encountered	A-36
HA-26	TBD	1	Groundwater not encountered	A-36
HA-27	TBD	0.5	Groundwater not encountered	A-37
HA-28	TBD	0.5	Surface Water at Location	A-37
HA-29	TBD	0.5	Surface Water at Location	A-38
HA-30	TBD	0.5	Groundwater not encountered	A-38
HA-31	TBD	0.3	Surface Water at Location	A-39
HA-32	TBD	0.5	Groundwater not encountered	A-39
HA-33	TBD	3.3	Groundwater not encountered	A-40

APPENDIX A

Exploration Summary Logs

Soil Classification System

	MAJOR DIVISIONS		GRAPHIC SYMBOL	USCS LETTER SYMBOL[1]	TYPICAL DESCRIPTIONS[2][3]
COARSE-GRAINED SOIL (More than 50% of material is larger than No. 200 sieve size)	GRAVEL AND GRAVELLY SOIL (More than 50% of coarse fraction retained on No. 4 sieve)	CLEAN GRAVEL (Little or no fines)		GW	Well-graded gravel; gravel/sand mixture(s); little or no fines
				GP	Poorly graded gravel; gravel/sand mixture(s); little or no fines
		GRAVEL WITH FINES (Appreciable amount of fines)		GM	Silty gravel; gravel/sand/silt mixture(s)
				GC	Clayey gravel; gravel/sand/clay mixture(s)
	SAND AND SANDY SOIL (More than 50% of coarse fraction passed through No. 4 sieve)	CLEAN SAND (Little or no fines)		SW	Well-graded sand; gravelly sand; little or no fines
				SP	Poorly graded sand; gravelly sand; little or no fines
		SAND WITH FINES (Appreciable amount of fines)		SM	Silty sand; sand/silt mixture(s)
				SC	Clayey sand; sand/clay mixture(s)
FINE-GRAINED SOIL (More than 50% of material is smaller than No. 200 sieve size)	SILT AND CLAY (Liquid limit less than 50)			ML	Inorganic silt and very fine sand; rock flour; silty or clayey fine sand or clayey silt with slight plasticity
				CL	Inorganic clay of low to medium plasticity; gravelly clay; sandy clay; silty clay; lean clay
				OL	Organic silt; organic, silty clay of low plasticity
	SILT AND CLAY (Liquid limit greater than 50)			MH	Inorganic silt; micaceous or diatomaceous fine sand
				CH	Inorganic clay of high plasticity; fat clay
				OH	Organic clay of medium to high plasticity; organic silt
	HIGHLY ORGANIC SOIL			PT	Peat; humus; swamp soil with high organic content

OTHER MATERIALS	GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
PAVEMENT		AC or PC	Asphalt concrete pavement or Portland cement pavement
ROCK		RK	Rock (See Rock Classification)
WOOD		WD	Wood, lumber, wood chips
DEBRIS		DB	Construction debris, garbage

Notes:
1. USCS letter symbols correspond to symbols used by the Unified Soil Classification System and ASTM classification methods. Dual letter symbols (e.g., SP-SM for sand or gravel) indicate soil with an estimated 5-15% fines. Multiple letter symbols (e.g., ML/CL) indicate borderline or multiple soil classifications.
2. Soil descriptions are based on the general approach presented in the Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), outlined in ASTM D 2488. Where laboratory index testing has been conducted, soil classifications are based on the Standard Test Method for Classification of Soils for Engineering Purposes, as outlined in ASTM D 2487.
3. Soil description terminology is based on visual estimates (in the absence of laboratory test data) of the percentages of each soil type and is defined as follows:

Primary Constituent:	> 50% - "GRAVEL," "SAND," "SILT," "CLAY," etc.
Secondary Constituents:	> 30% and ≤ 50% - "very gravelly," "very sandy," "very silty," etc.
	> 15% and ≤ 30% - "gravelly," "sandy," "silty," etc.
Additional Constituents:	> 5% and ≤ 15% - "with gravel," "with sand," "with silt," etc.
	≤ 5% - "with trace gravel," "with trace sand," "with trace silt," etc., or not noted.

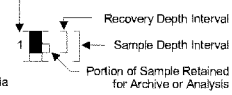
4. Soil density or consistency descriptions are based on judgement using a combination of sampler penetration blow counts, drilling or excavating conditions, field tests, and laboratory tests, as appropriate.

Drilling and Sampling Key

SAMPLER TYPE

Code	Description
a	3.25-inch O.D., 2.42-inch I.D. Split Spoon
b	2.00-inch O.D., 1.50-inch I.D. Split Spoon
c	Shelby Tube
d	Grab Sample
e	Single-Tube Core Barrel
f	Double-Tube Core Barrel
g	2.50-inch O.D., 2.00-inch I.D. WSDOT
h	3.00-inch O.D., 2.375-inch I.D. Mod. California
i	Other - See text if applicable
1	300-lb Hammer, 30-inch Drop
2	140-lb Hammer, 30-inch Drop
3	Pushed
4	Vibrocore (Rotosonic/Geoprobe)
5	Other - See text if applicable

SAMPLE NUMBER & INTERVAL



Field and Lab Test Data

Code	Description
PP = 1.0	Pocket Penetrometer, tsf
TV = 0.5	Torvane, tsf
PID = 100	Photoionization Detector VOC screening, ppm
W = 10	Moisture Content, %
D = 120	Dry Density, pcf
-200 = 60	Material smaller than No. 200 sieve, %
GS	Grain Size - See separate figure for data
AL	Atterberg Limits - See separate figure for data
GT	Other Geotechnical Testing
CA	Chemical Analysis

Groundwater

▽ Approximate water level at time of drilling (ATD)
▼ Approximate water level at time other than ATD

LANDAU ASSOCIATES

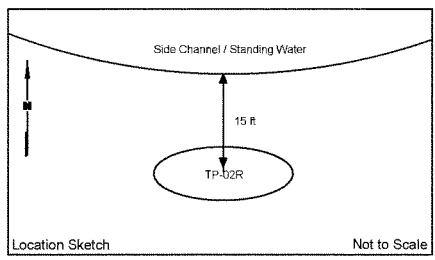
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Soil Classification System and Key	Figure A-1

TP-02R

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: 305C CR Mini Tracked Excavator Ground Elevation (ft): 61.9 Excavated By: Howard's Excavating (Howard) Logged By: Josh Elliott	
0						SM	Brown, very silty, fine to course SAND with gravel and organics (roots) (loose, moist) **(TOPSOIL)**	
	60					SP	Gray, very gravelly, medium to coarse SAND with trace silt (very loose to loose, moist) **(ALLUVIUM)**	
		S-1 8:43	d	GS W = 3				
	58						-grades to wet	Moderate Seepage
5		S-2 8:50	d	W = 8				
	56							
		S-3 9:00	d	W = 14				
10								
15								

Test Pit Completed 06/16/14
Total Depth of Test Pit = 7.0 ft.

-Test Pit excavated from 8:35 to 9:00.
-Backfilled with cuttings upon completion.
-Backfilled in 1.5' lifts and tamped with back of bucket and covered with vegetative spoils to control erosion.
-View Direction: North
-Vertical Scale 1 inch = 2.5 feet
-Horizontal Scale 1 inch = 5 feet
-Reviewed by: Calvin McCaughan, P.E.



Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

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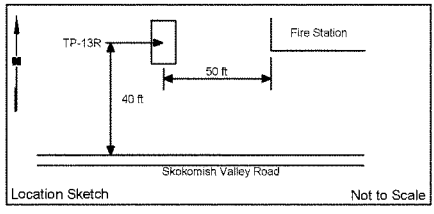
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Test Pit TP-02R	Figure A-2

TP-13R

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: 305C CR Mini Tracked Excavator Ground Elevation (ft): 46.3 Excavated By: Howard's Excavating (Howard) Logged By: Josh Elliott	
0	46					SM	3" Sod Brown, silty, fine to coarse SAND (medium dense, moist) (ALLUVIUM)	
	44					ML	Gray, very sandy SILT with trace organics (soft, wet) (ALLUVIUM)	
		S-1 14:25	d	GS W = 51			-grades to silt with sand	Slow Seepage
5	42							
	40	S-2 14:32	d	AL W = 44			with woody debris and organics	Rapid Seepage
	38					GP	Gray, sandy GRAVEL with trace silt (loose to medium dense, wet)	
		S-3 14:40	d	GS W = 8				
10								
15								

Test Pit Completed 06/16/14
Total Depth of Test Pit = 9.0 ft.

-Test Pit excavated from 14:12 to 14:40.
-Backfilled with cuttings upon completion.
-Backfilled from 14:40-15:10. Soft surface due to moisture, flagged pit location and plan to return 6/17/2014.
-Completed restoration with jute net, grass seed, and straw at 07:55 on 6/17/2014.
-View Direction: West
-Vertical Scale 1 inch = 2.5 feet
-Horizontal Scale 1 inch = 5 feet
-Reviewed by: Calvin McCaughan, P.E.



Notes: 1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

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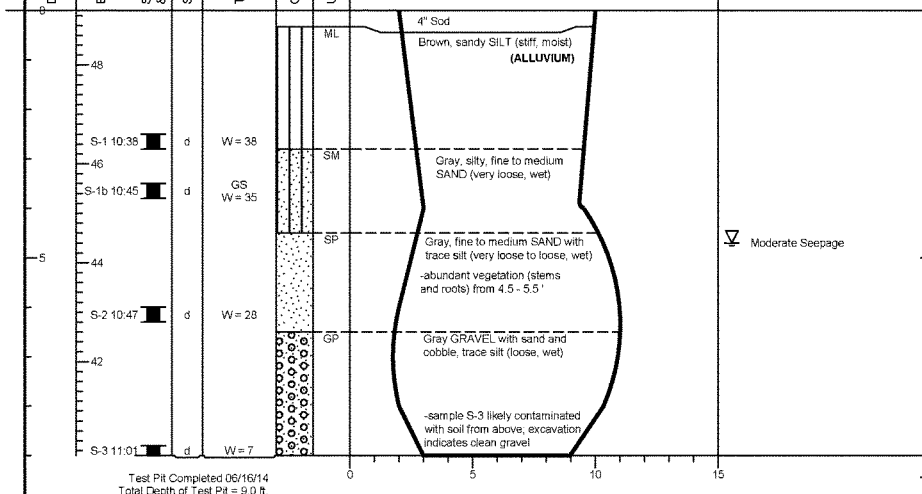
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Test Pit TP-13R	Figure A-3

TP-17R

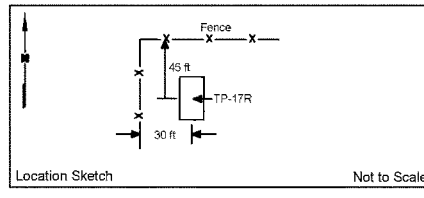
SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol		

Excavation Method: 305C CR Mini Tracked Excavator
Ground Elevation (ft): 49.1
Excavated By: Howard's Excavating (Howard)
Logged By: Josh Elliott



Test Pit Completed 06/16/14
Total Depth of Test Pit = 9.0 ft.

-Test Pit excavated from 10:30 to 11:01.
-Backfilled with cuttings upon completion.
-Test pit full of water and not draining during backfilling. Finished backfilling at 12:05, soft and saturated, will return on 6/17/2014 to check.
-Completed restoration with jute net, grass seed, and straw at 09:20 on 6/17/2014.
-View Direction: West
-Scale 1 inch = 2.5 feet
-Scale 1 inch = 5 feet
-Reviewed by: Calvin McCaughan, P.E.



Notes: 1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

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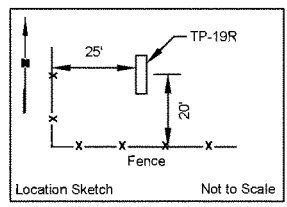
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Test Pit TP-17R	Figure A-4

TP-19R

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: 305C CR Mini Tracked Excavator Ground Elevation (ft): 47.4 Excavated By: Howard's Excavating (Howard) Logged By: Josh Elliott	
0	46	S-1 12:58	d	Organic Content = 3.7% W = 14		SP-SM	4" Sod Brown, fine to coarse SAND with silt, gravel, and organics (roots) (loose, moist to wet) **(ALLUVIUM)** -trace roots below 1.5'	
	44	S-2 13:02	d	GS W = 44		SM	Brown, very silty, fine to medium SAND with trace clay (loose, wet)	Moderate Seepage
5	42	S-3 13:13	d	W = 51		GP	Gray, sandy GRAVEL with trace silt (loose, wet)	
	40	S-4 13:20	d	W = 7				
10								
15								

Test Pit Completed 06/16/14
Total Depth of Test Pit = 8.0 ft.

-Test Pit excavated from 12:25 to 13:20, Thunderstorm delay from 12:35 to 12:55.
-Backfilled with cuttings upon completion.
-Finished backfilling at 13:40. Completed surface restoration with jute net, grass seed, and straw at 08:45 on 6/17/2014.
-View Direction: West
-Vertical Scale 1 inch = 2.5 feet
-Horizontal Scale 1 inch = 5 feet
-Reviewed by: Calvin McCaughan, P.E.



Notes: 1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Test Pit TP-19R

Figure A-5

TP-23R

SAMPLE DATA				SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	

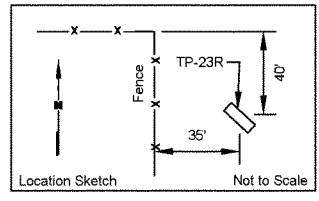
Excavation Method: 305C CR Mini Tracked Excavator
Ground Elevation (ft): 36.5
Excavated By: Howard's Excavating (Howard)
Logged By: Josh Elliott

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	USCS Symbol	Description
0	36				SM	3" Sod Brown, silty, fine to coarse SAND with clay (medium dense, moist to wet) (ALLUVIUM)
	34	S-1 09:43	d	GS W = 67	ML	Mottled gray and brown, very sandy SILT (soft, wet)
		S-2 09:46	d	W = 57		
5	32					
		S-3 09:56	d	AL GS W = 53		
	30					
	28					-gray
10		S-4 10:02	d	W = 44		
15						

GROUNDWATER: Moderate Seepage; Rapid Seepage

Test Pit Completed 06/17/14
Total Depth of Test Pit = 9.5 ft.

-Test Pit excavated from 9:35 to 10:02
-Backfilled with cuttings upon completion.
-Began backfilling at 10:12. Completed backfilling at 10:25. Completed surface restoration with jute net, grass seed, and straw at 10:40.
-View Direction: Northeast
-Vertical Scale 1 inch = 2.5 feet
-Horizontal Scale 1 inch = 5 feet
-Reviewed by: Calvin McCaughan, P.E.



Notes: 1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Test Pit TP-23R

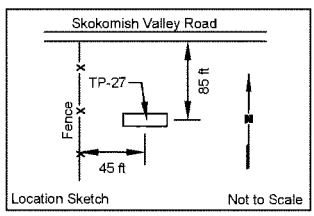
Figure A-6

TP-27

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: 305C CR Mini Tracked Excavator Ground Elevation (ft): 38.7 Excavated By: Howard's Excavating (Howard) Logged By: Josh Elliott	
0						ML	3" Sod Brown SILT with organics (roots) (medium stiff, moist) **(ALLUVIUM)**	
	38	S-1 11:27	d	Organic Content = 5.8% W = 34				
	36	S-2 11:30	d	GS W = 34		SM	Brown, silty, fine to medium SAND (loose, moist to wet)	
5	34					ML	Mottled brown and gray SILT (medium stiff, wet) -with organics (roots) from 5' to 6'	Moderate Seepage
		S-3 11:36	d	W = 59				
	32					SM	Brown, silty, fine to medium sand (medium dense, wet)	
	30	S-4 11:50	d	AL GS W = 61				
10								
15								

Test Pit Completed 06/17/14
Total Depth of Test Pit = 9.0 ft.

-Test Pit excavated from 11:20 to 11:50
-Backfilled with cuttings upon completion.
-Began backfilling at 11:57. Finished backfilling at 12:05. Completed surface restoration with jute net, grass seed, and straw at 12:20.
-View Direction: North
-Vertical Scale 1 inch = 2.5 feet
-Horizontal Scale 1 inch = 5 ft
-Reviewed by: Calvin McCaughan, P.E.



Notes: 1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Test Pit TP-27	Figure A-7

HA-01X

SAMPLE DATA				SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel/Hand Auger Ground Elevation (ft): 60.0 Excavated By: Landau Associates Logged By: Josh Elliott
0	60						3" Forest Duff
						ML	Brown SILT with sand, abundant debris [metal, glass, and cinder block (10") no other indication of previous structure, debris likely dumped at site] (medium stiff, moist) **(FILL)** -organics (roots)
	58						
		S-1 16:14	d	GS W = 38			Dug/Shovel to 2.0 ft, Hand Auger below 2.0 ft
						SM	Gray, very silty, fine SAND with clay (very loose, wet) **(ALLUVIUM)**
	56						ATE
5		S-2 16:21	d	W = 45			

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 5.5 ft.

-Hand Auger Boring Completed from 15:35 to 16:27
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

10

15

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SINGLE TEST PIT LOG

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Boring HA-01X

Figure A-8

BH-01

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 61.2
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Profile	Groundwater
0					13:02 - 13:03	SM	Brown, silty SAND with gravel (loose, damp) **(FILL)**	
	60							
2		1-13:04	b2	9	W = 8 GS	GW	Brown, very sandy, fine to coarse GRAVEL with trace silt (loose, wet) **(ALLUVIUM)**	
		1CAL-13:06	h2					
	58							4.1 ft @ 14:02
4					13:08 - 13:09			
	56	2-13:10	b2	2	W = 11		-grades to very loose -rock in sampler	
6								
	54							
8					13:11 - 13:12			
	52							
10		3-13:14	b2	6	W = 16		-grades to loose with trace cobble -rock in shoe	
		3CAL-13:21	h2					
	50							
12					13:24 - 13:25			
	48							
14		4-13:36	b2			SP	Brown, fine to coarse SAND with gravel, trace silt (medium dense, wet)	
	46							
16		5-13:42	b2	17	GS W = 16			
	44				13:40 - 13:49			

Moisture Content (%): Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ △ Non-Standard N-Value △: 20 40 60 80
× Fines Content (%) ×: 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-01

Figure A-9 (1 of 2)

BH-01

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 61.2
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater	Moisture Content (%) / SPT N-Value / Fines Content (%)
18	42						GW	Brown, sandy, fine to coarse GRAVEL with trace silt (medium dense, wet)		
20		6-13:51	b2	13				-small recovery		▲
	40	6CAL-14:07	h2							
22	38				13:55 - 14:00					
24	36	7-14:16	b2	18	W = 10			-overdrove sample in attempt to recover more sample		● ▲
26	34									
28	32				14:21 - 14:22					
30		8-14:23	b2	16	GS W = 7					● ▲
	30	8CAL-14:27	h2							
32										
34										

Boring Completed 06/11/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 13:02 to 14:30
-Drilled with Track-mounted Diedrich D-50
-14:30 - 14:43-Removed drill string
Hole caved to the surface, no bentonite
-3-1/4" ID-7" OD
-Vertical elevations based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-01

Figure A-9 (2 of 2)

BH-02

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 57.4
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
0					7:27 - 7:28		ML	Brown, sandy SILT (very soft, moist) **(ALLUVIUM)**	2.9 ft @ 8:32
2	56								
	54	1-7:29	b2	1				-grades to wet	
4					7:31 - 7:32				
	52	2A-7:33 2B-7:33	b2	22	W = 39		GP-GM	Brown, sandy GRAVEL with silt (medium dense, wet)	
6									
	50								
8					7:35 - 7:36				
	48								
10		3-7:38	b2	36	W = 11			-dense -rock in shoe	
	46								
12					7:40 - 7:41		SP	Brown, fine to medium SAND with trace silt (medium dense, wet)	
	44								
14									
	42	4-7:42 4CAL-7:46	b2 h2	27	GS W = 21				
16					7:48 - 7:50				

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-02

Figure A-10 (1 of 3)

BH-02

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 57.4
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
	40						SP	Brown, fine to medium SAND with trace silt (medium dense, wet)	
18									
	38								
20		5-7:54	b2	19					
	36							-break in drilling 7:55 - 8:08	
22									
					7:55 - 8:10				
	34								
24									
	32	6-8:12 6CAL-8:16	b2 h2	20	GS W = 11			-grades to gravelly	
26									
	30								
28					8:21 - 8:22				
	28								
30		7-8:23	b2	23					
	26								
32									
34									

Boring Completed 06/11/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 7:27 to 8:20
-Drilled with Track-mounted Diedrich D-50
-8:33 - 8:41- Removed drill string
-9:10 9:15 - Backfilled hole with bentonite
-Combined sample 6 CAL and 7 for grain size analysis
-3-1/4" ID-7" OD
-Vertical elevations based on NAVD88

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80
× Fines Content (%) × 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

6210004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-02

Figure A-10 (2 of 3)

BH-02

LAI Project No: 0621004.010

SAMPLE DATA								SOIL PROFILE		Moisture Content (%) Plastic Limit — Liquid Limit 20 40 60 80 ▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80 ╳ Fines Content (%) ╳ 20 40 60 80
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 57.4 Drilled By: Holocene Drilling Inc. (Dave/Nunsie) Logged By: Craig Jordan Date: 06/11/14 -Scale 1 inch = 2.5 feet -Reviewed by: Calvin McCaughan, P.E.	Groundwater	

36
38
40
42
44
46
48
50

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Boring BH-02	Figure A-10 (3 of 3)

BH-02B

LAI Project No: 0621004.010

SAMPLE DATA						SOIL PROFILE			
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 62.5 Drilled By: Holocene Drilling Inc. (Dave/Nunsie) Logged By: Craig Jordan Date: 06/11/14	Groundwater
0	62				8:41 - 8:42		ML	Brown sandy SILT (very soft, wet) **(ALLUVIUM)**	Groundwater Not Encountered
2	60	1-8:44	b2	0				-No sample recovery, abandoned hole	
4									
6									
8									
10									
12									
14									
16									

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Boring Completed 06/11/14
Total Depth of Boring = 3.5 ft.

-Boring Drilled from 8:44 to 8:45
-Drilled with Track-mounted Diedrich D-50
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-02B

Figure A-11

BH-02C

LAI Project No: 0621004.010

SAMPLE DATA						SOIL PROFILE			
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 62.5 Drilled By: Holocene Drilling Inc. (Dave/Nunsie) Logged By: Craig Jordan Date: 06/11/14	Groundwater
0	62				8:52 - 8:53		ML	Brown sandy SILT (very soft, wet) **(ALLUVIUM)**	Groundwater Not Encountered
2	60	1-8:54	c2		GT GS W = 50 AL			-sample rest 8:54 - 9:05	
4	58								

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ (△ Non-Standard N-Value △) 20 40 60 80

× Fines Content (%) × 20 40 60 80

H ● ×

Boring Completed 06/11/14
Total Depth of Boring = 5.0 ft.

-Boring Drilled from 8:52 to 9:08
-Drilled with Track-mounted Diedrich D-50
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-02C

Figure A-12

BH-03R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 55.6
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Description
0					7:46 - 7:47	ML	Brown, sandy SILT with trace gravel and organics (roots and fine) **(ALLUVIUM)**
	54						
2		1A-7:49	b2	16	W = 36		
		1B-7:49			GS W = 8	GP	Brown, very sandy, fine to coarse GRAVEL with trace silt (medium dense, wet) -fractured rock in shoe
	52						
4					7:50 - 7:51	GW	Brown, very sandy, fine to coarse GRAVEL with trace silt (medium dense, wet)
		2-7:52	b2	12	GS W = 6		-fractured rock in shoe
	50						
6		2CAL-7:55	h2				
	48						
8					7:56 - 7:57		
						SP	Brown, gravelly, fine to coarse SAND with trace silt (dense, wet)
	46						
10		3-7:59	b2	31	W = 12		
	44						
12					8:02 - 8:19		
	42						
14		4-8:20	b2	58	GS W = 18		-very dense
	40						-fractured rock in shoe
16		4CAL-8:23	h2				

Groundwater: 3.7 ft @ 9:08

Moisture Content (%): Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ △ Non-Standard N-Value △: 20 40 60 80
× Fines Content (%) ×: 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-03R

Figure A-13 (1 of 2)

BH-03R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 55.6
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
	38						SP	Brown, gravelly, fine to coarse SAND with trace silt (dense, wet)	
18					8:26 - 8:27				
	36								
20		5-8:30	b2	38				-dense	
		5CAL-8:32	h2					-fractured rock in shoe	
	34								
22					8:34 - 8:35				
	32								
24		6-8:39	b2	13				-medium dense	
	30								
26									
	28				8:46 - 8:47		SW	Brown, very gravelly, fine to coarse SAND with trace silt (very dense, wet)	
28									
	26								
30		7-8:50	b2	56	GS			-fractured rock in shoe	
		7CAL-8:56	h2		W = 9				
32									
34									

Moisture Content (%): Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ △ Non-Standard N-Value △: 20 40 60 80
× Fines Content (%) ×: 20 40 60 80

Boring Completed 06/12/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 7:46 to 9:00
-Drilled with Track-mounted Diedrich D-50
-9:03 - 9:10 - Removed drill string
-Backfilled hole with bentonite
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 9/20/14 Y:\0621\004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-03R

Figure A-13 (2 of 2)

BH-04

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 53.4
Drilled By: Holocene Drilling Inc. (Jarrod/Raymond)
Logged By: Craig Jordan Date: 06/09/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Profile	Groundwater
0						AC	0.75' hot mixed asphalt	
					8:31 - 8:35	GM / ML	Brown, silty, fine to coarse GRAVEL with sand (medium dense, moist) **(FILL)**	
2	52						Brown, very sandy SILT with clay (soft, moist) **(ALLUVIUM)**	
		1-8:36	b2	4				
4	50				GS AL W = 34 8:37 - 8:38			
		2-8:38	b2	0	W = 28		-very soft	
6	48							
	46					SM	Brown, silty, fine to medium SAND (loose, wet)	8.1 ft @ 9:07
8					8:41 - 8:42			
	44							
10		3A-8:43	b2	5	W = 36			
		3B-8:43			W = 29	SP-SM	Brown, fine to coarse SAND with silt (loose, wet)	
12	42				8:45 - 8:46			
	40							
14								
	38	4A-8:48	b2	2	W = 23			
16		4B-8:48			AL W = 43	SM	Gray, silty, fine to medium SAND with clay (very loose, wet)	
							-driller noted gravel	

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80
× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-04

Figure A-14 (1 of 3)

BH-04

LAI Project No: 0621004.010

SAMPLE DATA | **SOIL PROFILE**

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 53.4
Drilled By: Holocene Drilling Inc. (Jarrod/Raymond)
Logged By: Craig Jordan Date: 06/09/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Description	Groundwater
	36						SM	Gray, silty, fine to medium SAND with clay (very loose, wet)	
18					9:02 - 9:04				
	34								
20		5A-9:06 / 5B-9:06	b2	2	GS W = 36				
							SP-SM	Brown, fine to coarse SAND with silt and gravel (very loose, wet)	
	32								
22					9:10 - 9:11				
	30								
24									
	28	6-9:12	b2	18	GS W = 24				
26									
	26				9:16 - 9:17				
28									
	24								
30		7A-9:19 / 7B-9:19	b2	21					
	22							-grades to medium to coarse SAND with silt and gravel	
32									
34									

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80
× Fines Content (%) × — 20 40 60 80

Boring Completed 06/09/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 8:31 to 9:20
-Drilled with Truck-mounted BK-81
-9:24 - 9:36 - Removed drill string
-9:45 - 9:57 - Backfilled with bentonite and concrete
-Samples 1 and 2 were compiled for GS testing
-4-1/4" ID-9" OD

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-04

Figure A-14 (2 of 3)

BH-04

LAI Project No: 0621004.010

SAMPLE DATA								SOIL PROFILE		
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 53.4 Drilled By: Holocene Drilling Inc. (Jarrod/Raymond) Logged By: Craig Jordan Date: 06/09/14	Groundwater	Moisture Content (%) Plastic Limit 20 40 60 80 Liquid Limit ▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80 × Fines Content (%) × 20 40 60 80

-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

36
38
40
42
44
46
48
50

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Boring BH-04	Figure A-14 (3 of 3)

BH-05R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 54.8
Drilled By: Holocene Drilling Inc. (Jarrod/Raymond)
Logged By: Craig Jordan Date: 06/09/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Profile	Groundwater
0						AC	0.875' hot mixed asphalt	
	54				10:16 - 10:20	GM	Brown, silty, gravelly, fine to coarse SAND (medium dense, moist) **(FILL)**	
2								
	52	1A-10:21	b2	5	GS W = 29			
		1B-10:21			W = 13	ML	Brown, very sandy SILT with trace clay (medium stiff, moist) **(ALLUVIUM)**	
4					10:23 - 10:24			
	50							
		2-10:25	b2	3	GS W = 32		-soft, wet	6.6 ft @11:39
6								
	48				10:26 - 10:27			
8								
	46							
10						SM	Brown, silty, fine SAND with trace clay (very loose, wet)	
	44	3-10:29	b2	0	GS W = 41		-liquefiable	
12					10:32 - 10:33			
	42							
14		4-10:45	c3		GT AL W = 40		-sample rest 10:37 - 10:45	
	40							
		5A-10:58	b2	13	10:50 - 10:54			
		5B-10:58						
16						GP-GM	Brown, sandy, fine to coarse GRAVEL with silt (medium dense, wet)	
	38							

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-05R

Figure A-15 (1 of 3)

BH-05R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 54.8
Drilled By: Holocene Drilling Inc. (Jarrod/Raymond)
Logged By: Craig Jordan Date: 06/09/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
18	36				11:02 - 11:03		GP-GM	Brown, sandy, fine to coarse GRAVEL with silt (medium dense, wet)	
20	34	6A-11:04 / 6B-11:04	b2	11	GS W = 28		SP-SM	Brown, fine to medium SAND with silt (medium dense, wet)	
22	32				11:08 - 11:12		GP	Brown, sandy, fine to coarse GRAVEL with trace silt (medium dense, wet)	
24	30	7-11:14	b2	50 for 5.5"			OL	Wood (very dense, wet) -driller noted woody	
26	28				11:19 - 11:22		GP	-driller backed auger out and used hammer to clear wood from auger Brown, sandy GRAVEL with trace silt (medium dense, wet) -driller noted drilling through wood at 27 feet	
28	26				11:30 - 11:31				
30	24	8-11:32	b2	24					
32									
34									

Moisture Content (%) — Plastic Limit 20, 40, 60, 80, Liquid Limit
▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20, 40, 60, 80
× Fines Content (%) × — 20, 40, 60, 80

Boring Completed 06/09/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 10:16 to 11:34
-Drilled with Truck-mounted BK-81
-11:40 - 11:50 - Removed drill string
-11:50 - Backfilled with bentonite and concrete
-4-1/4" ID-9" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

6210004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-05R

Figure A-15 (2 of 3)

BH-05R

LAI Project No: 0621004.010

SAMPLE DATA								SOIL PROFILE		
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 54.8 Drilled By: Holocene Drilling Inc. (Jarrod/Raymond) Logged By: Craig Jordan Date: 06/09/14 -Reviewed by: Calvin McCaughan, P.E.	Groundwater	Moisture Content (%) Plastic Limit 20 40 60 80 Liquid Limit ▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80 × Fines Content (%) × 20 40 60 80
	36									
	38									
	40									
	42									
	44									
	46									
	48									
	50									

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-05R

Figure A-15 (3 of 3)

BH-07R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 46.6
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
0	46				12:53 - 12:54		ML	Brown, sandy SILT with trace clay (very soft, moist) **(ALLUVIUM)**	
2	44								
4	42	1-12:38	c3		GT GS W = 31 AL			-sample rest 12:38 - 12:51	
		2A-12:54	b2	0	W = 42				6.2 ft @ 13:50
6	40	2B-12:54			GS W = 38		SP-SM	Brown, fine SAND with silt and trace clay (very loose, wet)	
8	38				12:56 - 12:57		SP	Brown, gravelly, fine to coarse SAND with trace silt (medium dense, wet)	
10	36	3-12:58	b2	25	GS W = 18			-fractured rock in sampler	
		3CAL-13:00	h2						
12	34				13:02 - 13:11			-break in drilling 13:05 - 13:11	
14	32	4-13:12	b2	24	W = 12			-low recovery in SPT sampler; flushed hole of sand prior to Cal. Sampler	
		4CAL-13:20	h2						
16	30								

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80
× Fines Content (%) × 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Mason County, Washington

Log of Boring BH-07R

Figure A-16 (1 of 3)

BH-07R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 46.6
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
							SP	Brown, gravelly, fine to coarse SAND with trace silt (medium dense, wet)	
18									
	28				13:22 - 13:23		GW	Brown, very sandy, fine to coarse GRAVEL with trace silt (dense, wet)	
20		5-13:25	b2	41	GS W = 10			-fractured rock in sampler	
	26	5CAL-13:29	h2						
22									
	24				13:30 - 13:32				
24									
	22							-fractured rock	
		6-13:36	b2	25					
26									
	20								
28					13:39 - 13:40				
	18								
30								-fractured rock in sampler	
	16	7-13:44	b2	20					
		7CAL-13:48	h2						
32									
34									

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80

⨯ Fines Content (%) ⨯ — 20 40 60 80

Boring Completed 06/12/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 12:32 to 13:50
-Drilled with Track-mounted Diedrich D-50
-13:52 - 14:01-Removed drill string
-14:03 - 14:26 - Backfilled with bentonite and concrete
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-07R

Figure A-16 (2 of 3)

BH-07R

LAI Project No: 0621004.010

SAMPLE DATA								SOIL PROFILE		
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 46.6 Drilled By: Holocene Drilling Inc. (Dave/Nunsie) Logged By: Craig Jordan Date: 06/12/14 -Reviewed by: Calvin McCaughan, P.E.	Groundwater	Moisture Content (%) Plastic Limit 20 40 60 80 Liquid Limit ▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80 × Fines Content (%) × 20 40 60 80
36										
38										
40										
42										
44										
46										
48										
50										

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Boring BH-07R	Figure A-16 (3 of 3)

BH-08

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 47.7
Drilled By: Holocene Drilling Inc. (Jarrod/Raymond)
Logged By: Craig Jordan Date: 06/09/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
0							AC	0.625' hot mixed asphalt	
					13:12 - 13:15		GM	Brown, silty, fine to coarse GRAVEL with sand (medium dense, moist)	
							SM	(FILL)	
2	46							Brown, very silty, fine to medium SAND with clay (loose, moist) (ALLUVIUM)	
		1-13:16	b2	6	GS AL W = 29				
4	44				13:17 - 13:18				
		2-13:20	b2	0				-grades to very loose, wet	6.2 ft @ 14:26
6	42				13:22 - 13:23				
							ML	Brown, very sandy SILT (very stiff, wet)	
8	40							-hit something hard in shelby sample, slough in sampler	
		3-13:28	c3		GT GS AL W = 41				
	38				13:45 - 13:46				
10		4A-13:47	b2	17	W = 35				
		4B-13:47			W = 11		SP-SM	Brown, gravelly, fine to coarse SAND with silt (medium dense, wet)	
12	36							-fractured rock in shoe	
	34				13:49 - 13:50				
14		5-13:52	b2	13	GS W = 14				
16	32								

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-08

Figure A-17 (1 of 3)

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

BH-08

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 47.7
Drilled By: Holocene Drilling Inc. (Jarrod/Raymond)
Logged By: Craig Jordan Date: 06/09/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
	30				13:54 - 13:55		SP-SM	Brown, gravelly, fine to coarse SAND with silt (medium dense, wet) -grades to gravel	
18									
	28								
20		6-14:00	b2	27	GS W = 20		SP	Brown, very gravelly, fine to coarse SAND with trace silt (medium dense, wet) -fractured rock in shoe	
		6CAL-14:02	h2						
	26								
22									
					14:08 - 14:10				
	24								
24								-segregation in sampler due to washing, no heave noted	
	22	7-14:11	b2	21					
26									
	20								
28					14:15 - 14:16				
	18								
30		8CAL-14:20	h2						
		8-14:17	b2	23				-rock in shoe, no recovery in Cal. sampler	
32									
34									

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80
× Fines Content (%) × 20 40 60 80

Boring Completed 06/09/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 13:12 to 14:26
-Drilled with Truck-mounted BK-81
-14:24 - 14:35 - Removed drill string
-14:37 - Backfilled with bentonite and concrete
-Combined sample 1 and 2 for AL and GS
-4-1/4" ID-9" OD
-Vertical elevation based on NAVD88

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\041T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-08

Figure A-17 (2 of 3)

BH-08

LAI Project No: 0621004.010

SAMPLE DATA								SOIL PROFILE		
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Drilling Method: Hollow-Stem Auger Ground Elevation (ft): 47.7 Drilled By: Holocene Drilling Inc. (Jarrod/Raymond) Logged By: Craig Jordan Date: 06/09/14 -Scale 1 inch = 2.5 feet -Reviewed by: Calvin McCaughan, P.E.	Groundwater	Moisture Content (%) Plastic Limit 20 40 60 80 Liquid Limit ▲ SPT N-Value ▲ △ Non-Standard N-Value △ 20 40 60 80 × Fines Content (%) × 20 40 60 80
	36									
	38									
	40									
	42									
	44									
	46									
	48									
	50									

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 9/20/14 Y:\0621004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-08

Figure A-17 (3 of 3)

BH-09R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 44.4
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Description
0	44				10:05 - 10:06	ML	Brown, sandy SILT with clay (soft, moist) **(ALLUVIUM)**
2	42	1-10:08	c3		GS W = 33 Al.		-rough bottom of sample, last 6 inches seemed to have gravel -sample rest 10:08 - 10:18
4	40	2-10:26	b2	14	10:20 - 10:21 W = 10	GP-GM	Brown, sandy, fine to coarse GRAVEL with silt (medium dense, wet)
6	38				10:27 - 10:28		
8	36					SP	Gray, very gravelly, fine to coarse SAND with trace silt and organics (woody debris) (medium dense, wet)
10	34	3-10:30 3CAL-10:32	b2 h2	16	Organic Content = 1.7% GS W = 18		-fractured rock in sampler
12	32				10:36 - 10:37		
14	30	4-10:40 4CAL-10:46	b2 h2	14	W = 8		-no sample recovery in SPT sampler
16	28						

Groundwater: 3.9 ft @ 11:20

Moisture Content (%) — Plastic Limit 20, 40, 60, 80, Liquid Limit
▲ SPT N-Value ▲ — △ Non Standard N-Value △ — 20, 40, 60, 80
× Fines Content (%) × — 20, 40, 60, 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-09R

Figure A-18 (1 of 2)

BH-09R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 44.4
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater	Moisture Content (%) (Plastic Limit – Liquid Limit) 20 40 60 80 / ▲ SPT N-Value ▲ (△ Non-Standard N-Value △) 20 40 60 80 / × Fines Content (%) × 20 40 60 80
18	26				10:48 - 10:49		SP	Gray, very gravelly, fine to coarse SAND with trace silt and organics (woody debris) (medium dense, wet)		
20	24	5-10:51	b2	19	GS W = 14		GW	Brown, very sandy, fine to coarse GRAVEL with trace silt (medium dense, wet)		
		5CAL-10:55	h2					-fractured rock in sampler		
22	22				10:58 - 10:59					
24	20							-dense		
		6-11:02	b2	38				-fractured rock in sample		
26	18									
28	16				11:05 - 11:06					
30	14	7-11:06	b2	49				-fractured rock in sampler		
		7CAL-11:14	h2							
32										
34										

Boring Completed 06/12/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 10:05 to 11:18
-Drilled with Track-mounted Diedrich D-50
-11:20 - 11:26 - Removed drill string
-11:27 - 11:30 - Backfilled with bentonite
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-09R

Figure A-18 (2 of 2)

BH-10

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 44.3
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
0	44						SM	Gray-brown, silty fine SAND (very loose, moist) **(ALLUVIUM)**	
					14:34 - 14:35				
2	42	1-14:36	b2	0	AL GS W = 41			-weight of hammer; non-plastic	4.0 ft @ 15:50
4	40				14:37 - 14:38			-wet -grades to very silty, fine to medium sand with clay	
6	38	2-14:39	b2	0	AL GS W = 31			-trace organics (old root) -weight of hammer; some plasticity	
8	36	3-14:43	c3		GT Organic Content = 4.5% AL W = 36			-sample rest 14:43 - 14:54	
					14:46 - 14:47				
10	34	4-14:58	b2	6	W = 25		SP-SM	Gray, fine to medium SAND with silt and trace organics (woody debris) (loose, wet)	
12	32				15:01 - 15:02				
14	30							-medium dense	
16	28	5-15:03	b2	20	GS W = 22				

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80
× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

6210004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-10

Figure A-19 (1 of 2)

BH-10

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 44.3
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/12/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Description
					15:04 - 15:05	SP-SM	Gray, fine to medium SAND with silt and trace organics (woody debris) (loose, wet)
18	26						
20	24	6A-15:16 6B-15:16	b2	29			-fractured rock in sampler
22	22				15:16 - 15:17	GP-GM	Brown, very sandy GRAVEL with silt (medium dense, wet)
24	20	7-15:22	b2	31	W = 9		-dense -fractured rock in sampler
26	18						
					15:28 - 15:29		
28	16					SP	Gray, fine to medium SAND with trace silt (dense, wet)
30	14	8-15:33	b2	34			-low recovery in SPT sample
32							
34							

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80
× Fines Content (%) × — 20 40 60 80

Boring Completed 06/12/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 14:37 to 15:40
-Drilled with Track-mounted Diedrich D-50
-15:45 - 15:53 - Removed drill string
-15:56 - 15:59 - Backfilled with bentonite
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-10

Figure A-19 (2 of 2)

BH-14R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 32.0
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/13/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Profile	Groundwater
0	32					SM	Gray-brown, very silty, fine to medium SAND with clay and trace organics (roots) (very loose, wet) **(ALLUVIUM)**	
2	30	1-7:48 1CAL-7:50 2-7:53	b2 h3 d	1	W = 49 AL W = 50		-no recovery in SPT sampler -grab sample from 2 to 3'	3.5 ft @ 9:57
4	28							
		3-7:54 3CAL-8:08	b2 h2	0	GS W = 55 7:55 - 8:08		-weight of hammer, low recovery -no organics	
6	26							
8	24							
10	22	4-8:13	b2	0	GS W = 47		-gray	
12	20				8:14 - 8:24			
14	18							
16	16	5A-8:26 5B-8:26	b2	2	W = 43 W = 31	SP-SM	Gray, fine SAND with silt (very loose, wet)	

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit
▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80
× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-14R

Figure A-20 (1 of 2)

BH-14R

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 32.0
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/13/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Description
					8:31 - 8:36	OL	Wood -driller noted dense material
18	14						
20	12	6-8:39	b2	69			-solid wood in sampler
22	10						
					8:50 - 8:56	GP	Brown, sandy, fine to coarse GRAVEL with trace silt (dense, wet) -driller noted easier drilling
24	8						
		7-8:57	b2	40			
26	6						
					9:34 - 9:35		-flushed auger to clear heave
28	4	8-9:38	b2	31			-rock in sample
					9:39 - 9:41		
30	2	9-9:46	b2	25	W = 10		-low recovery in SPT sampler, no recovery in Cal. sampler
		9CAL-9:50	h2				-medium dense
32							
34							

Groundwater

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non-Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Boring Completed 06/13/14
Total Depth of Boring = 31.5 ft.

-Boring Drilled from 7:46 to 9:54
-Drilled with Track-mounted Diedrich D-50
-10:11 - 10:20 - Removed drill string
-10:20 - 10:22 - Backfilled with bentonite
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-14R

Figure A-20 (2 of 2)

BH-15

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 62.9
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	USCS Symbol	Soil Profile	Groundwater	Moisture Content (%) / SPT N-Value / Fines Content (%)
0	62				9:38 - 9:42	SM	Brown, fine to coarse SAND with silt and gravel (dense, moist) **(ALLUVIUM)**		
2	60	1A-9:43 / 1B-9:43	b2	49	GS W = 5		-rough drilling		
						GW	Gray, very sandy, fine to coarse GRAVEL with trace silt (dense, moist)		
4	58				9:45 - 9:46				
		2-9:48	b2	31	W = 8		-fractured rock in sampler	6.2 ft @ 11:31	
6	56						-wet		
8	54				9:52 - 10:12				
10	52	3-10:12 / 3CAL-10:13	b2 / h2	11	GS W = 10		-medium dense -fractured rock in sampler		
12	50				10:18 - 10:19				
14	48	4-10:20 / 4CAL-10:22	b2 / h2	8	W = 14		-loose -small recovery, no sample taken in SPT sampler		
16	46								

Moisture Content (%): Plastic Limit 20 — 40 — 60 — 80 Liquid Limit
▲ SPT N-Value ▲ △ Non Standard N-Value △: 20 40 60 80
× Fines Content (%) ×: 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

6210004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-15

Figure A-21 (1 of 3)

BH-15

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 62.9
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
18	44				10:24 - 10:26		GW	Gray, very sandy, fine to coarse GRAVEL with trace silt (dense, moist)	
20	42	5-10:30	b2	24	GS W = 13		SP	Brown, gravelly, fine to coarse SAND with trace silt (medium dense, wet)	
22	40				10:33 - 10:34				
24	38	6-10:35	b2	50	W = 12		SP-SM	Brown, fine to coarse SAND with silt (medium dense, wet) -grades to very dense	
26	36				10:39 - 10:41				
28	34	7-10:46	b2	59					
30	32				10:48 - 10:50				
32	30								
34									

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Boring BH-15

Figure A-21 (2 of 3)

BH-15

LAI Project No: 0621004.010

Drilling Method: Hollow-Stem Auger
Ground Elevation (ft): 62.9
Drilled By: Holocene Drilling Inc. (Dave/Nunsie)
Logged By: Craig Jordan Date: 06/11/14

Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Blows/Foot	Test Data	Graphic Symbol	USCS Symbol	Soil Profile	Groundwater
	28						SP-SM	Brown, fine to coarse SAND with silt (medium dense, wet)	
36		8-10:54	b2	58	GS W = 17				
	26								
38					11:00 - 11:01				
	24								
40		9-11:03	b2	67				-likely pushing a cobble (overstate N-Value)	
	22	9CAL-11:13	h2					-no sample recovery in SPT sampler	
42									
44									
46									
48									
50									

Moisture Content (%) — Plastic Limit 20 40 60 80 Liquid Limit

▲ SPT N-Value ▲ — △ Non Standard N-Value △ — 20 40 60 80

× Fines Content (%) × — 20 40 60 80

Boring Completed 06/11/14
Total Depth of Boring = 41.5 ft.

-Boring Drilled from 9:38 to 11:21
-Drilled with Track-mounted Diedrich D-50
-11:30 - 11:37 - Removed drill string
-11:45 - 11:48 - Backfilled with bentonite and concrete
-3-1/4" ID-7" OD
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.
4. # Cal indicates location of California sampler driven over SPT sampler.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ SOIL BORING LOG WITH GRAPH

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Boring BH-15	Figure A-21 (3 of 3)

HA-01

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan	
0						SP-SM	Dark brown, fine SAND with silt and trace organics (roots and fine) (loose, moist) **(FILL)**	Groundwater not encountered.
		1-14:15	d/i	PID = 0.0 No Staining CA		SM	Brown, silty, fine to coarse SAND with trace gravel and organics -with gravel 2" lense of organics at 3' (roots, woody debris)	
2								
4								
6								

Hand Auger Boring Completed 06/02/14
Total Depth of Hand Auger Boring = 3.5 ft.

-Hand Auger Boring Completed from 14:05 to 14:20
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-02

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SM	Dark brown, fine to medium SAND with silt, trace organics (roots) (loose, damp) **(FILL)**	Groundwater not encountered.
2		2-15:20	d/i	PID = 0.0 No Staining CA		SM	Brown, silty, fine to medium SAND with trace gravel and organics (roots)	
4								
6								

Hand Auger Boring Completed 06/02/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 15:15 to 15:30
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-22

HA-02B

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						SM	Dark brown, fine SAND with silt, trace organics (roots) (loose, damp) **(FILL)**	Groundwater not encountered.
		1-15:30	d	GS W = 13				
2								
4								
6								

Hand Auger Boring Completed 06/17/14
Total Depth of Hand Auger Boring = 1.8 ft.

-Hand Auger Boring Completed from 15:24 to 15:33
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-03

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP-SM	Brown, gravelly, fine to coarse SAND with silt and organics (roots and fine) (loose, moist) **(FILL)**	Groundwater not encountered.
2		3-10:20	d/i	PID = 0.0 No Staining CA			-medium dense	
4								
6								

Hand Auger Boring Completed 06/03/14
Total Depth of Hand Auger Boring = 3.3 ft.

-Hand Auger Boring Completed from 10:07 to 10:20
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-23

HA-04

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SM	Brown, silty, gravelly, fine to coarse SAND with trace organics (roots and fine) (loose, damp) **(FILL)**	Groundwater not encountered.
		1-10:55	d/i	PID = 0.0 No Staining CA			-with gravel	
2							-moist	

Hand Auger Boring Completed 06/03/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 10:49 to 11:00
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

4

6

HA-05

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP-SM	Brown, gravelly, fine to coarse SAND with silt and trace organics (roots and fine) (loose, damp) **(FILL)**	Groundwater not encountered.
							-with gravel	
2		2-11:30	d/i	PID = 0.0 No Staining CA			-moist	

Hand Auger Boring Completed 06/03/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 11:20 to 11:35
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

4

6

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-24

HA-06

SAMPLE DATA				SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP-SM	Brown, gravelly, fine to coarse SAND with silt and trace organics (roots and fine) (loose, moist) **(FILL)** -with gravel	Groundwater not encountered.
2		3-12:00	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/03/14
Total Depth of Hand Auger Boring = 3.3 ft.

-Hand Auger Boring Completed from 11:55 to 12:05
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-07

SAMPLE DATA				SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP	Brown, very gravelly, fine to coarse SAND with trace silt and organics (roots and fine) (loose, moist) **(FILL)**	Groundwater not encountered.
2		1-14:15	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/03/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 14:10 to 14:23
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-25

HA-07B

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						SP	Brown, very gravelly, fine to coarse SAND with trace silt and organics (roots and fine) (loose, moist) (FILL)	Groundwater not encountered.
		1-15:00	d	GS W = 5				
2								
4								
6								

Hand Auger Boring Completed 06/17/14
Total Depth of Hand Auger Boring = 1.3 ft.

-Hand Auger Boring Completed from 14:55 to 15:02
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-08

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP	Brown, gravelly, fine to coarse SAND with trace silt and organics (roots and fine) (loose, damp) (FILL)	Groundwater not encountered.
2		2-15:05	d/i	PID = 0.0 No Staining CA			-very gravelly	
4								
6								

Hand Auger Boring Completed 06/03/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 14:08 to 15:13
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

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Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-26

HA-09

SAMPLE DATA				SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP-SM	Brown, fine to coarse SAND with silt and gravel, trace organics (roots) (loose, damp) **(FILL)**	Groundwater not encountered.
						SP	Brown, gravelly, fine to coarse SAND with trace silt and organics (roots) (loose, moist)	
2				PID = 0.0 No Staining				
		3-10:00	d/i	CA		SP-SM	Brown, gravelly, fine to coarse SAND with silt and trace organics (roots) (medium dense, moist)	
4								
6								

Hand Auger Boring Completed 06/04/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 9:30 to 10:00
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-10

SAMPLE DATA				SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						SP-SM	Brown, gravelly, fine to coarse SAND with silt and trace organics (roots) (loose, damp) **(FILL)**	Groundwater not encountered.
		1-10:40	d/i	PID = 0.0 No Staining CA				
2						GP-GM	Brown, sandy GRAVEL with silt (loose, moist) **(ALLUVIUM)**	
4								
6								

Hand Auger Boring Completed 06/04/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 10:35 to 11:17
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-27

HA-11

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan	
0						SP-SM	Brown, gravelly, fine to coarse SAND with silt (loose, moist) (FILL)	Groundwater not encountered.
2		2-12:05	d/i	PID = 0.0 No Staining CA		GP-GM	Brown, very sandy GRAVEL with silt (loose, moist)	
4								
6								

Hand Auger Boring Completed 06/04/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 11:45 to 12:40
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-12

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0						SP-SM	Brown, fine SAND with silt and trace organics (roots) (loose, damp) (FILL)	Groundwater not encountered.
2		3-14:00	d/i	PID = 0.0 No Staining CA		SM	Brown, silty, fine SAND with gravel (loose, moist)	
4								
6								

Hand Auger Boring Completed 06/04/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 13:50 to 14:10
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-28

HA-13

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0		1-15:15	d/i	PID = 0.0 No Staining CA		SM	Brown, silty, fine SAND (loose, moist) **(FILL)** -organics (roots and woody debris)	Groundwater not encountered.
2						SP-SM	Brown, fine to coarse sand with silt (medium dense, moist)	
4								
6								

Hand Auger Boring Completed 06/04/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 15:10 to 15:30
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-14

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0						SP	Brown, very gravelly, fine to coarse SAND with trace silt and organics (roots) (loose, damp) **(FILL)**	Groundwater not encountered.
2		2-16:30	d/i	PID = 0.0 No Staining CA		GP	Brown GRAVEL with trace sand (medium dense, moist)	
4								
6								

Hand Auger Boring Completed 06/04/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 16:00 to 17:10
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-29

HA-14B

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0		1-14:20	d	GS W = 4		SP	Brown, very gravelly, fine to coarse SAND with trace silt and organics (roots) (loose, damp) (FILL)	Groundwater not encountered.

Hand Auger Boring Completed 06/17/14
Total Depth of Hand Auger Boring = 1.0 ft.

-Hand Auger Boring Completed from 14:15 to 14:25
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

2
4
6

HA-15

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0						GP-GM	Brown, sandy, fine to coarse GRAVEL with silt and trace organics (roots) (medium dense, moist) (FILL)	Groundwater not encountered.
2		3-10:00	d/i	PID = 0.0 No Staining CA		SM	Brown, silty, fine to coarse SAND with gravel (medium dense, moist)	

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 9:45 to 10:00
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

4
6

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 9/20/14 Y:\0621\004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-30

HA-16

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0		1-10:40	d/i	PID = 0.0 No Staining CA		SP-SM	Brown, gravelly SAND with silt with trace cobble and organics (roots) (medium dense, moist) **(FILL)**	Groundwater not encountered.
2								
4								
6								

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 10:30 to 11:00
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-17

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0		2-11:35	d/i	PID = 0.0 No Staining CA		GP-GM	Brown, sandy, fine to coarse GRAVEL with silt, trace cobble and organics (roots) (loose, damp) **(FILL)**	Groundwater not encountered.
2								
4								
6								

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 11:15 to 11:45
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-31

HA-18

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0						SP-SM	Brown, gravelly, fine to coarse SAND with silt (medium dense, moist) **(FILL)**	Groundwater not encountered.
2		3-12:50	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 12:20 to 13:15
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-19

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0						GP	Brown, sandy, fine to coarse GRAVEL with trace silt (medium dense, moist) **(FILL)**	Groundwater not encountered.
2		1-13:30	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 13:20 to 13:55
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-32

HA-20

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0						GP	Brown, very sandy, fine to coarse GRAVEL with trace silt (loose, moist) **(FILL)** -medium dense	Groundwater not encountered.
2		2-14:20	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 14:05 to 15:00
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-20B

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						GP	Brown, very sandy, fine to coarse GRAVEL with trace silt (loose, moist) **(FILL)** -medium dense	Groundwater not encountered.
		1-13:50	d	GS W = 5				
2								
4								
6								

Hand Auger Boring Completed 06/17/14
Total Depth of Hand Auger Boring = 1.0 ft.

-Hand Auger Boring Completed from 13:45 to 13:52
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-33

HA-21

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						GM	Brown, silty, sandy GRAVEL with trace cobble (medium dense, moist)	Groundwater not encountered.
						SP-SM	(FILL) Light brown, very gravelly, fine to coarse SAND with silt and trace cobble (medium dense, moist)	
2		3-10:50	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 3.3 ft.

-Hand Auger Boring Completed from 10:03 to 10:50
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-22

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						GP	Brownish-gray, very sandy GRAVEL with cobble and trace silt (loose, moist) (FILL)	Groundwater not encountered.
		1-11:35	d/i	PID = 0.0 No Staining CA				
2		2-11:40	d	PID = 0.0 No Staining GS W = 3				
4								
6								

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 11:20 to 11:50
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-34

HA-23

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						GP	Brownish-gray, very sandy GRAVEL with trace silt (loose, moist) **(FILL)**	Groundwater not encountered.
2		2-12:15	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 3.0 ft.

-Hand Auger Boring Completed from 12:07 to 12:20
-Backfilled with cuttings upon completion
-Equipment wash sample was collected after soil sampling and equipment wash
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

HA-24

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0		1-15:55	d/i	PID = 0.0 No Staining CA		SM	Dark brown, silty, fine to medium SAND with organics (loose, moist) **(ALLUVIUM)**	Groundwater not encountered.
2								
4								
6								

Hand Auger Boring Completed 06/05/14
Total Depth of Hand Auger Boring = 1.0 ft.

-Hand Auger Boring Completed from 15:40 to 16:00
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Sample collected below NE corner of Car Body #2
-Engine removed, Battery removed
-Fuel tank remains
-No visible signs/indicators of contamination
-Exterior paint is chipping
-Vehicle is overgrown with vegetation
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-35

HA-25

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Dave Rupert	
0		1-16:05	d/i	PID = 0.0 No Staining CA		SM	Dark brown, silty, fine to medium SAND with organics (loose, moist) **(ALLUVIUM)**	Groundwater not encountered.
		Hand Auger Boring Completed 06/05/14 Total Depth of Hand Auger Boring = 1.0 ft.					-Hand Auger Boring Completed from 16:00 to 16:15 -Backfilled with cuttings upon completion -Vertical elevation based on NAVD88 -Scale 1 inch = 2.5 feet -Sample collected below NW corner of Car Body #1 -Engine removed, Battery removed -Fuel tank not visible -No visible signs/indicators of contamination -Vehicle is rusting, paint is worn -Interior has been removed -Reviewed by: Calvin McCaughan, P.E.	
2								
4								
6								

HA-26

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Craig Jordan	
0		1-12:15	d/i	PID = 0.0 No Staining CA		SP-SM	Brown, fine to medium SAND with silt and trace organics (roots and fine) (loose, moist) **(ALLUVIUM)**	Groundwater not encountered.
		Hand Auger Boring Completed 06/06/14 Total Depth of Hand Auger Boring = 1.0 ft.					-Hand Auger Boring Completed from 12:05 to 12:20 -Backfilled with cuttings upon completion -Vertical elevation based on NAVD88 -Scale 1 inch = 2.5 feet -Sample collected below NW corner of Car Body #3 (rear) -Car body is 80 percent buried -No battery visible -No fuel tank visible -No tire visible -No visible signs/indicators of contamination -Reviewed by: Calvin McCaughan, P.E.	
2								
4								
6								

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-36

HA-27

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: James Raspen/Craig Jordan	
0	.5-12:35		d/i	PID = 0.0 No Staining CA		SP-SM	Brown, fine to medium SAND with silt and trace organics (roots and fine) (loose, moist) **(ALLUVIUM)**	Groundwater not encountered.
	Hand Auger Boring Completed 06/06/14 Total Depth of Hand Auger Boring = 0.5 ft.						-Hand Auger Boring Completed from 12:30 to 12:45 -Backfilled with cuttings upon completion -Vertical elevation based on NAVD88 -Scale 1 inch = 1 foot -Sample collect near corner of fuel tank of Car Body #4 -Car body is ~50 percent buried -No engine visible, No battery visible, No tires visible -No visible signs/indicators of contamination -Fuel tank visible (hole in center) -Reviewed by: Calvin McCaughan, P.E.	
1								
2								

HA-28

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0	.5-13:55		d/i	PID = 0.0 No Staining CA		SP-SM	Dark brown, fine to medium SAND with silt and trace organics (roots and fine) (loose, wet) **(ALLUVIUM)**	Surface water at location.
	Hand Auger Boring Completed 06/06/14 Total Depth of Hand Auger Boring = 0.5 ft.						-Hand Auger Boring Completed from 13:50 to 14:05 -Backfilled with cuttings upon completion -Vertical elevation based on NAVD88 -Scale 1 inch = 1 foot -Sample collected below downed telephone pole where transformer would have landed -No transformer visible -Non-treated telephone pole -No visible signs/indicators of contamination -Reviewed by: Calvin McCaughan, P.E.	
1								
2								

Notes:
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2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-37

HA-29

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0	.25-10:55		d/i	PID = 0.0 No Staining CA		SM	Brown, medium to coarse SAND with occasional gravel, trace silt (loose, wet) **(ALLUVIUM)**	Surface water at location.

Hand Auger Boring Completed 06/06/14
Total Depth of Hand Auger Boring = 0.5 ft.

1

2

-Located within stream channel
-Hand Auger Boring Completed from 10:50 to 11:20
-Backfilled with cuttings upon completion
-Sample collected at most fine grained location within river channel. Majority of channel is medium to coarse with cobble and sand
-Sediment sample adjacent to soil sample HA-30
-Vertical elevation based on NAVD88
-Scale 1 inch = 1 foot
-Reviewed by: Calvin McCaughan, P.E.

HA-30

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Scoop Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/James Raspen	
0	.50-11:35		d/i	PID = 0.0 No Staining CA		SP-SM	Brown, fine to medium SAND with silt and trace organics (roots) (loose, damp) **(ALLUVIUM)**	Groundwater not encountered.

Hand Auger Boring Completed 06/06/14
Total Depth of Hand Auger Boring = 0.5 ft.

1

2

-Hand Auger Boring Completed from 11:30 to 11:35
-Backfilled with cuttings upon completion
-Vertical data based on NAVD88
-Scale 1 inch = 1 foot
-Reviewed by: Calvin McCaughan, P.E.

Notes:
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2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-38

HA-31

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Hand Auger/Sediment Sampler Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0	00-15:25		d/i	PID = 0.0 No Staining CA		SP	Gray, medium to coarse SAND with gravel and trace silt (loose, wet) **(ALLUVIUM)**	Surface water at location.

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 0.3 ft.

-Hand Auger Boring Completed from 15:15 to 15:30
-Backfilled with cuttings upon completion
-Sample collected at most fine grained location within river channel. Majority of channel is medium to coarse with cobble and sand
-Sediment sample adjacent to soil sample HA-32
-NAVD88
-Scale 1 inch = 1 foot
-Reviewed by: Calvin McCaughan, P.E.

1

2

HA-32

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0	1-16:00		d/i	PID = 0.0 No Staining CA		SP	Brown, fine to coarse SAND with gravel and trace silt (loose, moist) **(ALLUVIUM)**	Groundwater not encountered.

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 0.5 ft.

-Hand Auger Boring Completed from 15:55 to 16:00
-Backfilled with cuttings upon completion
-NAVD88
-Scale 1 inch = 1 foot
-Reviewed by: Calvin McCaughan, P.E.

1

2

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621\004\T\0621004.010.GPJ TEST PIT LOG W/ ELEVATION

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Log of Hand Auger Borings	Figure A-39

HA-33

SAMPLE DATA					SOIL PROFILE			GROUNDWATER
Depth (ft)	Elevation (ft)	Sample Number & Interval	Sampler Type	Test Data	Graphic Symbol	USCS Symbol	Excavation Method: Shovel Ground Elevation (ft): TBD Excavated By: Landau Associates Logged By: Craig Jordan/Josh Elliott	
0						GP-GM	Brown, sandy, cobbly GRAVEL with silt (medium dense, moist) (FILL)	Groundwater not encountered.
2		3-13:35	d/i	PID = 0.0 No Staining CA				
4								
6								

Hand Auger Boring Completed 06/18/14
Total Depth of Hand Auger Boring = 3.3 ft.

-Hand Auger Boring Completed from 13:10 to 13:35
-Backfilled with cuttings upon completion
-Vertical elevation based on NAVD88
-Scale 1 inch = 2.5 feet
-Reviewed by: Calvin McCaughan, P.E.

Notes:
1. Stratigraphic contacts are based on field interpretations and are approximate.
2. Reference to the text of this report is necessary for a proper understanding of subsurface conditions.
3. Refer to "Soil Classification System and Key" figure for explanation of graphics and symbols.

621004.01 8/20/14 Y:\0621004\T0621004.010.GPJ TEST PIT LOG W/ ELEVATION

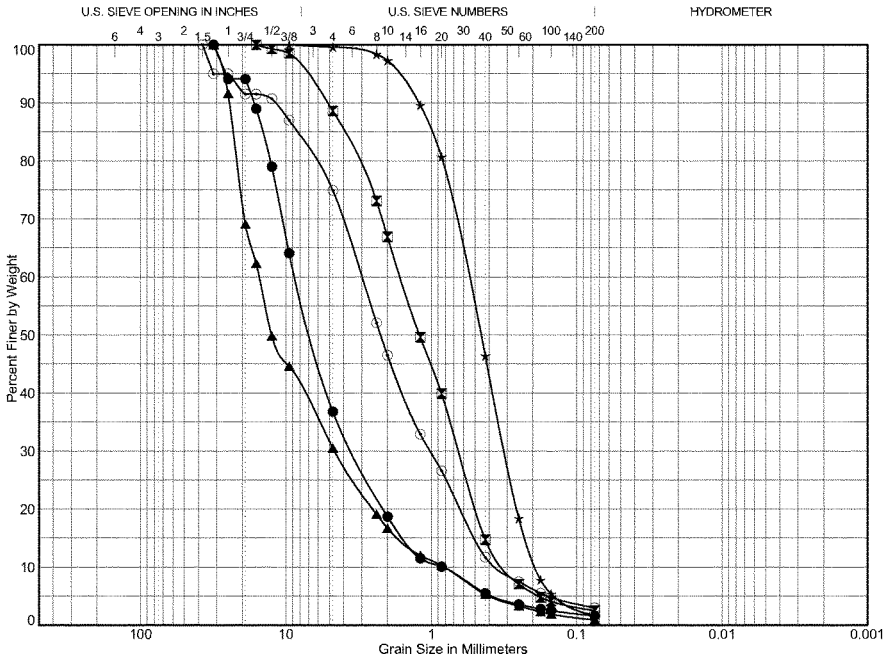
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Log of Hand Auger Borings

Figure A-40

Geotechnical Laboratory Summary



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	BH-01	2.5	S-1 CAL Well graded GRAVEL with sand (GW)				1.64	10.22
⧗	BH-01	15.0	S-5 Poorly graded SAND (SP)				0.84	5.31
▲	BH-01	30.0	S-8 Well graded GRAVEL with sand (GW)				1.70	18.75
★	BH-02	15.0	S-4/S-4 CAL Poorly graded SAND (SP)				0.91	2.94
⊙	BH-02	25.0	S-6CAL/S-7 Poorly graded SAND with gravel (SP)				1.00	8.82

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	BH-01	2.5	31.5	8.561	6.641	3.432	0.837	5.9	57.3	18.1	13.2	3.9	1.6
⧗	BH-01	15.0	16	1.626	1.204	0.647	0.306	0.0	11.4	21.7	52.2	12.2	2.5
▲	BH-01	30.0	31.5	15.29	12.549	4.608	0.815	30.9	38.6	13.8	11.4	4.4	0.9
★	BH-02	15.0	9.5	0.559	0.457	0.311	0.19	0.0	0.4	2.3	50.9	44.7	1.7
⊙	BH-02	25.0	37.5	3.024	2.23	1.019	0.343	8.5	16.6	28.4	34.8	8.7	3.0

$C_c = D_{30}^2/(D_{60} * D_{10})$ To be well graded: $1 < C_c < 3$ and

$C_u = D_{60}/D_{10}$ $C_u > 4$ for GW or $C_u > 6$ for SW

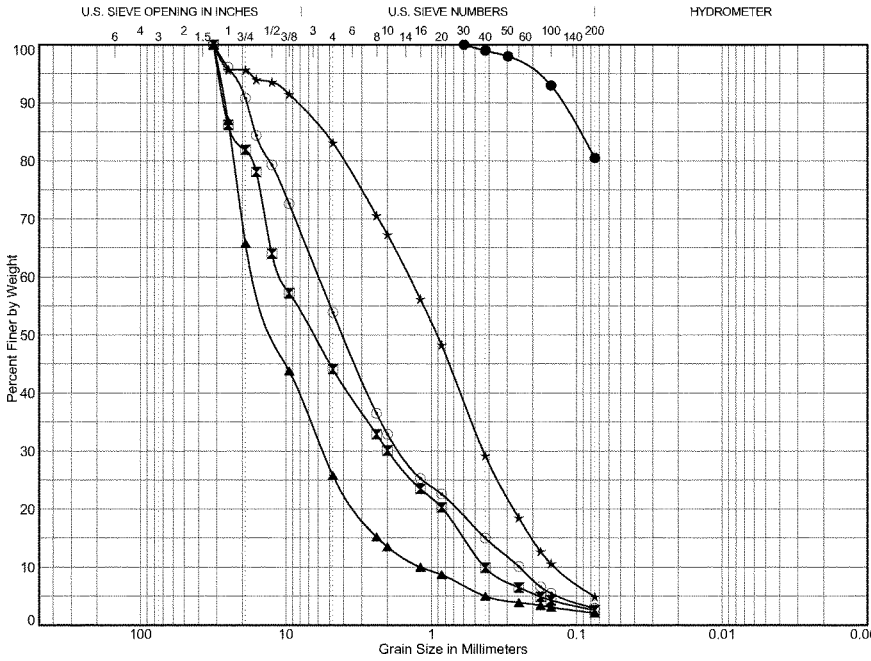
621004.01 8/14/14 Y:\06210041T06210041.010.GPJ GRAIN SIZE W/STATS

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-1



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	BH-02C	2.5	S-1 SILT with sand (ML)	31	27	4		
⧗	BH-03R	3.0	S-1B Poorly graded GRAVEL with sand (GP)				0.87	24.86
▲	BH-03R	5.0	S-2/S-2 CAL Well graded GRAVEL with sand (GW)				1.66	13.30
★	BH-03R	15.0	S-4/S-4 CAL Poorly graded SAND with gravel (SP)				0.97	10.19
⊙	BH-03R	30.0	S-7/S-7 CAL Well graded SAND with gravel (SW)				1.83	24.06

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	BH-02C	2.5	0.595					0.0	0.0	0.0	1.0	18.5	80.5
⧗	BH-03R	3.0	31.5	10.637	6.49	1.984	0.428	18.1	37.8	14.0	20.2	7.3	2.6
▲	BH-03R	5.0	31.5	15.827	11.549	5.584	1.19	34.2	40.0	12.3	8.5	2.9	2.1
★	BH-03R	15.0	31.5	1.421	0.914	0.438	0.139	4.3	12.6	15.8	38.1	24.3	4.9
⊙	BH-03R	30.0	31.5	5.955	4.068	1.641	0.248	9.2	36.9	21.0	17.9	12.1	2.9

$C_c = D_{30}^2/(D_{60} * D_{10})$
$C_u = D_{60}/D_{10}$

To be well graded: $1 < C_c < 3$ and $C_u > 4$ for GW or $C_u > 6$ for SW

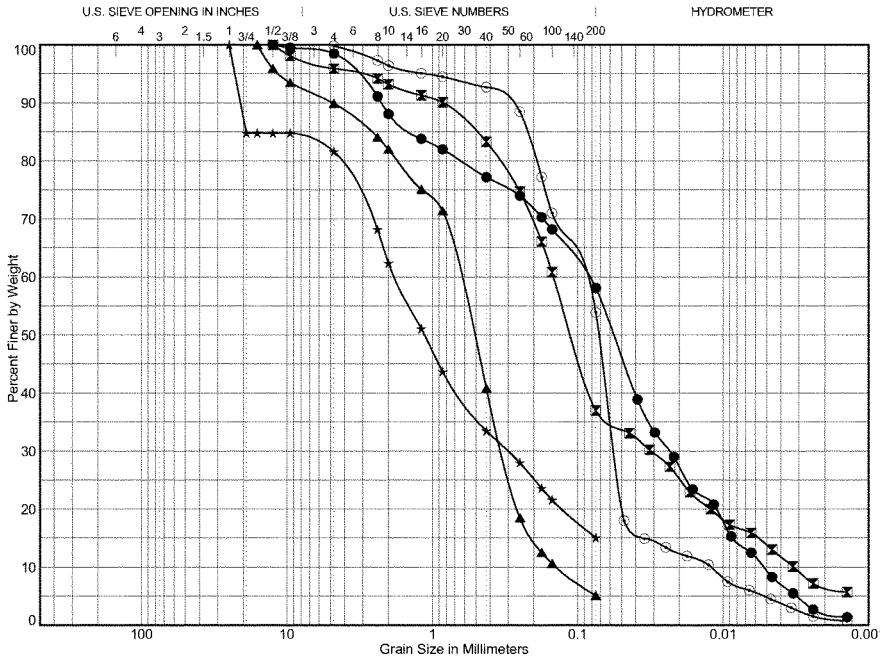
621004.01 8/14/14 Y:\0621\004\T\0621004.010.GPJ GRAIN SIZE W/STATS

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-2



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	BH-04	3.8	S-1 Sandy SILT (ML)	NP	NP	NP	1.22	16.25
⧗	BH-04	20.0	S-5A Silty SAND (SM)				2.05	44.90
▲	BH-04	25.0	S-6 Poorly graded SAND with silt (SP-SM)				1.18	4.72
★	BH-05R	2.5	S-1A Silty SAND with gravel (SM)					
⊙	BH-05R	5.0	S-2 Sandy SILT (ML)				2.68	7.95

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	BH-04	3.8	12.5	0.085	0.057	0.023	0.005	0.0	1.5	10.4	10.9	19.1	58.1
⧗	BH-04	20.0	12.5	0.147	0.11	0.031	0.003	0.0	4.1	2.7	9.9	46.3	37.0
▲	BH-04	25.0	16	0.657	0.523	0.329	0.139	0.0	10.1	7.9	41.2	35.7	5.1
★	BH-05R	2.5	25	1.791	1.132	0.303		15.2	3.2	19.2	28.9	18.4	15.1
⊙	BH-05R	5.0	4.75	0.096	0.071	0.056	0.012	0.0	0.0	3.4	3.7	38.8	53.9

$C_c = D_{30}^2/(D_{60} * D_{10})$ To be well graded: $1 < C_c < 3$ and

$C_u = D_{60}/D_{10}$ $C_u > 4$ for GW or $C_u > 6$ for SW

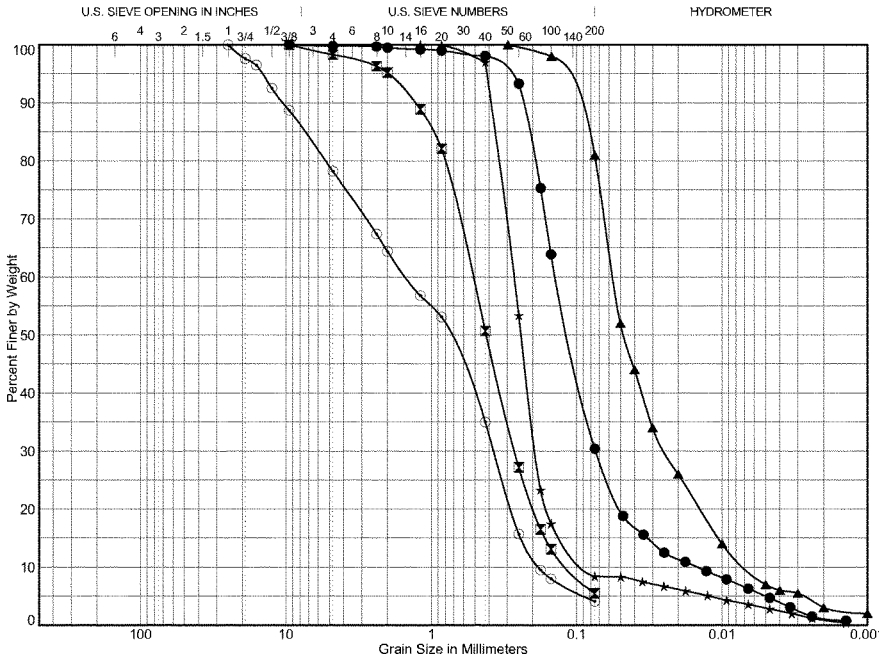
621004.01 8/14/14 Y:\0621\004\T0621004.010.GPJ GRAIN SIZE W/STATS

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-3



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	BH-05R	10.0	S-3 Silty SAND (SM)				2.66	9.34
⧗	BH-05R	20.0	S-6A Poorly graded SAND with silt (SP-SM)				1.20	4.62
▲	BH-07R	2.5	S-1 SILT with sand (ML)	31	27	4	1.59	8.31
★	BH-07R	6.0	S-2B Poorly graded SAND with silt (SP-SM)				1.59	3.20
⊙	BH-07R	10.0	S-3 CAL Poorly graded SAND with gravel (SP)				0.51	8.14

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	BH-05R	10.0	9.5	0.138	0.113	0.074	0.015	0.0	0.2	0.3	1.4	67.7	30.4
⧗	BH-05R	20.0	9.5	0.522	0.418	0.266	0.113	0.0	1.7	3.1	44.5	45.2	5.5
▲	BH-07R	2.5	0.297	0.056	0.047	0.024	0.007	0.0	0.0	0.0	0.0	19.0	81.0
★	BH-07R	6.0	1.19	0.271	0.24	0.191	0.085	0.0	0.0	0.0	3.0	88.6	8.4
⊙	BH-07R	10.0	25	1.481	0.755	0.37	0.182	2.4	19.4	13.8	29.4	30.9	4.1

$C_c = D_{30}^2/(D_{60} * D_{10})$

$C_u = D_{60}/D_{10}$

To be well graded: $1 < C_c < 3$ and $C_u > 4$ for GW or $C_u > 6$ for SW

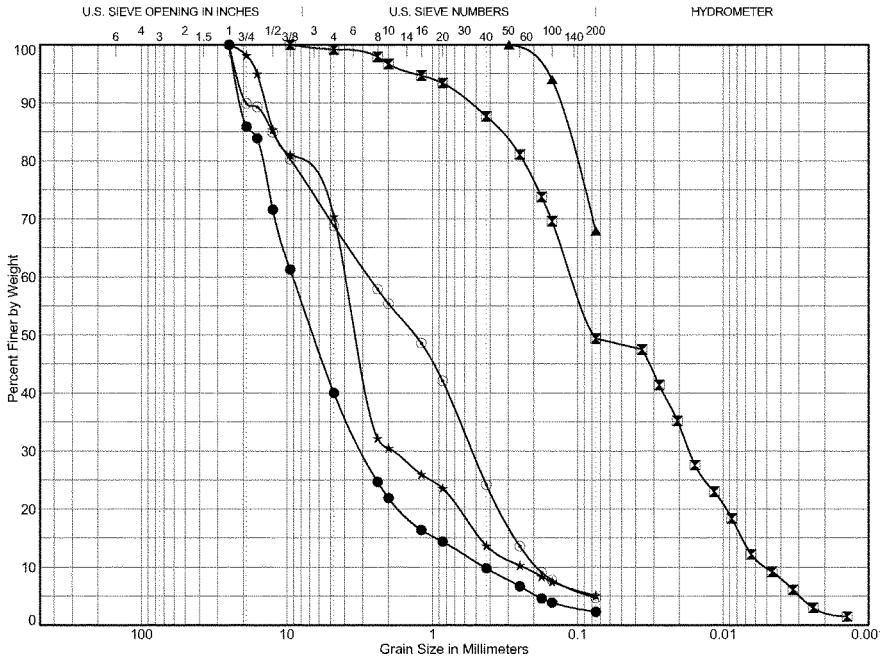
621004.01 8/14/14 Y:\0621\004\T\0621004.010.GPJ GRAIN SIZE W/STATS

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-4



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	BH-07R	20.0	S-5/S-5 CAL Well graded GRAVEL with sand (GW)				2.29	20.79
⧗	BH-08	3.0	S-1 Silty SAND (SM)	NP	NP	NP	0.54	21.48
▲	BH-08	7.5	S-3 Sandy SILT (ML)	NP	NP	NP		
★	BH-08	15.0	S-5 Poorly graded SAND with silt and gravel (SP-SM)				3.83	16.62
⊙	BH-08	20.0	S-6/S-6 CAL Poorly graded SAND with gravel (SP)				0.55	14.34

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	BH-07R	20.0	25	9.106	6.577	3.024	0.438	14.1	45.9	18.1	12.1	7.5	2.3
⧗	BH-08	3.0	9.5	0.108	0.077	0.017	0.005	0.0	0.8	2.5	9.0	38.3	49.4
▲	BH-08	7.5	0.297					0.0	0.0	0.0	0.0	32.1	67.9
★	BH-08	15.0	25	3.935	3.284	1.888	0.237	1.8	27.8	39.9	16.8	8.6	5.1
⊙	BH-08	20.0	25	2.719	1.324	0.532	0.19	10.1	21.1	13.4	31.2	19.5	4.7

$C_c = D_{30}^2/(D_{60} * D_{10})$

$C_u = D_{60}/D_{10}$

To be well graded: $1 < C_c < 3$ and $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\06210041T\06210041.010.GPJ GRAIN SIZE W/STATS

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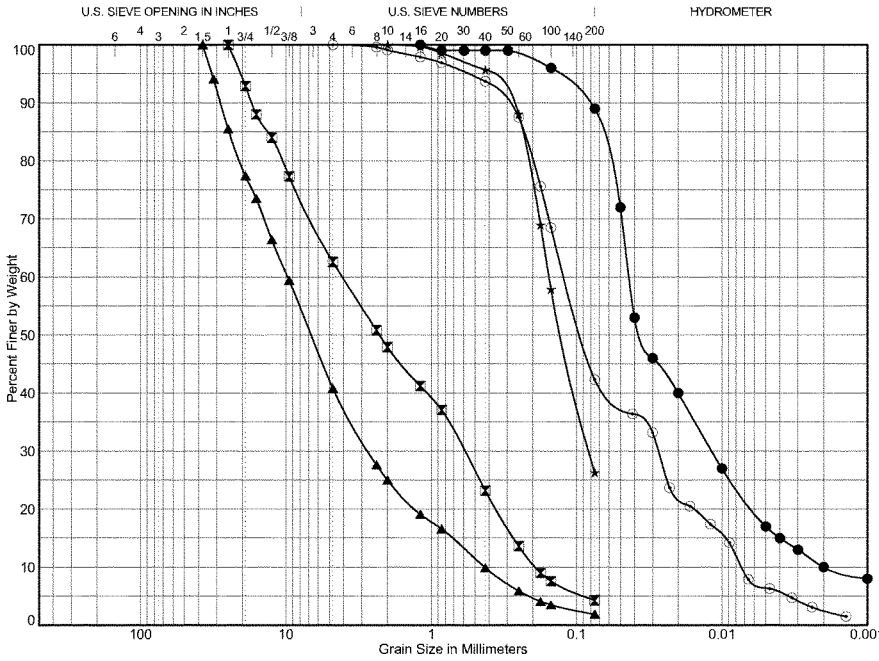
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-5



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Point	Depth	Classification	LL	PL	PI	C_c	C_u
● BH-09R	2.5	S-1 Sandy SILT (ML)	43	32	11	1.59	21.71
⧗ BH-09R	10.0	S-3/S-3 CAL Poorly graded SAND with gravel (SP)				0.46	21.38
▲ BH-09R	20.0	S-5/S-5 CAL Well graded GRAVEL with sand (GW)				1.74	22.65
★ BH-10	2.5	S-1 Silty SAND (SM)	NP	NP	NP		
⊙ BH-10	5.0	S-2 Silty SAND (SM)	NP	NP	NP	0.86	16.43

Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
● BH-09R	2.5	1.19	0.043	0.035	0.012	0.002	0.0	0.0	0.0	1.0	10.0	89.0
⧗ BH-09R	10.0	25	4.079	2.268	0.597	0.191	7.1	30.3	14.7	24.7	18.9	4.3
▲ BH-09R	20.0	37.5	9.726	6.693	2.699	0.429	22.6	36.6	15.8	15.1	8.0	1.9
★ BH-10	2.5	2	0.155	0.126	0.081		0.0	0.0	0.0	4.3	69.4	26.3
⊙ BH-10	5.0	4.75	0.12	0.092	0.027	0.007	0.0	0.0	0.9	5.4	51.4	42.3

$C_c = D_{30}^2/(D_{60} * D_{10})$ To be well graded: $1 < C_c < 3$ and

$C_u = D_{60}/D_{10}$ $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\0621\004\T\0621004.010.GPJ GRAIN SIZE W/STATS

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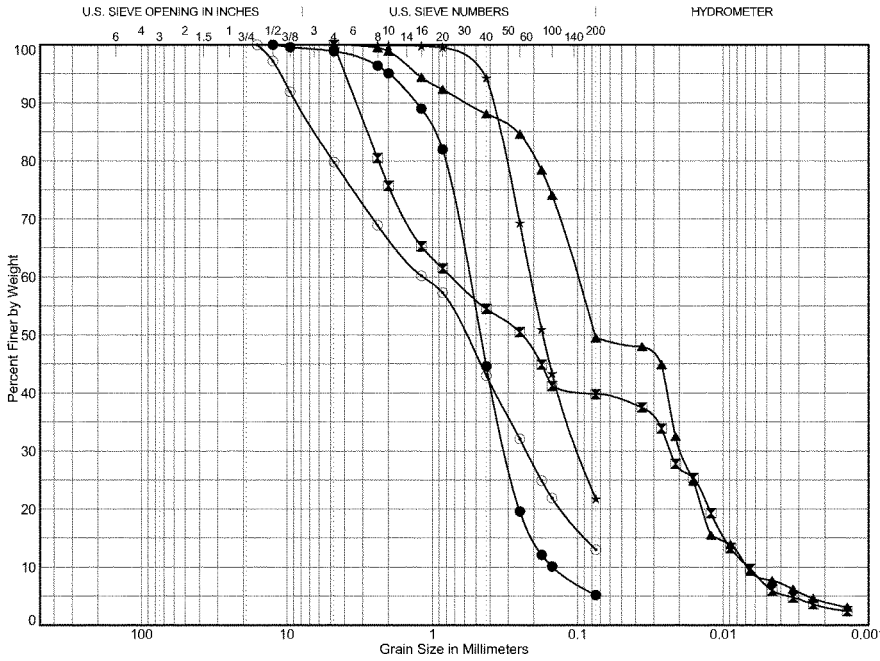
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-6



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

Point	Depth	Classification	LL	PL	PI	C_c	C_u
● BH-10	15.0	S-5 Poorly graded SAND with silt (SP-SM)				1.16	3.82
⧗ BH-14R	5.0	S-3/3 Cal Silty SAND (SM)	NP	NP	NP	0.11	109.81
▲ BH-14R	10.0	S-4 Silty SAND (SM)				0.54	14.79
★ BH-14R	15.5	S-5A Silty SAND (SM)					
⊙ BH-15	2.5	S-1A SAND with silt and gravel (SM)					

Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
● BH-10	15.0	12.5	0.565	0.47	0.312	0.148	0.0	1.1	3.8	50.5	39.4	5.2
⧗ BH-14R	5.0	4.75	0.733	0.242	0.023	0.007	0.0	0.0	24.3	21.2	14.7	39.8
▲ BH-14R	10.0	4.75	0.101	0.076	0.019	0.007	0.0	0.0	1.1	10.8	38.6	49.5
★ BH-14R	15.5	4.75	0.21	0.173	0.098		0.0	0.0	0.1	5.6	72.5	21.8
⊙ BH-15	2.5	16	1.163	0.597	0.226		0.0	20.2	13.1	23.7	30.0	13.0

$C_c = D_{30}^2/(D_{60} * D_{10})$

$C_u = D_{60}/D_{10}$

To be well graded: $1 < C_c < 3$ and $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\0621\004\T0621004.010.GPJ GRAIN SIZE W/STATS

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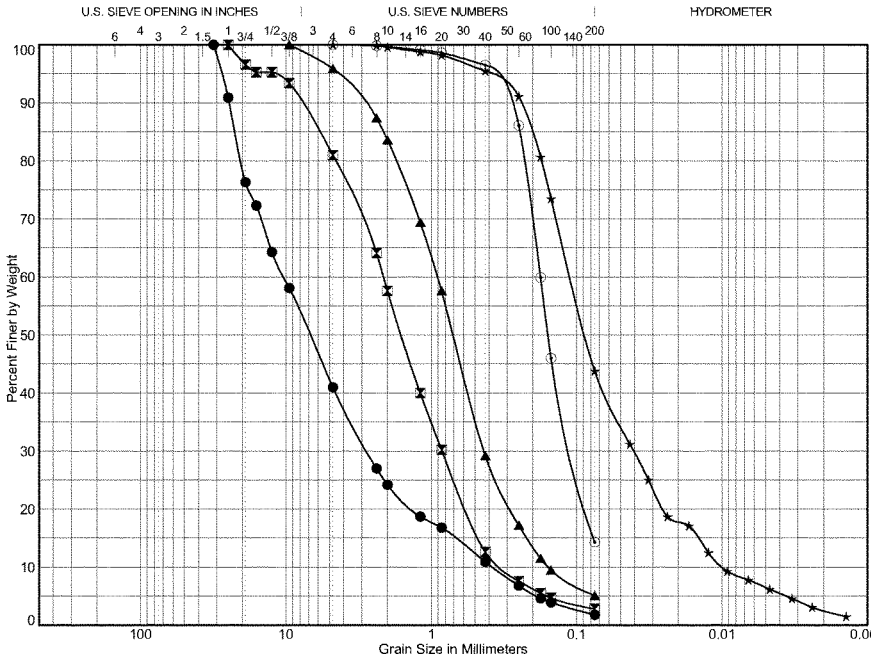
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-7



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	BH-15	10.0	S-3/S-3 CAL Well graded GRAVEL with sand (GW)				1.95	27.32
⧗	BH-15	20.0	S-5 Poorly graded SAND with gravel (SP)				1.03	6.61
▲	BH-15	35.0	S-8 Poorly graded SAND with silt (SP-SM)				1.32	5.82
★	HA-01X	5.0	S-2 Silty SAND (SM)				1.53	11.15
⊙	HA-02B	1.5	S-1 Silty SAND (SM)					

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	BH-15	10.0	31.5	10.334	6.841	2.76	0.378	23.7	35.3	16.8	13.3	9.1	1.8
⧗	BH-15	20.0	25	2.133	1.598	0.843	0.323	3.4	15.6	23.4	45.0	9.8	2.8
▲	BH-15	35.0	9.5	0.91	0.706	0.433	0.156	0.0	4.1	12.3	54.4	24.1	5.1
★	HA-01X	5.0	4.75	0.109	0.087	0.041	0.01	0.0	0.0	0.4	4.1	51.7	43.8
⊙	HA-02B	1.5	4.75	0.177	0.157	0.106		0.0	0.0	0.4	3.1	82.2	14.3

$C_c = D_{30}^2/(D_{60} * D_{10})$
$C_u = D_{60}/D_{10}$

To be well graded: $1 < C_c < 3$ and $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\0621\004\T0621004.010.GPJ GRAIN SIZE W/STATS

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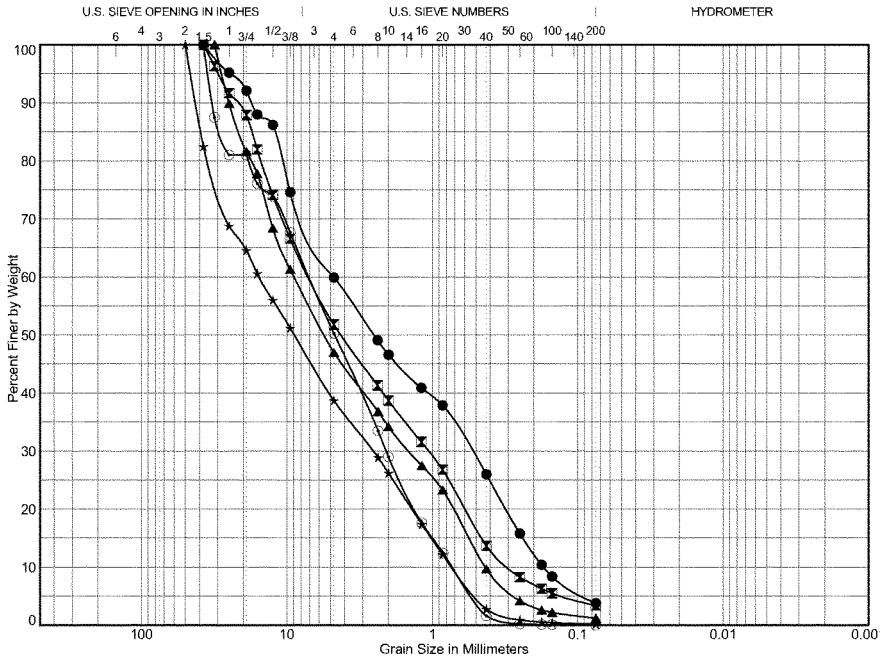
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-8



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	HA-07B	1.0	S-1 Poorly graded SAND with gravel (SP)				0.35	27.87
⧗	HA-14B	0.5	S-1 Poorly graded SAND with gravel (SP)				0.55	23.60
▲	HA-20B	0.8	S-1 Poorly graded GRAVEL with sand (GP)				0.54	20.67
★	HA-22	2.0	S-2 Poorly graded GRAVEL with sand (GP)				0.58	21.44
⊙	TP-02R	3.0	S-1 Poorly graded SAND with gravel (SP)				0.85	9.67

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	HA-07B	1.0	37.5	4.772	2.521	0.537	0.171	7.9	32.2	13.3	20.6	22.2	3.8
⧗	HA-14B	0.5	37.5	6.974	4.219	1.064	0.295	12.1	36.1	13.1	25.0	10.3	3.4
▲	HA-20B	0.8	31.5	8.92	5.493	1.437	0.432	18.4	34.6	12.8	24.5	8.5	1.2
★	HA-22	2.0	50	15.493	8.888	2.553	0.723	35.4	25.9	12.5	23.4	2.6	0.2
⊙	TP-02R	3.0	37.5	6.991	4.691	2.075	0.723	19.0	30.7	21.3	27.4	1.6	0.0

$C_c = D_{30}^2/(D_{60} * D_{10})$ To be well graded: $1 < C_c < 3$ and

$C_u = D_{60}/D_{10}$ $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\0621004\T0621004.010.GPJ GRAIN SIZE W/STATS

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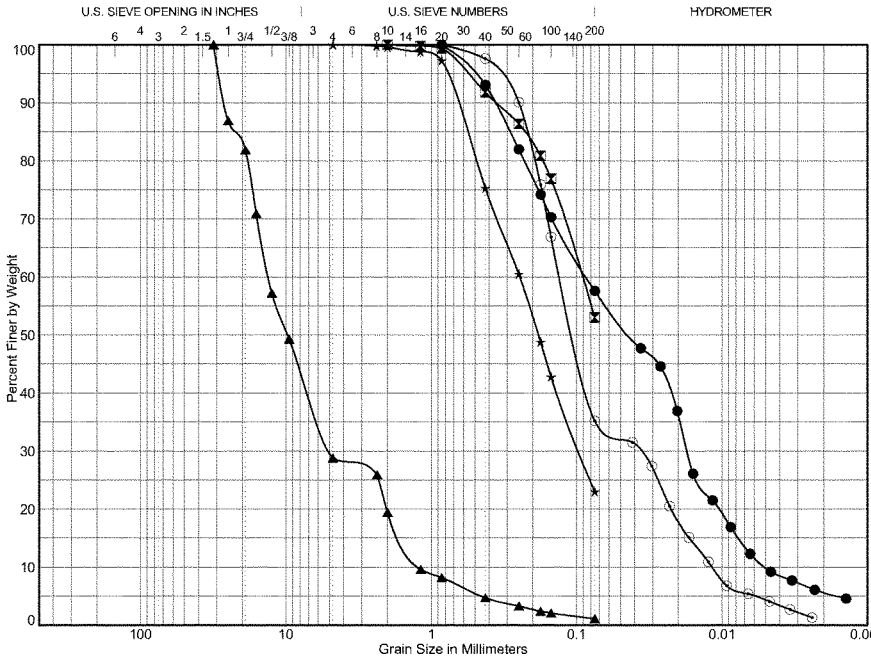
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-9



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	TP-13R	3.0	S-1 Sandy SILT (ML)				0.70	17.07
⧗	TP-13R	6.0	S-2 Sandy SILT (ML)	NP	NP	NP		
▲	TP-13R	8.7	S-3 Well graded GRAVEL with sand (GW)				1.54	10.90
★	TP-17R	3.5	S-1B Silty SAND (SM)					
⊙	TP-19R	3.0	S-2 Silty SAND (SM)				0.91	11.08

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	TP-13R	3.0	0.85	0.085	0.043	0.017	0.005	0.0	0.0	0.0	6.9	35.5	57.6
⧗	TP-13R	6.0	2	0.092				0.0	0.0	0.0	8.2	38.8	53.0
▲	TP-13R	8.7	31.5	13.147	9.734	4.947	1.206	18.1	53.1	9.4	14.7	3.6	1.1
★	TP-17R	3.5	4.75	0.246	0.183	0.096		0.0	0.0	0.4	24.3	52.3	23.0
⊙	TP-19R	3.0	0.85	0.129	0.104	0.037	0.012	0.0	0.0	0.0	2.4	62.4	35.2

$C_c = D_{30}^2/(D_{60} * D_{10})$
$C_u = D_{60}/D_{10}$

To be well graded: $1 < C_c < 3$ and $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\0621\004\T0621004.010.GPJ GRAIN SIZE W/STATS

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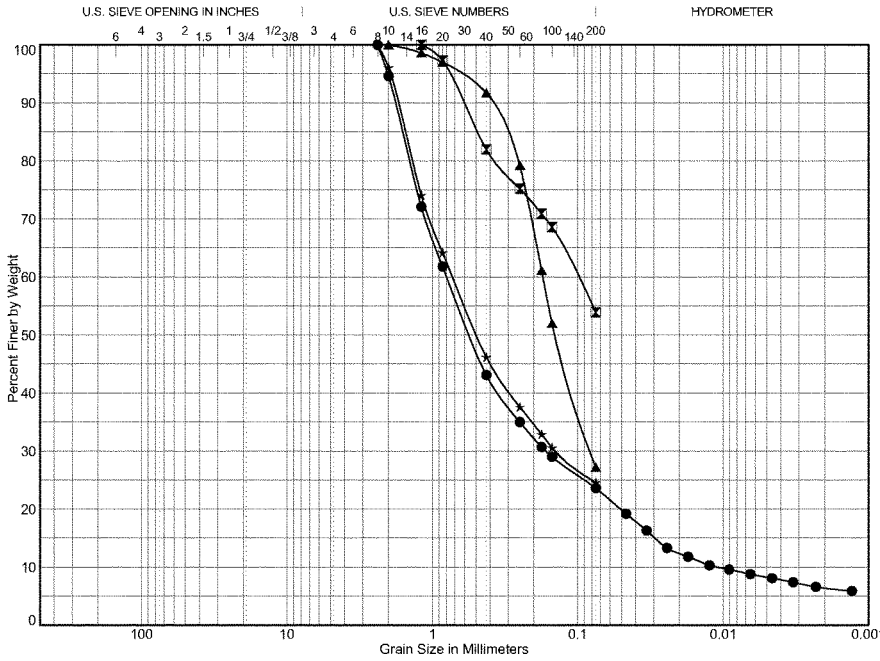
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-10



Cobbles	Gravel		Sand			Silt or Clay
	coarse	fine	coarse	medium	fine	

	Point	Depth	Classification	LL	PL	PI	C_c	C_u
●	TP-23R	2.5	S-1 Silty SAND (SM)				3.17	73.22
⧗	TP-23R	6.0	S-3 Sandy SILT (ML)	NP	NP	NP		
▲	TP-27	3.0	S-2 Silty SAND (SM)					
★	TP-27	8.7	S-4 Silty SAND (SM)	NP	NP	NP		

	Point	Depth	D_{100}	D_{60}	D_{50}	D_{30}	D_{10}	%Coarse Gravel	% Fine Gravel	% Coarse Sand	% Medium Sand	% Fine Sand	% Fines
●	TP-23R	2.5	2.38	0.795	0.549	0.165	0.011	0.0	0.0	5.4	51.5	19.5	23.6
⧗	TP-23R	6.0	1.19	0.1				0.0	0.0	0.0	18.0	28.1	53.9
▲	TP-27	3.0	2	0.173	0.142	0.081		0.0	0.0	0.0	8.3	64.5	27.2
★	TP-27	8.7	2.38	0.723	0.492	0.14		0.0	0.0	3.9	49.9	21.6	24.6

$C_c = D_{30}^2/(D_{60} * D_{10})$ To be well graded: $1 < C_c < 3$ and

$C_u = D_{60}/D_{10}$ $C_u > 4$ for GW or $C_u > 6$ for SW

621004.01 8/14/14 Y:\0621\004\T0621004.010.GPJ GRAIN SIZE W/STATS

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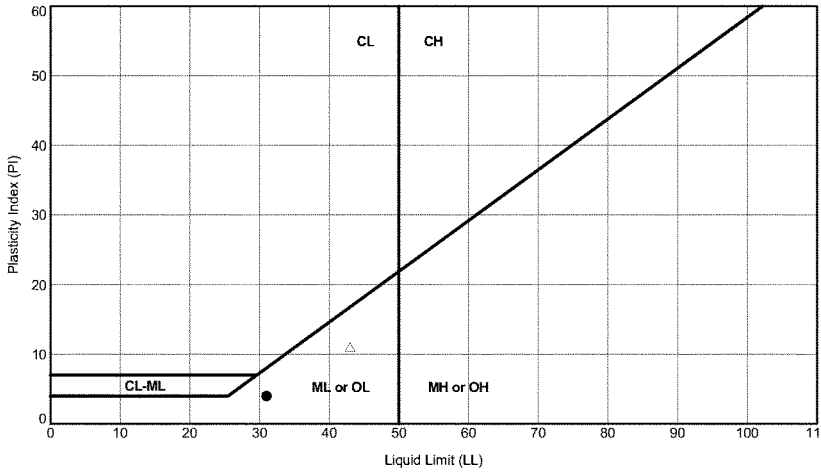
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Grain Size Test Data

Figure B-11



ATTERBERG LIMIT TEST RESULTS

Symbol	Exploration Number	Sample Number	Depth (ft)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Moisture (%)	Soil Description	Unified Soil Classification
●	BH-02C	S-1	2.5	31	27	4	50	S-1 SILT with sand	ML
	BH-04	S-1	3.8	NP	NP	NP	34	S-1 Sandy SILT	ML
	BH-04	S-4B	15.5	NP	NP	NP	43	S-4B Silty SAND	SM
	BH-05R	S-4	12.5	NP	NP	NP	40	S-4 Silty SAND	SM
⊙	BH-07R	S-1	2.5	31	27	4	31	S-1 SILT with sand	ML
	BH-08	S-1	3.0	NP	NP	NP	29	S-1 Silty SAND	SM
	BH-08	S-3	7.5	NP	NP	NP	41	S-3 Sandy SILT	ML
△	BH-09R	S-1	2.5	43	32	11	33	S-1 Sandy SILT	ML
	BH-10	S-1	2.5	NP	NP	NP	41	S-1 Silty SAND	SM
	BH-10	S-2	5.0	NP	NP	NP	31	S-2 Silty SAND	SM

ASTM D 4318 Test Method

621004.01 8/21/14 Y:\0621\004\T\0621004.010.GPJ ATTERBERG LIMITS FIGURE_PRINTS NP

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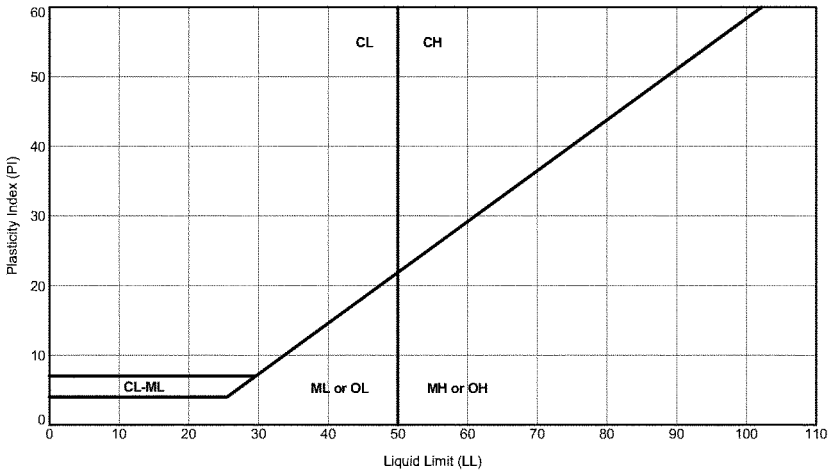
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

Plasticity Chart

Figure B-12



ATTERBERG LIMIT TEST RESULTS

Symbol	Exploration Number	Sample Number	Depth (ft)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Natural Moisture (%)	Soil Description	Unified Soil Classification
	BH-10	S-3	6.5	NP	NP	NP	36	S-3 Silty SAND	SM
	BH-14R	S-2	3.0	NP	NP	NP	50	S-2 Silty SAND	SM
	BH-14R	S-3/3 Cal	5.0	NP	NP	NP	55	S-3/3 Cal Silty SAND	SM
	TP-13R	S-2	6.0	NP	NP	NP	44	S-2 Sandy SILT	ML
	TP-23R	S-3	6.0	NP	NP	NP	53	S-3 Sandy SILT	ML
	TP-27	S-4	8.7	NP	NP	NP	61	S-4 Silty SAND	SM

ASTM D 4318 Test Method

621004.01 8/21/14 Y:\0621\004\T\0621004.010.GPJ ATTERBERG LIMITS FIGURE_PRINTS NP

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	Plasticity Chart	Figure B-13

APPENDIX C

Geotechnical Laboratory Reports

Northwest Testing, Inc.
A Division of Northwest Geotech, Inc.
9120 SW Pioneer Court, Suite B • Wilsonville, Oregon 97070 503/682-1880 FAX: 503/682-2753

TECHNICAL REPORT

Report To:	Mr. Craig Jordan Landau Associates, Inc. 1115 West Bay Drive NW Suite 201 Olympia, WA 98502	**Date:** **Lab No.:**	7/21/14 14-239
Project:	Laboratory Testing	**Project No.:**	2823.1.1

Report of: Moisture content, Atterberg limits, sieve analysis, hydrometer sieve analysis, organic content, and one-dimensional consolidation.

Sample Identification

NTI completed moisture content, Atterberg limits, sieve analysis, hydrometer sieve analysis, organic content, and one-dimensional consolidation testing on samples of soil delivered to our laboratory on June 11, 2014. Testing was performed in accordance with the standards indicated. Our laboratory test results are summarized on the following tables and attached pages.

Laboratory Testing

Moisture Content of Soil and Dry Density (ASTM D2216)	
Sample ID	**Moisture Content (Percent)**
BH-09R S-1 @ 2.5 ft.	32.6

Atterberg Limits (ASTM D4318)			
Sample ID	**Liquid Limit**	**Plastic Limit**	**Plasticity Index**
BH-02C S-1 @ 2.5 ft.	31	27	4
BH-05R S-4 @ 12.5 ft.	NP	NP	NP
BH-07R S-1 @ 2.5 ft.	31	27	4
BH-08 S-3 @ 7.5 ft.	NP	NP	NP
BH-09R S-1 @ 2.5 ft.	43	32	11
BH-10 S-3 @ 6.5 ft.	NP	NP	NP

Moisture Content and Organic Content of Soils (ASTM D 2974)				
Sample ID	**Moisture Content As Received Mass (Percent)**	**Moisture Content Oven-dried Mass (Percent)**	**Ash Content (Percent)**	**Organic Content (Percent)**
BH-10 S-3 @ 6.5 ft.	26.5	36.0	95.5	4.5

Attachments: Laboratory Test Results

Copies: Addressee

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Northwest Testing, Inc.
A Division of Northwest Geotech, Inc.
9120 SW Pioneer Court, Suite B • Wilsonville, Oregon 97070 503/682-1880 FAX: 503/682-2753

TECHNICAL REPORT

Report To:	Mr. Craig Jordan Landau Associates, Inc. 1115 West Bay Drive NW Suite 201 Olympia, WA 98502	**Date:**	7/21/14
		Lab No.:	14-239
Project:	Laboratory Testing	**Project No.:**	2823.1.1

Laboratory Test Results

Sieve Analysis of Aggregates (ASTM C136/C117)		
Sieve Size	**BH-02C S-1 @ 2.5 ft. Percent Passing**	**BH-08 S-3 @ 7.5 ft. Percent Passing**
#30	100	100
#40	99	100
#50	98	100
#100	93	94
#200	80.5	67.9

Sample ID: BH-02C S-1 @ 2.5 ft. ft.

One Dimensional Consolidation of Soil (ASTM D 2435)		
Test	**Initial Conditions**	**Final Conditions**
Moisture Content, (%)	50.3	46.5
Dry Unit Weight, (pcf)	69.0	78.4
Height of Specimen, (inches)	0.7500	0.6608

One-Dimensional Consolidation Properties of Soils (ASTM D 2435)			
Load (tsf)	**Dial Reading (inches)**	**Load (tsf)**	**Dial Reading (inches)**
Initial	0.0001	2000	0.0570
250	0.0067	4000	0.0976
500	0.0134	1000	0.0940
1000	0.0276	250	0.0893

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Northwest Testing, Inc.
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TECHNICAL REPORT

Report To:	Mr. Craig Jordan Landau Associates, Inc. 1115 West Bay Drive NW Suite 201 Olympia, WA 98502	**Date:** **Lab No.:**	7/21/14 14-239
Project:	Laboratory Testing	**Project No.:**	2823.1.1

Laboratory Test Results

Sample ID: BH-05R S-4 @ 12.5 ft. ft.

One Dimensional Consolidation of Soil (ASTM D 2435)		
Test	**Initial Conditions**	**Final Conditions**
Moisture Content, (%)	39.7	38.7
Dry Unit Weight, (pcf)	80.5	86.3
Height of Specimen, (inches)	0.7500	0.6991

One-Dimensional Consolidation Properties of Soils (ASTM D 2435)			
Load (tsf)	**Dial Reading (inches)**	**Load (tsf)**	**Dial Reading (inches)**
Initial	0.0001	2000	0.0337
250	0.0054	4000	0.0607
500	0.0098	1000	0.0568
1000	0.0179	250	0.0510

Sample ID: BH-07R S-1 @ 2.5 ft. ft.

One Dimensional Consolidation of Soil (ASTM D 2435)		
Test	**Initial Conditions**	**Final Conditions**
Moisture Content, (%)	30.5	31.7
Dry Unit Weight, (pcf)	85.8	88.8
Height of Specimen, (inches)	0.7500	0.7244

One-Dimensional Consolidation Properties of Soils (ASTM D 2435)			
Load (tsf)	**Dial Reading (inches)**	**Load (tsf)**	**Dial Reading (inches)**
Initial	0.0002	2000	0.0232
250	0.0049	4000	0.0328
500	0.0096	1000	0.0296
1000	0.0154	250	0.0258

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Northwest Testing, Inc.
A Division of Northwest Geotech, Inc
9120 SW Pioneer Court, Suite B • Wilsonville, Oregon 97070 503/682-1880 FAX: 503/682-2753

TECHNICAL REPORT

Report To:	Mr. Craig Jordan Landau Associates, Inc. 1115 West Bay Drive NW Suite 201 Olympia, WA 98502	**Date:**	7/21/14
		Lab No.:	14-239
Project:	Laboratory Testing	**Project No.:**	2823.1.1

Laboratory Test Results

Sample ID: BH-08 S-3 @ 7.5 ft. ft.

One Dimensional Consolidation of Soil (ASTM D 2435)		
Test	**Initial Conditions**	**Final Conditions**
Moisture Content, (%)	40.7	38.5
Dry Unit Weight, (pcf)	79.8	87.7
Height of Specimen, (inches)	1.0000	0.9096

One-Dimensional Consolidation Properties of Soils (ASTM D 2435)			
Load (tsf)	**Dial Reading (inches)**	**Load (tsf)**	**Dial Reading (inches)**
Initial	0.0000	2000	0.0625
250	0.0123	4000	0.0975
500	0.0220	1000	0.0942
1000	0.0351	250	0.0904

Sample ID: BH-10 S-3 @ 6.5 ft. ft.

One Dimensional Consolidation of Soil (ASTM D 2435)		
Test	**Initial Conditions**	**Final Conditions**
Moisture Content, (%)	35.7	31.9
Dry Unit Weight, (pcf)	75.6	87.4
Height of Specimen, (inches)	0.7500	0.8656

One-Dimensional Consolidation Properties of Soils (ASTM D 2435)			
Load (tsf)	**Dial Reading (inches)**	**Load (tsf)**	**Dial Reading (inches)**
Initial	0.0002	2000	0.1143
250	0.0472	4000	0.1430
500	0.0644	1000	0.1394
1000	0.0866	250	0.1346

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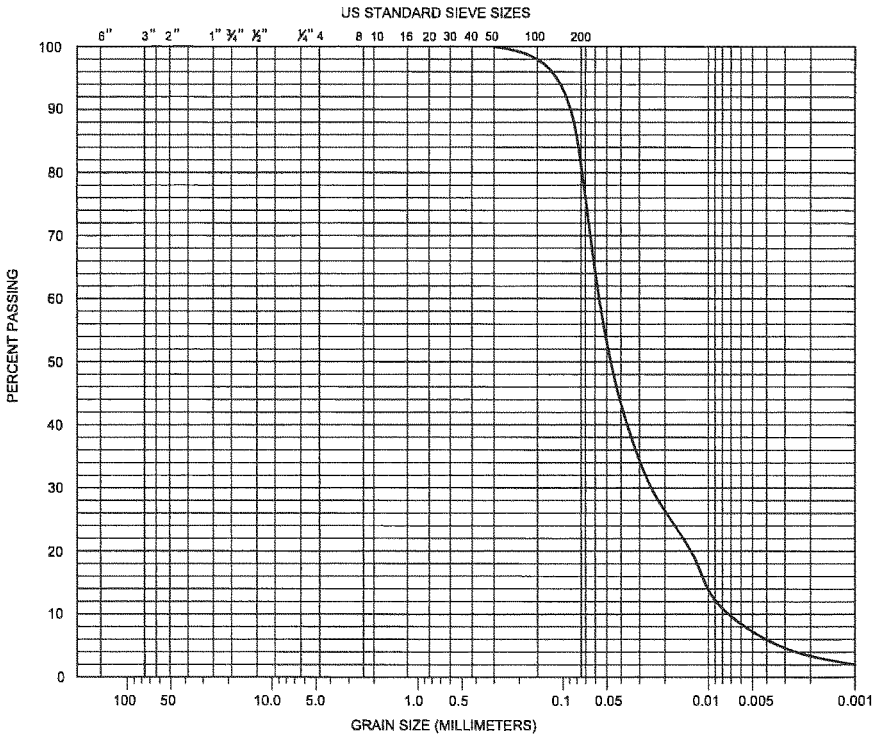

COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING 2 μ	UNIFIED SOIL CLASSIFICATION
———	BH-07R S-1 @ 2.5 FT.	--	81	3	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
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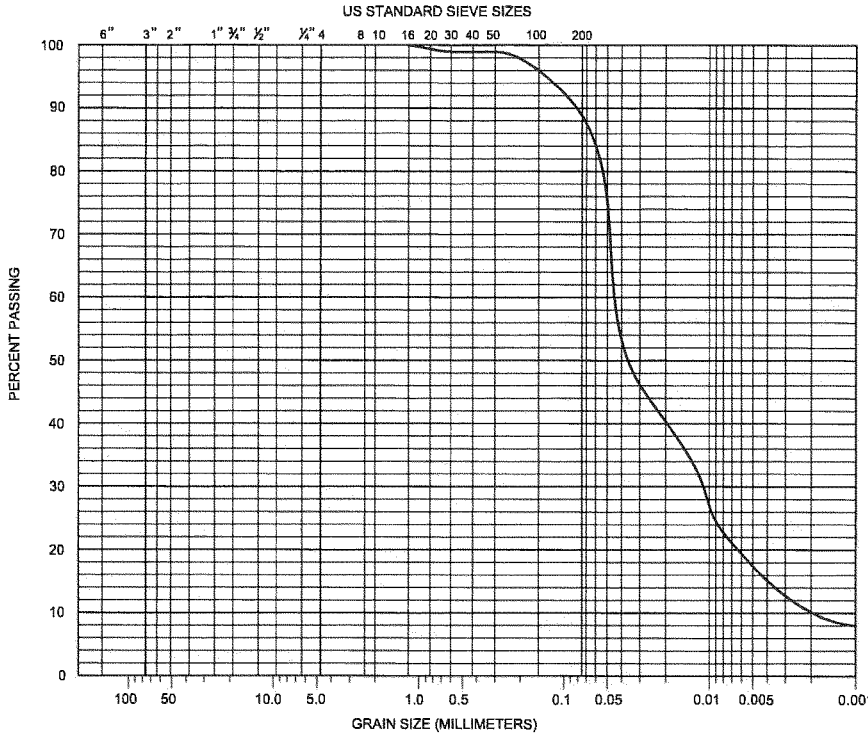

COBBLES	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SYMBOL	SAMPLE LOCATION	FIELD MOISTURE (%)	% PASSING NO. 200 SIEVE	% PASSING 2 μ	UNIFIED SOIL CLASSIFICATION
———	BH-09R S-1 @ 2.5 FT.	--	89	10	--

GRADATION TEST RESULTS – ASTM D422

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
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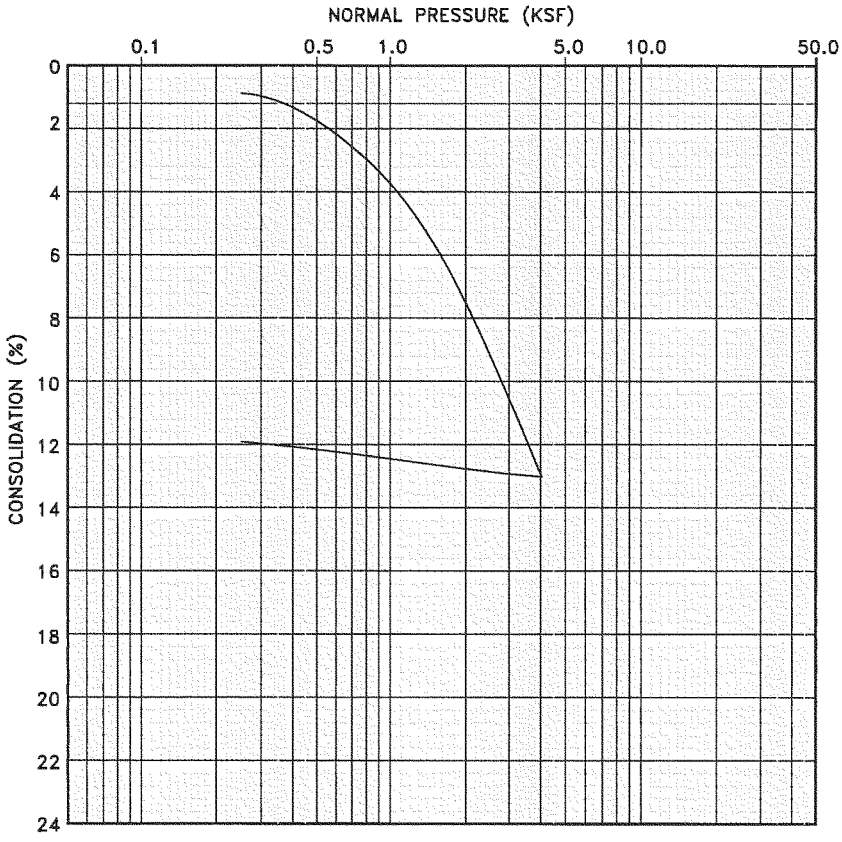
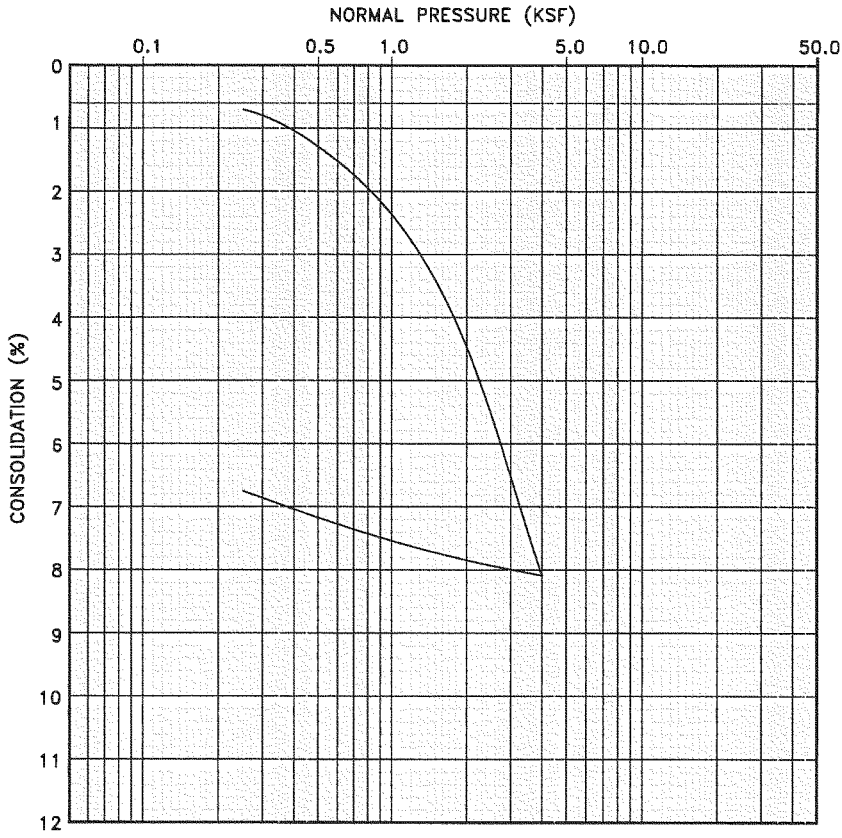


SYMBOL	SAMPLE LOCATION	NORMAL PRESSURE AT SATURATION (KSF)
———	BH-02C S-1 @ 2.5 FT.	0.25

CONSOLIDATION TEST RESULTS – ASTM D2435

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
A Division of Northwest Geotech, Inc.



SYMBOL	SAMPLE LOCATION	NORMAL PRESSURE AT SATURATION (KSF)
———	BH-05R S-4 @ 12.5 FT.	0.25

CONSOLIDATION TEST RESULTS – ASTM D2435

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
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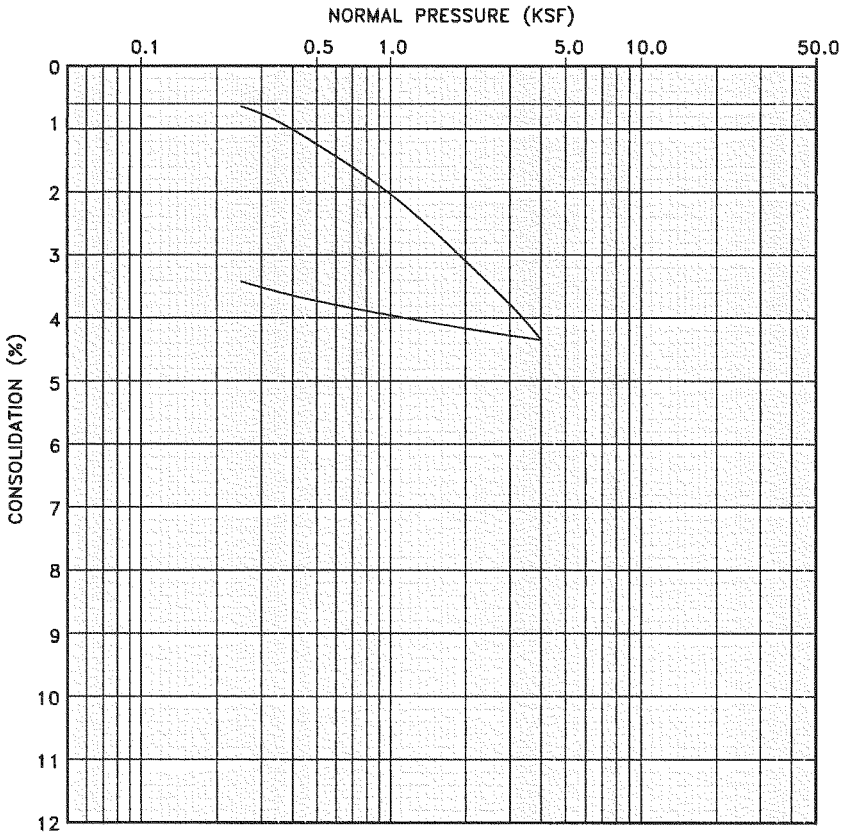

SYMBOL	SAMPLE LOCATION	NORMAL PRESSURE AT SATURATION (KSF)
———	BH-07R S-1 @ 2.5 FT.	0.25

CONSOLIDATION TEST RESULTS – ASTM D2435

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
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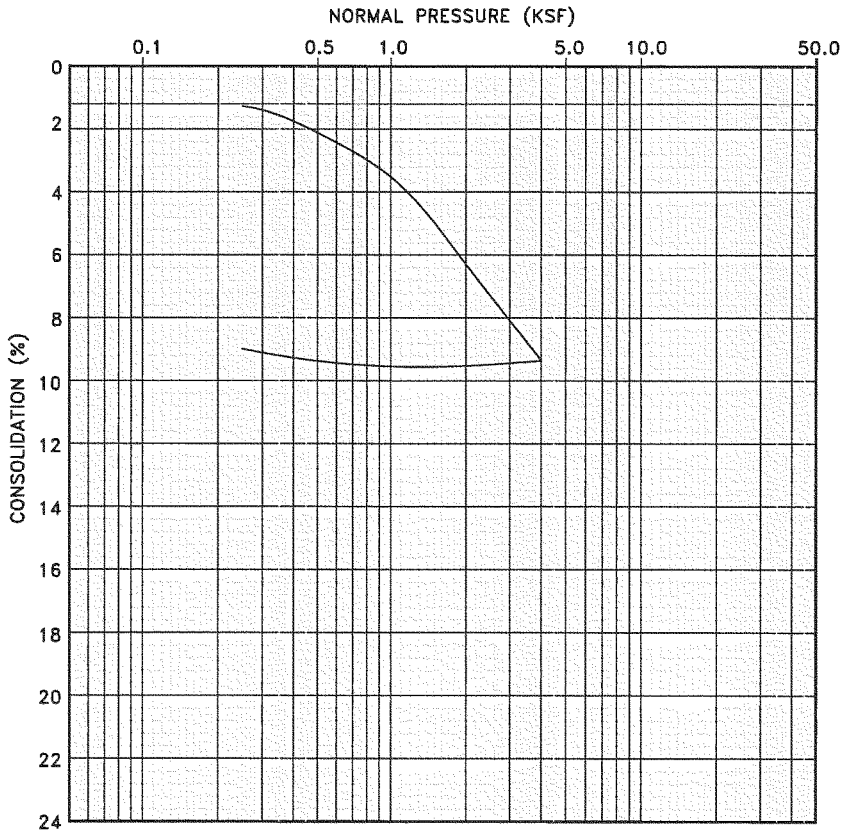

SYMBOL	SAMPLE LOCATION	NORMAL PRESSURE AT SATURATION (KSF)
———	BH-08 S-3 @ 7.5 FT.	0.25

CONSOLIDATION TEST RESULTS – ASTM D2435

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
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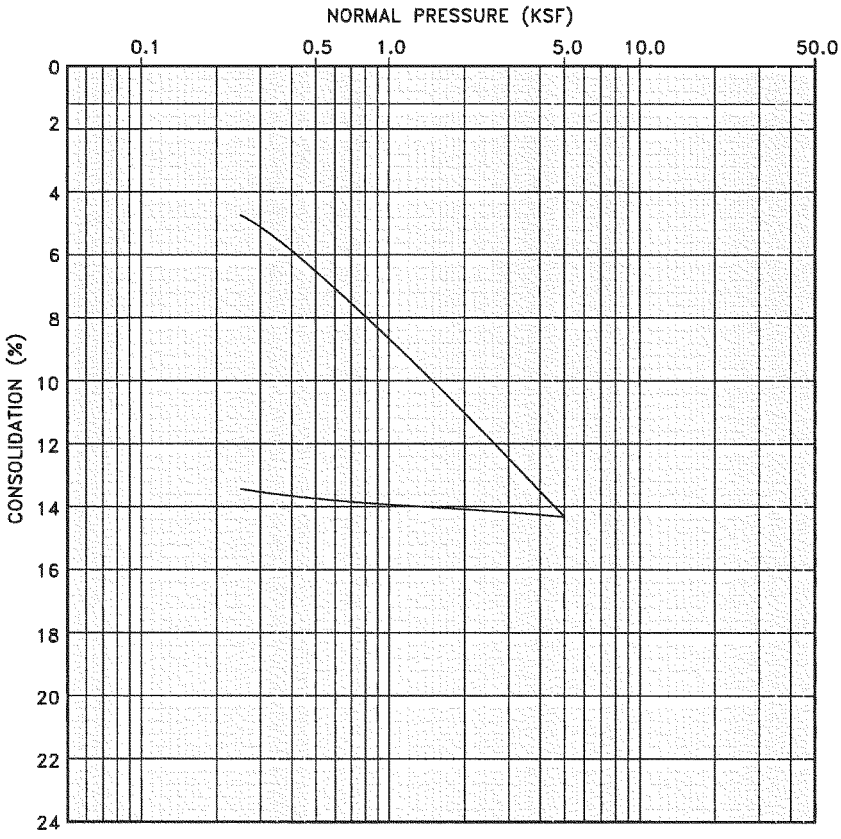


SYMBOL	SAMPLE LOCATION	NORMAL PRESSURE AT SATURATION (KSF)
———	BH-10 S-3 @ 6.5 FT.	0.25

CONSOLIDATION TEST RESULTS – ASTM D2435

PROJECT NO. 2823.1.1	LANDAU ASSOCIATES, INC. LABORATORY TESTING	LAB NO. 14-239

Northwest Testing, Inc.
A Division of Northwest Geotech, Inc.

Krazan & ASSOCIATES, INC.

GEOTECHNICAL ENGINEERING • ENVIRONMENTAL ENGINEERING
CONSTRUCTION TESTING & INSPECTION

July 28, 2014

066-14179

Craig Jordan
Landau Associates
1115 West Bay Drive N.W. Suite 201.
Olympia, WA 98502

RE: Moisture Content Test Results for Skokomish.

Dear Mr. Jordan,

In accordance with your request and authorization, we have performed laboratory testing and analysis on samples 14L329 to 14L433, received on 5/23/2014.

Sample ID #	Location	Sample #	Moisture Content (ASTM D2216)
14L329	BH-01	1 Cal	8.1%
14L330	BH-01	2	10.7%
14L331	BH-01	3	15.9%
14L332	BH-01	5	15.5%
14L333	BH-01	7	9.7%
14L334	BH-01	8	Was Not Tested For Moisture
14L335	BH-01	8Cal	7.2%
14L336	BH-02	2A	38.5%
14L337	BH-02	3	10.6%
14L338	BH-02	4	20.9%
14L339	BH-02	4 Cal	Was Not Tested For Moisture
14L340	BH-02	6	10.6%
14L341	BH-02	6 Cal	Was Not Tested For Moisture
14L342	BH-02	7	Was Not Tested For Moisture
14L343	BH-03R	1A	36.0%
14L344	BH-03R	1B	7.5%
14L345	BH-03R	2	Was Not Tested For Moisture
14L346	BH-03R	2 Cal	6.4%
14L347	BH-03R	3	12.2%
14L348	BH-03R	4	Was Not Tested For Moisture
14L349	BH-03R	4 Cal	18.2%
14L350	BH-03R	7	Was Not Tested For Moisture
14L351	BH-03R	7 Cal	9.4%
14L352	BH-04	1	34.3%
14L353	BH-04	2	27.8%
14L354	BH-04	3A	36.1%

Sample ID #	Location	Sample #	Moisture Content (ASTM D2216)
14L355	BH-04	3B	29.3%
14L356	BH-04	4A	23.0%
14L357	BH-04	4B	43.2%
14L358	BH-04	5A	36.0%
14L359	BH-04	6	24.2%
14L360	BH-05R	1A	28.6%
14L361	BH-05R	1B	13.0%
14L362	BH-05R	2	32.4%
14L363	BH-05R	3	40.9%
14L364	BH-05R	6A	28.1%
14L365	BH-07R	2A	41.7%
14L366	BH-07R	2B	38.0%
14L367	BH-07R	3Cal	17.6%
14L368	BH-07R	4	12.0%
14L369	BH-07R	5	Was Not Tested For Moisture
14L370	BH-07R	5 Cal	9.9%
14L371	BH-08	1	28.9
14L372	BH-08	2	39.1
14L373	BH-08	4A	35.3%
14L374	BH-08	4B	11.3%
14L375	BH-08	5	13.8%
14L376	BH-08	6	Was Not Tested For Moisture
14L377	BH-08	6 Cal	19.5%
14L378	BH-09R	2	9.5%
14L379	BH-09R	3	Was Not Tested For Moisture
14L380	BH-09R	3 Cal	18.3%
14L381	BH-09R	4 Cal	8.3%
14L382	BH09-R	5	Was Not Tested For Moisture
14L383	BH-09R	5 Cal	13.6%
14L384	BH-10	1	41.3%
14L385	BH-10	2	30.8
14L386	BH-10	4	25.1%
14L387	BH-10	5	21.9%
14L388	BH-10	7	9.0%
14L389	BH-14R	1 Cal	48.9%
14L390	BH-14R	2	49.5%
14L392	BH-14R	3 Cal	55.1%
14L393	BH-14R	4	47.3%
14L394	BH-14R	5A	43.4%
14L395	BH-14R	5B	31.0%
14L396	BH-14R	9	10.4%
14L397	BH-15	1A	4.9%
14L398	BH-15	2	7.5%
14L399	BH-15	3	Was Not Tested For Moisture
14L400	BH-15	3 Cal	10.0%
14L401	BH-15	4	13.6%
14L402	BH-15	5	13.6
14L403	BH-15	6	11.9%
14L404	BH-15	8	16.5%
14L405	HA-01X	S1	37.7%

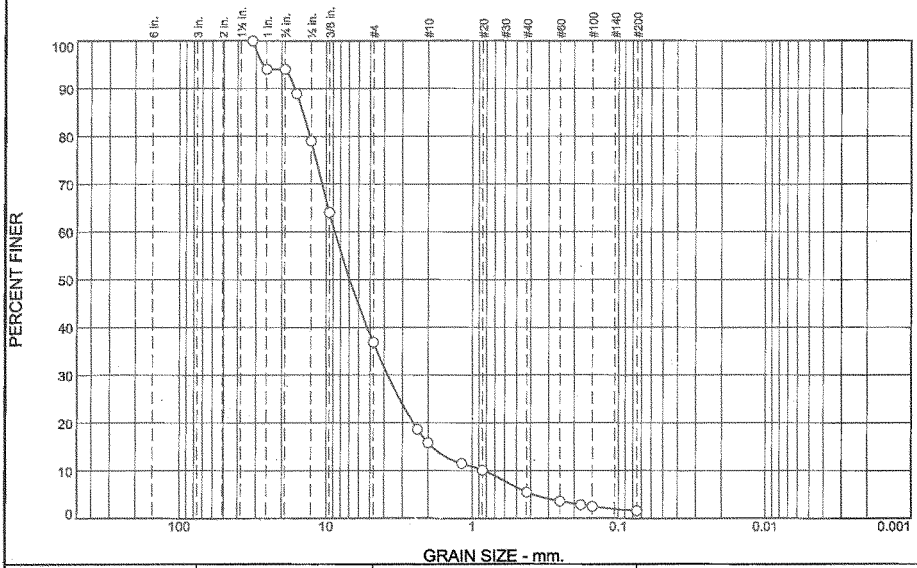
Sample ID #	Location	Sample #	Moisture Content (ASTM D2216)
14L406	HA-01X	S2	44.8%
14L407	HA-02B	1	12.5%
14L408	HA-07B	1	4.7%
14L409	HA-14B	1	4.1%
14L410	HA-20B	1	5.0%
14L411	HA-22	2	3.3%
14L412	TP-02R	S1	2.5%
14L413	TP-02R	S2	8.0%
14L414	TP-02R	S3	13.6%
14L415	TP-13R	S1	50.6%
14L416	TP-13R	S2	44.3%
14L417	TP-13R	S3	8.4%
14L418	TP-17R	S1	37.6%
14L419	TP-17R	S1B	34.7%
14L420	TP-17R	S2	27.9%
14L421	TP-17R	S3	6.5%
14L422	TP-19R	S1	14.2%
14L423	TP-19R	S2	43.9%
14L424	TP19R	S3	51.2%
14L425	TP-19R	S4	7.4%
14L426	TP-23R	S1	67.2%
14L427	TP-23R	S2	57.4
14L428	TP-23R	S3	53.0%
14L429	TP-23R	S4	43.6
14L430	TP-27	S1	34.2%
14L431	TP-27	S2	33.5%
14L332	TP-27	S3	59.0%
14L333	TP-27	S4	60.6%

If you have any questions or need any additional information, please do not hesitate to contact our office at (253) 939-2500

Respectfully submitted,
KRAZAN & ASSOCIATES, INC.

Michael Thomas
Laboratory Manager
Krazan and Associates, Inc.
Phone: (253) 939-2500
Email: Mikethomas@krazan.com

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	5.9	57.3	21.0	10.3	3.9	1.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	94.1		
.75	94.1		
.625	89.0		
.5	79.0		
.375	64.1		
#4	36.8		
#8	18.7		
#10	15.8		
#16	11.5		
#20	10.1		
#40	5.5		
#60	3.6		
#80	2.8		
#100	2.5		
#200	1.6		

* (no specification provided)

Material Description

Well graded gravel with sand.

Atterberg Limits

PL= LL= PI= NP

Coefficients

D_{90}= 16.3201 D_{85}= 14.4242 D_{60}= 8.7555
D_{50}= 6.9308 D_{30}= 3.7815 D_{15}= 1.8795
D_{10}= 0.8346 C_u= 10.49 C_c= 1.96

Classification

USCS= GW AASHTO=

Remarks

Sample ID:14L329. Sampled on 6-11-14 Received on 7-3-14
Moisture Content(ASTM D2216):8.1%

Location: BH-01 (1 CAL)
Sample Number: 14L329

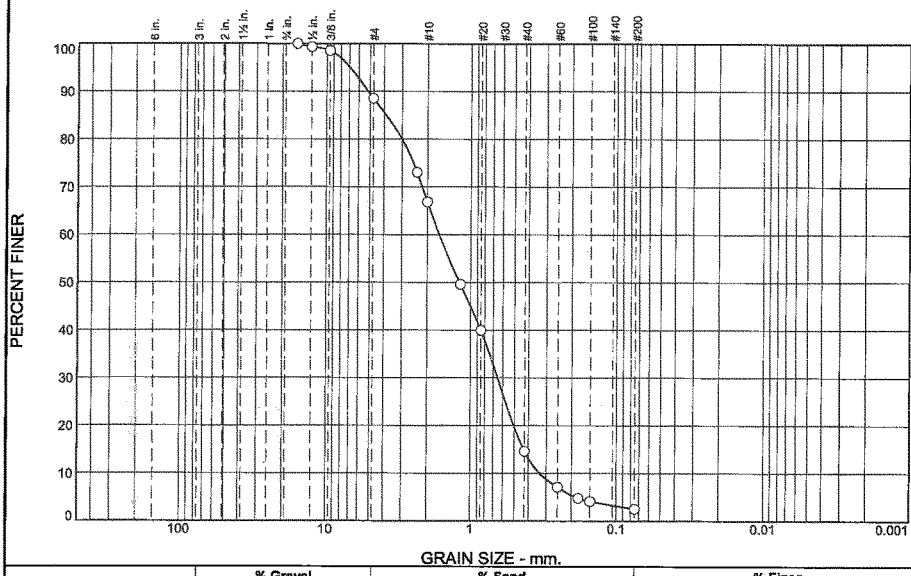
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	11.4	21.7	52.2	12.2	2.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.625	100.0		
.5	99.3		
.375	98.5		
#4	88.6		
#8	73.1		
#10	66.9		
#16	49.6		
#20	39.9		
#40	14.7		
#60	7.1		
#80	4.8		
#100	4.1		
#200	2.5		

* (no specification provided)

Material Description

Poorly graded sand.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 5.1581 D_{85}= 3.8588 D_{60}= 1.6502
D_{50}= 1.1974 D_{30}= 0.6537 D_{15}= 0.4306
D_{10}= 0.3336 C_u= 4.95 C_c= 0.78

Classification

USCS= SP AASHTO=

Remarks

Sample ID:14L332. Sampled 6-11-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):15.5%

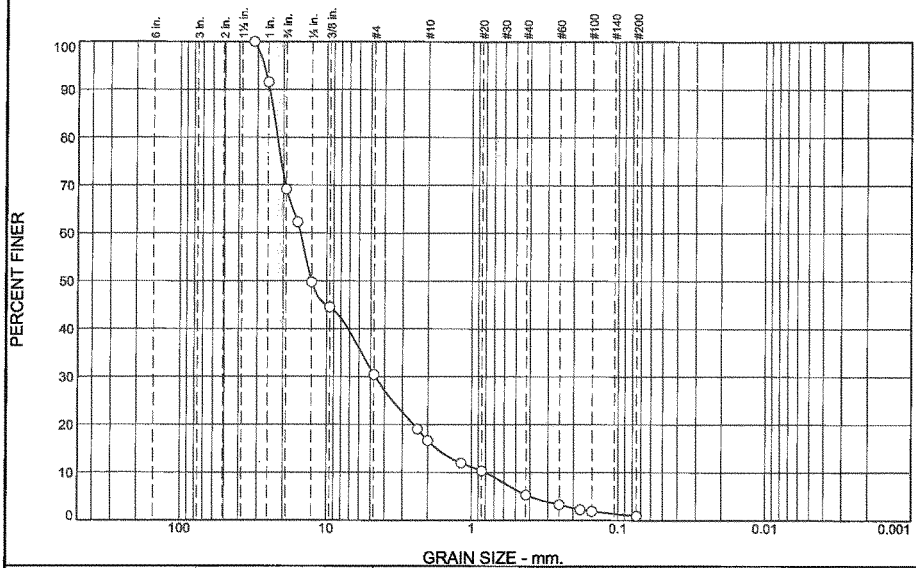
Location: BH-01 (5)
Sample Number: 14L332 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	30.9	38.6	13.8	11.4	4.4	0.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	91.6		
.75	69.1		
.625	62.3		
.5	49.8		
.375	44.6		
#4	30.5		
#8	19.1		
#10	16.7		
#16	12.0		
#20	10.3		
#40	5.3		
#60	3.3		
#80	2.3		
#100	1.9		
#200	0.9		

* (no specification provided)

Soil Description

Well graded gravel with sand.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 24.8241 D_{85}= 23.3064 D_{60}= 15.1637
D_{50}= 12.7678 D_{30}= 4.6498 D_{15}= 1.7428
D_{10}= 0.8043 C_u= 18.85 C_c= 1.77

Classification

USCS= GW AASHTO=

Remarks

Sample ID:14L334/14L335 Sampled 6-11-14 Recieved 7-3-14.
Moisture Content(ASTM D 2216):7.2%
Samples 14L334 & 14L335 combined for sieve per client

Location: BH-01 (8 Cal)
Sample Number: 14L334/14L335

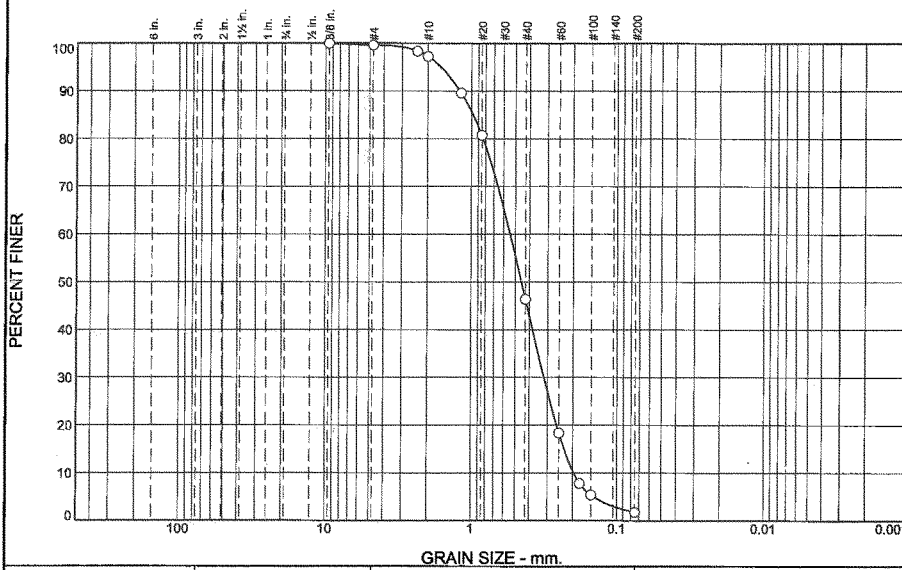
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.4	2.3	50.9	44.7	1.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.6		
#8	98.4		
#10	97.3		
#16	89.6		
#20	80.7		
#40	46.4		
#60	18.4		
#80	7.8		
#100	5.4		
#200	1.7		

* (no specification provided)

Material Description

Poorly graded sand.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.2048 D_{85}= 0.9749 D_{60}= 0.5418
D_{50}= 0.4529 D_{30}= 0.3174 D_{15}= 0.2301
D_{10}= 0.1976 C_u= 2.74 C_c= 0.94

Classification

USCS= SP AASHTO=

Remarks

Sample ID:14L338/14L339 Sampled 6-11-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):20.9%
Samples 14L338&14L339 combined for sieve per client

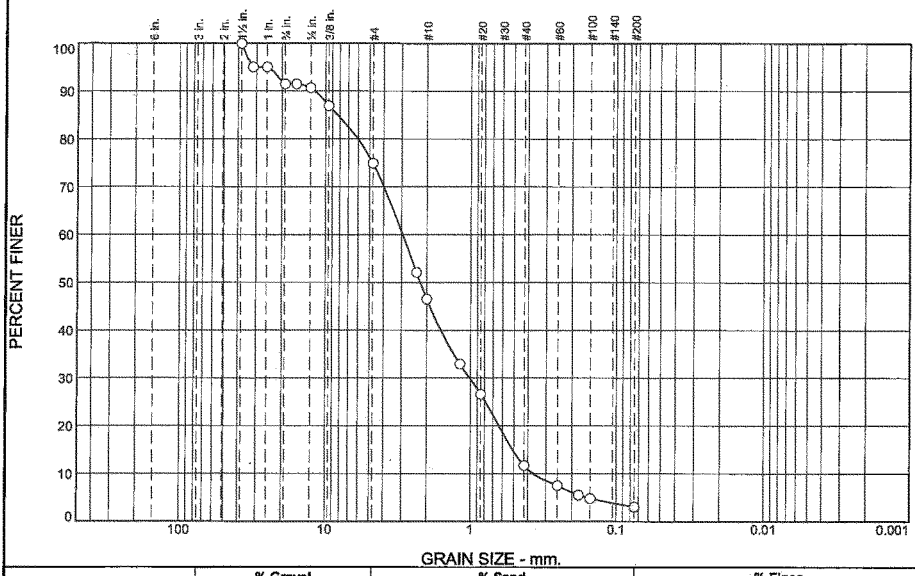
Location: BH-02 (4/4 Cal)
Sample Number: 14L338/14L339 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	8.5	16.6	28.4	34.8	8.7	3.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1.25	95.0		
1	95.0		
.75	91.5		
.625	91.5		
.5	90.7		
.375	87.0		
#4	74.9		
#8	52.1		
#10	46.5		
#16	32.9		
#20	26.6		
#40	11.7		
#60	7.5		
#80	5.5		
#100	4.8		
#200	3.0		

* (no specification provided)

Material Description

Poorly graded sand with gravel.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 11.8617 D_{85}= 8.3015 D_{60}= 2.9501
D_{50}= 2.2214 D_{30}= 1.0123 D_{15}= 0.5106
D_{10}= 0.3674 C_u= 8.03 C_c= 0.95

Classification

USCS= SP AASHTO=

Remarks

Sample ID:14L341/14L342 Sampled 6-11-14 Recieved 7-3-14. Samples 14L341 &14L342 combined for sieve per clients request.

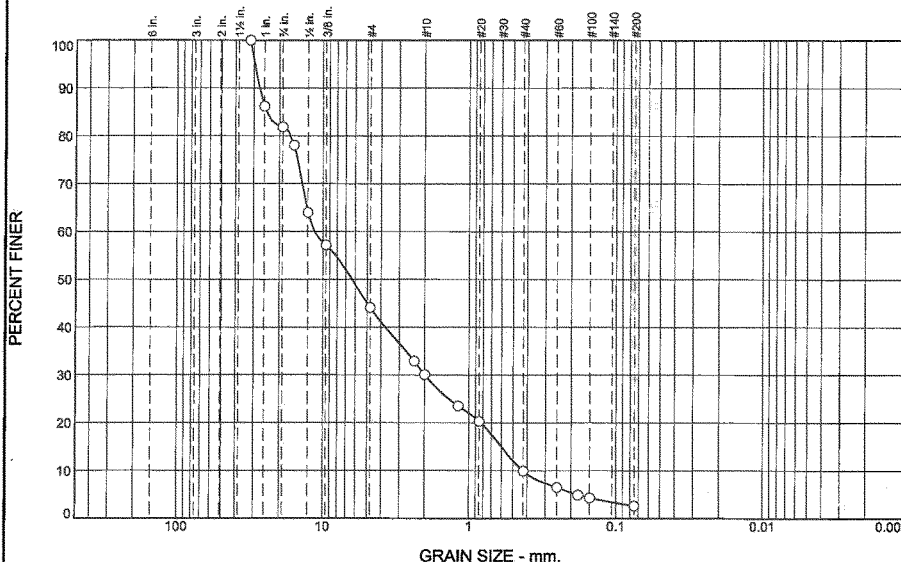
Location: BH-02 (6 Cal/7)
Sample Number: 14L341/14L342 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	18.1	37.8	14.0	20.2	7.3	2.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	86.2		
.75	81.9		
.625	78.1		
.5	64.0		
.375	57.2		
#4	44.1		
#8	32.9		
#10	30.1		
#16	23.5		
#20	20.3		
#40	9.9		
#60	6.5		
#80	4.9		
#100	4.3		
#200	2.6		

* (no specification provided)

Material Description

Poorly graded gravel with sand.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 27.4026 D_{85}= 24.5641 D_{60}= 11.4562
D_{50}= 6.3285 D_{30}= 1.9924 D_{15}= 0.5998
D_{10}= 0.4285 C_u= 26.74 C_c= 0.81

Classification

USCS= GP AASHTO=

Remarks

Sample ID:14L344 Sampled 6-12-14 Recieved 7-3-14
Moisture Content(ASTM D2216):7.5%

Location: BH 03R (1B)
Sample Number: 14L344

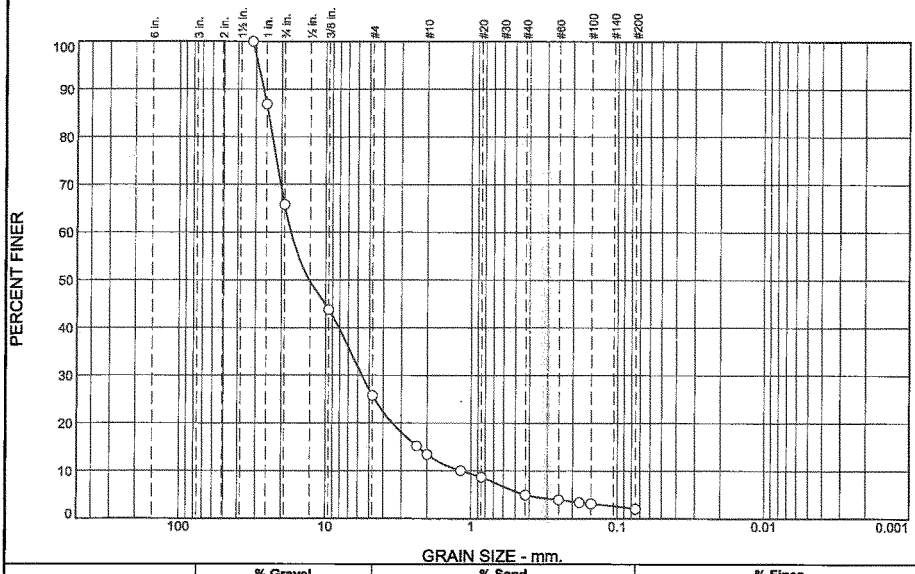
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	34.2	40.0	12.3	8.5	2.9	2.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	86.9		
.75	65.8		
.375	43.8		
#4	25.8		
#8	15.2		
#10	13.5		
#16	10.0		
#20	8.7		
#40	5.0		
#60	3.9		
#80	3.4		
#100	3.1		
#200	2.1		

* (no specification provided)

Material Description

Well graded gravel with sand.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 26.6349 D_{85}= 24.7256 D_{60}= 17.2058
D_{50}= 12.9094 D_{30}= 5.6312 D_{15}= 2.3091
D_{10}= 1.1709 C_u= 14.70 C_c= 1.57

Classification

USCS= GW AASHTO=

Remarks

Sample ID:14L345/14L346 Sampled 6-12-14 Received 7-3-14.
Moisture Content(ASTM D2216)6.4%
Sample 14L345 & 14L346 combined for sieve per client

Location: BH-03R (2/2 Cal)
Sample Number: 14L345/14L346

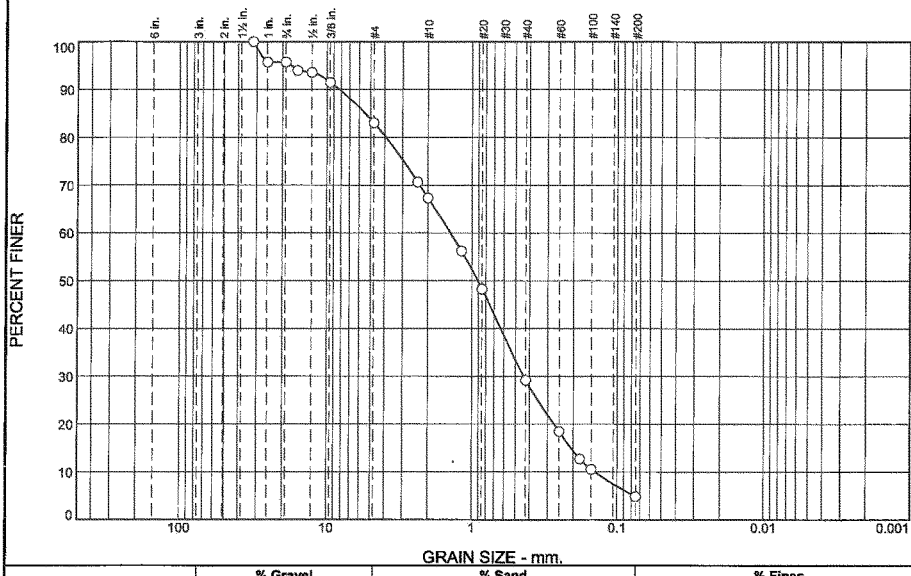
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.3	12.6	15.8	38.1	24.3	4.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	95.7		
.75	95.7		
.625	94.0		
.5	93.6		
.375	91.5		
#4	83.1		
#8	70.6		
#10	67.3		
#16	56.2		
#20	48.3		
#40	29.2		
#60	18.5		
#80	12.7		
#100	10.6		
#200	4.9		

* (no specification provided)

Material Description

Poorly graded sand with gravel.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 8.2574 D_{85}= 5.4391 D_{60}= 1.4033
D_{50}= 0.9082 D_{30}= 0.4392 D_{15}= 0.2076
D_{10}= 0.1417 C_u= 9.90 C_c= 0.97

Classification

USCS= SP AASHTO=

Remarks

Sample ID:14L348/14L349 Sampled 6-12-14 Received 7-3-14.
Moisture Content(ASTM D2216):18.2%
samples 14L348 & 14L349 combined for sieve.

Location: BH-03R (4/4 Cal)
Sample Number: 14L348/14L349

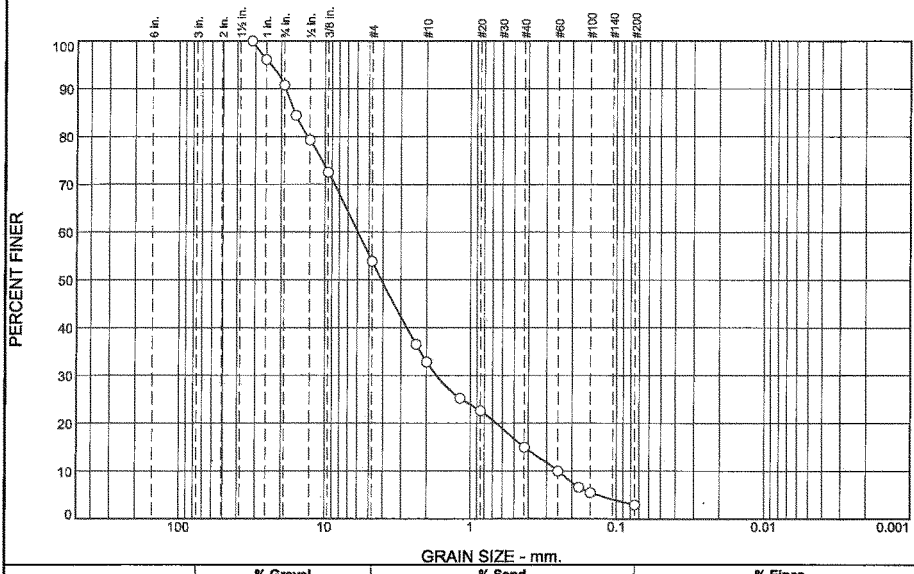
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.2	36.9	21.0	17.9	12.1	2.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	96.1		
.75	90.8		
.625	84.4		
.5	79.3		
.375	72.6		
#4	53.9		
#8	36.5		
#10	32.9		
#16	25.3		
#20	22.6		
#40	15.0		
#60	10.1		
#80	6.6		
#100	5.5		
#200	2.9		

* (no specification provided)

Material Description

Well graded sand with gravel.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 18.6018 D_{85}= 16.1542 D_{60}= 5.9575
D_{50}= 4.0941 D_{30}= 1.7151 D_{15}= 0.4254
D_{10}= 0.2487 C_u= 23.96 C_c= 1.99

Classification

USCS= SW AASHTO=

Remarks

Sample ID:14L350/14L351 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):9.4%
Samples 14L350/14L351 combined for sieve per clients

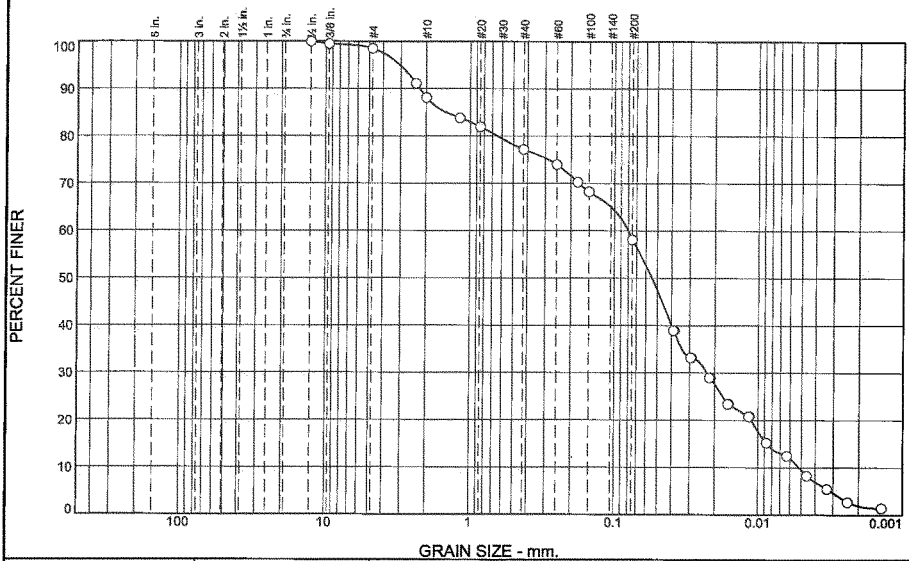
Location: BH-03R (7/7Cal)
Sample Number: 14L350/14L351 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.5	10.4	10.9	19.1	48.6	9.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.5	100.0		
.375	99.5		
#4	98.5		
#8	91.1		
#10	88.1		
#16	83.8		
#20	82.0		
#40	77.2		
#60	74.0		
#80	70.3		
#100	68.2		
#200	58.1		
.0388mm	38.9		
.0295mm	33.2		
.0218mm	29.0		
.0162mm	23.4		
.0116mm	20.8		
.0088mm	15.3		
.0064mm	12.5		
.0046mm	8.3		
.0033mm	5.5		
.0024mm	2.7		
.0014mm	1.4		

* (no specification provided)

Material Description

Sandy Silt

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 2.2202 D_{85}= 1.4766 D_{60}= 0.0801
D_{50}= 0.0545 D_{30}= 0.0227 D_{15}= 0.0086
D_{10}= 0.0052 C_u= 15.44 C_c= 1.24

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample ID:14L352/14L353 Sampled 6-12-14 Recieved 7-3-14. Moisture Content(ASTM D2216):34.3%/27.8% respectively. Samples combined for testing per clients request

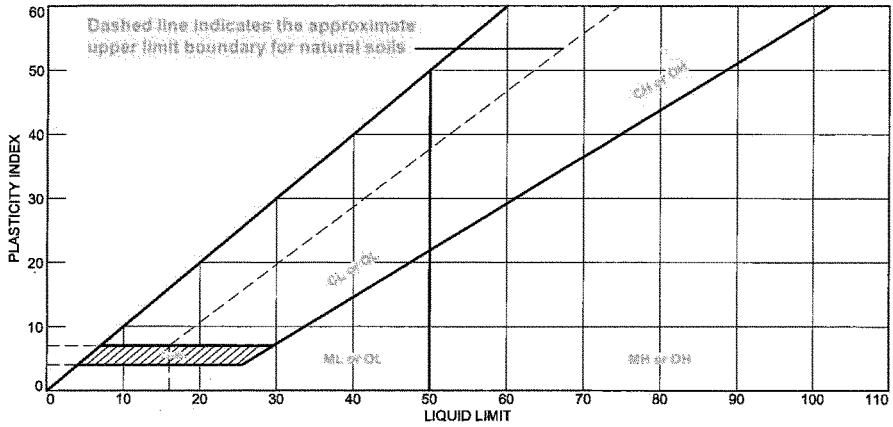
Location: BH 04 (1)
Sample Number: 14L352/14L353 **Date:** 7-3-14

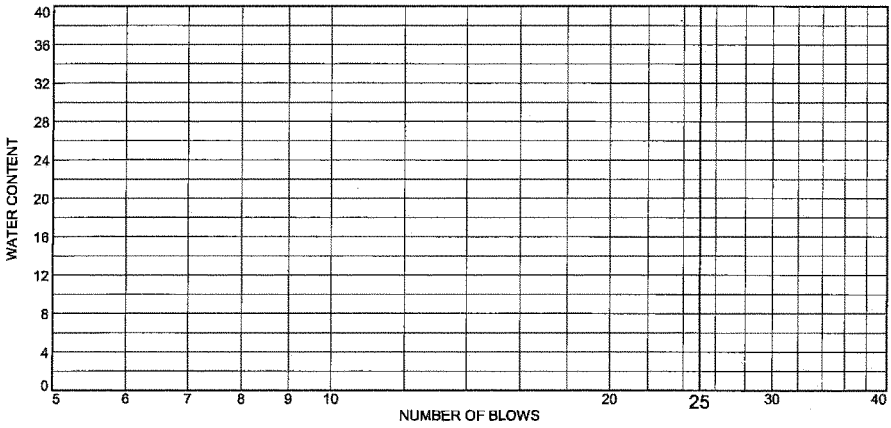
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Silt	NV	NP	NP	77.2	58.1	ML

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: BH 04 (1)
Sample Number: 14L352/14L353

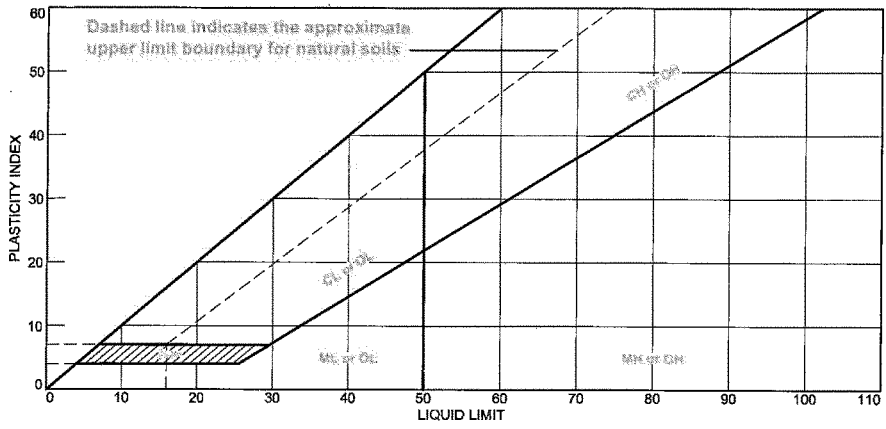
Krazan

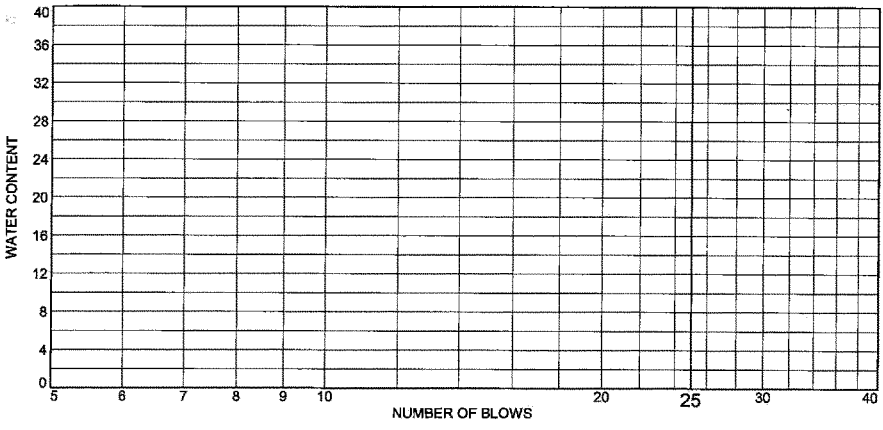
Remarks:
● Material was determined to be Non Plastic Per ASTM D4318 Section 18.1.1, Liquid Limit could not be determined.

Figure

Tested By: M.Thomas **Checked By:** M.Thomas VL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●		NV	NP	NP			

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: Bh 04 (4B)
Sample Number: 14L357

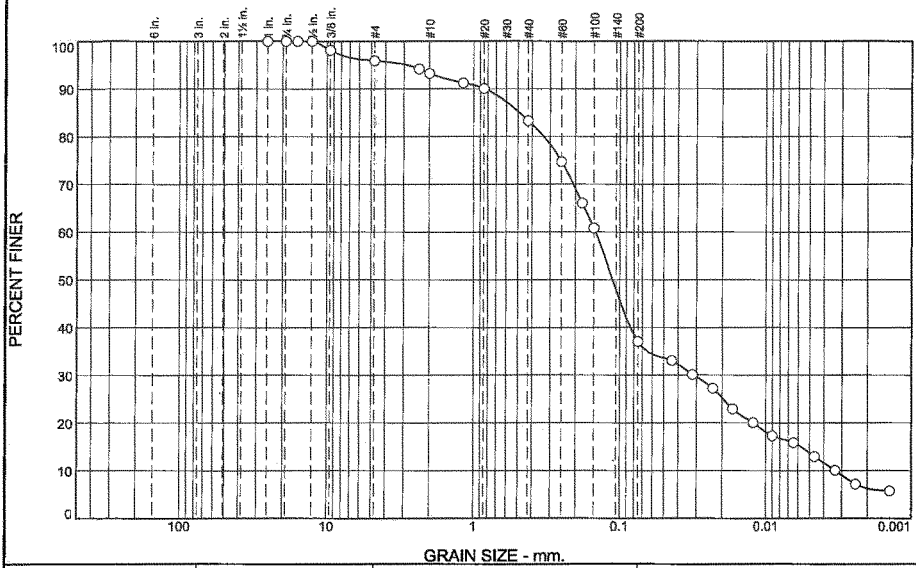
Remarks:
- Material was determined to be Non Plastic per ASTM D4318 Section 18.1.1, Liquid Limit could not be determined.

Krazan

Figure

Tested By: M.Thomas **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	4.1	2.7	9.9	46.3	23.3	13.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	100.0		
.625	100.0		
.5	100.0		
.375	98.1		
#4	95.9		
#8	94.2		
#10	93.2		
#16	91.3		
#20	90.1		
#40	83.3		
#60	74.7		
#80	66.1		
#100	60.8		
#200	37.0		
0.0441 mm.	33.1		
0.0320 mm.	30.2		
0.0232 mm.	27.3		
0.0169 mm.	23.9		
0.0122 mm.	20.0		
0.0090 mm.	17.3		
0.0064 mm.	15.9		
0.0046 mm.	13.0		
0.0033 mm.	10.1		
0.0024 mm.	7.2		
0.0014 mm.	5.7		

* (no specification provided)

Soil Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.8358 D_{85}= 0.4873 D_{60}= 0.1464
D_{50}= 0.1120 D_{30}= 0.0314 D_{15}= 0.0057
D_{10}= 0.0033 C_u= 44.20 C_c= 2.03

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample ID:14L358. Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):36.0%

Location: BH 04 (5A)
Sample Number: 14L358

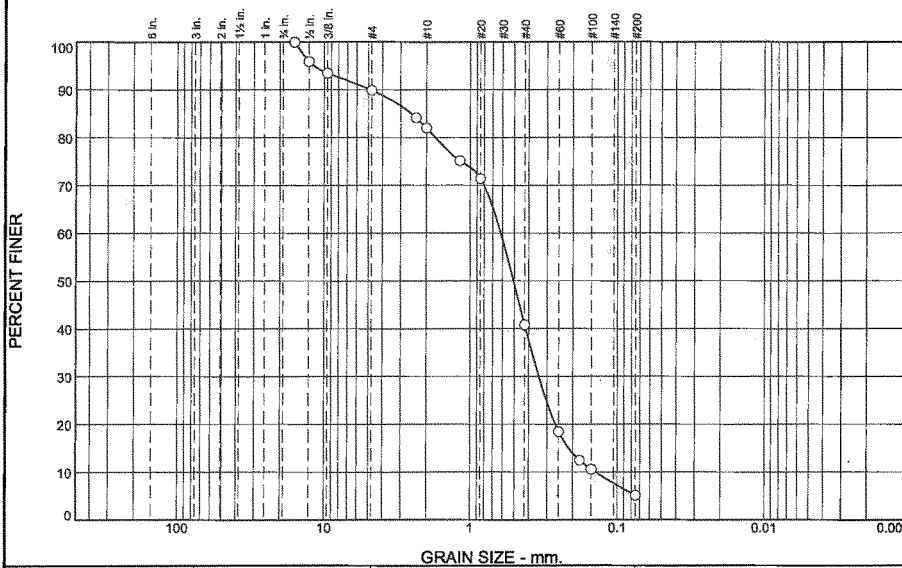
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	10.1	7.9	41.2	35.7	5.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.625	100.0		
.5	95.9		
.375	93.5		
#4	89.9		
#8	84.1		
#10	82.0		
#16	75.1		
#20	71.4		
#40	40.8		
#60	18.5		
#80	12.5		
#100	10.6		
#200	5.1		

* (no specification provided)

Material Description

Poorly graded sand with silt.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 4.8403 D_{85}= 2.5468 D_{60}= 0.6174
D_{50}= 0.5059 D_{30}= 0.3411 D_{15}= 0.2143
D_{10}= 0.1409 C_u= 4.38 C_c= 1.34

Classification

USCS= SP-SM AASHTO= A-1-b

Remarks

Sample ID:14L359 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216)24.2%

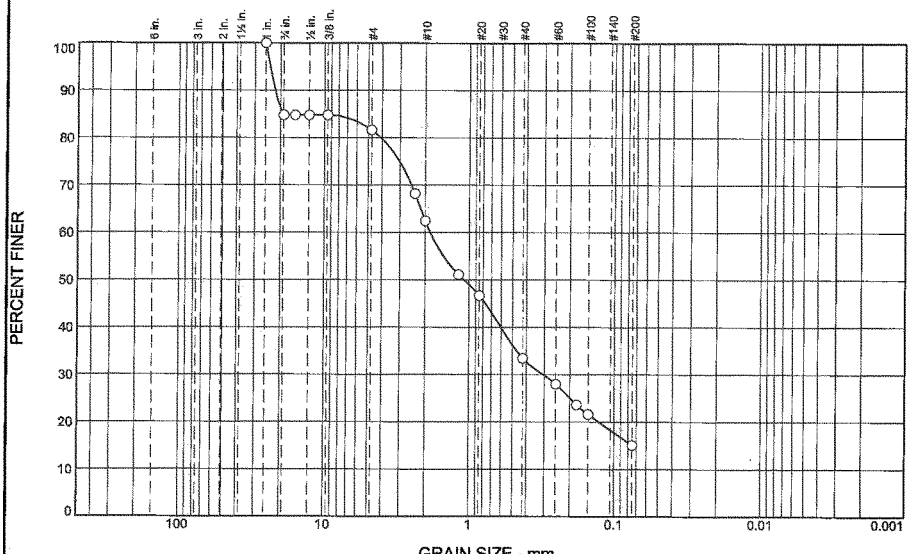
Location: BH 04 (6)
Sample Number: 14L359 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	15.2	3.2	19.2	28.9	18.4	15.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	84.8		
.625	84.8		
.5	84.8		
.375	84.8		
#4	81.6		
#8	68.2		
#10	62.4		
#16	51.1		
#20	46.7		
#40	33.5		
#60	28.0		
#80	23.6		
#100	21.6		
#200	15.1		

* (no specification provided)

Soil Description

Silty sand with gravel.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 21.7790 D_{85}= 19.2486 D_{60}= 1.8486
D_{50}= 1.0840 D_{30}= 0.3055 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample ID:14L360 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):28.6%

Location: BH 05R (1A)
Sample Number: 14L360

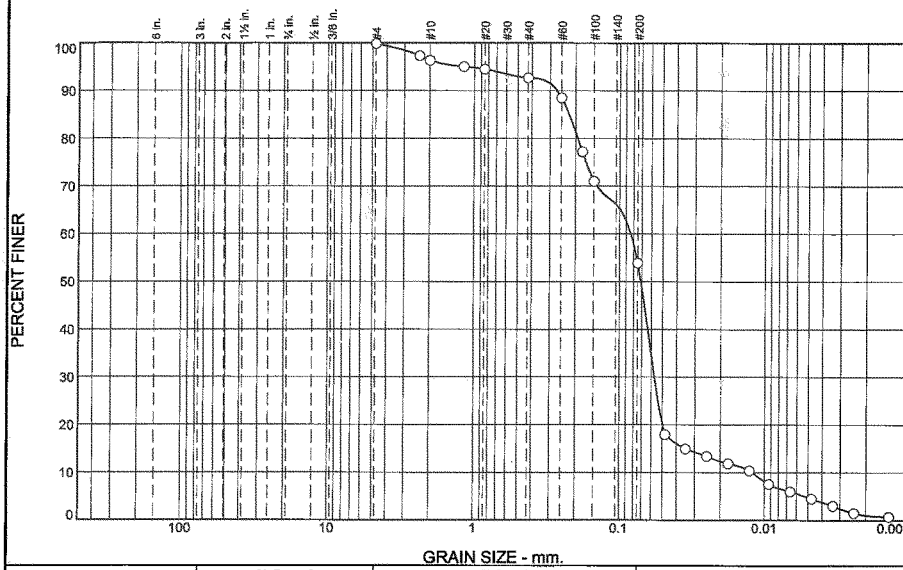
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
			3.4	3.7	38.8	49.1	4.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	99.8		
#8	97.3		
#10	96.4		
#16	95.1		
#20	94.5		
#40	92.7		
#60	88.5		
#80	77.2		
#100	71.0		
#200	53.9		
0.0480 mm.	18.0		
0.0347 mm.	14.9		
0.0248 mm.	13.4		
0.0177 mm.	11.9		
0.0126 mm.	10.4		
0.0093 mm.	7.5		
0.0066 mm.	6.0		
0.0047 mm.	4.5		
0.0034 mm.	3.0		
0.0024 mm.	1.5		
0.0014 mm.	0.7		

* (no specification provided)

Soil Description

Sandy silt.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2681 D_{85}= 0.2217 D_{60}= 0.0836
D_{50}= 0.0712 D_{30}= 0.0570 D_{15}= 0.0350
D_{10}= 0.0121 C_u= 6.92 C_c= 3.22

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample ID:14L362 Sampled 6-12-14 Recieved 7-3-14
Moisture Content(ASTM D2216):32.4%

Location: BH 05R (2)
Sample Number: 14L362

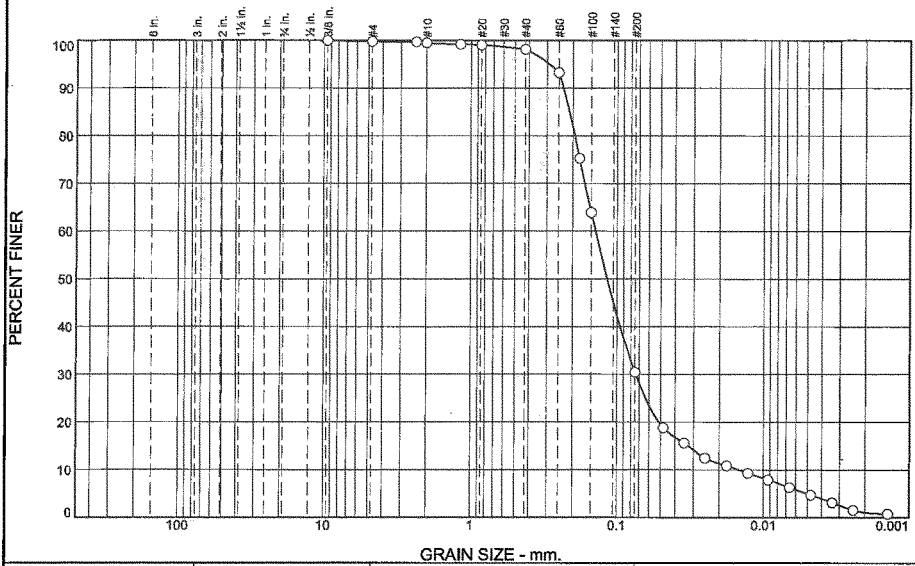
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.2	0.3	1.4	67.7	25.4	5.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.8		
#8	99.7		
#10	99.5		
#16	99.2		
#20	99.0		
#40	98.1		
#60	93.3		
#80	75.3		
#100	63.9		
#200	30.4		
0.0480 mm.	18.8		
0.0347 mm.	15.6		
0.0250 mm.	12.5		
0.0179 mm.	10.9		
0.0128 mm.	9.3		
0.0093 mm.	7.9		
0.0066 mm.	6.3		
0.0047 mm.	4.7		
0.0034 mm.	3.1		
0.0024 mm.	1.5		
0.0014 mm.	0.8		

* (no specification provided)

Soil Description

Silty sand.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2316 D_{85}= 0.2108 D_{60}= 0.1405
D_{50}= 0.1171 D_{30}= 0.0741 D_{15}= 0.0324
D_{10}= 0.0148 C_u= 9.52 C_c= 2.65

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample ID:14L362 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):40.9%

Location: BH 05R (3)
Sample Number: 14L363

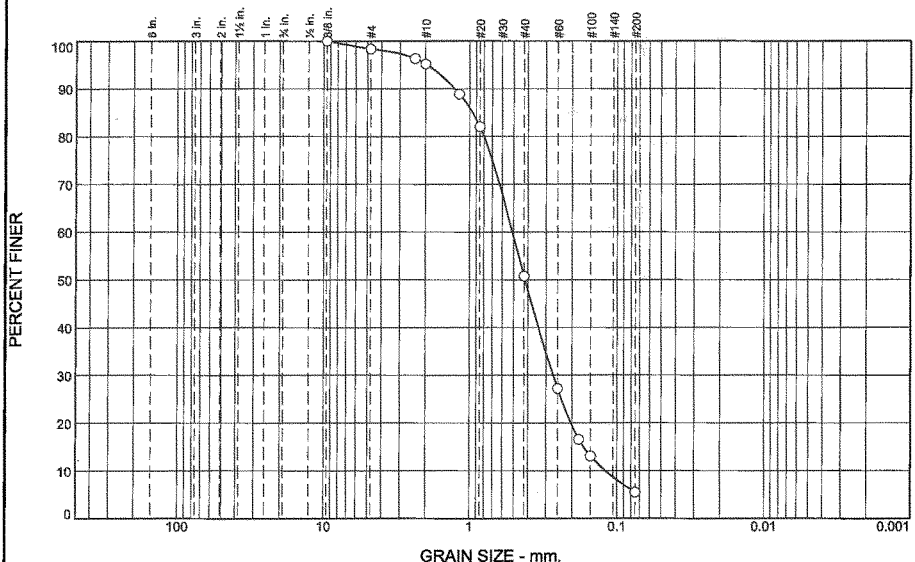
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.7	3.1	44.5	45.2	5.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	98.3		
#8	96.3		
#10	95.2		
#16	88.9		
#20	82.1		
#40	50.7		
#60	27.2		
#80	16.5		
#100	13.1		
#200	5.5		

* (no specification provided)

Soil Description

Poorly graded sand with silt.

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.2682 D_{85}= 0.9522 D_{60}= 0.5104
D_{50}= 0.4187 D_{30}= 0.2683 D_{15}= 0.1676
D_{10}= 0.1198 C_u= 4.26 C_c= 1.18

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Sample ID:14L364 Sampled 6-10-14 Recieved 7-3-14.

Location: BH 05R (6A)
Sample Number: 14L364

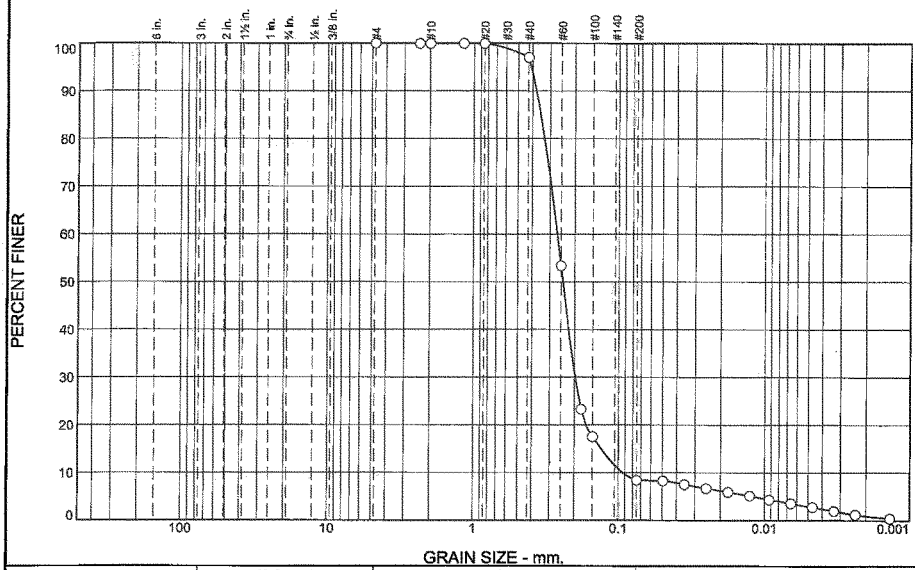
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	3.0	88.6	5.5	2.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	100.0		
#10	100.0		
#16	100.0		
#20	99.9		
#40	97.0		
#60	53.4		
#80	23.3		
#100	17.5		
#200	8.4		
0.0497 mm.	8.3		
0.0353 mm.	7.5		
0.0251 mm.	6.7		
0.0178 mm.	5.9		
0.0126 mm.	5.1		
0.0093 mm.	4.3		
0.0066 mm.	3.6		
0.0047 mm.	2.8		
0.0033 mm.	2.0		
0.0024 mm.	1.2		
0.0014 mm.	0.4		

* (no specification provided)

Soil Description

poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.3745 D_{85}= 0.3492 D_{60}= 0.2662
D_{50}= 0.2423 D_{30}= 0.1983 D_{15}= 0.1315
D_{10}= 0.0933 C_u= 2.85 C_c= 1.58

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Sample ID:14L366 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):38.0%

Location: BH 07R (2B)
Sample Number: 14L366

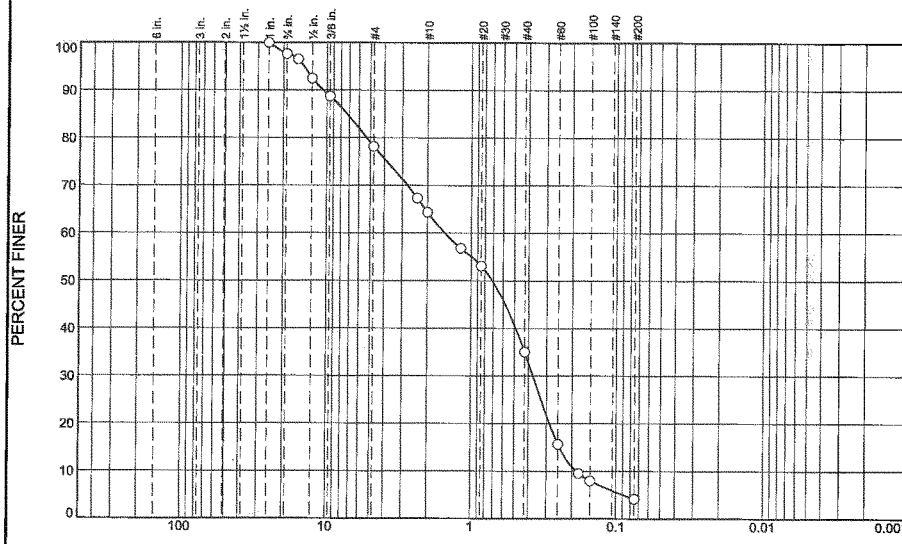
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.4	19.4	13.8	29.4	30.9	4.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	97.6		
.625	96.5		
.5	92.5		
.375	88.7		
#4	78.2		
#8	67.4		
#10	64.4		
#16	56.8		
#20	53.1		
#40	35.0		
#60	15.7		
#80	9.5		
#100	8.0		
#200	4.1		

* (no specification provided)

Soil Description

poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 10.6400 D_{85}= 7.2628 D_{60}= 1.5229
D_{50}= 0.7136 D_{30}= 0.3727 D_{15}= 0.2441
D_{10}= 0.1877 C_u= 8.11 C_c= 0.49

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample ID:14L367 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):17.6%

Location: BH 07R (3 Cal)
Sample Number: 14L367

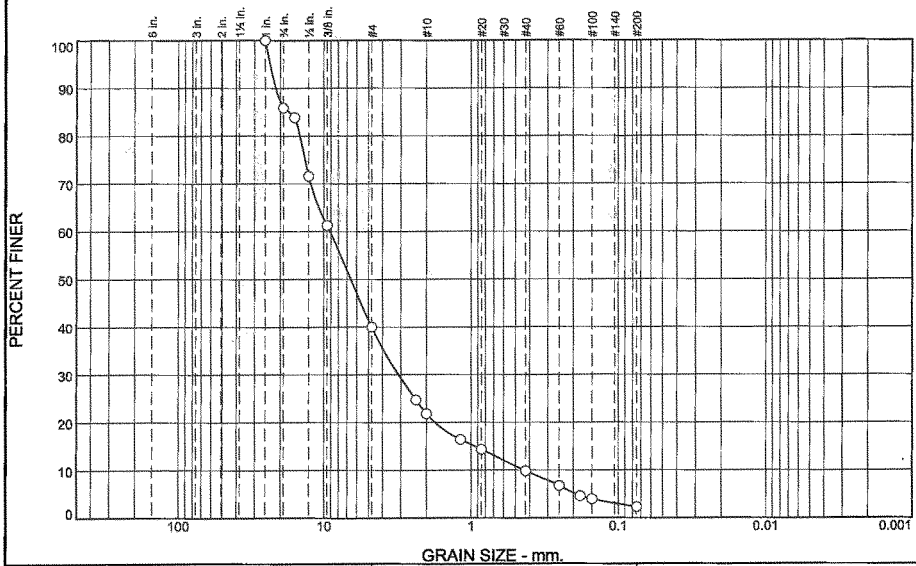
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	14.1	45.9	18.1	12.1	7.5	2.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	85.9		
.625	83.9		
.5	71.6		
.375	61.3		
#4	40.0		
#8	24.7		
#10	21.9		
#16	16.4		
#20	14.4		
#40	9.8		
#60	6.7		
#80	4.6		
#100	3.9		
#200	2.3		

* (no specification provided)

Soil Description

well-graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 21.4824 D_{85}= 16.9927 D_{60}= 9.1035
D_{50}= 6.5936 D_{30}= 3.1097 D_{15}= 0.9412
D_{10}= 0.4364 C_u= 20.86 C_c= 2.43

Classification

USCS= GW AASHTO= A-1-a

Remarks

Sample ID:14L369/14L370 Sampled 6-12-14 recieved 7-3-14.
Moisture Content(ASTM D2216):9.9%
samples 14L369 & 14L370 combined for sieve per client

Location: BH 07R (5Cal/5)
Sample Number: 14L369/14L370

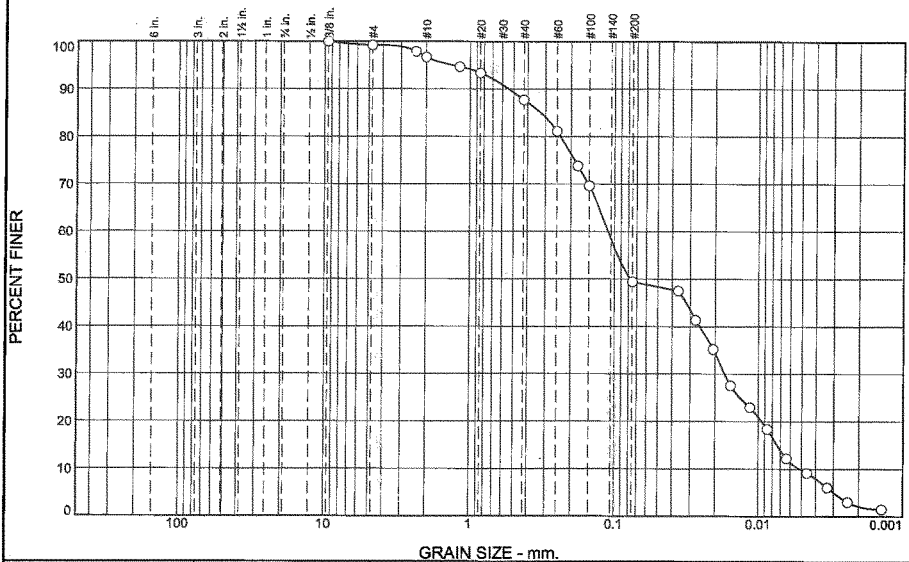
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.8	2.5	9.0	38.3	39.6	9.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	99.2		
#8	97.9		
#10	96.7		
#16	94.2		
#20	93.4		
#40	87.7		
#60	81.1		
#80	73.8		
#100	69.6		
#200	49.4		
0.0362 mm.	47.5		
0.0273 mm.	41.4		
0.0206 mm.	35.2		
0.0156 mm.	27.6		
0.0115 mm.	23.0		
0.0087 mm.	18.4		
0.0064 mm.	12.2		
0.0046 mm.	9.2		
0.0033 mm.	6.1		
0.0024 mm.	3.0		
0.0014 mm.	1.5		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= NP LL= PI=

Coefficients

D_{90}= 0.5446 D_{85}= 0.3241 D_{60}= 0.1110
D_{50}= 0.0780 D_{30}= 0.0172 D_{15}= 0.0074
D_{10}= 0.0052 C_u= 21.49 C_c= 0.51

Classification

USCS= AASHTO=

Remarks

Sample ID:14L371/14L372 Sampled 6-9-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):28.9%
Samples 14L371 & 14L372 combined for testing per client

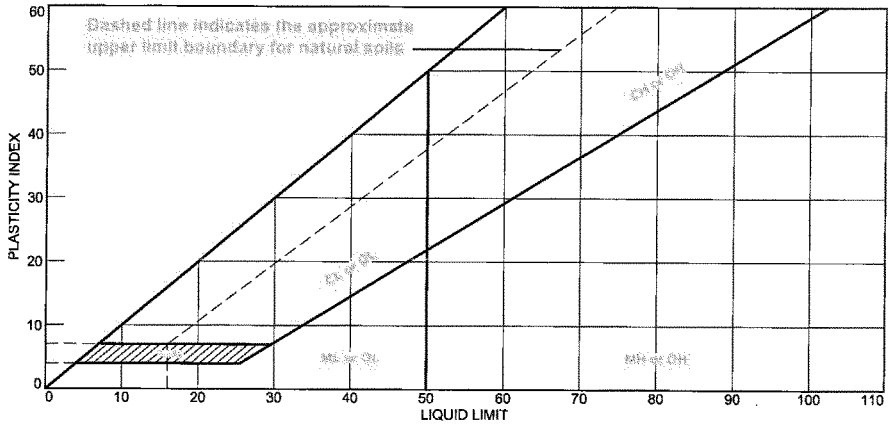
Location: BH 08 (1/2)
Sample Number: 14L371/14L372 **Date:** 7-3-14

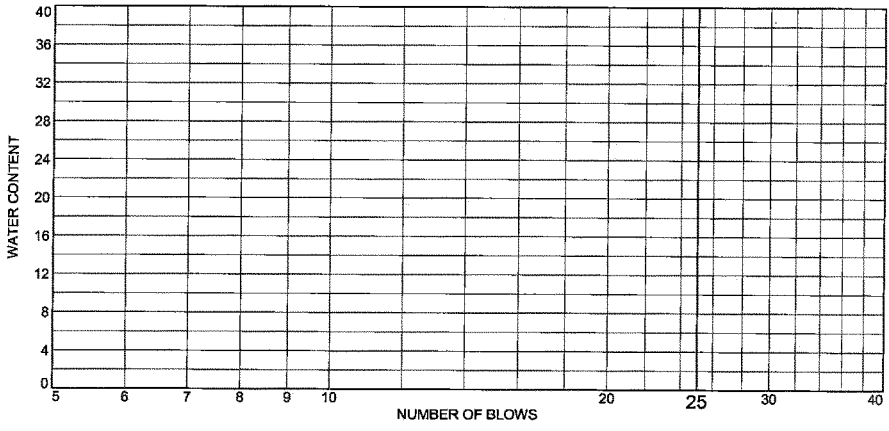
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	silty sand	NV	NP	NP	87.7	49.4	SM

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: BH 08 (1/2)
Sample Number: 14L371/14L372

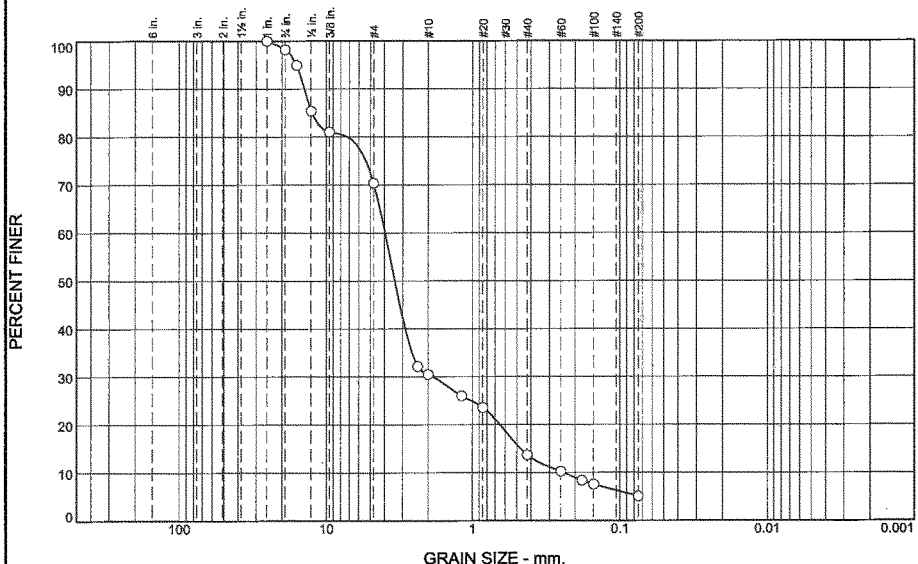
Remarks:
- Material was determined to be non plastic per ASTM D 4318 section 18.1.1.

Krazan

Figure

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	1.8	27.8	39.9	16.8	8.6	5.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	98.2		
.625	95.0		
.5	85.4		
.375	81.1		
#4	70.4		
#8	32.2		
#10	30.5		
#16	26.0		
#20	23.6		
#40	13.7		
#60	10.3		
#80	8.4		
#100	7.5		
#200	5.1		

* (no specification provided)

Soil Description

poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 14.1175 D_{85}= 12.5481 D_{60}= 3.9543
D_{50}= 3.3956 D_{30}= 1.8527 D_{15}= 0.4720
D_{10}= 0.2383 C_u= 16.59 C_c= 3.64

Classification

USCS= AASHTO=

Remarks

Sample ID:14L375 Sampled 6-9-14 Recieved 7-3-14.

Location: BH 08 (5)
Sample Number: 14L375

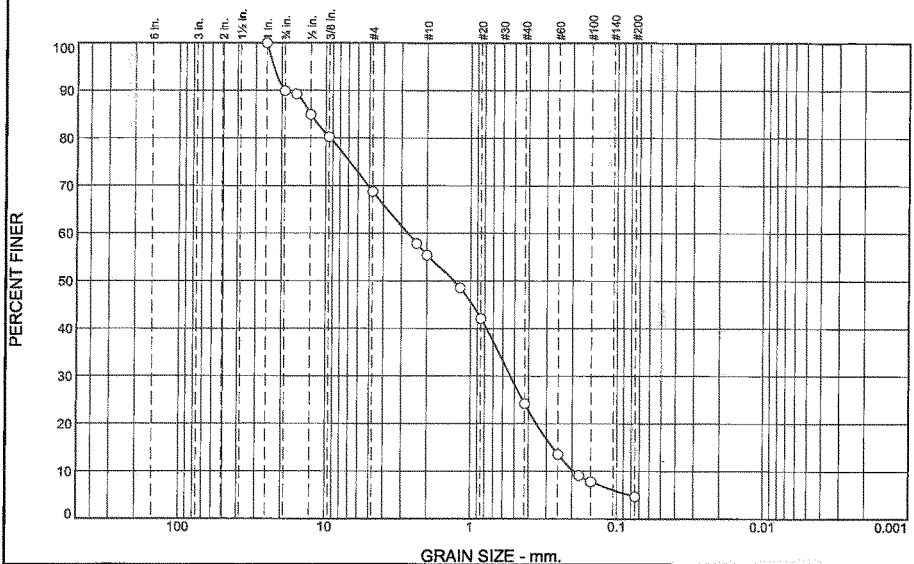
Date: 7-1-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	10.1	21.1	13.4	31.2	19.5	4.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	89.9		
.625	89.3		
.5	84.9		
.375	80.3		
#4	68.8		
#8	57.9		
#10	55.4		
#16	48.6		
#20	42.1		
#40	24.2		
#60	13.6		
#80	9.1		
#100	7.8		
#200	4.7		

* (no specification provided)

Soil Description

poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 19.1275 D_{85}= 12.7305 D_{60}= 2.7139
D_{50}= 1.3014 D_{30}= 0.5330 D_{15}= 0.2720
D_{10}= 0.1953 C_u= 13.90 C_c= 0.54

Classification

USCS= SP AASHTO= A-1-b

Remarks

sample ID:14L376/14L377 Sampled 6-9-14 Recieved 7-3-14
Moisture Content(ASTM D2216):19.5%
Samples 14L376/14L377 combined for sieve per client request.

Location: BH 08 (6/6 Cal)
Sample Number: 14L376/14L377

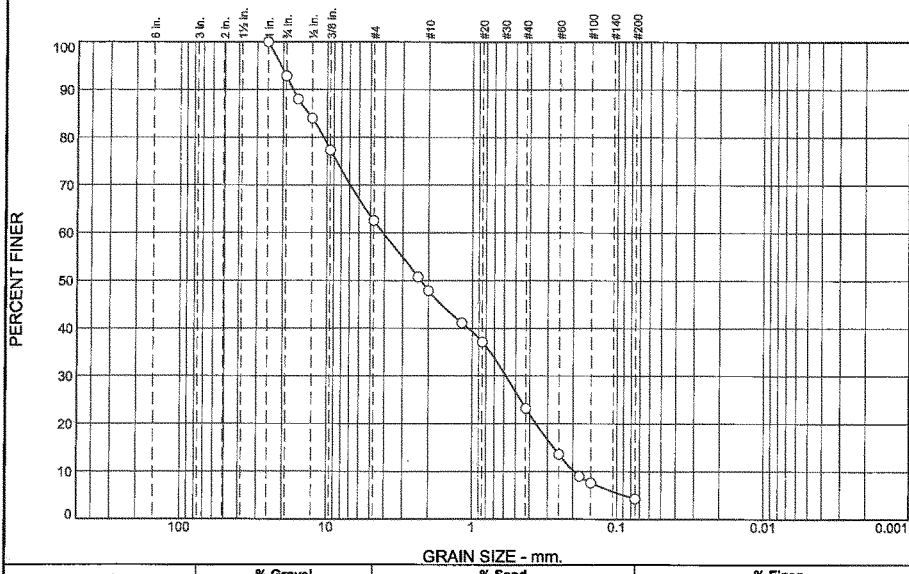
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	7.1	30.3	14.7	24.7	18.9	4.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	92.9		
.625	88.0		
.5	84.0		
.375	77.3		
#4	62.6		
#8	50.8		
#10	47.9		
#16	41.2		
#20	37.1		
#40	23.2		
#60	13.6		
#80	9.0		
#100	7.6		
#200	4.3		

* (no specification provided)

Soil Description

poorly graded sand with gravel
Organic Content(ASTM D2974):1.7%

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 17.1675 D_{85}= 13.4370 D_{60}= 4.0993
D_{50}= 2.2587 D_{30}= 0.5834 D_{15}= 0.2719
D_{10}= 0.1965 C_u= 20.86 C_c= 0.42

Classification

USCS= SP AASHTO= A-1-a

Remarks

Sample ID:14L379/14L380 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):18.3%
Samples 14L379 & 14L380 combined for sieve per client

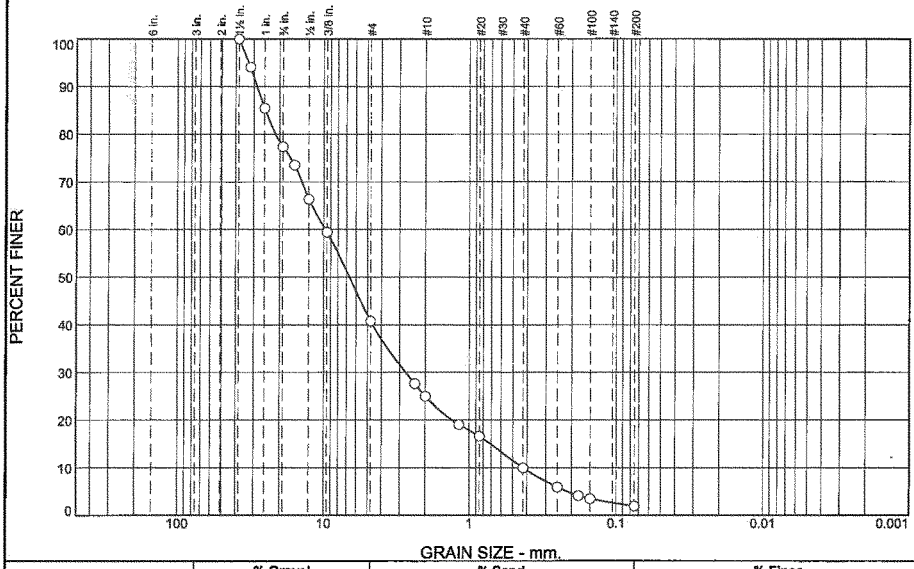
Location: BH 09R (3/3 Cal)
Sample Number: 14L379/14L380 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	22.6	36.6	15.8	15.1	8.0	1.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1.25	94.1		
1	85.5		
.75	77.4		
.625	73.5		
.5	66.4		
.375	59.4		
#4	40.8		
#8	27.6		
#10	25.0		
#16	19.1		
#20	16.6		
#40	9.9		
#60	5.9		
#80	4.1		
#100	3.5		
#200	1.9		

* (no specification provided)

Soil Description

well-graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 28.5517 D_{85}= 25.0849 D_{60}= 9.7688
D_{50}= 6.6741 D_{30}= 2.7255 D_{15}= 0.7101
D_{10}= 0.4278 C_u= 22.83 C_c= 1.78

Classification

USCS= GW AASHTO= A-1-a

Remarks

Sample ID:14L382/14L383 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):13.6%
Samples 14L382 & 14L383 combined for sieve per client

Location: BH 09 (5/5Cal)
Sample Number: 14L382/14L383

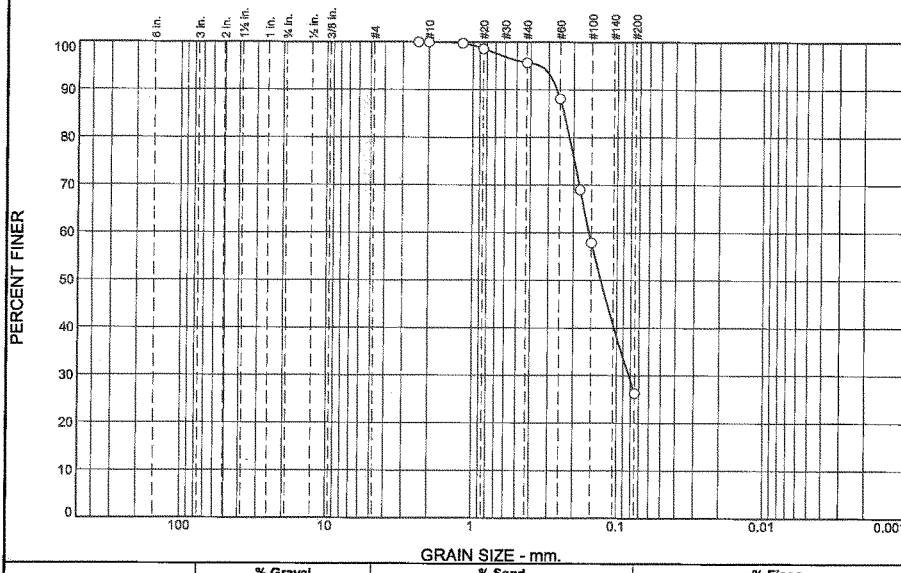
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	4.3	69.4	26.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0		
#10	100.0		
#16	99.7		
#20	98.6		
#40	95.7		
#60	88.1		
#80	69.0		
#100	57.9		
#200	26.3		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 0.2626 D_{85}= 0.2339 D_{60}= 0.1556
D_{50}= 0.1295 D_{30}= 0.0823 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample ID:14L384 Sampled 6-12-14 Recieved 7-3-14
Moisture Content(ASTM D2216):41.3%

Location: BH-10 (1)
Sample Number: 14L384

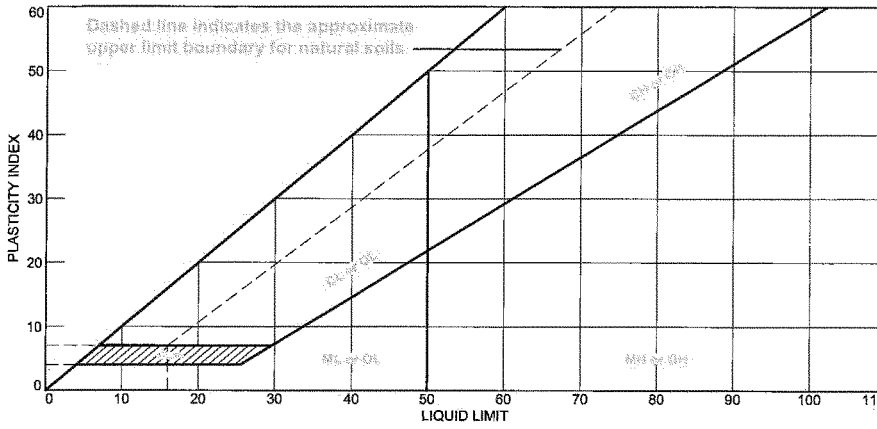
Date: 7-3-14

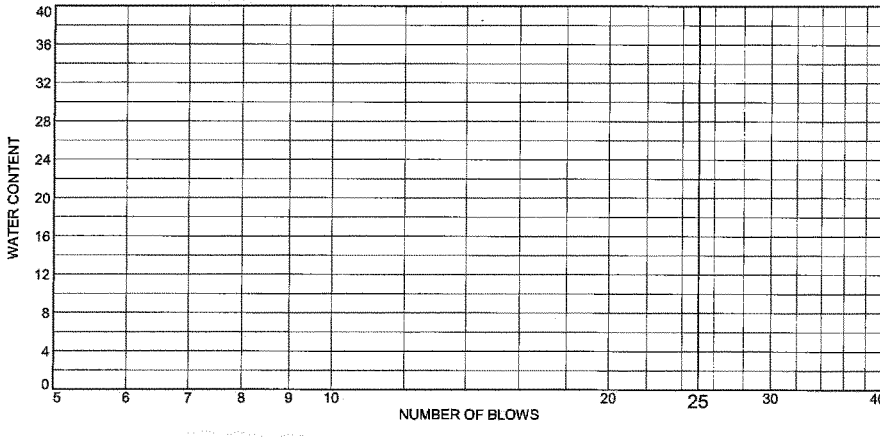
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	silty sand	NV	NP	NP	95.7	26.3	SM

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: BH-10 (1)
Sample Number: 14L384

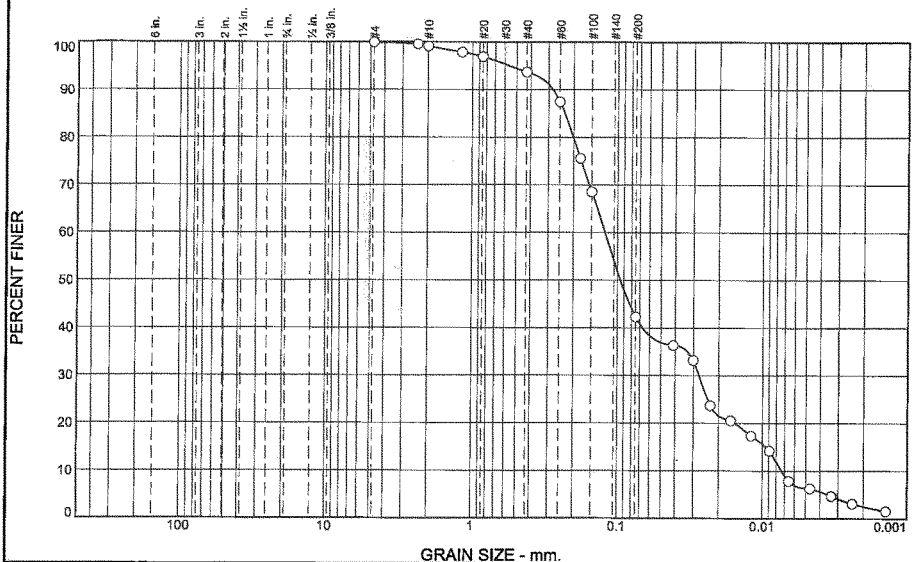
Krazan

Remarks:
● Material was determined to be Non-Plastic per ASTM D4318 Section 18.1.1.

Figure

Tested By: N.Adams **Checked By:** M.Thomas

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.9	5.4	51.4	35.9	6.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	99.6		
#10	99.1		
#16	97.9		
#20	96.9		
#40	93.7		
#60	87.5		
#80	75.6		
#100	68.5		
#200	42.3		
0.0413 mm.	36.4		
0.0300 mm.	33.2		
0.0229 mm.	23.7		
0.0166 mm.	20.5		
0.0120 mm.	17.4		
0.0089 mm.	14.2		
0.0066 mm.	7.9		
0.0047 mm.	6.3		
0.0033 mm.	4.7		
0.0024 mm.	3.1		
0.0014 mm.	1.5		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 0.2793 D_{85}= 0.2305 D_{60}= 0.1221
D_{50}= 0.0955 D_{30}= 0.0273 D_{15}= 0.0094
D_{10}= 0.0074 C_u= 16.60 C_c= 0.83

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample ID:14L385 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):30.8%

Location: BH-10 (2)
Sample Number: 14L385

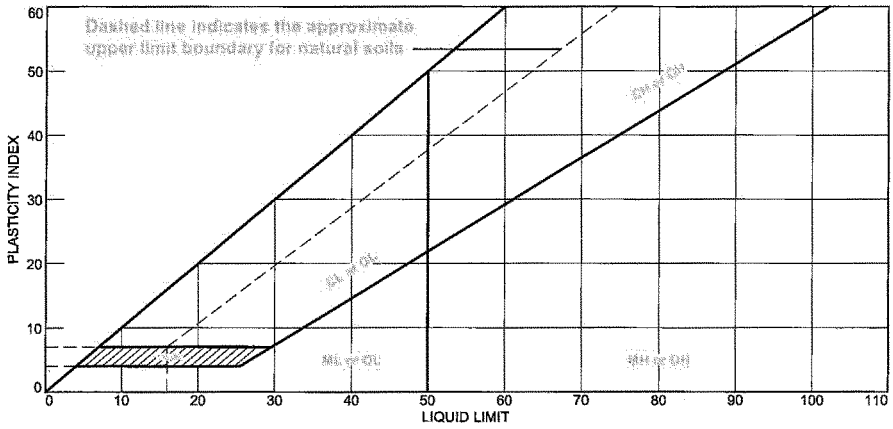
Date: 7-3-14

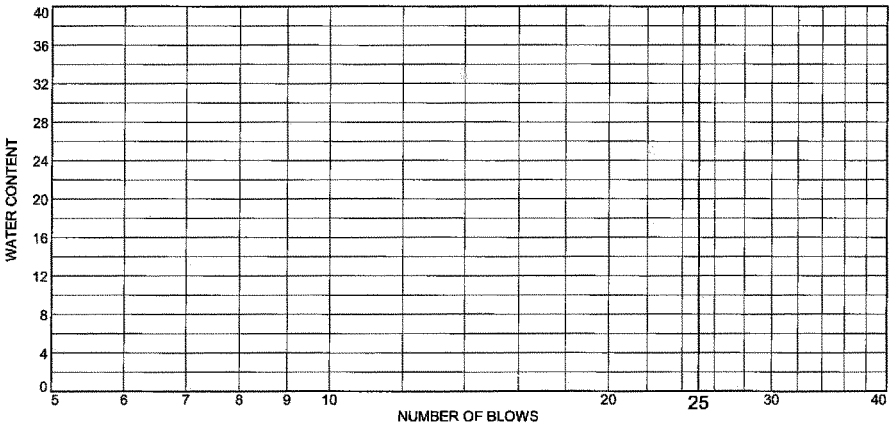
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	silty sand	NV	NP	NP	93.7	42.3	SM

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: BH-10 (2)
Sample Number: 14L385

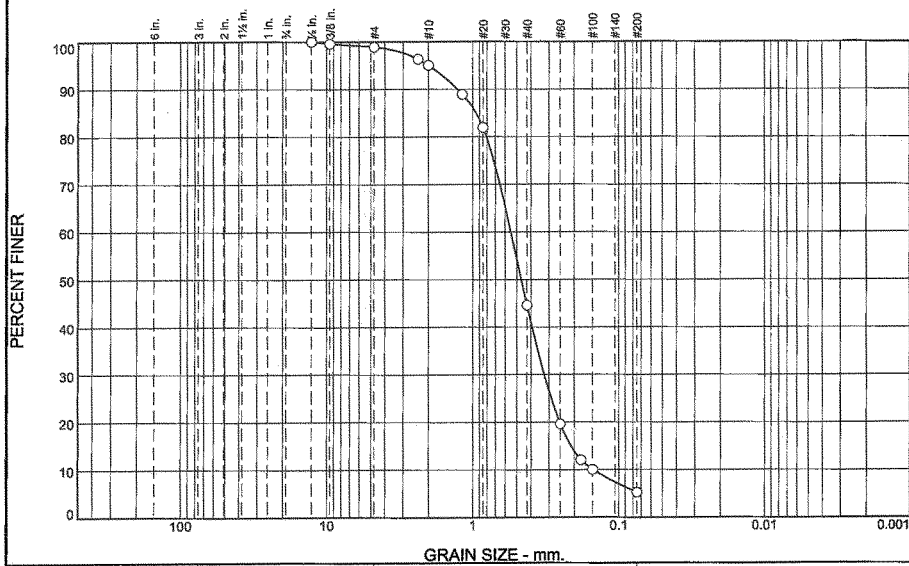
Krazan

Remarks:
- Material was determined to be non plastic per ASTM D4318 section 18.1.1.

Figure

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.1	3.8	50.5	39.4	5.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.5	100.0		
.375	99.6		
#4	98.9		
#8	96.4		
#10	95.1		
#16	89.0		
#20	82.0		
#40	44.6		
#60	19.6		
#80	12.1		
#100	10.1		
#200	5.2		

* (no specification provided)

Soil Description

poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.2707 D_{85}= 0.9457 D_{60}= 0.5483
D_{50}= 0.4654 D_{30}= 0.3233 D_{15}= 0.2113
D_{10}= 0.1490 C_u= 3.68 C_c= 1.28

Classification

USCS= SP-SM AASHTO= A-1-b

Remarks

Sample ID:14L387 Sampled 6-12-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):21.9%

Location: BH-10 (5)
Sample Number: 14L387

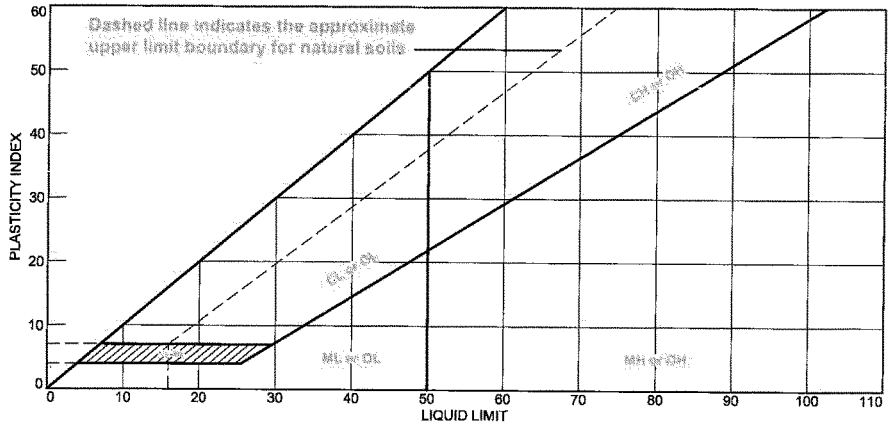
Date: 7-3-14

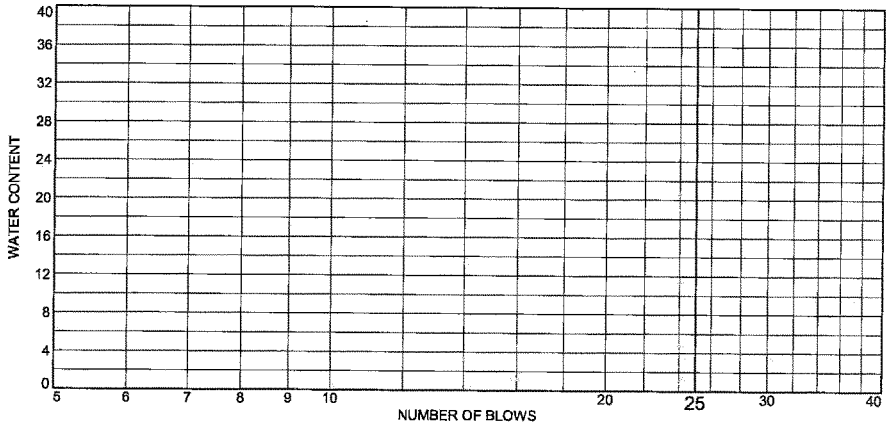
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	ML	NV	NP	NP			

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: BH-14R (2)
Sample Number: 14L390

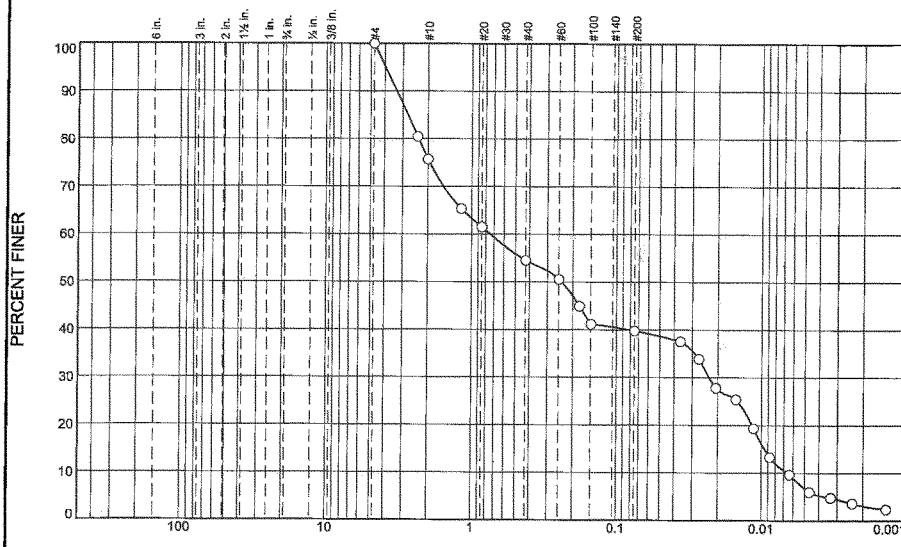
Krazan

Remarks:
- Material was determined to be Non Plastic per ASTM D3418 Section 18.1.1.

Figure

Tested By: A.Ayres **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	24.3	21.2	14.7	33.1	6.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	80.5		
#10	75.7		
#16	65.3		
#20	61.5		
#40	54.5		
#60	50.5		
#80	44.9		
#100	41.2		
#200	39.8		
0.0362 mm.	37.5		
0.0270 mm.	33.9		
0.0206 mm.	27.8		
0.0150 mm.	25.4		
0.0113 mm.	19.3		
0.0087 mm.	13.3		
0.0064 mm.	9.7		
0.0046 mm.	6.0		
0.0033 mm.	4.8		
0.0024 mm.	3.6		
0.0014 mm.	2.4		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 3.2975 D_{85}= 2.7602 D_{60}= 0.7445
D_{50}= 0.2397 D_{30}= 0.0230 D_{15}= 0.0095
D_{10}= 0.0066 C_u= 112.90 C_c= 0.11

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample ID:14L391/14L392 Sampled 6-13-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):55.1%
Sample 14L391 & 14L392 combined for testing per client

Location: BH-14R (3/3 Cal)
Sample Number: 14L391/14L392

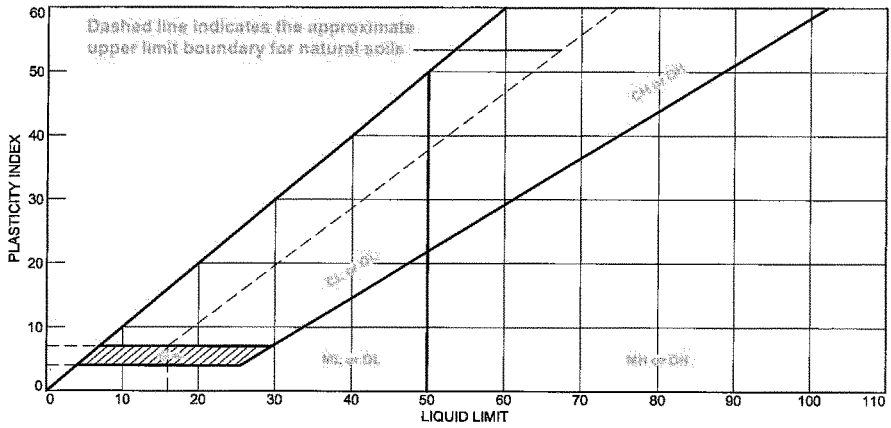
Date: 7-3-14

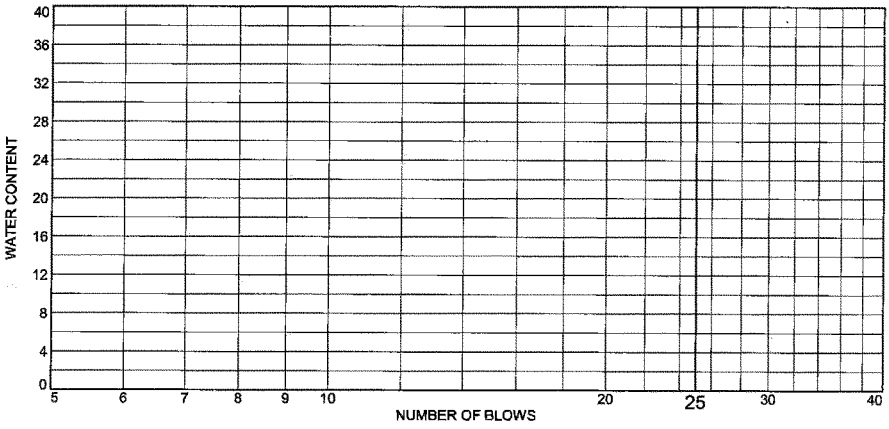
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	silty sand	NV	NP	NP	54.5	26.8	SM

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: BH-14R (3/3 Cal)
Sample Number: 14L391/14L392

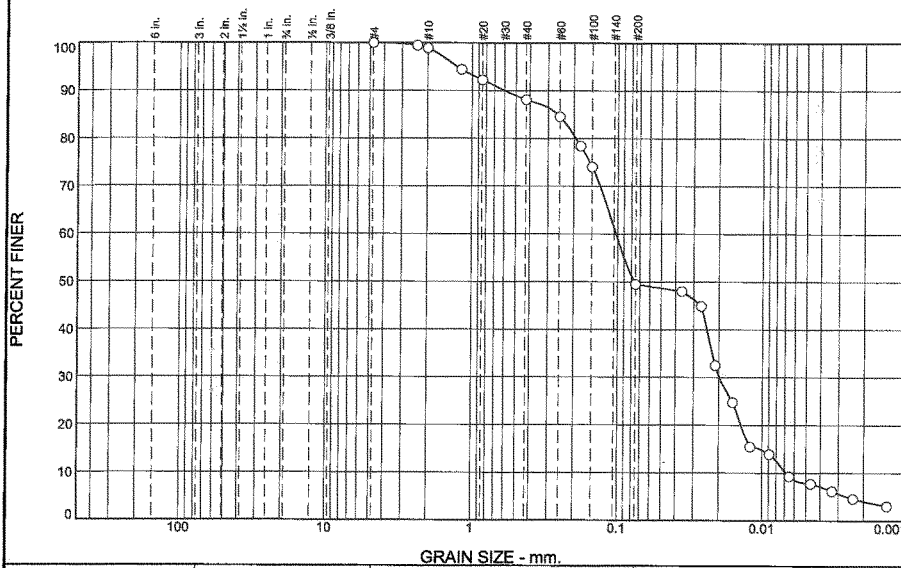
Krazan

Remarks:
- Material was determined to be Non Plastic per ASTM D4318 Section 18.1.1.

Figure

Tested By: A.Ayres **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	1.1	10.8	38.6	41.6	7.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	99.5		
#10	98.9		
#16	94.4		
#20	92.3		
#40	88.1		
#60	84.6		
#80	78.4		
#100	74.1		
#200	49.5		
0.0362 mm.	48.0		
0.0265 mm.	44.9		
0.0212 mm.	32.5		
0.0160 mm.	24.8		
0.0121 mm.	15.5		
0.0089 mm.	13.9		
0.0065 mm.	9.3		
0.0046 mm.	7.7		
0.0033 mm.	6.2		
0.0024 mm.	4.6		
0.0014 mm.	3.1		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.5974 D_{85}= 0.2586 D_{60}= 0.1027
D_{50}= 0.0767 D_{30}= 0.0199 D_{15}= 0.0103
D_{10}= 0.0069 C_u= 14.98 C_c= 0.56

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample ID:14L393 Sampled 6-13-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):47.3%

Location: BH-14R (4)
Sample Number: 14L393

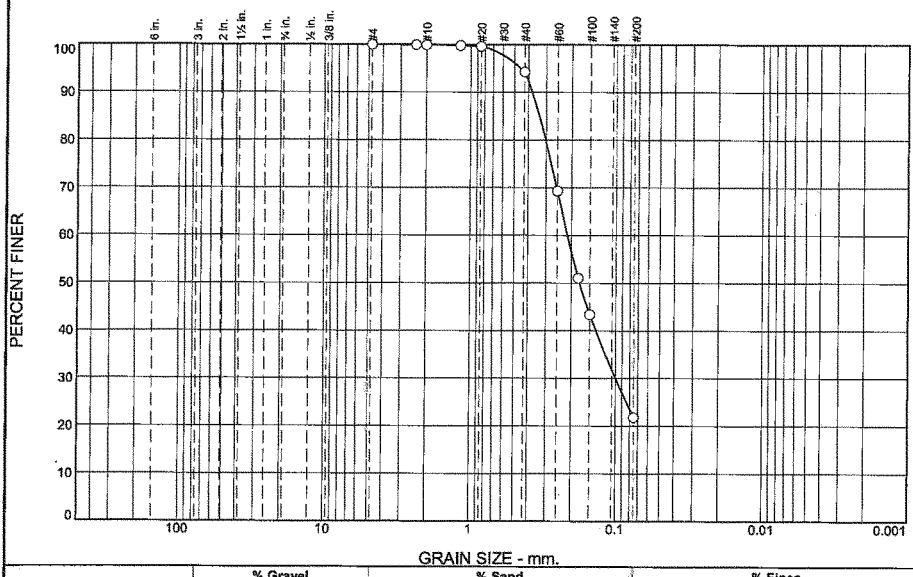
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.1	5.6	72.5	21.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	99.9		
#10	99.9		
#16	99.8		
#20	99.6		
#40	94.3		
#60	69.3		
#80	51.0		
#100	43.4		
#200	21.8		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.3752 D_{85}= 0.3344 D_{60}= 0.2132
D_{50}= 0.1762 D_{30}= 0.1000 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample ID14L395 Sample 6-13-14 Recieved 7-3-14
Moisture Content(ASTM D2216):31.0%

Location: BH-14R (5B)
Sample Number: 14L395

Date: 7-3-14

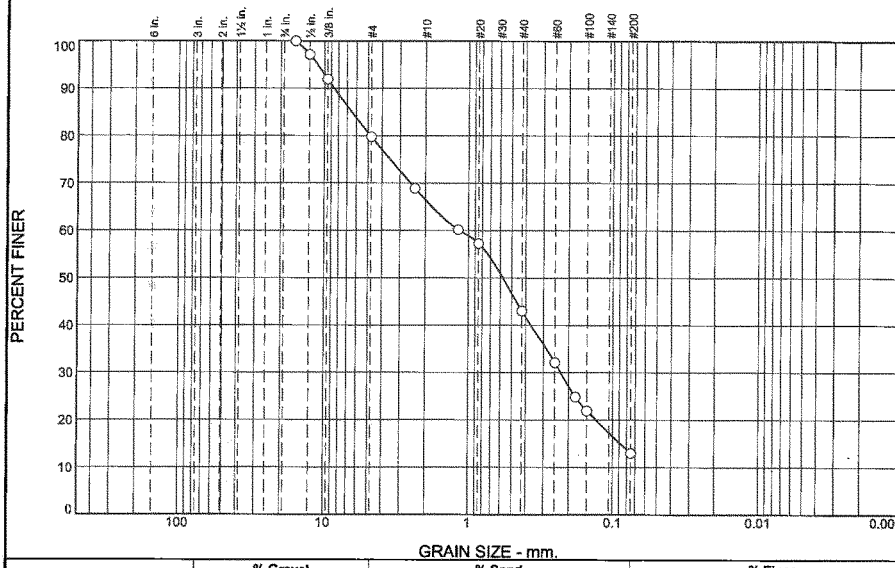
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179

Figure

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	20.2	13.3	23.5	30.0	13.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.625	100.0		
.5	97.2		
.375	91.9		
#4	79.8		
#8	68.9		
#16	60.2		
#20	57.3		
#40	43.0		
#60	32.1		
#80	24.9		
#100	21.9		
#200	13.0		

* (no specification provided)

Soil Description

silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 8.5974 D_{85}= 6.4934 D_{60}= 1.1553
D_{50}= 0.5764 D_{30}= 0.2279 D_{15}= 0.0883
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample ID:14L397 Sampled 6-11-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):4.9%

Location: BH-15 (1A)
Sample Number: 14L397

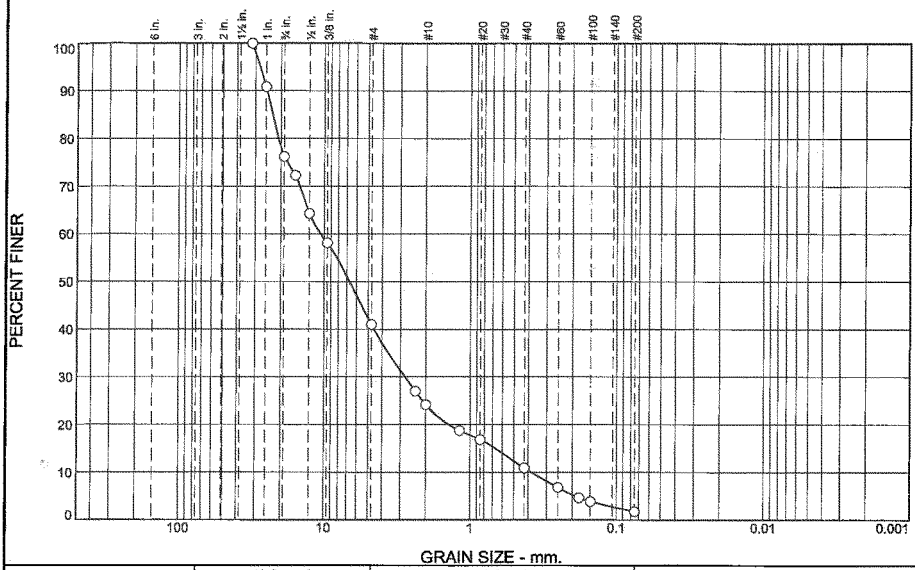
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	23.7	35.3	16.8	13.3	9.1	1.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	90.9		
.75	76.3		
.625	72.3		
.5	64.3		
.375	58.1		
#4	41.0		
#8	27.0		
#10	24.2		
#16	18.7		
#20	16.8		
#40	10.9		
#60	6.8		
#80	4.6		
#100	3.9		
#200	1.8		

* (no specification provided)

Soil Description

well-graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 24.9723 D_{85}= 22.8357 D_{60}= 10.6126
D_{50}= 6.7124 D_{30}= 2.7915 D_{15}= 0.6696
D_{10}= 0.3824 C_u= 27.75 C_c= 1.92

Classification

USCS= GW AASHTO= A-1-a

Remarks

Sample ID:14L399/14L400 Sampled 6-13-14 Recieved 7-3-14
Moisture Content(ASTM D2216):10.0%
Samples 14L399 & 14L400 combined for sieve per client

Location: BH-15 (3/3 Cal)
Sample Number: 14L399/14L400

Date: 7-3-14

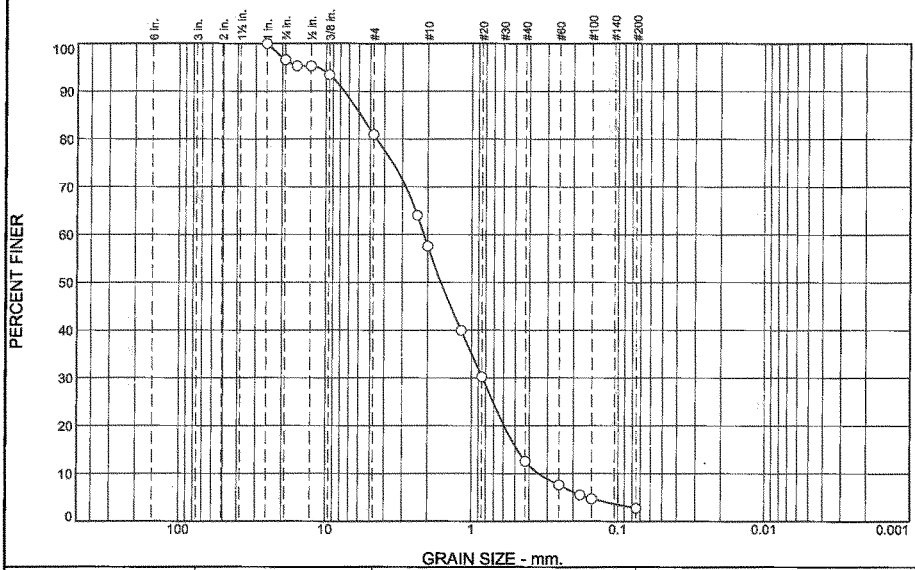
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

VL

Tested By: N.Adams **Checked By:** M.Thomas

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	3.4	15.6	23.4	45.0	9.8	2.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1	100.0		
.75	96.6		
.625	95.3		
.5	95.3		
.375	93.4		
#4	81.0		
#8	64.1		
#10	57.6		
#16	40.0		
#20	30.2		
#40	12.6		
#60	7.6		
#80	5.5		
#100	4.7		
#200	2.8		

* (no specification provided)

Soil Description

poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 7.5477 D_{85}= 5.8140 D_{60}= 2.1250
D_{50}= 1.6238 D_{30}= 0.8437 D_{15}= 0.4836
D_{10}= 0.3457 C_u= 6.15 C_c= 0.97

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample ID:14L402 Sampled 6-11-14 Recieved 7-3-14
Moisture Content(ASTM D2216):13.4%

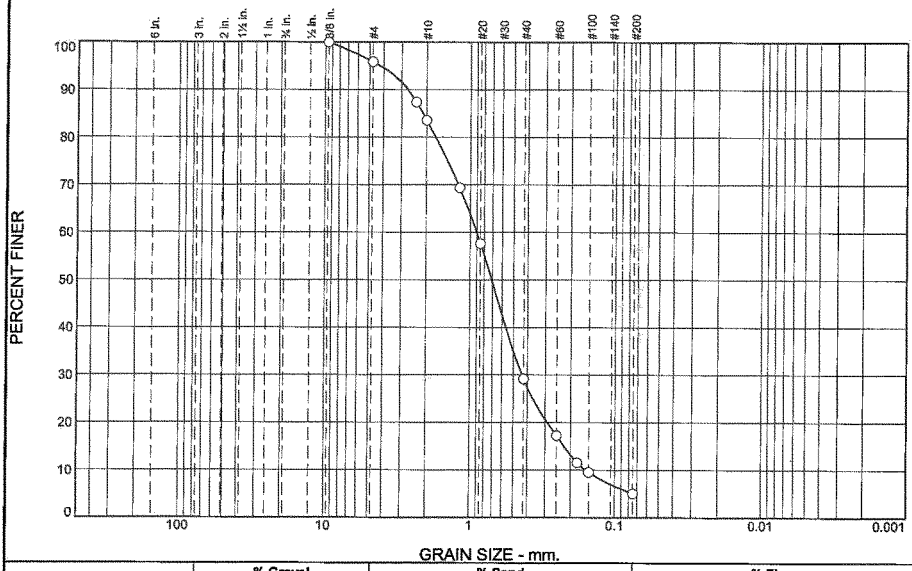
Location: BH-15 (5)
Sample Number: 14L402 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	4.1	12.3	54.4	24.1	5.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375	100.0		
#4	95.9		
#8	87.4		
#10	83.6		
#16	69.4		
#20	57.6		
#40	29.2		
#60	17.2		
#80	11.5		
#100	9.5		
#200	5.1		

* (no specification provided)

Soil Description

poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 2.7128 D_{85}= 2.1231 D_{60}= 0.9022
D_{50}= 0.7100 D_{30}= 0.4362 D_{15}= 0.2219
D_{10}= 0.1575 C_u= 5.73 C_c= 1.34

Classification

USCS= SP-SM AASHTO= A-1-b

Remarks

Sample ID:14L404 Sampled 6-11-14 Recieved 7-3-14
Moisture Content(ASTM D2216):16.5%

Location: BH-15 (8)
Sample Number: 14L404

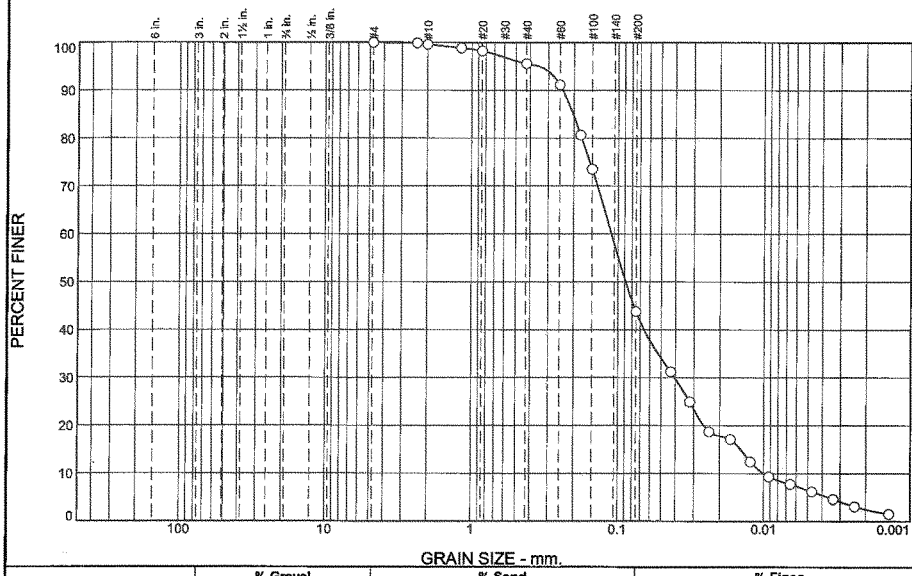
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.4	4.1	51.7	37.3	6.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	99.9		
#10	99.6		
#16	98.8		
#20	98.2		
#40	95.5		
#60	91.1		
#80	80.7		
#100	73.5		
#200	43.8		
0.0430 mm.	31.2		
0.0320 mm.	25.0		
0.0237 mm.	18.7		
0.0169 mm.	17.1		
0.0124 mm.	12.5		
0.0092 mm.	9.3		
0.0066 mm.	7.8		
0.0047 mm.	6.2		
0.0033 mm.	4.6		
0.0024 mm.	3.1		
0.0014 mm.	1.5		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2386 D_{85}= 0.2028 D_{60}= 0.1110
D_{50}= 0.0886 D_{30}= 0.0404 D_{15}= 0.0144
D_{10}= 0.0100 C_u= 11.06 C_c= 1.47

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample ID:14L406 Sampled 6-16-14 Recieved 7-3-143
Moisture Content(ASTM D2216):44.8%

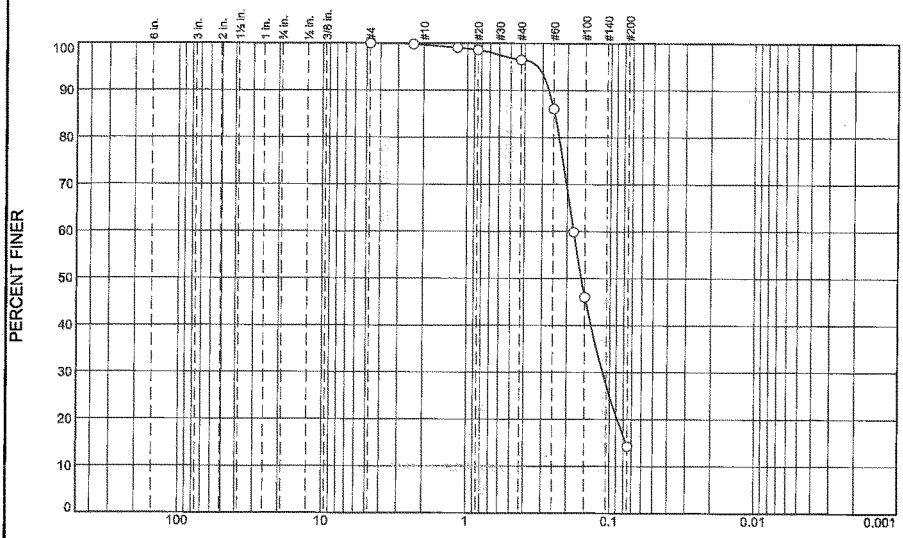
Location: HA-01X (S2)
Sample Number: 14L406 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.3	3.2	82.2	14.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	99.8		
#16	99.1		
#20	98.6		
#40	96.5		
#60	86.1		
#80	59.9		
#100	46.0		
#200	14.3		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2703 D_{85}= 0.2457 D_{60}= 0.1803
D_{50}= 0.1587 D_{30}= 0.1127 D_{15}= 0.0766
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample ID:14L407 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):12.5%

Location: HA-02B (1)
Sample Number: 14L407

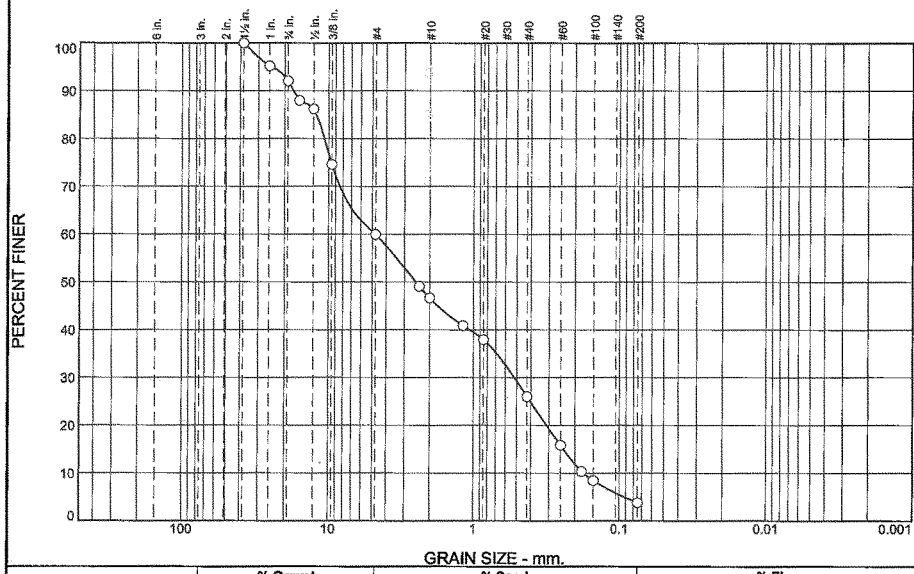
Date: 7-13-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	7.9	32.2	13.3	20.6	22.2	3.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	95.2		
.75	92.1		
.625	88.0		
.5	86.2		
.375	74.6		
#4	59.9		
#8	49.1		
#10	46.6		
#16	40.9		
#20	37.9		
#40	26.0		
#60	15.8		
#80	10.4		
#100	8.4		
#200	3.8		

* (no specification provided)

Soil Description

poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 17.4871 D_{85}= 12.1282 D_{60}= 4.7690
D_{50}= 2.5010 D_{30}= 0.5204 D_{15}= 0.2391
D_{10}= 0.1749 C_u= 27.27 C_c= 0.32

Classification

USCS= SP AASHTO= A-1-a

Remarks

Sample ID:14L408 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):4.7%

Location: HA-07B (1)
Sample Number: 14L408

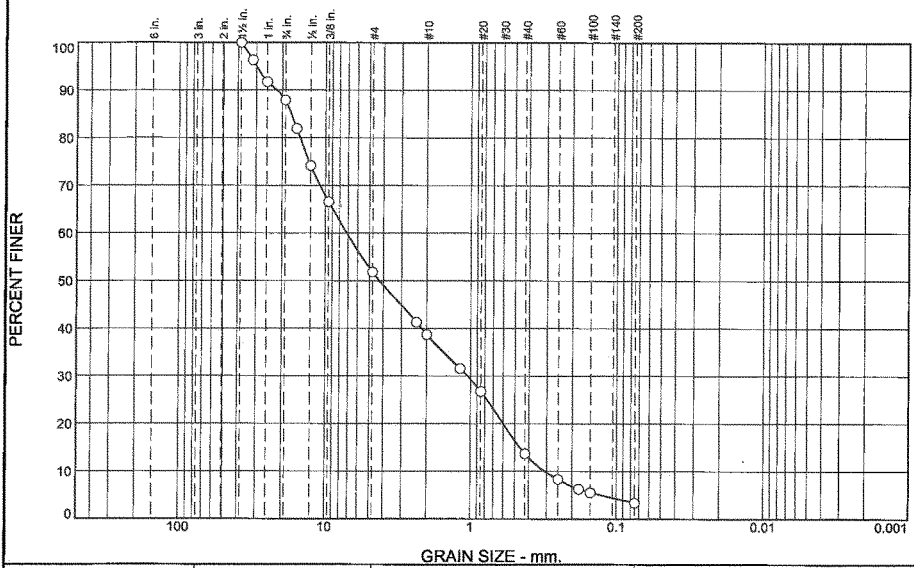
Date: 7-13-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	12.1	36.1	13.1	25.0	10.3	3.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1.25	96.3		
1	91.7		
.75	87.9		
.625	82.0		
.5	74.1		
.375	66.6		
#4	51.8		
#8	41.3		
#10	38.7		
#16	31.6		
#20	26.8		
#40	13.7		
#60	8.3		
#80	6.3		
#100	5.5		
#200	3.4		

* (no specification provided)

Soil Description

poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 21.7081 D_{85}= 17.2637 D_{60}= 7.1468
D_{50}= 4.2514 D_{30}= 1.0492 D_{15}= 0.4611
D_{10}= 0.3095 C_u= 23.09 C_c= 0.50

Classification

USCS= SP AASHTO= A-1-a

Remarks

Sample ID:14L409 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content ASTM D2216):4.1%

Location: HA-14B (1)
Sample Number: 14L409

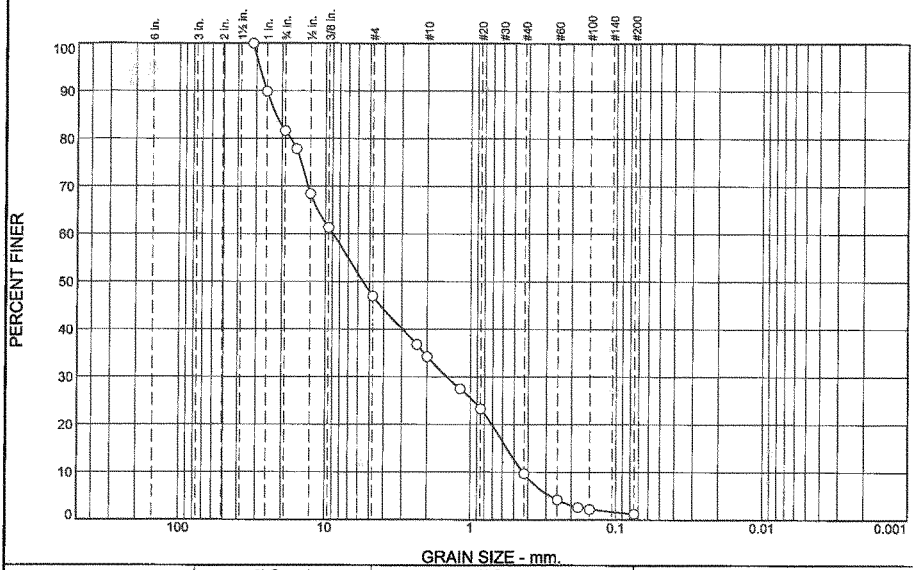
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	18.4	34.6	12.8	24.5	8.5	1.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	89.9		
.75	81.6		
.625	77.8		
.5	68.4		
.375	61.3		
#4	47.0		
#8	36.8		
#10	34.2		
#16	27.5		
#20	23.3		
#40	9.7		
#60	4.2		
#80	2.6		
#100	2.2		
#200	1.2		

* (no specification provided)

Soil Description

poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 25.4552 D_{85}= 21.9872 D_{60}= 8.8925
D_{50}= 5.5594 D_{30}= 1.4616 D_{15}= 0.5604
D_{10}= 0.4337 C_u= 20.50 C_c= 0.55

Classification

USCS= GP AASHTO=

Remarks

Sample ID:14L410 Sampled 6-17-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):5.0%

Location: HA-20B (1)
Sample Number: 14L410

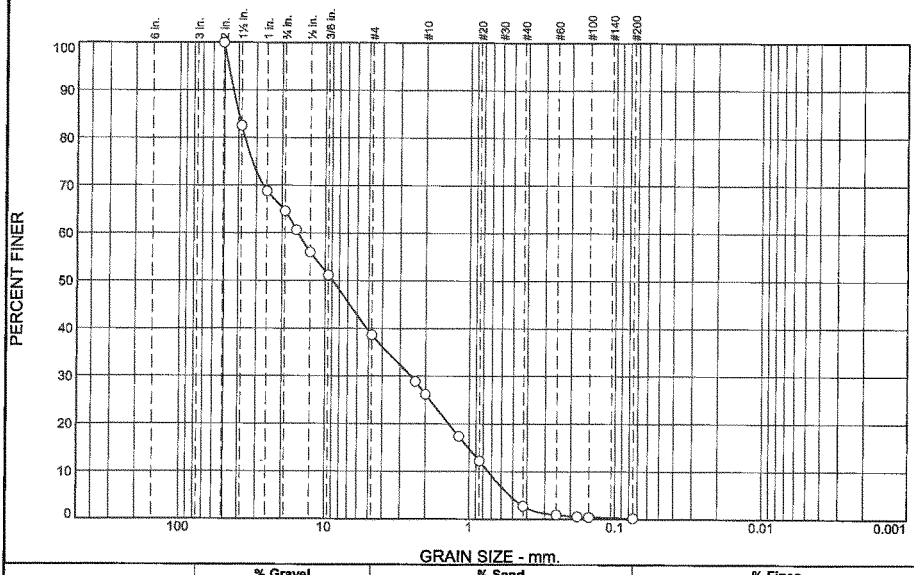
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	35.4	25.9	12.5	23.4	2.6	0.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	82.5		
1	68.8		
.75	64.6		
.625	60.6		
.5	56.0		
.375	51.2		
#4	38.7		
#8	28.9		
#10	26.2		
#16	17.4		
#20	12.2		
#40	2.8		
#60	0.9		
#80	0.5		
#100	0.4		
#200	0.2		

* (no specification provided)

Soil Description

poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 43.4413 D_{85}= 39.8887 D_{60}= 15.4365
D_{50}= 8.8959 D_{30}= 2.5412 D_{15}= 1.0142
D_{10}= 0.7401 C_u= 20.86 C_c= 0.57

Classification

USCS= GP AASHTO=

Remarks

Sample ID:14L411 Sampled 6-18-14 Recieved 7-3-14
Moisture Content(ASTM D2216):3.3%

Location: HA-22 (2)
Sample Number: 14L411

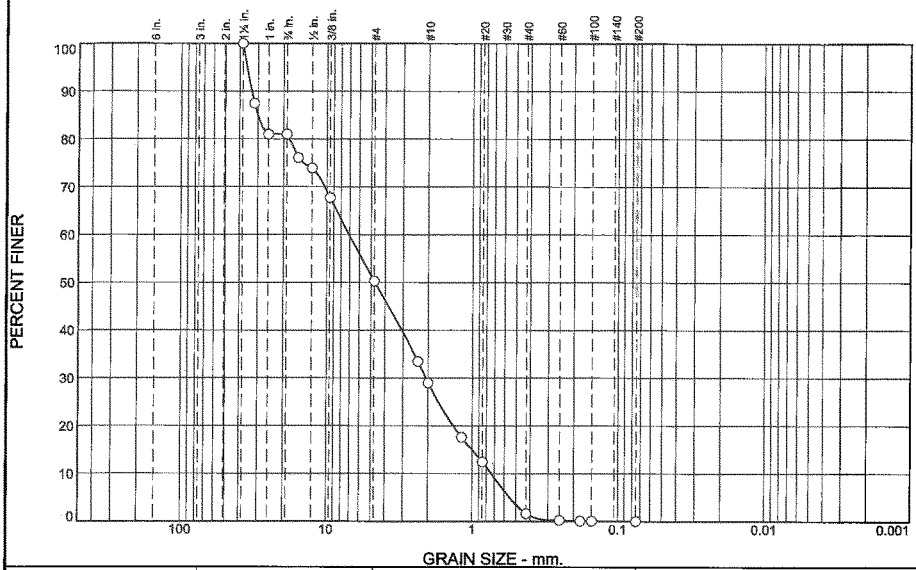
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.0	30.7	21.3	27.4	1.6	0.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1.25	87.5		
1	81.0		
.75	81.0		
.625	76.1		
.5	73.9		
.375	67.7		
#4	50.3		
#8	33.5		
#10	29.0		
#16	17.6		
#20	12.4		
#40	1.6		
#60	0.2		
#80	0.1		
#100	0.1		
#200	0.0		

* (no specification provided)

Soil Description

poorly graded sand with gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 33.1391 D_{85}= 30.1527 D_{60}= 7.0721
D_{50}= 4.6898 D_{30}= 2.0771 D_{15}= 1.0022
D_{10}= 0.7383 C_u= 9.58 C_c= 0.83

Classification

USCS= SP AASHTO= A-1-a

Remarks

Sample ID:14L412 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):2.5%

Location: TP-02R (S1)
Sample Number: 14L412

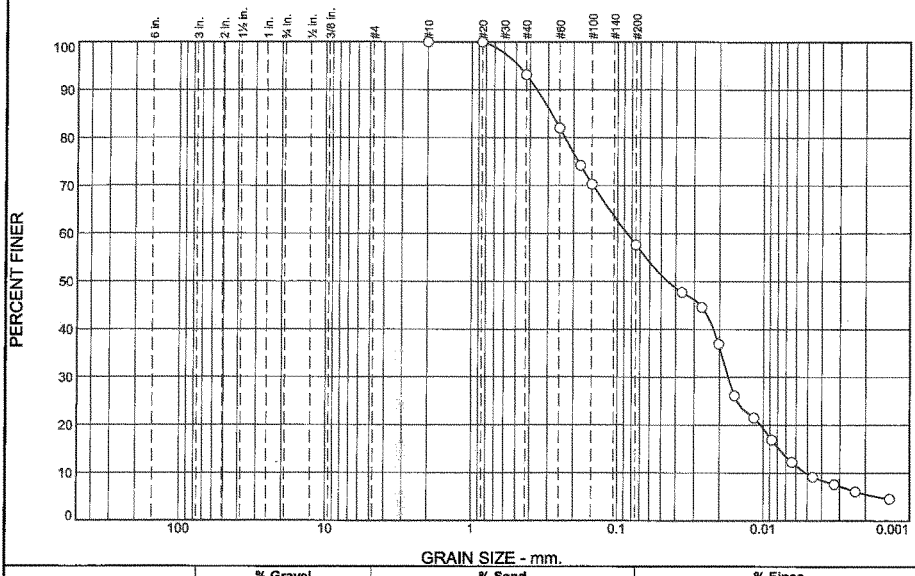
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	6.9	35.5	47.8	9.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#20	100.0		
#40	93.1		
#60	82.0		
#80	74.2		
#100	70.3		
#200	57.6		
0.0362 mm.	47.7		
0.0265 mm.	44.6		
0.0203 mm.	36.9		
0.0158 mm.	26.1		
0.0116 mm.	21.5		
0.0087 mm.	16.9		
0.0064 mm.	12.3		
0.0046 mm.	9.2		
0.0033 mm.	7.7		
0.0023 mm.	6.1		
0.0014 mm.	4.6		

* (no specification provided)

Soil Description

sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.3579 D_{85}= 0.2837 D_{60}= 0.0862
D_{50}= 0.0453 D_{30}= 0.0175 D_{15}= 0.0078
D_{10}= 0.0051 C_u= 16.83 C_c= 0.69

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample ID:14L415 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):50.6%

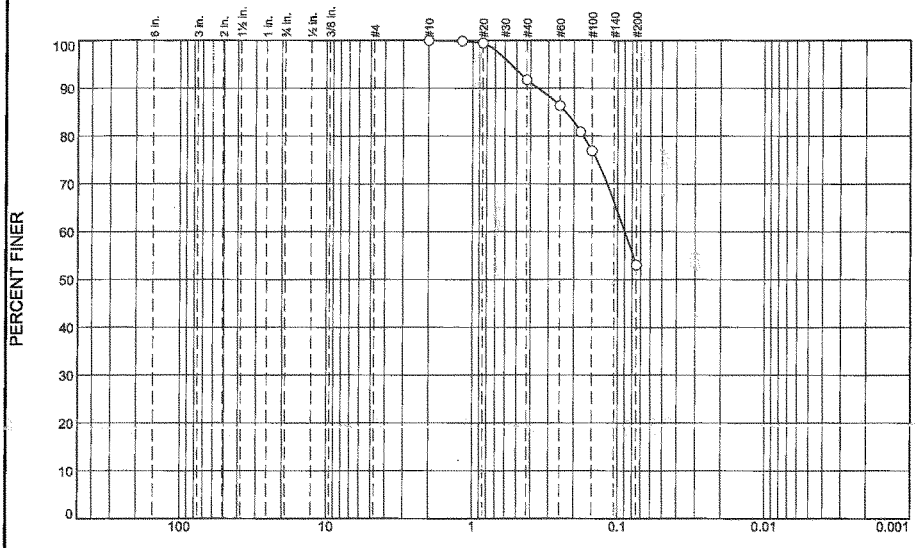
Location: TP-13R (S1)
Sample Number: 14L415 **Date:** 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	8.2	38.8	53.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#16	99.8		
#20	99.4		
#40	91.8		
#60	86.4		
#80	80.9		
#100	76.9		
#200	53.0		

* (no specification provided)

Soil Description

sandy silt

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 0.3561 D_{85}= 0.2270 D_{60}= 0.0897
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample ID:14L416 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):44.3%

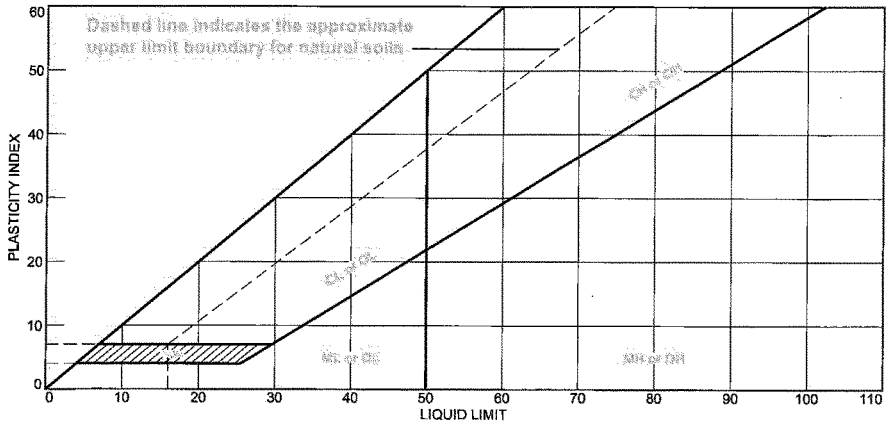
Location: TP-13R (S2)
Sample Number: 14L416 **Date:** 7-3-14

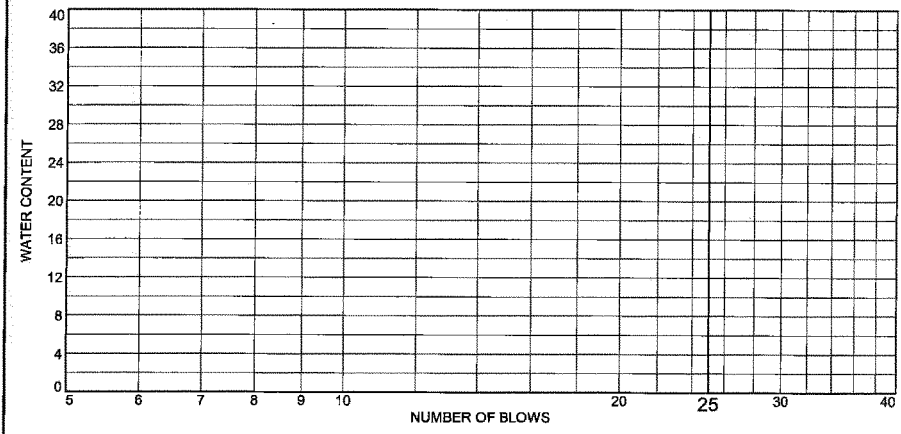
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	sandy silt	NV	NP	NP	91.8	53.0	ML

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: TP-13R (S2)
Sample Number: 14L416

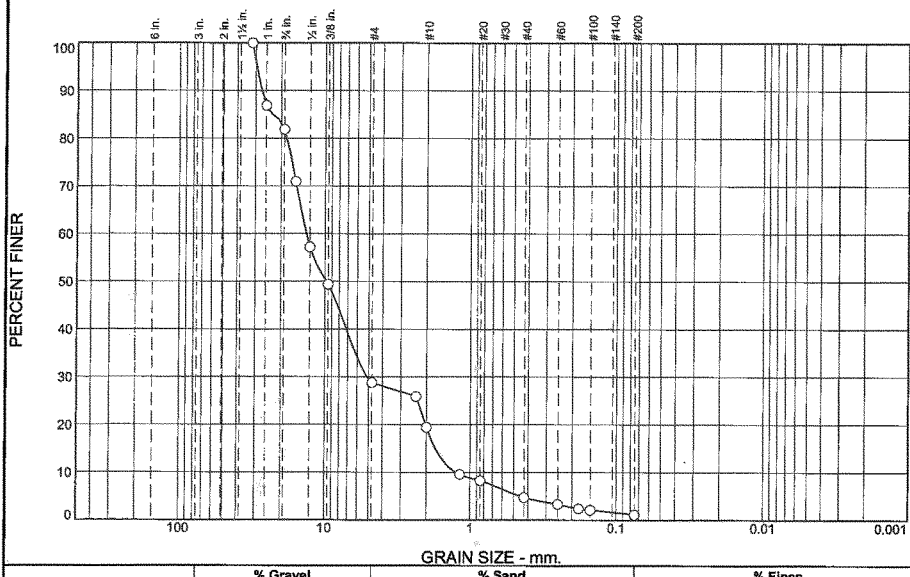
Krazan

Remarks:
● Material was determined to be Non Plastic per ASTM D4318 Section 18.1.1.

Figure

Tested By: A.Ayres **Checked By:** m.tHOMAS VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	18.1	53.1	9.4	14.7	3.6	1.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.25	100.0		
1	86.9		
.75	81.9		
.625	70.9		
.5	57.2		
.375	49.3		
#4	28.8		
#8	25.9		
#10	19.4		
#16	9.6		
#20	8.2		
#40	4.7		
#60	3.3		
#80	2.4		
#100	2.1		
#200	1.1		

* (no specification provided)

Soil Description

well-graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 27.2664 D_{85}= 23.1017 D_{60}= 13.4243
D_{50}= 9.7935 D_{30}= 5.1417 D_{15}= 1.7418
D_{10}= 1.2571 C_u= 10.68 C_c= 1.57

Classification

USCS= GW AASHTO= A-1-a

Remarks

Sample ID:14L417 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):8.4%

Location: TP-13R (S3)
Sample Number: 14L417

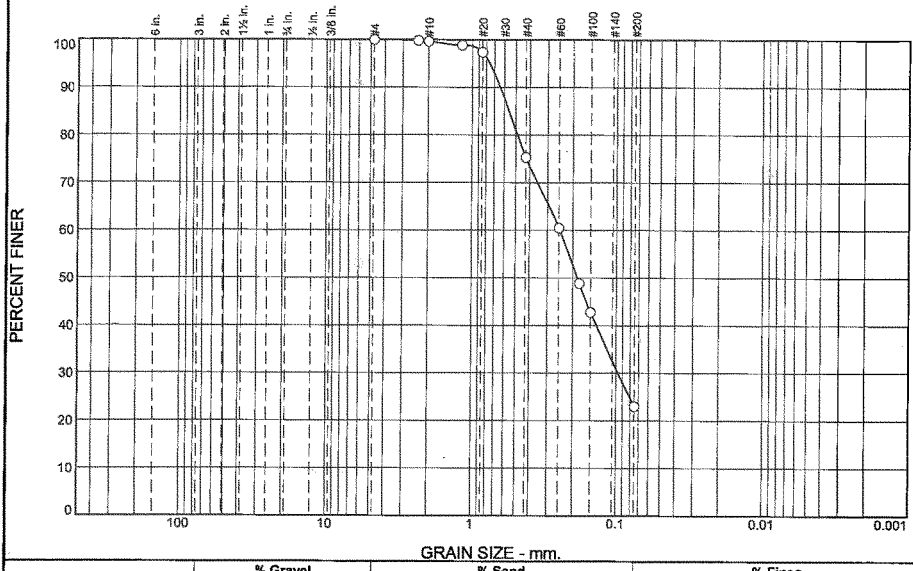
Date: 7-13-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.4	24.3	52.3	23.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#8	99.8		
#10	99.6		
#16	98.8		
#20	97.3		
#40	75.3		
#60	60.5		
#80	48.8		
#100	42.8		
#200	23.0		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.6390 D_{85}= 0.5563 D_{60}= 0.2463
D_{50}= 0.1859 D_{30}= 0.0970 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

sample ID:14L419 sampled 6-16-14 Recieved 7-3-14
Moisture Content(ASTM D2216):34.7%

Location: TP-17R (S1B)
Sample Number: 14L419

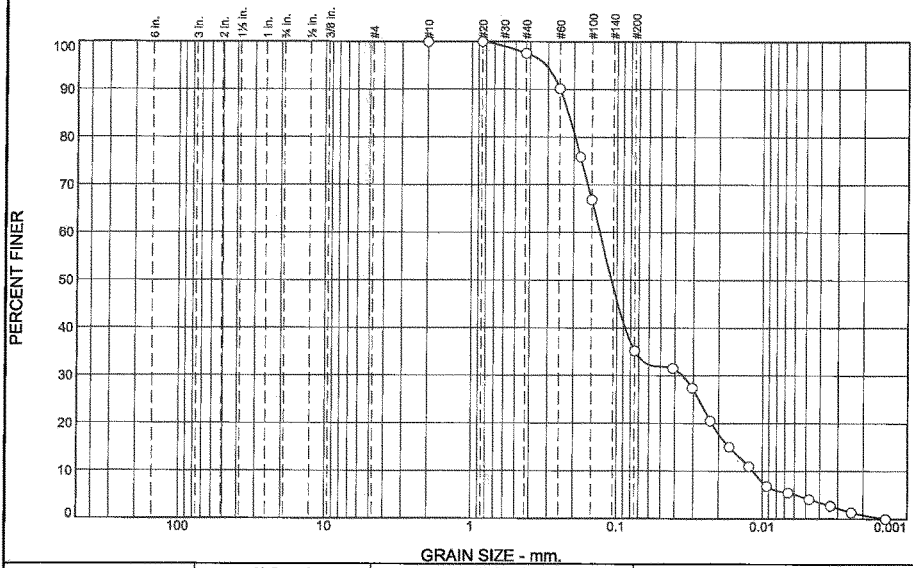
Date: 7-13-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	2.4	62.4	30.9	4.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#20	100.0		
#40	97.6		
#60	90.1		
#80	75.9		
#100	66.9		
#200	35.2		
0.0413 mm.	31.5		
0.0304 mm.	27.4		
0.0229 mm.	20.5		
0.0169 mm.	15.1		
0.0124 mm.	10.9		
0.0093 mm.	6.8		
0.0066 mm.	5.4		
0.0047 mm.	4.1		
0.0034 mm.	2.7		
0.0024 mm.	1.3		
0.0014 mm.			

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2489 D_{85}= 0.2186 D_{60}= 0.1317
D_{50}= 0.1091 D_{30}= 0.0353 D_{15}= 0.0169
D_{10}= 0.0116 C_u= 11.33 C_c= 0.81

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample ID:14L423 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):43.9%

Location: TP19R (S2)
Sample Number: 14L423

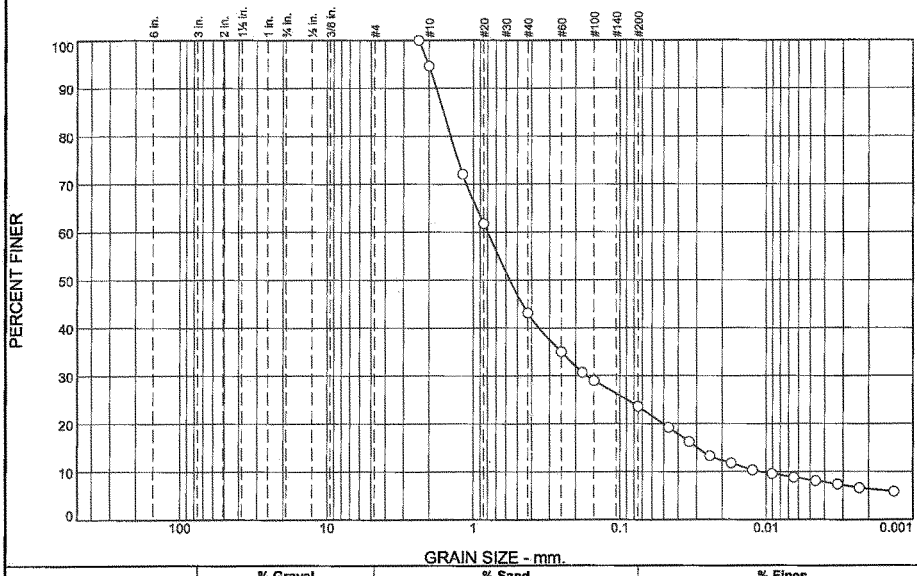
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	5.4	51.5	19.5	15.3	8.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0		
#10	94.6		
#16	72.1		
#20	61.8		
#40	43.1		
#60	35.0		
#80	30.7		
#100	29.0		
#200	23.6		
0.0465 mm.	19.2		
0.0336 mm.	16.3		
0.0243 mm.	13.3		
0.0174 mm.	11.8		
0.0124 mm.	10.3		
0.0091 mm.	9.6		
0.0065 mm.	8.8		
0.0046 mm.	8.1		
0.0033 mm.	7.4		
0.0023 mm.	6.6		
0.0013 mm.	5.9		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.7786 D_{85}= 1.5879 D_{60}= 0.8004
D_{50}= 0.5656 D_{30}= 0.1681 D_{15}= 0.0296
D_{10}= 0.0111 C_u= 72.16 C_c= 3.18

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample ID:14L426 Sampled 6-16-14 recieved 7-3-14.
Moisture Content(ASTM D2216):67.2%

Location: TP-23R (S1)
Sample Number: 14L426

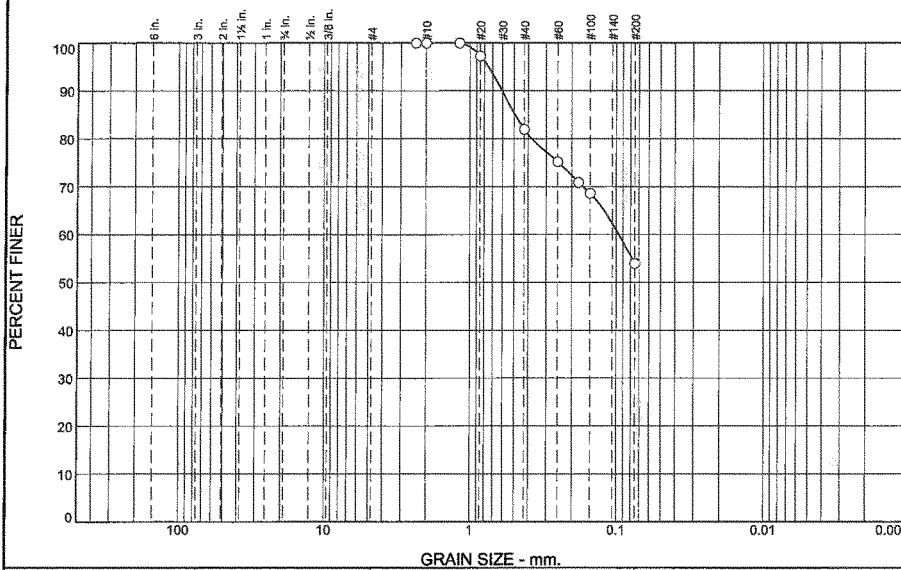
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	18.0	28.1	53.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0		
#10	100.0		
#16	100.0		
#20	97.3		
#40	82.0		
#60	75.2		
#80	70.9		
#100	68.6		
#200	53.9		

* (no specification provided)

Soil Description

sandy silt

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 0.6030 D_{85}= 0.4913 D_{60}= 0.0962
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample ID:14L428 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):53.0%

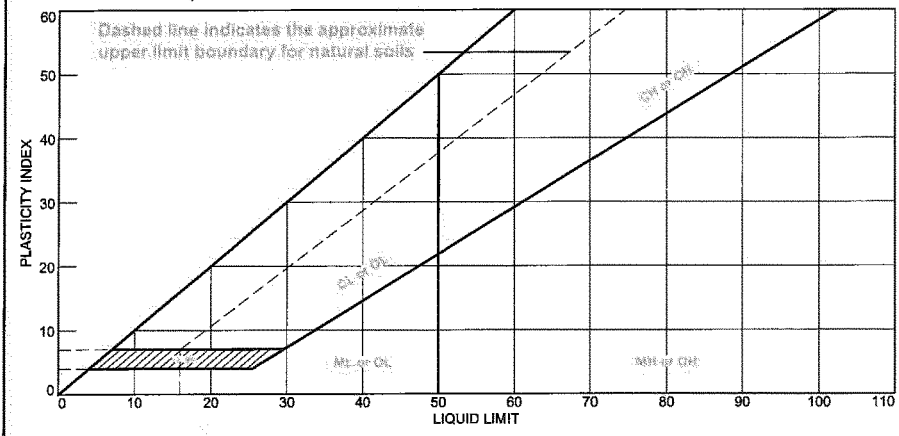
Location: TP23R (S3)
Sample Number: 14L428 **Date:** 7-3-14

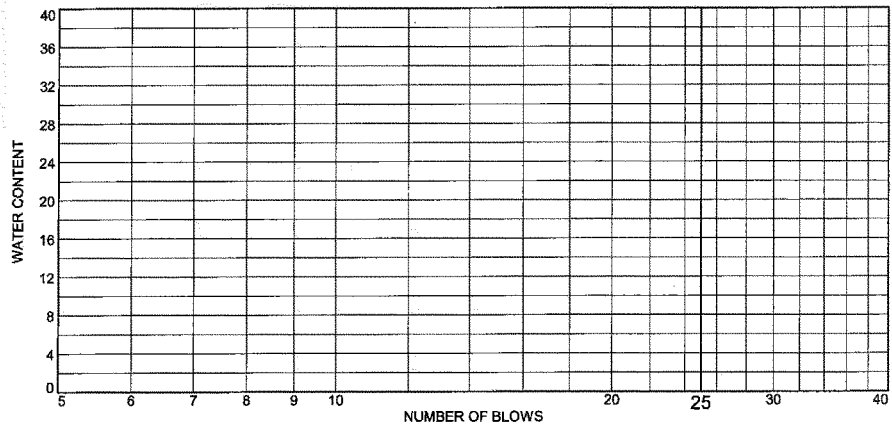
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	sandy silt	NV	NP	NP	82.0	53.9	ML

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: TP23R (S3)
Sample Number: 14L428

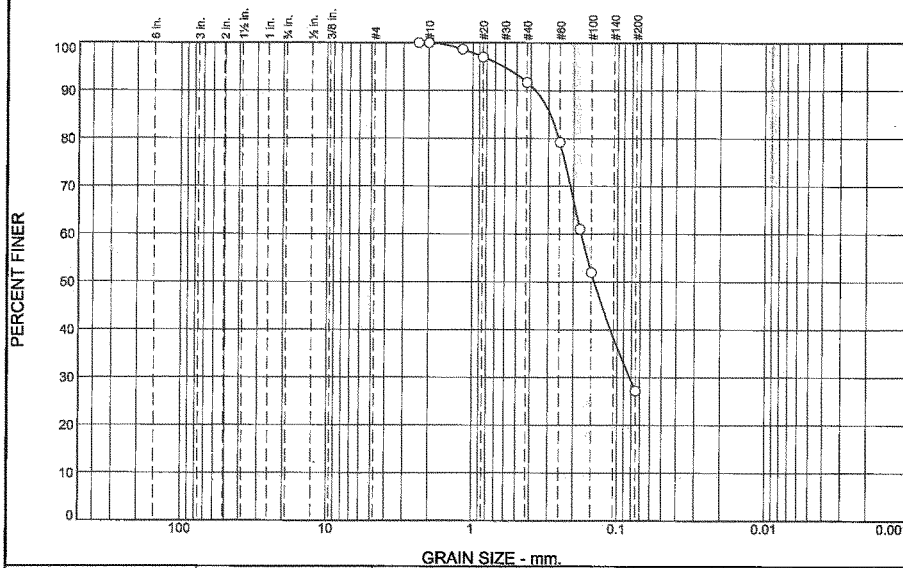
Krazan

Remarks:
- Material was determined to be Non Plastic per ASTM D4318 Section 18.1.1.

Figure

Tested By: A.Ayres **Checked By:** M.Thomas

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	8.3	64.5	27.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0		
#10	100.0		
#16	98.6		
#20	97.0		
#40	91.7		
#60	79.2		
#80	61.1		
#100	52.0		
#200	27.2		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.3697 D_{85}= 0.2920 D_{60}= 0.1765
D_{50}= 0.1435 D_{30}= 0.0820 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample ID:14L431 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):33.5%

Location: TP-27 (S2)
Sample Number: 14L431

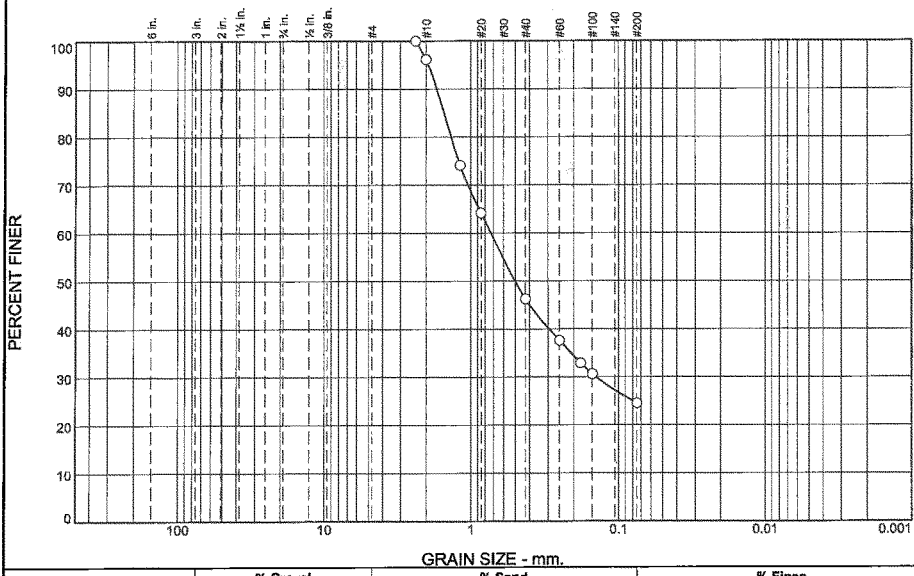
Date: 7-3-14

Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	3.9	49.9	21.6	24.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0		
#10	96.1		
#16	74.1		
#20	64.2		
#40	46.2		
#60	37.6		
#80	32.9		
#100	30.6		
#200	24.6		

* (no specification provided)

Soil Description

silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Coefficients

D_{90}= 1.6922 D_{85}= 1.5130 D_{60}= 0.7289
D_{50}= 0.5015 D_{30}= 0.1422 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample ID:14L433 Sampled 6-16-14 Recieved 7-3-14.
Moisture Content(ASTM D2216):60.6%

Location: TP-27 (S4)
Sample Number: 14L433

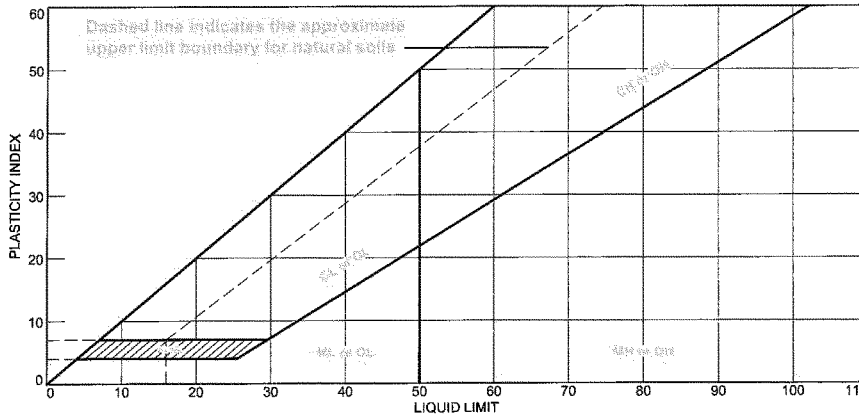
Date: 7-3-14

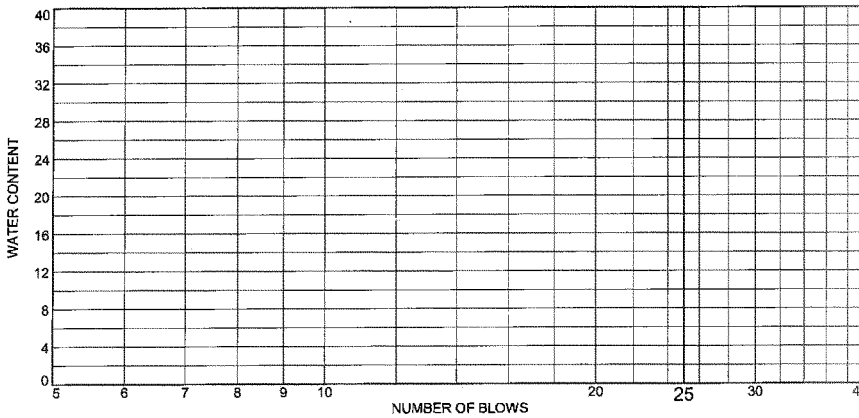
Krazan

Client: Landau Associates
Project: Skokomish
Project No: 066-14179 **Figure**

Tested By: N.Adams **Checked By:** M.Thomas VL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	silty sand	NV	NP	NP	46.2	24.6	SM

Project No. 066-14179 **Client:** Landau Associates

Project: Skokomish

Location: TP-27 (S4)
Sample Number: 14L433

Remarks:
- Material was determined to be Non-Plastic Per ASTM D4318 Section 18.1.1.

Krazan

Figure

Tested By: A.Ayres **Checked By:** M.Thomas

Krazan & ASSOCIATES, INC.

GEOTECHNICAL ENGINEERING • ENVIRONMENTAL ENGINEERING
CONSTRUCTION TESTING & INSPECTION

July 18, 2014 066-14179

Craig Jordan
Landau Associates
1115 West Bay Drive N.W., Suite 201.
Olympia, WA 98502

RE: Organic Content Test Results for Skokomish

Dear Mr. Jordan,

In accordance with your request and authorization, we have performed laboratory testing and analysis on samples 14L379, 14L380, 14L422 & 14L430 received on 7/3/2014.

Sample ID #	Location	Sample #	Organic Content (ASTM D2974)
*14L379/14L380	BH-09R	3/3 Cal	1.7%
14L422	TP-19R	S1	3.7%
14L430	TP-27	S1	5.8%

*Samples were combined for testing per client request.

If you have any questions or need any additional information, please do not hesitate to contact our office at (253) 939-2500

VC

Respectfully submitted,
KRAZAN & ASSOCIATES, INC

Michael Thomas
Laboratory Manager
Krazan and Associates, Inc.
Phone: (253) 939-2500
Email: Mikethomas@krazan.com

Analytical Testing Summary

TABLE D-1
SOIL ANALYTICAL RESULTS
SKOKOMISH GI

	HA-01-01 580-43883-1 6/2/2014		HA-02-02 580-43883-2 6/2/2014		HA-03-03 580-43883-3 6/3/2014		HA-04-01 580-43883-4 6/3/2014		HA-05-02 580-43883-5 6/3/2014		HA-06-03 580-43883-6 6/3/2014		HA-07-01 580-43883-7 6/3/2014		HA-08-02 580-43883-8 6/3/2014		HA-09-03 580-43886-1 6/4/2014	
TOTALS METALS (mg/kg)																		
Method 6010B																		
Lead	1.7	U	1.7	U	1.2	U	1.6	U	1.8	U	1.4	U	1.6	U	1.5	U	1.4	U
TOTAL PETROLEUM HYDROCARBONS (mg/kg)																		
NWTPH-Dx																		
#2 Diesel (C10-C24)	30	U	29	U	26	U	27	U	30	U	26	U	26	U	27	U	31	U
Motor Oil (>C24-C36)	60	U	**62**	J	52	U	55	U	**110**		53	U	52	U	54	U	61	U
NWTPH-Gx																		
Gasoline	5.6	U	7.1	U	4.4	U	4.6	U	6.4	U	5.5	U	4.5	U	5.2	U	5.6	U
CONVENTIONALS (mg/kg)																		
Total Organic Carbon (9060_PSEP)																		
GRAIN SIZE (%)																		
PSEP Plumb 1981																		
Cobbles																		
Gravel																		
Sand																		
Very Coarse Sand																		
Coarse Sand																		
Medium Sand																		
Fine Sand																		
Very Fine Sand																		
Silt																		
Coarse Silt																		
Medium Silt																		
Fine Silt																		
Very Fine Silt																		
Clay																		
Coarse Clay																		
Medium Clay																		

U = Indicates the compound was not detected at the reported concentration.
J = Indicates the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
Bold = Detected compound.

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TABLE D-1
SOIL ANALYTICAL RESULTS
SKOKOMISH GI

	HA-10-01 580-43886-2 6/4/2014		HA-11-02 580-43886-3 6/4/2014		HA-12-03 580-43886-4 6/4/2014		HA-13-01 580-43886-5 6/4/2014		HA-14-02 580-43886-6 6/4/2014		HA-15-03 580-43886-7 6/5/2014		HA-16-01 580-43886-8 6/5/2014		HA-17-02 580-43886-9 6/5/2014		HA-18-03 580-43886-10 6/5/2014	
TOTALS METALS (mg/kg)																		
Method 6010B																		
Lead	**4.0**		0.95	U	1.2	U	1.5	U	1.0	U	1.5	U	1.4	U	1.1	U	1.5	U
TOTAL PETROLEUM HYDROCARBONS (mg/kg)																		
NWTPH-Dx																		
#2 Diesel (C10-C24)	30	U	26	U	26	U	30	U	26	U	29	U	29	U	26	U	29	U
Motor Oil (>C24-C36)	59	U	52	U	51	U	60	U	52	U	58	U	58	U	51	U	58	U
NWTPH-Gx																		
Gasoline	**13**		4.1	U	4.2	U	6.1	U	3.7	U	4.4	U	5.0	U	4.9	U	5.5	U
CONVENTIONALS (mg/kg)																		
Total Organic Carbon (9060_PSEP)																		
GRAIN SIZE (%)																		
PSEP Plumb 1981																		
Cobbles																		
Gravel																		
Sand																		
Very Coarse Sand																		
Coarse Sand																		
Medium Sand																		
Fine Sand																		
Very Fine Sand																		
Silt																		
Coarse Silt																		
Medium Silt																		
Fine Silt																		
Very Fine Silt																		
Clay																		
Coarse Clay																		
Medium Clay																		

U = Indicates the compound was not detected at the reported concentration.
J = Indicates the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
Bold = Detected compound.

TABLE D-1
SOIL ANALYTICAL RESULTS
SKOKOMISH GI

	HA-19-01 580-43886-11 6/5/2014		HA-20-02 580-43886-12 6/5/2014		HA-21-03 580-44186-1 6/18/2014		HA-22-01 580-44186-2 6/18/2014		HA-23-02 580-44186-3 6/18/2014		HA-24-01 580-43886-13 6/4/2014		HA-25-01 580-43886-14 6/4/2014		HA-26-01 580-43885-1 6/6/2014		HA-27-0.5 580-43885-2 6/6/2014	
TOTALS METALS (mg/kg)																		
Method 6010B																		
Lead	1.2	U	1.1	U	**2.9**		**1.7**		**1.5**		1.4	U	1.5	U	**2.5**		**1.8**	
TOTAL PETROLEUM HYDROCARBONS (mg/kg)																		
NWTPH-Dx																		
#2 Diesel (C10-C24)	26	U	27	U	27	U	26	U	26	U	28	U	28	U	28	U	27	U
Motor Oil (>C24-C36)	52	U	53	U	54	U	52	U	52	U	57	U	56	U	57	U	53	U
NWTPH-Gx																		
Gasoline	4.3	U	4.6	U	**51**		**8.2**		**4.5**		5.8	U	62	U	5.8	U	4.9	U
CONVENTIONALS (mg/kg)																		
Total Organic Carbon (9060_PSEP)																		
GRAIN SIZE (%)																		
PSEP Plumb 1981																		
Cobbles																		
Gravel																		
Sand																		
Very Coarse Sand																		
Coarse Sand																		
Medium Sand																		
Fine Sand																		
Very Fine Sand																		
Silt																		
Coarse Silt																		
Medium Silt																		
Fine Silt																		
Very Fine Silt																		
Clay																		
Coarse Clay																		
Medium Clay																		

U = Indicates the compound was not detected at the reported concentration.
J = Indicates the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
Bold = Detected compound.

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TABLE D-1
SOIL ANALYTICAL RESULTS
SKOKOMISH GI

	HA-28-0.5 580-43885-3 6/6/2014		HA-29-0.5 580-43885-4 6/6/2014		HA-30-0.5 580-43885-5 6/6/2014		HA-31-00 580-44186-6 6/18/2014		HA-32-0.25 580-44186-7 6/18/2014		HA-33-03 580-44186-5 6/18/2014	
TOTALS METALS (mg/kg)												
Method 6010B												
Lead	**2.8**		1.8	U	**1.5**		1.3	U	**0.97**		**2.4**	
TOTAL PETROLEUM HYDROCARBONS (mg/kg)												
NWTPH-Dx												
#2 Diesel (C10-C24)	42	U	31	U	25	U	30	U	26	U	26	U
Motor Oil (>C24-C36)	83	U	61	U	50	U	60	U	51	U	52	U
NWTPH-Gx												
Gasoline	12	U	4.9	U	4.1	U	5.2	U	**13**		4.7	U
CONVENTIONALS (mg/kg)												
Total Organic Carbon (9060_PSEP)			2000	U			**2400**					
GRAIN SIZE (%)												
PSEP Plumb 1981												
Cobbles			0.00				0.00					
Gravel			59				48					
Sand							52					
Very Coarse Sand			15				46					
Coarse Sand			5.9				5.4					
Medium Sand			15				0.60					
Fine Sand			5.4				0.10					
Very Fine Sand			0.30				0.10					
Silt							0.20					
Coarse Silt			0.10				0.00					
Medium Silt			0.30				0.10					
Fine Silt			-0.10				0.10					
Very Fine Silt			0.10				0.00					
Clay							-0.10					
Coarse Clay			0.00				0.00					
Medium Clay			0.00				0.00					

U = Indicates the compound was not detected at the reported concentration.
J = Indicates the analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
Bold = Detected compound.

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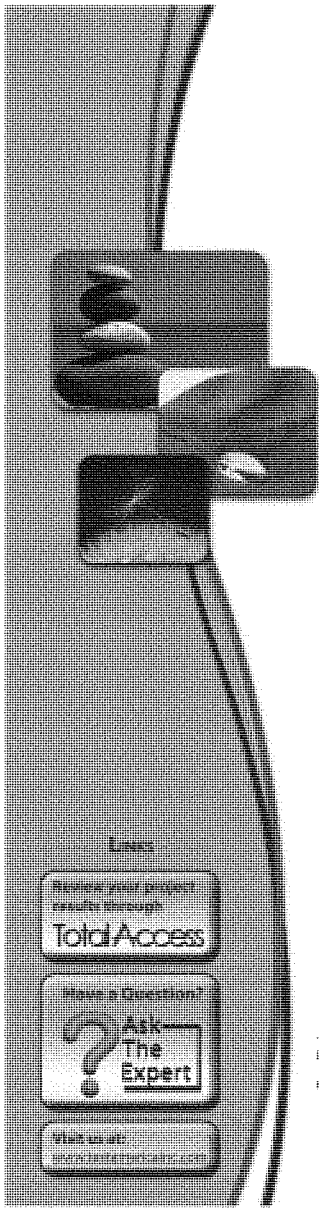
APPENDIX E

Analytical Reports



TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Seattle
5755 8th Street East
Tacoma, WA 98424
Tel: (253)922-2310

TestAmerica Job ID: 580-43883-1
Client Project/Site: Skokomish GI WA

For:
Landau & Associates, Inc.
1115 West Bay Drive NW
Suite 201
Olympia, Washington 98502

Attn: Craig Jordan

Authorized for release by:
6/17/2014 10:46:25 AM

Melissa Armstrong, Project Manager II
(253)248-4975
melissa.armstrong@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

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Sample Summary 5
Chain of Custody 6
Receipt Checklists 7
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Case Narrative

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Job ID: 580-43883-1

Laboratory: TestAmerica Seattle

Narrative

Receipt
The samples were received on 6/4/2014 3:30 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperature of the cooler at receipt was 1.9° C.

Except:
A trip blank was submitted for analysis with these samples; however, it was not listed on the Chain of Custody (COC). Analysis was not added to the Trip Blank.

GC/MS VOA
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

GC Semi VOA - Method(s) NWTPH-Dx
For samples HA-02-02 (580-43883-2) and HA-05-02 (580-43883-5), the results in the Motor Oil (>C24-C36) range is due to what most closely resembles a complex mixture of motor oil range products. The affected analyte ranges have been "Y" qualified and reported.

In analytical batch 161171, the laboratory control sample (LCS) and laboratory control standard duplicate (LCSD) exceeded the RPD limits for #2 Diesel Fuel (C10-C24) and Motor Oil (>C24-C36). Both the individual recoveries of the LCS and LCSD are passing for both compounds.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Organic Prep
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Definitions/Glossary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Qualifiers

GC Semi VOA

Qualifier	Qualifier Description
*	RPD of the LCS and LCSD exceeds the control limits
Y	The chromatographic response resembles a typical fuel pattern.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Sample Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
580-43883-1	HA-01-01	Solid	06/02/14 14:15	06/04/14 15:30
580-43883-2	HA-02-02	Solid	06/02/14 15:20	06/04/14 15:30
580-43883-3	HA-03-03	Solid	06/03/14 10:20	06/04/14 15:30
580-43883-4	HA-04-01	Solid	06/03/14 10:55	06/04/14 15:30
580-43883-5	HA-05-02	Solid	06/03/14 11:30	06/04/14 15:30
580-43883-6	HA-06-03	Solid	06/03/14 12:00	06/04/14 15:30
580-43883-7	HA-07-01	Solid	06/03/14 14:15	06/04/14 15:30
580-43883-8	HA-08-02	Solid	06/03/14 15:05	06/04/14 15:30

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Seattle
5755 8th Street E.
Tacoma, WA 98424
Tel. 253-922-2310
Fax 253-922-5047
www.testamericainc.com

☐ Rush
☐ Short Hold

Chain of Custody Record

Client: Landau Associates	Client Contact: Calvin McCaughan / Craig Jordan	Date: 6/4/13	Chain of Custody Number: 22501
Address: 1115 West Bay Drive NW	Telephone Number (Area Code)/Fax Number: (360) 791-3178	Lab Number: 43883	Page 1 of 1
City: Olympia; State: WA; Zip Code: 98502	Sampler: Craig Jordan / Beth Roberts; Lab Contact: Melissa Armstrong		
Project Name and Location (State): Skokomish GI WA	Billing Contact: Calvin McCaughan		
Contract/Purchase Order/Quote No.: 0621004.010.011			

Analysis (Attach list if more space is needed): NWTPH-Gx; NWTPH-Dx; Lead 6010C

Special Instructions/ Conditions of Receipt

	Sample I.D. and Location/Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	MeOH	NWTPH-Gx	NWTPH-Dx	Lead 6010C
-1	HA-01-01	6/2/14	14:05				X	X						X	X	X	X
-2	HA-02-02	6/2/14	15:20				X	X						X	X	X	X
-3	HA-03-03	6/3/14	10:20				X	X						X	X	X	X
-4	HA-04-01	6/3/14	10:55				X	X						X	X	X	X
-5	HA-05-02	6/3/14	11:30				X	X						X	X	X	X
-6	HA-06-03	6/3/14	12:00				X	X						X	X	X	X
-7	HA-07-01	6/3/14	14:15				X	X						X	X	X	X
-8	HA-08-02	6/3/14	15:05				X	X						X	X	X	X
-9	Trip Blank																

580-43883 Chain of Custody

Cooler/LB Dsg/IR cor 3.9°C unc 2.4°C
Cooler Dsc Lc Blue/6/4/14@ Lab 1530
Wet/Packs Packing Bubble
w/cs A1

Cooler: ☒ Yes ☐ No Cooler Temp: _____

Possible Hazard Identification: ☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For _____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required (business days): ☐ 24 Hours ☐ 48 Hours ☐ 5 Days ☒ 10 Days ☐ 15 Days ☐ Other _____

QC Requirements (Specify)

	Date	Time		Date	Time
1. Relinquished By Sign/Print: Craig Jordan	6/4/14	7:00	1. Received By Sign/Print: Beth Roberts	6/4/14	8:01
2. Relinquished By Sign/Print: Beth Roberts	6/4/14	1123	2. Received By Sign/Print: Francisco Luna, Jr.	6/4/14	1123
3. Relinquished By Sign/Print:			3. Received By Sign/Print:		

Comments

DISTRIBUTION: WHITE – Stays with the Samples; CANARY – Returned to Client with Report; PINK – Field Copy

TAL-8274-580 (0210)

Login Sample Receipt Checklist

Client: Landau & Associates, Inc.

Job Number: 580-43883-1

Login Number: 43883
List Number: 1
Creator: Blankinship, Tom X

List Source: TestAmerica Seattle

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	False	Received Trip Blank(s) not listed on COC.
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-01-01
Date Collected: 06/02/14 14:15
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-1
Matrix: Solid
Percent Solids: 82.5

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.6		mg/Kg	☼	06/09/14 15:15	06/10/14 20:34	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	97		*50 - 150*	*06/09/14 15:15*	*06/10/14 20:34*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	30		mg/Kg	☼	06/11/14 16:29	06/16/14 13:10	1
Motor Oil (>C24-C36)	ND	*	60		mg/Kg	☼	06/11/14 16:29	06/16/14 13:10	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*79*		*50 - 150*	*06/11/14 16:29*	*06/16/14 13:10*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.7		mg/Kg	☼	06/14/14 10:20	06/16/14 12:01	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	82		0.10		%			06/10/14 16:17	1
Percent Moisture	18		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-02-02
Date Collected: 06/02/14 15:20
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-2
Matrix: Solid
Percent Solids: 84.5

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		7.1		mg/Kg	☼	06/09/14 15:15	06/10/14 21:41	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*97*		*50 - 150*	*06/09/14 15:15*	*06/10/14 21:41*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	29		mg/Kg	☼	06/11/14 16:29	06/14/14 20:07	1
Motor Oil (>C24-C36)	62	* Y	57		mg/Kg	☼	06/11/14 16:29	06/14/14 20:07	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*91*		*50 - 150*	*06/11/14 16:29*	*06/14/14 20:07*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.7		mg/Kg	☼	06/14/14 10:20	06/16/14 12:05	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	84		0.10		%			06/10/14 16:17	1
Percent Moisture	16		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-03-03
Date Collected: 06/03/14 10:20
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-3
Matrix: Solid
Percent Solids: 94.0

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.4		mg/Kg	☼	06/09/14 15:15	06/10/14 22:15	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*97*		*50 - 150*	*06/09/14 15:15*	*06/10/14 22:15*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	26		mg/Kg	☼	06/11/14 16:29	06/14/14 20:25	1
Motor Oil (>C24-C36)	ND	*	52		mg/Kg	☼	06/11/14 16:29	06/14/14 20:25	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*92*		*50 - 150*	*06/11/14 16:29*	*06/14/14 20:25*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.2		mg/Kg	☼	06/14/14 10:20	06/16/14 12:08	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	94		0.10		%			06/10/14 16:17	1
Percent Moisture	6.0		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-04-01
Date Collected: 06/03/14 10:55
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-4
Matrix: Solid
Percent Solids: 88.5

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.6		mg/Kg	☼	06/09/14 15:15	06/10/14 22:49	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*97*		*50 - 150*	*06/09/14 15:15*	*06/10/14 22:49*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	27		mg/Kg	☼	06/11/14 16:29	06/14/14 20:43	1
Motor Oil (>C24-C36)	ND	*	55		mg/Kg	☼	06/11/14 16:29	06/14/14 20:43	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*93*		*50 - 150*	*06/11/14 16:29*	*06/14/14 20:43*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.6		mg/Kg	☼	06/14/14 10:20	06/16/14 12:11	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	88		0.10		%			06/10/14 16:17	1
Percent Moisture	12		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-05-02
Date Collected: 06/03/14 11:30
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-5
Matrix: Solid
Percent Solids: 82.4

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		6.4		mg/Kg	☼	06/09/14 15:15	06/10/14 23:23	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*95*		*50 - 150*	*06/09/14 15:15*	*06/10/14 23:23*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	30		mg/Kg	☼	06/11/14 16:29	06/14/14 21:01	1
Motor Oil (>C24-C36)	110	* Y	59		mg/Kg	☼	06/11/14 16:29	06/14/14 21:01	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*88*		*50 - 150*	*06/11/14 16:29*	*06/14/14 21:01*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.8		mg/Kg	☼	06/14/14 10:20	06/16/14 12:14	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	82		0.10		%			06/10/14 16:17	1
Percent Moisture	18		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-06-03
Date Collected: 06/03/14 12:00
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-6
Matrix: Solid
Percent Solids: 90.7

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.5		mg/Kg	☼	06/09/14 15:15	06/10/14 23:57	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*96*		*50 - 150*	*06/09/14 15:15*	*06/10/14 23:57*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	26		mg/Kg	☼	06/11/14 16:29	06/14/14 21:19	1
Motor Oil (>C24-C36)	ND	*	53		mg/Kg	☼	06/11/14 16:29	06/14/14 21:19	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*86*		*50 - 150*	*06/11/14 16:29*	*06/14/14 21:19*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.4		mg/Kg	☼	06/14/14 10:20	06/16/14 12:18	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	91		0.10		%			06/10/14 16:17	1
Percent Moisture	9.3		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-07-01
Date Collected: 06/03/14 14:15
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-7
Matrix: Solid
Percent Solids: 93.9

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.5		mg/Kg	☼	06/09/14 15:15	06/11/14 00:30	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*98*		*50 - 150*	*06/09/14 15:15*	*06/11/14 00:30*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	26		mg/Kg	☼	06/11/14 16:29	06/14/14 21:55	1
Motor Oil (>C24-C36)	ND	*	52		mg/Kg	☼	06/11/14 16:29	06/14/14 21:55	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*123*		*50 - 150*	*06/11/14 16:29*	*06/14/14 21:55*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.6		mg/Kg	☼	06/14/14 10:20	06/16/14 12:21	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	94		0.10		%			06/10/14 16:17	1
Percent Moisture	6.1		0.10		%			06/10/14 16:17	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-08-02
Date Collected: 06/03/14 15:05
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-8
Matrix: Solid
Percent Solids: 88.6

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.2		mg/Kg	☼	06/09/14 15:15	06/11/14 01:04	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*99*		*50 - 150*	*06/09/14 15:15*	*06/11/14 01:04*	*1*

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND	*	27		mg/Kg	☼	06/11/14 16:29	06/16/14 13:46	1
Motor Oil (>C24-C36)	ND	*	54		mg/Kg	☼	06/11/14 16:29	06/16/14 13:46	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
o-Terphenyl	*77*		*50 - 150*	*06/11/14 16:29*	*06/16/14 13:46*	*1*

Method: 6010B - Metals (ICP)

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg	☼	06/14/14 10:20	06/16/14 12:24	1

General Chemistry

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	89		0.10		%			06/10/14 16:17	1
Percent Moisture	11		0.10		%			06/10/14 16:17	1

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-160686/1-A
Matrix: Solid
Analysis Batch: 160758

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 160686

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.0		mg/Kg		06/09/14 15:15	06/10/14 15:30	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/09/14 15:15	06/10/14 15:30	1

Lab Sample ID: LCS 580-160686/2-A
Matrix: Solid
Analysis Batch: 160758

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 160686

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Gasoline	32.0	34.5		mg/Kg		108	68 - 120

Surrogate	LCS %Recovery	LCS Qualifier	Limits
4-Bromofluorobenzene (Surr)	102		50 - 150

Lab Sample ID: LCSD 580-160686/3-A
Matrix: Solid
Analysis Batch: 160758

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 160686

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Gasoline	32.0	35.2		mg/Kg		110	68 - 120	2	25

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
4-Bromofluorobenzene (Surr)	102		50 - 150

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup

Lab Sample ID: MB 580-160909/1-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 160909

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		25		mg/Kg		06/11/14 16:29	06/14/14 15:31	1
Motor Oil (>C24-C36)	ND		50		mg/Kg		06/11/14 16:29	06/14/14 15:31	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	106		50 - 150	06/11/14 16:29	06/14/14 15:31	1

Lab Sample ID: LCS 580-160909/2-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 160909

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
#2 Diesel (C10-C24)	500	539		mg/Kg		108	54 - 127
Motor Oil (>C24-C36)	502	544		mg/Kg		108	70 - 125

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Method: NWTPH-Dx - Semi-Volatile Petroleum Products by NWTPH with Silica Gel Cleanup (Continued)

Lab Sample ID: LCS 580-160909/2-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 160909

Surrogate	LCS %Recovery	LCS Qualifier	Limits
o-Terphenyl	106		50 - 150

Lab Sample ID: LCSD 580-160909/3-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 160909

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
#2 Diesel (C10-C24)	500	414	*	mg/Kg		83	64 - 127	26	16
Motor Oil (>C24-C36)	502	443	*	mg/Kg		88	70 - 125	20	17

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
o-Terphenyl	112		50 - 150

Lab Sample ID: 580-43883-1 DU
Matrix: Solid
Analysis Batch: 161250

Client Sample ID: HA-01-01
Prep Type: Total/NA
Prep Batch: 160909

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
#2 Diesel (C10-C24)	ND	*	ND	*	mg/Kg		NC	35
Motor Oil (>C24-C36)	ND	*	ND	*	mg/Kg		3	35

Surrogate	DU %Recovery	DU Qualifier	Limits
o-Terphenyl	84		50 - 150

Method: 6010B - Metals (ICP)

Lab Sample ID: MB 580-161109/18-A
Matrix: Solid
Analysis Batch: 161293

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 161109

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg		06/14/14 10:20	06/16/14 11:06	1

Lab Sample ID: LCS 580-161109/19-A
Matrix: Solid
Analysis Batch: 161293

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161109

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	50.0	45.3		mg/Kg		91	80 - 120

Lab Sample ID: LCSD 580-161109/20-A
Matrix: Solid
Analysis Batch: 161293

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 161109

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	50.0	45.8		mg/Kg		92	80 - 120	1	20

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Method: 6010B - Metals (ICP) (Continued)

Lab Sample ID: LCSSRM 580-161109/21-A
Matrix: Solid
Analysis Batch: 161293

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161109

Analyte	Spike Added	LCSSRM Result	LCSSRM Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	103	98.9		mg/Kg		96.0	70.9 - 128.2

Method: D 2216 - Percent Moisture

Lab Sample ID: 580-43883-8 DU
Matrix: Solid
Analysis Batch: 160794

Client Sample ID: HA-08-02
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Percent Solids	89		88		%		0.8	20
Percent Moisture	11		12		%		6	20

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-01-01
Date Collected: 06/02/14 14:15
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-1
Matrix: Solid
Percent Solids: 82.5

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 20:34	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161250	06/16/14 13:10	JJP	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:01	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-02-02
Date Collected: 06/02/14 15:20
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-2
Matrix: Solid
Percent Solids: 84.5

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 21:41	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/14/14 20:07	EKK	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:05	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-03-03
Date Collected: 06/03/14 10:20
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-3
Matrix: Solid
Percent Solids: 94.0

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 22:15	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/14/14 20:25	EKK	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:08	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-04-01
Date Collected: 06/03/14 10:55
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-4
Matrix: Solid
Percent Solids: 88.5

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-04-01
Date Collected: 06/03/14 10:55
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-4
Matrix: Solid
Percent Solids: 88.5

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 22:49	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/14/14 20:43	EKK	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:11	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-05-02
Date Collected: 06/03/14 11:30
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-5
Matrix: Solid
Percent Solids: 82.4

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 23:23	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/14/14 21:01	EKK	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:14	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-06-03
Date Collected: 06/03/14 12:00
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-6
Matrix: Solid
Percent Solids: 90.7

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 23:57	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/14/14 21:19	EKK	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:18	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-07-01
Date Collected: 06/03/14 14:15
Date Received: 06/04/14 15:30

Lab Sample ID: 580-43883-7
Matrix: Solid
Percent Solids: 93.9

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/11/14 00:30	IWH	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-43883-1

Client Sample ID: HA-07-01 — **Lab Sample ID: 580-43883-7**
Date Collected: 06/03/14 14:15 — Matrix: Solid
Date Received: 06/04/14 15:30 — Percent Solids: 93.9

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/14/14 21:55	EKK	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:21	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Client Sample ID: HA-08-02 — **Lab Sample ID: 580-43883-8**
Date Collected: 06/03/14 15:05 — Matrix: Solid
Date Received: 06/04/14 15:30 — Percent Solids: 88.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/11/14 01:04	IWH	TAL SEA
Total/NA	Prep	3546			160909	06/11/14 16:29	CTC	TAL SEA
Total/NA	Cleanup	3630C			161151	06/14/14 09:36	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161250	06/16/14 13:46	JJP	TAL SEA
Total/NA	Prep	3050B			161109	06/14/14 10:20	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161293	06/16/14 12:24	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160794	06/10/14 16:17	CLH	TAL SEA

Laboratory References:
TAL SEA = TestAmerica Seattle, 5755 8th Street East, Tacoma, WA 98424, TEL (253)922-2310

Certification Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

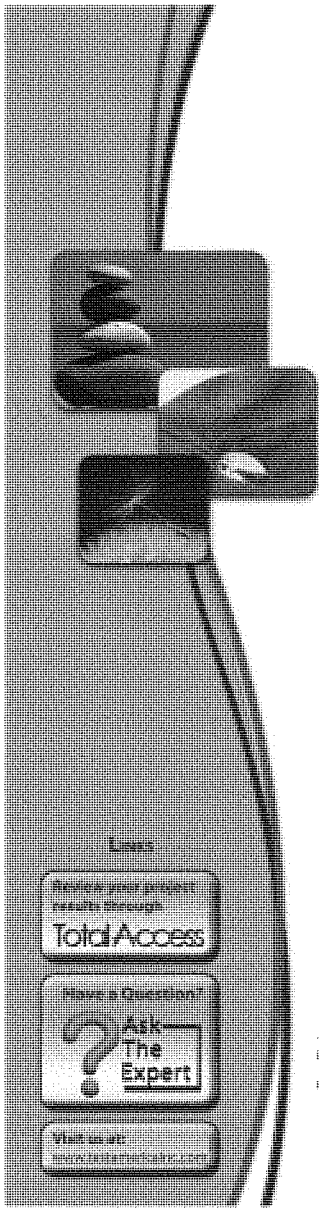
TestAmerica Job ID: 580-43883-1

Laboratory: TestAmerica Seattle

All certifications held by this laboratory are listed. Not all certifications are applicable to this report.

Authority	Program	EPA Region	Certification ID	Expiration Date
Alaska (UST)	State Program	10	UST-112	05-27-15
California	NELAP	9	01115CA	01-31-14 *
California	State Program	9	2901	01-31-15
L-A-B	DoD ELAP		L2236	01-19-16
L-A-B	ISO/IEC 17025		L2236	01-19-16
Montana (UST)	State Program	8	N/A	04-30-20
Oregon	NELAP	10	WA100007	11-06-14
USDA	Federal		P330-11-00222	04-08-17
Washington	State Program	10	C553	02-17-15

* Certification renewal pending - certification considered valid.



TestAmerica

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ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Seattle
5755 8th Street East
Tacoma, WA 98424
Tel: (253)922-2310

TestAmerica Job ID: 580-43885-1
Client Project/Site: Skokomish GI

For:
Landau & Associates, Inc.
1115 West Bay Drive NW
Suite 201
Olympia, Washington 98502

Attn: Craig Jordan

Authorized for release by:
6/20/2014 4:21:40 PM

Melissa Armstrong, Project Manager II
(253)248-4975
melissa.armstrong@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

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Case Narrative

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Job ID: 580-43885-1

Laboratory: TestAmerica Seattle

Narrative

Receipt
The samples were received on 6/6/2014 5:20 PM; the samples arrived in good condition, properly preserved and, where required, on ice.
The temperature of the cooler at receipt was 21.5° C.

GC/MS VOA - Method(s) NWTPH-Gx
Elevated reporting limits are provided for sample HA-28-0.5 (580-43885-3) due to insufficient sample provided for analysis. A sample volume of 925 uL was obtained from the sample vial rather than 1075 uL.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

GC Semi VOA
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Geotechnical
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Organic Prep
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Definitions/Glossary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Sample Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
580-43885-1	HA-26-01	Solid	06/06/14 12:15	06/07/14 17:20
580-43885-2	HA-27-0.5	Solid	06/06/14 12:35	06/07/14 17:20
580-43885-3	HA-28-0.5	Solid	06/06/14 13:55	06/07/14 17:20
580-43885-4	HA-29-0.5	Solid	06/06/14 10:55	06/07/14 17:20
580-43885-5	HA-30-0.5	Solid	06/06/14 11:35	06/07/14 17:20
580-43885-6	Trip Blank	Solid	06/06/14 00:00	06/07/14 17:20

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TestAmerica Seattle
5755 8th Street E.
Tacoma, WA 98424
Tel. 253-922-2310
Fax 253-922-5047
www.testamericainc.com

☐ Rush
☐ Short Hold

Chain of Custody Record

6/20/2014

Client: Landau Associates	Client Contact: Craig Jordan	Date: 6/6/14	Chain of Custody Number: 22503
Address: 1115 West Bay Drive Ste 201	Telephone Number (Area Code)/Fax Number: 360.791.3178	Lab Number: 43885	Page 1 of 1
City: Olympia; State: WA; Zip Code: 98502	Sampler: James Ruppen/ Craig Jordan; Lab Contact: Melissa Armstrong		
Project Name and Location (State): Skokomish GI	Billing Contact: Craig Jordan		
Contract/Purchase Order/Quote No.: 0621004.010.011			

	Sample I.D. and Location/Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	MeOH	N WTPH-Gx	N WTPH-Dx	Lead Total	9060A TOC	Grain Size PSEP							Special Instructions/ Conditions of Receipt
-1	HA-26-01	6/6/14	12:15				X	X						X	X	X	X									
-2	HA-27-0.5		12:35																							
-3	HA-28-0.5		13:55																							
-4	HA-29-0.5		10:55															X	X							
-5	HA-30-0.5		11:35											X	X	X	X									
-6	Trip Blank						X							X	X											

580-43885 Chain of Custody

IR 21.5 21.5
CG BLK WH
ICE BUBBLE
w/o CLIENT

Cooler: ☒ Yes ☐ No Cooler Temp: _____	Possible Hazard Identification: ☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown	Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For _____ Months	(A fee may be assessed if samples are retained longer than 1 month)
Turn Around Time Required (business days): ☐ 24 Hours ☐ 48 Hours ☐ 5 Days ☒ 10 Days ☐ 15 Days ☐ Other _____	QC Requirements (Specify)		

1. Relinquished By Sign/Print: Craig Jordan	Date: 6/6/14	Time: 3:45	1. Received By Sign/Print: Beth Roberts	Date: 6/6/14	Time: 3:45
2. Relinquished By Sign/Print: Beth Roberts	Date: 6/6/14	Time: 5:10	2. Received By Sign/Print: R.T. McDaniel	Date: 6/6/14	Time: 1720
3. Relinquished By Sign/Print	Date	Time	3. Received By Sign/Print	Date	Time

Comments

DISTRIBUTION: WHITE – Stays with the Samples; CANARY – Returned to Client with Report; PINK – Field Copy

TAL-8274-580 (0210)

Login Sample Receipt Checklist

Client: Landau & Associates, Inc.

Job Number: 580-43885-1

Login Number: 43885
List Number: 1
Creator: Blankinship, Tom X

List Source: TestAmerica Seattle

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	Received same day of collection; chilling process has begun.
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Client Sample ID: HA-26-01
Date Collected: 06/06/14 12:15
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-1
Matrix: Solid
Percent Solids: 86.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.8		mg/Kg	☼	06/09/14 15:15	06/10/14 17:45	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/09/14 15:15	06/10/14 17:45	1

Client Sample ID: HA-27-0.5
Date Collected: 06/06/14 12:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-2
Matrix: Solid
Percent Solids: 92.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.9		mg/Kg	☼	06/09/14 15:15	06/10/14 18:19	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	95		50 - 150	06/09/14 15:15	06/10/14 18:19	1

Client Sample ID: HA-28-0.5
Date Collected: 06/06/14 13:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-3
Matrix: Solid
Percent Solids: 57.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		12		mg/Kg	☼	06/09/14 15:15	06/10/14 18:53	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	96		50 - 150	06/09/14 15:15	06/10/14 18:53	1

Client Sample ID: HA-29-0.5
Date Collected: 06/06/14 10:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-4
Matrix: Solid
Percent Solids: 78.1

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.9		mg/Kg	☼	06/09/14 15:15	06/10/14 19:27	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/09/14 15:15	06/10/14 19:27	1

Client Sample ID: HA-30-0.5
Date Collected: 06/06/14 11:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-5
Matrix: Solid
Percent Solids: 96.7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.1		mg/Kg	☼	06/09/14 15:15	06/10/14 20:00	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	98		50 - 150	06/09/14 15:15	06/10/14 20:00	1

Client Sample ID: Trip Blank
Date Collected: 06/06/14 00:00
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-6
Matrix: Solid

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		0.94		mg/Kg	☼	06/09/14 15:15	06/10/14 17:12	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	96		50 - 150	06/09/14 15:15	06/10/14 17:12	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Client Sample ID: HA-26-01 — **Lab Sample ID: 580-43885-1**
Date Collected: 06/06/14 12:15 — **Matrix: Solid**
Date Received: 06/07/14 17:20 — **Percent Solids: 86.0**

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		28		mg/Kg	☼	06/14/14 11:37	06/15/14 01:34	1
Motor Oil (>C24-C36)	ND		57		mg/Kg	☼	06/14/14 11:37	06/15/14 01:34	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	68		50 - 150	06/14/14 11:37	06/15/14 01:34	1

Client Sample ID: HA-27-0.5 — **Lab Sample ID: 580-43885-2**
Date Collected: 06/06/14 12:35 — **Matrix: Solid**
Date Received: 06/07/14 17:20 — **Percent Solids: 92.0**

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		27		mg/Kg	☼	06/14/14 11:37	06/15/14 02:10	1
Motor Oil (>C24-C36)	ND		53		mg/Kg	☼	06/14/14 11:37	06/15/14 02:10	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	69		50 - 150	06/14/14 11:37	06/15/14 02:10	1

Client Sample ID: HA-28-0.5 — **Lab Sample ID: 580-43885-3**
Date Collected: 06/06/14 13:55 — **Matrix: Solid**
Date Received: 06/07/14 17:20 — **Percent Solids: 57.6**

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		42		mg/Kg	☼	06/14/14 11:37	06/15/14 02:28	1
Motor Oil (>C24-C36)	ND		83		mg/Kg	☼	06/14/14 11:37	06/15/14 02:28	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	79		50 - 150	06/14/14 11:37	06/15/14 02:28	1

Client Sample ID: HA-29-0.5 — **Lab Sample ID: 580-43885-4**
Date Collected: 06/06/14 10:55 — **Matrix: Solid**
Date Received: 06/07/14 17:20 — **Percent Solids: 78.1**

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		31		mg/Kg	☼	06/14/14 11:37	06/15/14 02:46	1
Motor Oil (>C24-C36)	ND		61		mg/Kg	☼	06/14/14 11:37	06/15/14 02:46	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	84		50 - 150	06/14/14 11:37	06/15/14 02:46	1

Client Sample ID: HA-30-0.5 — **Lab Sample ID: 580-43885-5**
Date Collected: 06/06/14 11:35 — **Matrix: Solid**
Date Received: 06/07/14 17:20 — **Percent Solids: 96.7**

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		25		mg/Kg	☼	06/14/14 11:37	06/15/14 03:03	1
Motor Oil (>C24-C36)	ND		50		mg/Kg	☼	06/14/14 11:37	06/15/14 03:03	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	87		50 - 150	06/14/14 11:37	06/15/14 03:03	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: 6010B - Metals (ICP)

Client Sample ID: HA-26-01
Date Collected: 06/06/14 12:15
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-1
Matrix: Solid
Percent Solids: 86.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	2.5		1.7		mg/Kg	☼	06/17/14 13:52	06/18/14 11:40	1

Client Sample ID: HA-27-0.5
Date Collected: 06/06/14 12:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-2
Matrix: Solid
Percent Solids: 92.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	1.8		1.5		mg/Kg	☼	06/17/14 13:52	06/18/14 12:03	1

Client Sample ID: HA-28-0.5
Date Collected: 06/06/14 13:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-3
Matrix: Solid
Percent Solids: 57.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	2.8		2.6		mg/Kg	☼	06/17/14 13:52	06/18/14 12:07	1

Client Sample ID: HA-29-0.5
Date Collected: 06/06/14 10:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-4
Matrix: Solid
Percent Solids: 78.1

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.8		mg/Kg	☼	06/17/14 13:52	06/18/14 12:09	1

Client Sample ID: HA-30-0.5
Date Collected: 06/06/14 11:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-5
Matrix: Solid
Percent Solids: 96.7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	1.5		0.94		mg/Kg	☼	06/17/14 13:52	06/18/14 12:13	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

General Chemistry

Client Sample ID: HA-26-01
Date Collected: 06/06/14 12:15
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-1
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	86		0.10		%			06/11/14 11:54	1
Percent Moisture	14		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-27-0.5
Date Collected: 06/06/14 12:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-2
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	92		0.10		%			06/11/14 11:54	1
Percent Moisture	8.0		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-28-0.5
Date Collected: 06/06/14 13:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-3
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	58		0.10		%			06/11/14 11:54	1
Percent Moisture	42		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-29-0.5
Date Collected: 06/06/14 10:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-4
Matrix: Solid

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Organic Carbon	ND		2000		mg/Kg			06/13/14 15:43	1

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	78		0.10		%			06/11/14 11:54	1
Percent Moisture	22		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-30-0.5
Date Collected: 06/06/14 11:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-5
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	97		0.10		%			06/11/14 11:54	1
Percent Moisture	3.3		0.10		%			06/11/14 11:54	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: PSEP Plumb 1981 - Grain Size (PSEP Plumb 1981)

Client Sample ID: HA-29-0.5
Date Collected: 06/06/14 10:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-4
Matrix: Solid

Analyte	Result	Qualifier	NONE	NONE	Unit	D	Prepared	Analyzed	Dil Fac
Cobbles	0.00				%			06/17/14 13:47	1
Gravel	59				%			06/17/14 13:47	1
Very Coarse Sand	15				%			06/17/14 13:47	1
Coarse Sand	5.9				%			06/17/14 13:47	1
Medium Sand	15				%			06/17/14 13:47	1
Fine Sand	5.4				%			06/17/14 13:47	1
Very Fine Sand	0.30				%			06/17/14 13:47	1
Coarse Silt	0.10				%			06/17/14 13:47	1
Medium Silt	0.30				%			06/17/14 13:47	1
Fine Silt	-0.10				%			06/17/14 13:47	1
Very Fine Silt	0.10				%			06/17/14 13:47	1
Coarse Clay	0.00				%			06/17/14 13:47	1
Medium Clay	0.00				%			06/17/14 13:47	1

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-160686/1-A
Matrix: Solid
Analysis Batch: 160758

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 160686

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.0		mg/Kg		06/09/14 15:15	06/10/14 15:30	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/09/14 15:15	06/10/14 15:30	1

Lab Sample ID: LCS 580-160686/2-A
Matrix: Solid
Analysis Batch: 160758

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 160686

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Gasoline	32.0	34.5		mg/Kg		108	68 - 120

Surrogate	LCS %Recovery	LCS Qualifier	Limits
4-Bromofluorobenzene (Surr)	102		50 - 150

Lab Sample ID: LCSD 580-160686/3-A
Matrix: Solid
Analysis Batch: 160758

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 160686

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Gasoline	32.0	35.2		mg/Kg		110	68 - 120	2	25

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
4-Bromofluorobenzene (Surr)	102		50 - 150

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-161162/1-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 161162

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		25		mg/Kg		06/14/14 11:37	06/15/14 00:40	1
Motor Oil (>C24-C36)	ND		50		mg/Kg		06/14/14 11:37	06/15/14 00:40	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	80		50 - 150	06/14/14 11:37	06/15/14 00:40	1

Lab Sample ID: LCS 580-161162/2-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161162

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
#2 Diesel (C10-C24)	500	417		mg/Kg		83	64 - 127
Motor Oil (>C24-C36)	502	439		mg/Kg		87	70 - 125

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC) (Continued)

Lab Sample ID: LCS 580-161162/2-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161162

Surrogate	LCS %Recovery	LCS Qualifier	Limits
o-Terphenyl	77		50 - 150

Lab Sample ID: LCSD 580-161162/3-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 161162

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
#2 Diesel (C10-C24)	500	461		mg/Kg		92	64 - 127	10	16
Motor Oil (>C24-C36)	502	492		mg/Kg		98	70 - 125	11	17

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
o-Terphenyl	81		50 - 150

Lab Sample ID: 580-43885-1 DU
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: HA-26-01
Prep Type: Total/NA
Prep Batch: 161162

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
#2 Diesel (C10-C24)	ND		ND		mg/Kg	☼	NC	35
Motor Oil (>C24-C36)	ND		ND		mg/Kg	☼	3	35

Surrogate	DU %Recovery	DU Qualifier	Limits
o-Terphenyl	72		50 - 150

Method: 6010B - Metals (ICP)

Lab Sample ID: MB 580-161428/21-A
Matrix: Solid
Analysis Batch: 161575

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 161428

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg		06/17/14 13:52	06/18/14 11:28	1

Lab Sample ID: LCS 580-161428/22-A
Matrix: Solid
Analysis Batch: 161575

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161428

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	50.0	50.8		mg/Kg		102	80 - 120

Lab Sample ID: LCSD 580-161428/23-A
Matrix: Solid
Analysis Batch: 161575

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 161428

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	50.0	51.3		mg/Kg		103	80 - 120	1	20

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Method: 6010B - Metals (ICP) (Continued)

Lab Sample ID: 580-43885-1 MS
Matrix: Solid
Analysis Batch: 161575

Client Sample ID: HA-26-01
Prep Type: Total/NA
Prep Batch: 161428

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	2.5		47.6	47.4		mg/Kg	☼	94	80 - 120

Lab Sample ID: 580-43885-1 MSD
Matrix: Solid
Analysis Batch: 161575

Client Sample ID: HA-26-01
Prep Type: Total/NA
Prep Batch: 161428

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	2.5		49.2	48.2		mg/Kg	☼	93	80 - 120	2	20

Lab Sample ID: 580-43885-1 DU
Matrix: Solid
Analysis Batch: 161575

Client Sample ID: HA-26-01
Prep Type: Total/NA
Prep Batch: 161428

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Lead	2.5		2.24		mg/Kg	☼	10	20

Method: 9060_PSEP - TOC (Puget Sound)

Lab Sample ID: MB 580-161103/3
Matrix: Solid
Analysis Batch: 161103

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Organic Carbon	ND		2000		mg/Kg			06/13/14 15:43	1

Lab Sample ID: LCS 580-161103/4
Matrix: Solid
Analysis Batch: 161103

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Organic Carbon	2850	3230		mg/Kg		113	27.8 - 170

Lab Sample ID: LCSD 580-161103/5
Matrix: Solid
Analysis Batch: 161103

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Total Organic Carbon	2850	3120		mg/Kg		110	27.8 - 170	3	35

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Client Sample ID: HA-26-01
Date Collected: 06/06/14 12:15
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-1
Matrix: Solid
Percent Solids: 86.0

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 17:45	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 01:34	EKK	TAL SEA
Total/NA	Prep	3050B			161428	06/17/14 13:52	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161575	06/18/14 11:40	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-27-0.5
Date Collected: 06/06/14 12:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-2
Matrix: Solid
Percent Solids: 92.0

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 18:19	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 02:10	EKK	TAL SEA
Total/NA	Prep	3050B			161428	06/17/14 13:52	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161575	06/18/14 12:03	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-28-0.5
Date Collected: 06/06/14 13:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-3
Matrix: Solid
Percent Solids: 57.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 18:53	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 02:28	EKK	TAL SEA
Total/NA	Prep	3050B			161428	06/17/14 13:52	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161575	06/18/14 12:07	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-29-0.5
Date Collected: 06/06/14 10:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-4
Matrix: Solid
Percent Solids: 78.1

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43885-1

Client Sample ID: HA-29-0.5
Date Collected: 06/06/14 10:55
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-4
Matrix: Solid
Percent Solids: 78.1

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 19:27	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 02:46	EKK	TAL SEA
Total/NA	Prep	3050B			161428	06/17/14 13:52	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161575	06/18/14 12:09	HJM	TAL SEA
Total/NA	Analysis	9060_PSEP		1	161103	06/13/14 15:43	TAA	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA
Total/NA	Analysis	PSEP Plumb 1981		1	161422	06/17/14 13:47	HJM	TAL SEA

Client Sample ID: HA-30-0.5
Date Collected: 06/06/14 11:35
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-5
Matrix: Solid
Percent Solids: 96.7

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 20:00	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 03:03	EKK	TAL SEA
Total/NA	Prep	3050B			161428	06/17/14 13:52	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161575	06/18/14 12:13	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: Trip Blank
Date Collected: 06/06/14 00:00
Date Received: 06/07/14 17:20

Lab Sample ID: 580-43885-6
Matrix: Solid

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160686	06/09/14 15:15	IWH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160758	06/10/14 17:12	IWH	TAL SEA

Laboratory References:
TAL SEA = TestAmerica Seattle, 5755 8th Street East, Tacoma, WA 98424, TEL (253)922-2310

Certification Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

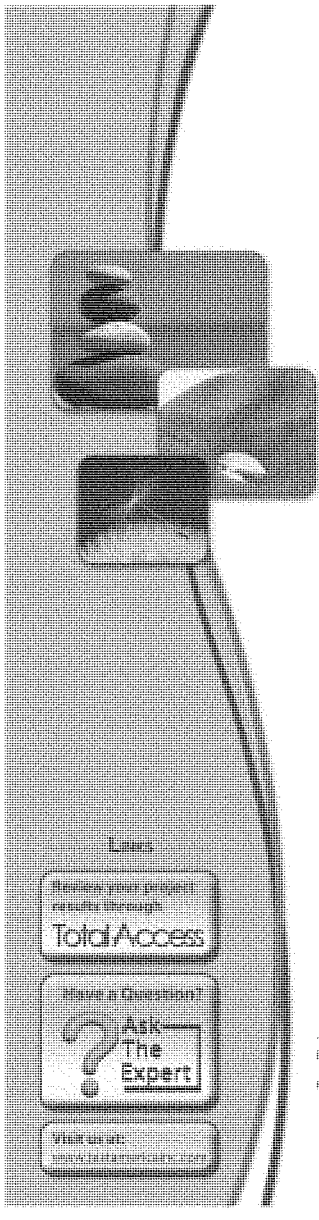
TestAmerica Job ID: 580-43885-1

Laboratory: TestAmerica Seattle

All certifications held by this laboratory are listed. Not all certifications are applicable to this report.

Authority	Program	EPA Region	Certification ID	Expiration Date
Alaska (UST)	State Program	10	UST-112	05-27-15
California	NELAP	9	01115CA	01-31-14 *
California	State Program	9	2901	01-31-15
L-A-B	DoD ELAP		L2236	01-19-16
L-A-B	ISO/IEC 17025		L2236	01-19-16
Montana (UST)	State Program	8	N/A	04-30-20
Oregon	NELAP	10	WA100007	11-06-14
USDA	Federal		P330-11-00222	04-08-17
Washington	State Program	10	C553	02-17-15

* Certification renewal pending - certification considered valid.



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ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Seattle
5755 8th Street East
Tacoma, WA 98424
Tel: (253)922-2310

TestAmerica Job ID: 580-43886-1
Client Project/Site: Skokomish GI

For:
Landau & Associates, Inc.
1115 West Bay Drive NW
Suite 201
Olympia, Washington 98502

Attn: Craig Jordan

Authorized for release by:
6/18/2014 4:12:25 PM

Melissa Armstrong, Project Manager II
(253)248-4975
melissa.armstrong@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

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Case Narrative

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Job ID: 580-43886-1

Laboratory: TestAmerica Seattle

Narrative

Receipt
The samples were received on 6/6/2014 4:20 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperature of the cooler at receipt was 3.5° C.

Except:
The container labels for the following samples did not match the information listed on the Chain-of-Custody (COC): HA-24-01 (580-43886-13), HA-25-01 (580-43886-14). The container labels list the sampling date 6/5/14 while the COC lists 6/4/14. The samples are logged in per COC.

GC/MS VOA
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

GC Semi VOA
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Organic Prep
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Definitions/Glossary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Sample Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
580-43886-1	HA-09-03	Solid	06/04/14 10:00	06/06/14 16:20
580-43886-2	HA-10-01	Solid	06/04/14 10:40	06/06/14 16:20
580-43886-3	HA-11-02	Solid	06/04/14 12:05	06/06/14 16:20
580-43886-4	HA-12-03	Solid	06/04/14 14:00	06/06/14 16:20
580-43886-5	HA-13-01	Solid	06/04/14 15:15	06/06/14 16:20
580-43886-6	HA-14-02	Solid	06/04/14 16:30	06/06/14 16:20
580-43886-7	HA-15-03	Solid	06/05/14 10:00	06/06/14 16:20
580-43886-8	HA-16-01	Solid	06/05/14 10:40	06/06/14 16:20
580-43886-9	HA-17-02	Solid	06/05/14 11:35	06/06/14 16:20
580-43886-10	HA-18-03	Solid	06/05/14 12:50	06/06/14 16:20
580-43886-11	HA-19-01	Solid	06/05/14 13:30	06/06/14 16:20
580-43886-12	HA-20-02	Solid	06/05/14 14:20	06/06/14 16:20
580-43886-13	HA-24-01	Solid	06/04/14 15:55	06/06/14 16:20
580-43886-14	HA-25-01	Solid	06/04/14 16:05	06/06/14 16:20
580-43886-15	Trip Blank	Solid	06/04/14 00:00	06/06/14 16:20

TestAmerica
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TestAmerica Seattle
5755 8th Street E.
Tacoma, WA 98424
Tel. 253-922-2310
Fax 253-922-5047
www.testamericainc.com

☐ Rush
☐ Short Hold

Chain of Custody Record

6/18/2014

Client: Landau Associates	Client Contact: Craig Jordan	Date: 6/6/14	Chain of Custody Number: 22502
Address: 1115 West Bay Drive Ste 201	Telephone Number (Area Code)/Fax Number: 360 791 3178	Lab Number: 438886	Page 1 of 2
City: Olympia; State: WA; Zip Code: 98502	Sampler: James Raspen; Lab Contact: Melissa Armstrong		
Project Name and Location (State): Skokomish 61	Billing Contact: Craig Jordan		
Contract/Purchase Order/Quote No.: 0621004.010.011			

Sample I.D. and Location/Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	MeOH	NWTPH-Dx	NWTPH-Gx	Lead 6010C	Analysis (Attach list if more space is needed)	Special Instructions/ Conditions of Receipt
-1 HA-09-03	6/4/14	10:00				X	X						X	X	X	X		
-2 HA-10-01		10:40																
-3 HA-11-02		12:05																
-4 HA-12-03		14:00																
-5 HA-13-01		15:15																
-6 HA-14-02		16:30																
-7 HA-15-03	6/5/14	10:00																
-8 HA-16-01		10:40																
-9 HA-17-02		11:35																
-10 HA-18-03		12:50																
-11 HA-19-01		13:30																
-12 HA-20-02		14:20																

580-43886 Chain of Custody

Cooler: ☒ Yes ☐ No Cooler Temp: _____

Possible Hazard Identification: ☒ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For _____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required (business days): ☐ 24 Hours ☐ 48 Hours ☐ 5 Days ☒ 10 Days ☐ 15 Days ☐ Other _____

QC Requirements (Specify):

1. Relinquished By Sign/Print: James Raspen	Date: 6/6/14	Time: 08:00	1. Received By Sign/Print: Beth Roberts	Date: 6/6/14	Time: 8:00
2. Relinquished By Sign/Print: Beth Roberts	Date: 6/6/14	Time: 12:07	2. Received By Sign/Print: Francisco Luna, Jr.	Date: 6/6/14	Time: 1207
3. Relinquished By Sign/Print	Date	Time	3. Received By Sign/Print	Date	Time

Comments

DISTRIBUTION: WHITE – Stays with the Samples; CANARY – Returned to Client with Report; PINK – Field Copy

TAL-3274-580 (0210)

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Seattle
5755 8th Street E.
Tacoma, WA 98424
Tel. 253-922-2310
Fax 253-922-5047
www.testamericainc.com

☐ Rush
☐ Short Hold

Chain of Custody Record

6/18/2014

Client: Landau Associates	Client Contact: Craig Jordan	Date: 6/6/14	Chain of Custody Number: 22504
Address: 1115 West Bay Drive Ste 201	Telephone Number (Area Code)/Fax Number: 360 791 3178	Lab Number: 43886	Page 2 of 2
City: Olympia; State: WA; Zip Code: 98502	Sampler: James Raspen	Lab Contact: Melissa Armstrong	
Project Name and Location (State): SKokomish 61	Billing Contact: Craig Jordan		
Contract/Purchase Order/Quote No.: 0621004.010.011			

Analysis (Attach list if more space is needed): NWTPH-Dx; NWTPH-Gx; Lead 6010C

Special Instructions/ Conditions of Receipt

Sample I.D. and Location/Description (Containers for each sample may be combined on one line)	Date	Time	Matrix: Air	Aqueous	Sed.	Soil	Containers & Preservatives: Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/ NaOH	MeOH	NWTPH-Dx	NWTPH-Gx	Lead 6010C
-13 HA-24-01	6/4/14	1555				X	X						X	X	X	X
-14 HA-25-01	6/4/14	1605				X	X						X	X	X	X
-15 Trip Blank						X							X		X	

Cooler/(TB) Dig/IR cor 3.5° unc 4.0°
Cooler Dsc Lg Blue/White @ Lab 1620
Wet/Packs Packing Bubble
w/es A1

Page 218 of 227

1000

Cooler: ☐ Yes ☐ No Cooler Temp: _____

Possible Hazard Identification: ☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal: ☐ Return To Client ☐ Disposal By Lab ☐ Archive For _____ Months (A fee may be assessed if samples are retained longer than 1 month)

Turn Around Time Required (business days): ☐ 24 Hours ☐ 48 Hours ☐ 5 Days ☐ 10 Days ☐ 15 Days ☐ Other _____

QC Requirements (Specify)

1. Relinquished By Sign/Print: James Raspen	Date: 6/6/14	Time: 08:00	1. Received By Sign/Print: Beth Roberts	Date: 6/6/14	Time: 8:00
2. Relinquished By Sign/Print: Beth Roberts	Date: 6/6/14	Time: 12:07	2. Received By Sign/Print: Francisco Luna Jr.	Date: 6/6/14	Time: 1207
3. Relinquished By Sign/Print	Date	Time	3. Received By Sign/Print	Date	Time

Comments

DISTRIBUTION: WHITE – Stays with the Samples; CANARY – Returned to Client with Report; PINK – Field Copy

TAL-8274-580 (0210)

Login Sample Receipt Checklist

Client: Landau & Associates, Inc.

Job Number: 580-43886-1

Login Number: 43886
List Number: 1
Creator: Blankinship, Tom X

List Source: TestAmerica Seattle

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	False	Date of -13 & -14
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Client Sample ID: HA-09-03
Date Collected: 06/04/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-1
Matrix: Solid
Percent Solids: 80.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.6		mg/Kg	☼	06/10/14 17:01	06/11/14 07:50	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	87		50 - 150	06/10/14 17:01	06/11/14 07:50	1

Client Sample ID: HA-10-01
Date Collected: 06/04/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-2
Matrix: Solid
Percent Solids: 82.9

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	13		5.7		mg/Kg	☼	06/10/14 17:01	06/11/14 08:24	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	99		50 - 150	06/10/14 17:01	06/11/14 08:24	1

Client Sample ID: HA-11-02
Date Collected: 06/04/14 12:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-3
Matrix: Solid
Percent Solids: 93.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.1		mg/Kg	☼	06/10/14 17:01	06/11/14 08:57	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	98		50 - 150	06/10/14 17:01	06/11/14 08:57	1

Client Sample ID: HA-12-03
Date Collected: 06/04/14 14:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-4
Matrix: Solid
Percent Solids: 93.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.2		mg/Kg	☼	06/10/14 17:01	06/11/14 09:31	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	96		50 - 150	06/10/14 17:01	06/11/14 09:31	1

Client Sample ID: HA-13-01
Date Collected: 06/04/14 15:15
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-5
Matrix: Solid
Percent Solids: 80.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.1		mg/Kg	☼	06/10/14 17:01	06/11/14 10:04	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	98		50 - 150	06/10/14 17:01	06/11/14 10:04	1

Client Sample ID: HA-14-02
Date Collected: 06/04/14 16:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-6
Matrix: Solid
Percent Solids: 94.2

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		3.7		mg/Kg	☼	06/10/14 17:01	06/11/14 10:38	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	98		50 - 150	06/10/14 17:01	06/11/14 10:38	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Client Sample ID: HA-15-03
Date Collected: 06/05/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-7
Matrix: Solid
Percent Solids: 84.3

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.4		mg/Kg	☼	06/10/14 17:01	06/11/14 11:45	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	98		50 - 150	06/10/14 17:01	06/11/14 11:45	1

Client Sample ID: HA-16-01
Date Collected: 06/05/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-8
Matrix: Solid
Percent Solids: 84.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.0		mg/Kg	☼	06/10/14 17:01	06/11/14 12:19	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/10/14 17:01	06/11/14 12:19	1

Client Sample ID: HA-17-02
Date Collected: 06/05/14 11:35
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-9
Matrix: Solid
Percent Solids: 94.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.9		mg/Kg	☼	06/10/14 17:01	06/11/14 12:53	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	99		50 - 150	06/10/14 17:01	06/11/14 12:53	1

Client Sample ID: HA-18-03
Date Collected: 06/05/14 12:50
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-10
Matrix: Solid
Percent Solids: 82.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.5		mg/Kg	☼	06/10/14 17:01	06/11/14 13:27	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	98		50 - 150	06/10/14 17:01	06/11/14 13:27	1

Client Sample ID: HA-19-01
Date Collected: 06/05/14 13:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-11
Matrix: Solid
Percent Solids: 93.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.3		mg/Kg	☼	06/10/14 17:01	06/11/14 14:01	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/10/14 17:01	06/11/14 14:01	1

Client Sample ID: HA-20-02
Date Collected: 06/05/14 14:20
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-12
Matrix: Solid
Percent Solids: 90.5

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.6		mg/Kg	☼	06/10/14 17:01	06/11/14 14:34	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/10/14 17:01	06/11/14 14:34	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Client Sample ID: HA-24-01
Date Collected: 06/04/14 15:55
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-13
Matrix: Solid
Percent Solids: 86.7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.8		mg/Kg	☼	06/10/14 17:01	06/11/14 15:08	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*89*		*50 - 150*	*06/10/14 17:01*	*06/11/14 15:08*	*1*

Client Sample ID: HA-25-01
Date Collected: 06/04/14 16:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-14
Matrix: Solid
Percent Solids: 86.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		62		mg/Kg	☼	06/10/14 17:01	06/11/14 15:42	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*97*		*50 - 150*	*06/10/14 17:01*	*06/11/14 15:42*	*1*

Client Sample ID: Trip Blank
Date Collected: 06/04/14 00:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-15
Matrix: Solid

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.0		mg/Kg		06/10/14 17:01	06/11/14 07:16	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*95*		*50 - 150*	*06/10/14 17:01*	*06/11/14 07:16*	*1*

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Client Sample ID: HA-09-03
Date Collected: 06/04/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-1
Matrix: Solid
Percent Solids: 80.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		31		mg/Kg	☼	06/14/14 11:37	06/15/14 03:21	1
Motor Oil (>C24-C36)	ND		61		mg/Kg	☼	06/14/14 11:37	06/15/14 03:21	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	84		50 - 150	06/14/14 11:37	06/15/14 03:21	1

Client Sample ID: HA-10-01
Date Collected: 06/04/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-2
Matrix: Solid
Percent Solids: 82.9

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		30		mg/Kg	☼	06/14/14 11:37	06/15/14 03:57	1
Motor Oil (>C24-C36)	ND		59		mg/Kg	☼	06/14/14 11:37	06/15/14 03:57	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	84		50 - 150	06/14/14 11:37	06/15/14 03:57	1

Client Sample ID: HA-11-02
Date Collected: 06/04/14 12:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-3
Matrix: Solid
Percent Solids: 93.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/14/14 11:37	06/15/14 04:15	1
Motor Oil (>C24-C36)	ND		52		mg/Kg	☼	06/14/14 11:37	06/15/14 04:15	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	76		50 - 150	06/14/14 11:37	06/15/14 04:15	1

Client Sample ID: HA-12-03
Date Collected: 06/04/14 14:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-4
Matrix: Solid
Percent Solids: 93.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/14/14 11:37	06/15/14 04:33	1
Motor Oil (>C24-C36)	ND		51		mg/Kg	☼	06/14/14 11:37	06/15/14 04:33	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	86		50 - 150	06/14/14 11:37	06/15/14 04:33	1

Client Sample ID: HA-13-01
Date Collected: 06/04/14 15:15
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-5
Matrix: Solid
Percent Solids: 80.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		30		mg/Kg	☼	06/14/14 11:37	06/15/14 04:51	1
Motor Oil (>C24-C36)	ND		60		mg/Kg	☼	06/14/14 11:37	06/15/14 04:51	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	82		50 - 150	06/14/14 11:37	06/15/14 04:51	1

Client Sample ID: HA-14-02
Date Collected: 06/04/14 16:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-6
Matrix: Solid
Percent Solids: 94.2

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/14/14 11:37	06/15/14 05:09	1
Motor Oil (>C24-C36)	ND		52		mg/Kg	☼	06/14/14 11:37	06/15/14 05:09	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC) (Continued)

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	79		50 - 150	06/14/14 11:37	06/15/14 05:09	1

Client Sample ID: HA-15-03
Date Collected: 06/05/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-7
Matrix: Solid
Percent Solids: 84.3

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		29		mg/Kg	☼	06/14/14 11:37	06/15/14 05:27	1
Motor Oil (>C24-C36)	ND		58		mg/Kg	☼	06/14/14 11:37	06/15/14 05:27	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	73		50 - 150	06/14/14 11:37	06/15/14 05:27	1

Client Sample ID: HA-16-01
Date Collected: 06/05/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-8
Matrix: Solid
Percent Solids: 84.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		29		mg/Kg	☼	06/14/14 11:37	06/15/14 05:45	1
Motor Oil (>C24-C36)	ND		58		mg/Kg	☼	06/14/14 11:37	06/15/14 05:45	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	95		50 - 150	06/14/14 11:37	06/15/14 05:45	1

Client Sample ID: HA-17-02
Date Collected: 06/05/14 11:35
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-9
Matrix: Solid
Percent Solids: 94.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/14/14 11:37	06/15/14 06:03	1
Motor Oil (>C24-C36)	ND		51		mg/Kg	☼	06/14/14 11:37	06/15/14 06:03	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	87		50 - 150	06/14/14 11:37	06/15/14 06:03	1

Client Sample ID: HA-18-03
Date Collected: 06/05/14 12:50
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-10
Matrix: Solid
Percent Solids: 82.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		29		mg/Kg	☼	06/14/14 11:37	06/15/14 06:21	1
Motor Oil (>C24-C36)	ND		58		mg/Kg	☼	06/14/14 11:37	06/15/14 06:21	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	80		50 - 150	06/14/14 11:37	06/15/14 06:21	1

Client Sample ID: HA-19-01
Date Collected: 06/05/14 13:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-11
Matrix: Solid
Percent Solids: 93.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/14/14 11:37	06/15/14 06:39	1
Motor Oil (>C24-C36)	ND		52		mg/Kg	☼	06/14/14 11:37	06/15/14 06:39	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	78		50 - 150	06/14/14 11:37	06/15/14 06:39	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Client Sample ID: HA-20-02
Date Collected: 06/05/14 14:20
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-12
Matrix: Solid
Percent Solids: 90.5

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		27		mg/Kg	☼	06/14/14 11:37	06/15/14 07:15	1
Motor Oil (>C24-C36)	ND		53		mg/Kg	☼	06/14/14 11:37	06/15/14 07:15	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	83		50 - 150	06/14/14 11:37	06/15/14 07:15	1

Client Sample ID: HA-24-01
Date Collected: 06/04/14 15:55
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-13
Matrix: Solid
Percent Solids: 86.7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		28		mg/Kg	☼	06/14/14 11:37	06/15/14 07:33	1
Motor Oil (>C24-C36)	ND		57		mg/Kg	☼	06/14/14 11:37	06/15/14 07:33	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	82		50 - 150	06/14/14 11:37	06/15/14 07:33	1

Client Sample ID: HA-25-01
Date Collected: 06/04/14 16:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-14
Matrix: Solid
Percent Solids: 86.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		28		mg/Kg	☼	06/14/14 11:37	06/15/14 07:51	1
Motor Oil (>C24-C36)	ND		56		mg/Kg	☼	06/14/14 11:37	06/15/14 07:51	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	76		50 - 150	06/14/14 11:37	06/15/14 07:51	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: 6010B - Metals (ICP)

Client Sample ID: HA-09-03
Date Collected: 06/04/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-1
Matrix: Solid
Percent Solids: 80.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.4		mg/Kg	☼	06/16/14 13:30	06/16/14 17:14	1

Client Sample ID: HA-10-01
Date Collected: 06/04/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-2
Matrix: Solid
Percent Solids: 82.9

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	4.0		1.5		mg/Kg	☼	06/16/14 13:31	06/16/14 17:36	1

Client Sample ID: HA-11-02
Date Collected: 06/04/14 12:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-3
Matrix: Solid
Percent Solids: 93.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		0.95		mg/Kg	☼	06/16/14 13:31	06/16/14 17:40	1

Client Sample ID: HA-12-03
Date Collected: 06/04/14 14:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-4
Matrix: Solid
Percent Solids: 93.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.2		mg/Kg	☼	06/16/14 13:31	06/16/14 17:43	1

Client Sample ID: HA-13-01
Date Collected: 06/04/14 15:15
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-5
Matrix: Solid
Percent Solids: 80.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg	☼	06/16/14 13:31	06/16/14 17:46	1

Client Sample ID: HA-14-02
Date Collected: 06/04/14 16:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-6
Matrix: Solid
Percent Solids: 94.2

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.0		mg/Kg	☼	06/16/14 13:31	06/16/14 17:49	1

Client Sample ID: HA-15-03
Date Collected: 06/05/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-7
Matrix: Solid
Percent Solids: 84.3

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg	☼	06/16/14 13:31	06/16/14 17:53	1

Client Sample ID: HA-16-01
Date Collected: 06/05/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-8
Matrix: Solid
Percent Solids: 84.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.4		mg/Kg	☼	06/16/14 13:31	06/16/14 18:02	1

Client Sample ID: HA-17-02
Date Collected: 06/05/14 11:35
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-9
Matrix: Solid
Percent Solids: 94.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.1		mg/Kg	☼	06/16/14 13:31	06/16/14 18:06	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: 6010B - Metals (ICP)

Client Sample ID: HA-18-03
Date Collected: 06/05/14 12:50
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-10
Matrix: Solid
Percent Solids: 82.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg	☼	06/16/14 13:31	06/16/14 18:09	1

Client Sample ID: HA-19-01
Date Collected: 06/05/14 13:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-11
Matrix: Solid
Percent Solids: 93.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.2		mg/Kg	☼	06/16/14 13:31	06/16/14 18:12	1

Client Sample ID: HA-20-02
Date Collected: 06/05/14 14:20
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-12
Matrix: Solid
Percent Solids: 90.5

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.1		mg/Kg	☼	06/16/14 13:31	06/16/14 18:16	1

Client Sample ID: HA-24-01
Date Collected: 06/04/14 15:55
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-13
Matrix: Solid
Percent Solids: 86.7

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.4		mg/Kg	☼	06/16/14 13:31	06/16/14 18:19	1

Client Sample ID: HA-25-01
Date Collected: 06/04/14 16:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-14
Matrix: Solid
Percent Solids: 86.4

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg	☼	06/16/14 13:31	06/16/14 18:22	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

General Chemistry

Client Sample ID: HA-09-03
Date Collected: 06/04/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-1
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	81		0.10		%			06/11/14 11:54	1
Percent Moisture	19		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-10-01
Date Collected: 06/04/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-2
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	83		0.10		%			06/11/14 11:54	1
Percent Moisture	17		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-11-02
Date Collected: 06/04/14 12:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-3
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	93		0.10		%			06/11/14 11:54	1
Percent Moisture	6.6		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-12-03
Date Collected: 06/04/14 14:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-4
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	94		0.10		%			06/11/14 11:54	1
Percent Moisture	6.2		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-13-01
Date Collected: 06/04/14 15:15
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-5
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	80		0.10		%			06/11/14 11:54	1
Percent Moisture	20		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-14-02
Date Collected: 06/04/14 16:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-6
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	94		0.10		%			06/11/14 11:54	1
Percent Moisture	5.8		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-15-03
Date Collected: 06/05/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-7
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	84		0.10		%			06/11/14 11:54	1
Percent Moisture	16		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-16-01
Date Collected: 06/05/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-8
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	85		0.10		%			06/11/14 11:54	1
Percent Moisture	15		0.10		%			06/11/14 11:54	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

General Chemistry

Client Sample ID: HA-17-02
Date Collected: 06/05/14 11:35
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-9
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	95		0.10		%			06/11/14 11:54	1
Percent Moisture	5.4		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-18-03
Date Collected: 06/05/14 12:50
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-10
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	83		0.10		%			06/11/14 11:54	1
Percent Moisture	17		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-19-01
Date Collected: 06/05/14 13:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-11
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	94		0.10		%			06/11/14 11:54	1
Percent Moisture	6.3		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-20-02
Date Collected: 06/05/14 14:20
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-12
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	90		0.10		%			06/11/14 11:54	1
Percent Moisture	9.5		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-24-01
Date Collected: 06/04/14 15:55
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-13
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	87		0.10		%			06/11/14 11:54	1
Percent Moisture	13		0.10		%			06/11/14 11:54	1

Client Sample ID: HA-25-01
Date Collected: 06/04/14 16:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-14
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	86		0.10		%			06/11/14 11:54	1
Percent Moisture	14		0.10		%			06/11/14 11:54	1

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-160803/1-A
Matrix: Solid
Analysis Batch: 160812

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 160803

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.0		mg/Kg		06/10/14 17:01	06/11/14 05:35	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150	06/10/14 17:01	06/11/14 05:35	1

Lab Sample ID: LCS 580-160803/2-A
Matrix: Solid
Analysis Batch: 160812

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 160803

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Gasoline	32.0	34.1		mg/Kg		107	68 - 120

Surrogate	LCS %Recovery	LCS Qualifier	Limits
4-Bromofluorobenzene (Surr)	103		50 - 150

Lab Sample ID: LCSD 580-160803/3-A
Matrix: Solid
Analysis Batch: 160812

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 160803

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Gasoline	32.0	35.9		mg/Kg		112	68 - 120	5	25

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
4-Bromofluorobenzene (Surr)	104		50 - 150

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-161162/1-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 161162

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		25		mg/Kg		06/14/14 11:37	06/15/14 00:40	1
Motor Oil (>C24-C36)	ND		50		mg/Kg		06/14/14 11:37	06/15/14 00:40	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	80		50 - 150	06/14/14 11:37	06/15/14 00:40	1

Lab Sample ID: LCS 580-161162/2-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161162

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
#2 Diesel (C10-C24)	500	417		mg/Kg		83	64 - 127
Motor Oil (>C24-C36)	502	439		mg/Kg		87	70 - 125

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC) (Continued)

Lab Sample ID: LCS 580-161162/2-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161162

Surrogate	LCS %Recovery	LCS Qualifier	Limits
o-Terphenyl	77		50 - 150

Lab Sample ID: LCSD 580-161162/3-B
Matrix: Solid
Analysis Batch: 161171

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 161162

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
#2 Diesel (C10-C24)	500	461		mg/Kg		92	64 - 127	10	16
Motor Oil (>C24-C36)	502	492		mg/Kg		98	70 - 125	11	17

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
o-Terphenyl	81		50 - 150

Method: 6010B - Metals (ICP)

Lab Sample ID: MB 580-161302/18-A
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 161302

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg		06/16/14 13:31	06/16/14 16:59	1

Lab Sample ID: LCS 580-161302/19-A
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161302

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	50.0	48.7		mg/Kg		97	80 - 120

Lab Sample ID: LCSD 580-161302/20-A
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 161302

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	50.0	48.6		mg/Kg		97	80 - 120	0	20

Lab Sample ID: LCSSRM 580-161302/21-A
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 161302

Analyte	Spike Added	LCSSRM Result	LCSSRM Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	103	104		mg/Kg		100.8	70.9 - 128.2

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Method: 6010B - Metals (ICP) (Continued)

Lab Sample ID: 580-43886-1 MS
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: HA-09-03
Prep Type: Total/NA
Prep Batch: 161302

Analyte	Sample Result	Sample Qualifier	Spike Added	MS Result	MS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	ND		49.7	46.9		mg/Kg	☼	92	80 - 120

Lab Sample ID: 580-43886-1 MSD
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: HA-09-03
Prep Type: Total/NA
Prep Batch: 161302

Analyte	Sample Result	Sample Qualifier	Spike Added	MSD Result	MSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	ND		48.0	44.4		mg/Kg	☼	90	80 - 120	5	20

Lab Sample ID: 580-43886-1 DU
Matrix: Solid
Analysis Batch: 161355

Client Sample ID: HA-09-03
Prep Type: Total/NA
Prep Batch: 161302

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Lead	ND		ND		mg/Kg	☼	NC	20

Method: D 2216 - Percent Moisture

Lab Sample ID: 580-43886-14 DU
Matrix: Solid
Analysis Batch: 160849

Client Sample ID: HA-25-01
Prep Type: Total/NA

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
Percent Solids	86		86		%		0.07	20
Percent Moisture	14		14		%		0.4	20

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Client Sample ID: HA-09-03
Date Collected: 06/04/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-1
Matrix: Solid
Percent Solids: 80.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 07:50	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 03:21	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:30	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:14	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-10-01
Date Collected: 06/04/14 10:40
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-2
Matrix: Solid
Percent Solids: 82.9

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 08:24	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 03:57	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:36	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-11-02
Date Collected: 06/04/14 12:05
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-3
Matrix: Solid
Percent Solids: 93.4

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 08:57	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 04:15	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:40	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-12-03
Date Collected: 06/04/14 14:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-4
Matrix: Solid
Percent Solids: 93.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Client Sample ID: HA-12-03
Date Collected: 06/04/14 14:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-4
Matrix: Solid
Percent Solids: 93.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 09:31	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 04:33	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:43	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-13-01
Date Collected: 06/04/14 15:15
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-5
Matrix: Solid
Percent Solids: 80.4

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 10:04	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 04:51	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:46	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-14-02
Date Collected: 06/04/14 16:30
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-6
Matrix: Solid
Percent Solids: 94.2

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 10:38	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 05:09	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:49	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-15-03
Date Collected: 06/05/14 10:00
Date Received: 06/06/14 16:20

Lab Sample ID: 580-43886-7
Matrix: Solid
Percent Solids: 84.3

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 11:45	IWH	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Client Sample ID: HA-15-03 — **Lab Sample ID: 580-43886-7**
Date Collected: 06/05/14 10:00 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 84.3

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 05:27	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 17:53	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-16-01 — **Lab Sample ID: 580-43886-8**
Date Collected: 06/05/14 10:40 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 84.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 12:19	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 05:45	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:02	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-17-02 — **Lab Sample ID: 580-43886-9**
Date Collected: 06/05/14 11:35 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 94.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 12:53	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 06:03	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:06	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-18-03 — **Lab Sample ID: 580-43886-10**
Date Collected: 06/05/14 12:50 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 82.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 13:27	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Client Sample ID: HA-18-03 — **Lab Sample ID: 580-43886-10**
Date Collected: 06/05/14 12:50 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 82.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 06:21	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:09	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-19-01 — **Lab Sample ID: 580-43886-11**
Date Collected: 06/05/14 13:30 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 93.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 14:01	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 06:39	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:12	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-20-02 — **Lab Sample ID: 580-43886-12**
Date Collected: 06/05/14 14:20 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 90.5

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 14:34	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 07:15	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:16	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-24-01 — **Lab Sample ID: 580-43886-13**
Date Collected: 06/04/14 15:55 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 86.7

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 15:08	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

TestAmerica Job ID: 580-43886-1

Client Sample ID: HA-24-01 — **Lab Sample ID: 580-43886-13**
Date Collected: 06/04/14 15:55 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 86.7

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 07:33	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:19	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: HA-25-01 — **Lab Sample ID: 580-43886-14**
Date Collected: 06/04/14 16:05 — Matrix: Solid
Date Received: 06/06/14 16:20 — Percent Solids: 86.4

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 15:42	IWH	TAL SEA
Total/NA	Prep	3546			161162	06/14/14 11:37	CTC	TAL SEA
Total/NA	Cleanup	3630C			161195	06/14/14 21:32	EKK	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	161171	06/15/14 07:51	EKK	TAL SEA
Total/NA	Prep	3050B			161302	06/16/14 13:31	PAB	TAL SEA
Total/NA	Analysis	6010B		1	161355	06/16/14 18:22	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	160849	06/11/14 11:54	CLH	TAL SEA

Client Sample ID: Trip Blank — **Lab Sample ID: 580-43886-15**
Date Collected: 06/04/14 00:00 — Matrix: Solid
Date Received: 06/06/14 16:20

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			160803	06/10/14 17:01	CRH	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	160812	06/11/14 07:16	IWH	TAL SEA

Laboratory References:

TAL SEA = TestAmerica Seattle, 5755 8th Street East, Tacoma, WA 98424, TEL (253)922-2310

Certification Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI

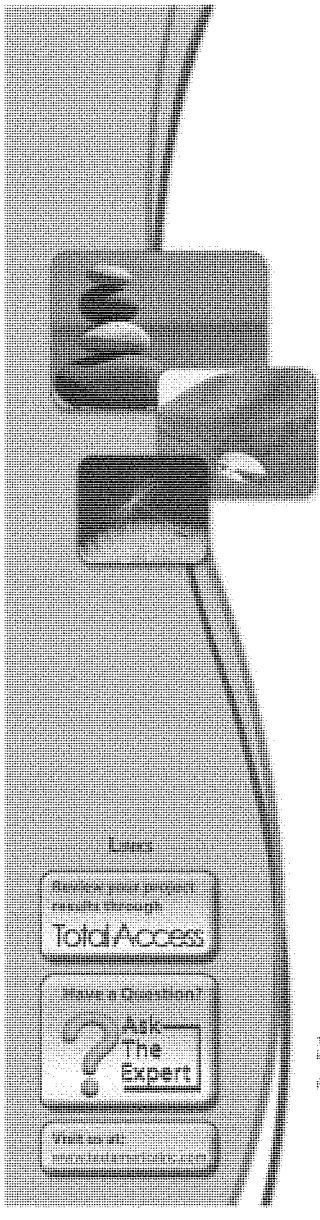
TestAmerica Job ID: 580-43886-1

Laboratory: TestAmerica Seattle

All certifications held by this laboratory are listed. Not all certifications are applicable to this report.

Authority	Program	EPA Region	Certification ID	Expiration Date
Alaska (UST)	State Program	10	UST-112	05-27-15
California	NELAP	9	01115CA	01-31-14 *
California	State Program	9	2901	01-31-15
L-A-B	DoD ELAP		L2236	01-19-16
L-A-B	ISO/IEC 17025		L2236	01-19-16
Montana (UST)	State Program	8	N/A	04-30-20
Oregon	NELAP	10	WA100007	11-06-14
USDA	Federal		P330-11-00222	04-08-17
Washington	State Program	10	C553	02-17-15

* Certification renewal pending - certification considered valid.



TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Seattle
5755 8th Street East
Tacoma, WA 98424
Tel: (253)922-2310

TestAmerica Job ID: 580-44186-1
Client Project/Site: Skokomish GI WA

For:
Landau & Associates, Inc.
1115 West Bay Drive NW
Suite 201
Olympia, Washington 98502

Attn: Craig Jordan

Authorized for release by:
7/10/2014 6:00:28 PM

Melissa Armstrong, Project Manager II
(253)248-4975
melissa.armstrong@testamericainc.com

This report has been electronically signed and authorized by the signatory. Electronic signature is intended to be the legally binding equivalent of a traditionally handwritten signature.

Results relate only to the items tested and the sample(s) as received by the laboratory.

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Case Narrative

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Job ID: 580-44186-1

Laboratory: TestAmerica Seattle

Narrative

Receipt
The samples were received on 6/20/2014 6:15 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperature of the cooler at receipt was 1.8° C.

GC/MS VOA - Method(s) NWTPH-Gx
The Gasoline Range Organics (GRO) concentration reported for the following sample(s) is due to the presence of discrete peaks: HA-32-0.25 (580-44186-7).

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

GC Semi VOA - Method(s) NWTPH-Dx
In analytical batch 162821, for the following samples from preparation batches 162722 and 162784: (LCS 580-162722/2-A), (LCSD 580-162722/3-A), (MB 580-162722/1-A), a retention time check was run in place of a CCV by accident, so there was 21 injections by the GC instrument instead of the usual 10. Two sets of method blanks and LCS/LCSDs were run with in this bracket and all are passing and with in acceptable range criteria as well as the rest of the QC through out the analytical batch to assure that the instrument running these samples was performing with in acceptable standards.

No additional analytical or quality issues were noted, other than those described above or in the Definitions/Glossary page.

Metals
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

General Chemistry
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Geotechnical
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Organic Prep
No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Definitions/Glossary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Sample Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
580-44186-1	HA-21-03	Solid	06/18/14 10:50	06/20/14 18:15
580-44186-2	HA-22-01	Solid	06/18/14 11:35	06/20/14 18:15
580-44186-3	HA-23-02	Solid	06/18/14 12:15	06/20/14 18:15
580-44186-4	Equipment Wash	Water	06/18/14 12:50	06/20/14 18:15
580-44186-5	HA-33-03	Solid	06/18/14 13:35	06/20/14 18:15
580-44186-6	HA-31-00	Solid	06/18/14 15:25	06/20/14 18:15
580-44186-7	HA-32-0.25	Solid	06/18/14 16:00	06/20/14 18:15
580-44186-8	Trip Blank 5/30/14	Solid	06/18/14 00:00	06/20/14 18:15
580-44186-9	Trip Blank	Water	06/18/14 00:00	06/20/14 18:15

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www.testamericainc.com

☐ Rush
☐ Short Hold

Chain of Custody Record

7/10/2014

Client: Landau Associates	Client Contact: Calvin McCaughan / Craig Jordan	Date: 6/18/14	Chain of Custody Number: 22301
Address: 1115 West Bay Dr. NW	Telephone Number (Area Code)/Fax Number: 360-791-3178	Lab Number: 44486	Page 1 of 1
City: Olympia; State: WA; Zip Code: 98502	Sampler: Craig Jordan, Josh Elliott; Lab Contact: Melissa Armstrong		
Project Name and Location (State): SKOKOMISH GI WA	Billing Contact: Calvin McCaughan		
Contract/Purchase Order/Quote No.: 0621004.010.011			

Analysis (Attach list if more space is needed)

Sample I.D. and Location/Description (Containers for each sample may be combined on one line)	Date	Time	Air	Aqueous	Sed.	Soil	Unpres.	H2SO4	HNO3	HCl	NaOH	ZnAc/NaOH	Arsenic	NWTPH-Gx	NWTPH-Dx	Lead 6010C	TOC	PSEP Grain Size	Special Instructions/ Conditions of Receipt
HA-21-03	6/18/14	1050				X	X						X	X	X	X			
HA-22-01	6/18/14	1135				X	X						X	X	X	X			
HA-23-02	6/18/14	1215				X	X						X	X	X	X			
Equipment Wash	6/18/14	1250	X						X	X				X	X	X			
HA-33-03	6/18/14	1335				X	X						X	X	X	X			
HA-31-00	6/18/14	1525			X		X						X	X	X	X	X	X	
HA-32-0.25	6/18/14	1600				X	X						X	X	X	X			
Trip Blank 5/31/14	6/18/14					X							X		X				
Trip Blank	6/18/14			X						X				X	X	X			

580-44186 Chain of Custody

Cooler/IB Dig IR corr 1.8° unc 2.1°
Cooler Dsc Lg Blue/White @ Lab 1315
Wet/Packs Packing Bubble
w/cs A1

Cooler: ☑ Yes ☐ No Cooler Temp: ____	Possible Hazard Identification: ☑ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown	Sample Disposal: ☐ Return To Client ☐ Archive For ____ Months ☐ Disposal By Lab	(A fee may be assessed if samples are retained longer than 1 month)
Turn Around Time Required (business days): ☐ 24 Hours ☐ 48 Hours ☐ 5 Days ☑ 10 Days ☐ 15 Days ☐ Other ____		QC Requirements (Specify):	

1. Relinquished By Sign/Print: Craig Jordan (12 total Days)	Date: 6/20/14	Time: 8:00	1. Received By Sign/Print: Beth Roberts	Date: 6/20/14	Time: 8:00
2. Relinquished By Sign/Print: Beth Roberts	Date: 6/20/14	Time: 12:10	2. Received By Sign/Print: Francisco Luna, Jr	Date: 6/20/14	Time: 12:10
3. Relinquished By Sign/Print	Date	Time	3. Received By Sign/Print	Date	Time

Comments

DISTRIBUTION: WHITE – Stays with the Samples; CANARY – Returned to Client with Report; PINK – Field Copy

TAL-8274-580 (0210)

Login Sample Receipt Checklist

Client: Landau & Associates, Inc.

Job Number: 580-44186-1

Login Number: 44186
List Number: 1
Creator: McDaniel, Ronald T

List Source: TestAmerica Seattle

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Client Sample ID: HA-21-03
Date Collected: 06/18/14 10:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-1
Matrix: Solid
Percent Solids: 90.9

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	51		4.3		mg/Kg	☼	06/28/14 13:42	06/29/14 00:51	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	113		50 - 150	06/28/14 13:42	06/29/14 00:51	1

Client Sample ID: HA-22-01
Date Collected: 06/18/14 11:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-2
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	8.2		4.0		mg/Kg	☼	06/28/14 13:42	06/29/14 01:40	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	90		50 - 150	06/28/14 13:42	06/29/14 01:40	1

Client Sample ID: HA-23-02
Date Collected: 06/18/14 12:15
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-3
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	4.5		4.0		mg/Kg	☼	06/28/14 13:42	06/29/14 02:05	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	95		50 - 150	06/28/14 13:42	06/29/14 02:05	1

Client Sample ID: Equipment Wash
Date Collected: 06/18/14 12:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-4
Matrix: Water

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		0.050		mg/L			07/01/14 21:41	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	97		50 - 150		07/01/14 21:41	1
Trifluorotoluene (Surr)	112		50 - 150		07/01/14 21:41	1

Client Sample ID: HA-33-03
Date Collected: 06/18/14 13:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-5
Matrix: Solid
Percent Solids: 92.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.7		mg/Kg	☼	06/28/14 13:42	06/29/14 02:29	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	91		50 - 150	06/28/14 13:42	06/29/14 02:29	1

Client Sample ID: HA-31-00
Date Collected: 06/18/14 15:25
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-6
Matrix: Solid
Percent Solids: 82.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		5.2		mg/Kg	☼	06/28/14 13:42	06/29/14 02:54	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	91		50 - 150	06/28/14 13:42	06/29/14 02:54	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Client Sample ID: HA-32-0.25
Date Collected: 06/18/14 16:00
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-7
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	13		4.3		mg/Kg	☼	06/28/14 13:42	06/29/14 03:19	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*88*		*50 - 150*	*06/28/14 13:42*	*06/29/14 03:19*	*1*

Client Sample ID: Trip Blank 5/30/14
Date Collected: 06/18/14 00:00
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-8
Matrix: Solid

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.0		mg/Kg		06/28/14 13:42	06/28/14 18:42	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*87*		*50 - 150*	*06/28/14 13:42*	*06/28/14 18:42*	*1*

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC) - RA

Client Sample ID: Trip Blank
Date Collected: 06/18/14 00:00
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-9
Matrix: Water

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		0.050		mg/L			06/30/14 15:20	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*90*		*50 - 150*		*06/30/14 15:20*	*1*
Trifluorotoluene (Surr)	*107*		*50 - 150*		*06/30/14 15:20*	*1*

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Client Sample ID: HA-21-03
Date Collected: 06/18/14 10:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-1
Matrix: Solid
Percent Solids: 90.9

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		27		mg/Kg	☼	06/30/14 16:00	07/03/14 13:26	1
Motor Oil (>C24-C36)	ND		54		mg/Kg	☼	06/30/14 16:00	07/03/14 13:26	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	71		50 - 150	06/30/14 16:00	07/03/14 13:26	1

Client Sample ID: HA-22-01
Date Collected: 06/18/14 11:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-2
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/30/14 16:00	07/03/14 13:41	1
Motor Oil (>C24-C36)	ND		52		mg/Kg	☼	06/30/14 16:00	07/03/14 13:41	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	73		50 - 150	06/30/14 16:00	07/03/14 13:41	1

Client Sample ID: HA-23-02
Date Collected: 06/18/14 12:15
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-3
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/30/14 16:00	07/03/14 13:57	1
Motor Oil (>C24-C36)	ND		52		mg/Kg	☼	06/30/14 16:00	07/03/14 13:57	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	85		50 - 150	06/30/14 16:00	07/03/14 13:57	1

Client Sample ID: Equipment Wash
Date Collected: 06/18/14 12:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-4
Matrix: Water

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		0.12		mg/L		07/01/14 12:04	07/03/14 03:51	1
Motor Oil (>C24-C36)	ND		0.24		mg/L		07/01/14 12:04	07/03/14 03:51	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	57		50 - 150	07/01/14 12:04	07/03/14 03:51	1

Client Sample ID: HA-33-03
Date Collected: 06/18/14 13:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-5
Matrix: Solid
Percent Solids: 92.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/30/14 16:00	07/03/14 14:12	1
Motor Oil (>C24-C36)	ND		52		mg/Kg	☼	06/30/14 16:00	07/03/14 14:12	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	81		50 - 150	06/30/14 16:00	07/03/14 14:12	1

Client Sample ID: HA-31-00
Date Collected: 06/18/14 15:25
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-6
Matrix: Solid
Percent Solids: 82.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		30		mg/Kg	☼	06/30/14 16:00	07/03/14 14:28	1
Motor Oil (>C24-C36)	ND		60		mg/Kg	☼	06/30/14 16:00	07/03/14 14:28	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC) (Continued)

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	80		50 - 150	06/30/14 16:00	07/03/14 14:28	1

Client Sample ID: HA-32-0.25
Date Collected: 06/18/14 16:00
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-7
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		26		mg/Kg	☼	06/30/14 16:13	07/03/14 15:15	1
Motor Oil (>C24-C36)	ND		51		mg/Kg	☼	06/30/14 16:13	07/03/14 15:15	1

Surrogate	%Recovery	Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	87		50 - 150	06/30/14 16:13	07/03/14 15:15	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: 6010B - Metals (ICP)

Client Sample ID: HA-21-03
Date Collected: 06/18/14 10:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-1
Matrix: Solid
Percent Solids: 90.9

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	2.9		1.0		mg/Kg	☼	07/01/14 08:18	07/01/14 21:15	1

Client Sample ID: HA-22-01
Date Collected: 06/18/14 11:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-2
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	1.7		1.5		mg/Kg	☼	07/01/14 08:18	07/01/14 21:18	1

Client Sample ID: HA-23-02
Date Collected: 06/18/14 12:15
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-3
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	1.5		0.96		mg/Kg	☼	07/01/14 08:18	07/01/14 21:21	1

Client Sample ID: HA-33-03
Date Collected: 06/18/14 13:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-5
Matrix: Solid
Percent Solids: 92.0

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	2.4		0.96		mg/Kg	☼	07/01/14 08:18	07/01/14 21:25	1

Client Sample ID: HA-31-00
Date Collected: 06/18/14 15:25
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-6
Matrix: Solid
Percent Solids: 82.6

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.3		mg/Kg	☼	07/01/14 08:18	07/01/14 21:28	1

Client Sample ID: HA-32-0.25
Date Collected: 06/18/14 16:00
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-7
Matrix: Solid
Percent Solids: 95.8

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	0.97		0.97		mg/Kg	☼	07/01/14 08:18	07/01/14 21:31	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: 6010B - Metals (ICP) - Total Recoverable

Client Sample ID: Equipment Wash
Date Collected: 06/18/14 12:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-4
Matrix: Water

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		0.030		mg/L		06/27/14 11:37	07/01/14 02:54	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

General Chemistry

Client Sample ID: HA-21-03
Date Collected: 06/18/14 10:50
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-1
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	91		0.10		%			07/01/14 18:33	1
Percent Moisture	9.1		0.10		%			07/01/14 18:33	1

Client Sample ID: HA-22-01
Date Collected: 06/18/14 11:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-2
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	96		0.10		%			07/01/14 18:33	1
Percent Moisture	4.2		0.10		%			07/01/14 18:33	1

Client Sample ID: HA-23-02
Date Collected: 06/18/14 12:15
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-3
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	96		0.10		%			07/01/14 18:33	1
Percent Moisture	4.2		0.10		%			07/01/14 18:33	1

Client Sample ID: HA-33-03
Date Collected: 06/18/14 13:35
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-5
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	92		0.10		%			07/01/14 18:33	1
Percent Moisture	8.0		0.10		%			07/01/14 18:33	1

Client Sample ID: HA-31-00
Date Collected: 06/18/14 15:25
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-6
Matrix: Solid

Analyte	Result	Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Organic Carbon	2400		2000		mg/Kg			06/26/14 10:45	1

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	83		0.10		%			07/01/14 18:33	1
Percent Moisture	17		0.10		%			07/01/14 18:33	1

Client Sample ID: HA-32-0.25
Date Collected: 06/18/14 16:00
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-7
Matrix: Solid

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
Percent Solids	96		0.10		%			07/01/14 18:33	1
Percent Moisture	4.2		0.10		%			07/01/14 18:33	1

Client Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: PSEP Plumb 1981 - Grain Size (PSEP Plumb 1981)

Client Sample ID: HA-31-00
Date Collected: 06/18/14 15:25
Date Received: 06/20/14 18:15

Lab Sample ID: 580-44186-6
Matrix: Solid

Analyte	Result	Qualifier	NONE	NONE	Unit	D	Prepared	Analyzed	Dil Fac
Cobbles	0.00				%			07/02/14 10:12	1
Gravel	48				%			07/02/14 10:12	1
Sand	52				%			07/02/14 10:12	1
Very Coarse Sand	46				%			07/02/14 10:12	1
Coarse Sand	5.4				%			07/02/14 10:12	1
Medium Sand	0.60				%			07/02/14 10:12	1
Fine Sand	0.10				%			07/02/14 10:12	1
Very Fine Sand	0.10				%			07/02/14 10:12	1
Silt	0.20				%			07/02/14 10:12	1
Coarse Silt	0.00				%			07/02/14 10:12	1
Medium Silt	0.10				%			07/02/14 10:12	1
Fine Silt	0.10				%			07/02/14 10:12	1
Very Fine Silt	0.00				%			07/02/14 10:12	1
Clay	-0.10				%			07/02/14 10:12	1
Coarse Clay	0.00				%			07/02/14 10:12	1
Medium Clay	0.00				%			07/02/14 10:12	1

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-162481/1-A
Matrix: Solid
Analysis Batch: 162483

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 162481

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		4.0		mg/Kg		06/28/14 13:41	06/28/14 16:39	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	88		50 - 150	06/28/14 13:41	06/28/14 16:39	1

Lab Sample ID: LCS 580-162481/2-A
Matrix: Solid
Analysis Batch: 162483

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 162481

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Gasoline	40.0	40.2		mg/Kg		101	68 - 120

Surrogate	LCS %Recovery	LCS Qualifier	Limits
4-Bromofluorobenzene (Surr)	96		50 - 150

Lab Sample ID: LCSD 580-162481/3-A
Matrix: Solid
Analysis Batch: 162483

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 162481

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Gasoline	40.0	43.8		mg/Kg		110	68 - 120	8	25

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
4-Bromofluorobenzene (Surr)	97		50 - 150

Lab Sample ID: MB 580-162590/5
Matrix: Water
Analysis Batch: 162590

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		0.050		mg/L			06/30/14 13:42	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	91		50 - 150		06/30/14 13:42	1
Trifluorotoluene (Surr)	104		50 - 150		06/30/14 13:42	1

Lab Sample ID: LCS 580-162590/6
Matrix: Water
Analysis Batch: 162590

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Gasoline	1.00	0.967		mg/L		97	79 - 110

Surrogate	LCS %Recovery	LCS Qualifier	Limits
4-Bromofluorobenzene (Surr)	96		50 - 150
Trifluorotoluene (Surr)	96		50 - 150

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Gx - Northwest - Volatile Petroleum Products (GC) (Continued)

Lab Sample ID: LCSD 580-162590/7
Matrix: Water
Analysis Batch: 162590

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Gasoline	1.00	0.990		mg/L		99	79 - 110	2	20

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
4-Bromofluorobenzene (Surr)	95		50 - 150
Trifluorotoluene (Surr)	95		50 - 150

Lab Sample ID: MB 580-162739/5
Matrix: Water
Analysis Batch: 162739

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Gasoline	ND		0.050		mg/L			07/01/14 18:15	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
4-Bromofluorobenzene (Surr)	95		50 - 150		07/01/14 18:15	1
Trifluorotoluene (Surr)	109		50 - 150		07/01/14 18:15	1

Lab Sample ID: LCS 580-162739/6
Matrix: Water
Analysis Batch: 162739

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Gasoline	1.00	0.988		mg/L		99	79 - 110

Surrogate	LCS %Recovery	LCS Qualifier	Limits
4-Bromofluorobenzene (Surr)	101		50 - 150
Trifluorotoluene (Surr)	96		50 - 150

Lab Sample ID: LCSD 580-162739/7
Matrix: Water
Analysis Batch: 162739

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Gasoline	1.00	1.01		mg/L		101	79 - 110	3	20

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
4-Bromofluorobenzene (Surr)	102		50 - 150
Trifluorotoluene (Surr)	98		50 - 150

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC)

Lab Sample ID: MB 580-162630/1-A
Matrix: Solid
Analysis Batch: 162951

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 162630

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		25		mg/Kg		06/30/14 16:00	07/03/14 12:39	1

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC) (Continued)

Lab Sample ID: MB 580-162630/1-A
Matrix: Solid
Analysis Batch: 162951

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 162630

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Motor Oil (>C24-C36)	ND		50		mg/Kg		06/30/14 16:00	07/03/14 12:39	1

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	83		50 - 150	06/30/14 16:00	07/03/14 12:39	1

Lab Sample ID: LCS 580-162630/2-C
Matrix: Solid
Analysis Batch: 162951

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 162630

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
#2 Diesel (C10-C24)	500	458		mg/Kg		92	64 - 127
Motor Oil (>C24-C36)	502	496		mg/Kg		99	70 - 125

Surrogate	LCS %Recovery	LCS Qualifier	Limits
o-Terphenyl	89		50 - 150

Lab Sample ID: LCSD 580-162630/3-C
Matrix: Solid
Analysis Batch: 162951

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 162630

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
#2 Diesel (C10-C24)	500	479		mg/Kg		96	64 - 127	5	16
Motor Oil (>C24-C36)	502	534		mg/Kg		106	70 - 125	7	17

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
o-Terphenyl	91		50 - 150

Lab Sample ID: 580-44186-6 DU
Matrix: Solid
Analysis Batch: 162951

Client Sample ID: HA-31-00
Prep Type: Total/NA
Prep Batch: 162630

Analyte	Sample Result	Sample Qualifier	DU Result	DU Qualifier	Unit	D	RPD	RPD Limit
#2 Diesel (C10-C24)	ND		ND		mg/Kg	☼	NC	35
Motor Oil (>C24-C36)	ND		ND		mg/Kg	☼	10	35

Surrogate	DU %Recovery	DU Qualifier	Limits
o-Terphenyl	83		50 - 150

Lab Sample ID: MB 580-162722/1-A
Matrix: Water
Analysis Batch: 162821

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 162722

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
#2 Diesel (C10-C24)	ND		0.13		mg/L		07/01/14 12:04	07/02/14 22:07	1
Motor Oil (>C24-C36)	ND		0.25		mg/L		07/01/14 12:04	07/02/14 22:07	1

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: NWTPH-Dx - Northwest - Semi-Volatile Petroleum Products (GC) (Continued)

Lab Sample ID: MB 580-162722/1-A
Matrix: Water
Analysis Batch: 162821

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 162722

Surrogate	MB %Recovery	MB Qualifier	Limits	Prepared	Analyzed	Dil Fac
o-Terphenyl	81		50 - 150	07/01/14 12:04	07/02/14 22:07	1

Lab Sample ID: LCS 580-162722/2-A
Matrix: Water
Analysis Batch: 162821

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 162722

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
#2 Diesel (C10-C24)	4.00	3.41		mg/L		85	59 - 120
Motor Oil (>C24-C36)	4.00	3.63		mg/L		91	71 - 140

Surrogate	LCS %Recovery	LCS Qualifier	Limits
o-Terphenyl	91		50 - 150

Lab Sample ID: LCSD 580-162722/3-A
Matrix: Water
Analysis Batch: 162821

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 162722

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
#2 Diesel (C10-C24)	4.00	3.35		mg/L		84	59 - 120	2	27
Motor Oil (>C24-C36)	4.00	3.70		mg/L		93	71 - 140	2	27

Surrogate	LCSD %Recovery	LCSD Qualifier	Limits
o-Terphenyl	89		50 - 150

Method: 6010B - Metals (ICP)

Lab Sample ID: MB 580-162656/21-A
Matrix: Solid
Analysis Batch: 162805

Client Sample ID: Method Blank
Prep Type: Total/NA
Prep Batch: 162656

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		1.5		mg/Kg		07/01/14 08:18	07/01/14 19:59	1

Lab Sample ID: LCS 580-162656/22-A
Matrix: Solid
Analysis Batch: 162805

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 162656

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	50.0	48.0		mg/Kg		96	80 - 120

Lab Sample ID: LCSD 580-162656/23-A
Matrix: Solid
Analysis Batch: 162805

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA
Prep Batch: 162656

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	50.0	48.5		mg/Kg		97	80 - 120	1	20

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: 6010B - Metals (ICP) (Continued)

Lab Sample ID: LCSSRM 580-162656/24-A
Matrix: Solid
Analysis Batch: 162805

Client Sample ID: Lab Control Sample
Prep Type: Total/NA
Prep Batch: 162656

Analyte	Spike Added	LCSSRM Result	LCSSRM Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	103	99.8		mg/Kg		96.9	70.9 - 128.2

Lab Sample ID: MB 580-162407/21-A
Matrix: Water
Analysis Batch: 162664

Client Sample ID: Method Blank
Prep Type: Total Recoverable
Prep Batch: 162407

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Lead	ND		0.030		mg/L		06/27/14 11:37	07/01/14 02:06	1

Lab Sample ID: LCS 580-162407/22-A
Matrix: Water
Analysis Batch: 162664

Client Sample ID: Lab Control Sample
Prep Type: Total Recoverable
Prep Batch: 162407

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	1.00	1.07		mg/L		107	80 - 120

Lab Sample ID: LCSD 580-162407/23-A
Matrix: Water
Analysis Batch: 162664

Client Sample ID: Lab Control Sample Dup
Prep Type: Total Recoverable
Prep Batch: 162407

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Lead	1.00	1.05		mg/L		105	80 - 120	2	20

Lab Sample ID: LCSSRM 580-162407/24-A
Matrix: Water
Analysis Batch: 162664

Client Sample ID: Lab Control Sample
Prep Type: Total Recoverable
Prep Batch: 162407

Analyte	Spike Added	LCSSRM Result	LCSSRM Qualifier	Unit	D	%Rec	%Rec. Limits
Lead	1.00	1.05		mg/L		105	80 - 120

Method: 9060_PSEP - TOC (Puget Sound)

Lab Sample ID: MB 580-162279/3
Matrix: Solid
Analysis Batch: 162279

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	MDL	Unit	D	Prepared	Analyzed	Dil Fac
Total Organic Carbon	ND		2000		mg/Kg			06/26/14 10:08	1

Lab Sample ID: LCS 580-162279/4
Matrix: Solid
Analysis Batch: 162279

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
Total Organic Carbon	2850	2920		mg/Kg		102	27.8 - 170

QC Sample Results

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Method: 9060_PSEP - TOC (Puget Sound) (Continued)

Lab Sample ID: LCSD 580-162279/5
Matrix: Solid
Analysis Batch: 162279

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
Total Organic Carbon	2850	3220		mg/Kg		113	27.8 - 170	10	35

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Client Sample ID: HA-21-03 — Lab Sample ID: 580-44186-1

Date Collected: 06/18/14 10:50 — Matrix: Solid
Date Received: 06/20/14 18:15 — Percent Solids: 90.9

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/29/14 00:51	IWH	TAL SEA
Total/NA	Prep	3546			162630	06/30/14 16:00	LHJ	TAL SEA
Total/NA	Cleanup	3630C			162780	07/01/14 17:37	CTC	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162951	07/03/14 13:26	JJP	TAL SEA
Total/NA	Prep	3050B			162656	07/01/14 08:18	KJV	TAL SEA
Total/NA	Analysis	6010B		1	162805	07/01/14 21:15	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	162788	07/01/14 18:33	CTC	TAL SEA

Client Sample ID: HA-22-01 — Lab Sample ID: 580-44186-2

Date Collected: 06/18/14 11:35 — Matrix: Solid
Date Received: 06/20/14 18:15 — Percent Solids: 95.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/29/14 01:40	IWH	TAL SEA
Total/NA	Prep	3546			162630	06/30/14 16:00	LHJ	TAL SEA
Total/NA	Cleanup	3630C			162780	07/01/14 17:37	CTC	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162951	07/03/14 13:41	JJP	TAL SEA
Total/NA	Prep	3050B			162656	07/01/14 08:18	KJV	TAL SEA
Total/NA	Analysis	6010B		1	162805	07/01/14 21:18	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	162788	07/01/14 18:33	CTC	TAL SEA

Client Sample ID: HA-23-02 — Lab Sample ID: 580-44186-3

Date Collected: 06/18/14 12:15 — Matrix: Solid
Date Received: 06/20/14 18:15 — Percent Solids: 95.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/29/14 02:05	IWH	TAL SEA
Total/NA	Prep	3546			162630	06/30/14 16:00	LHJ	TAL SEA
Total/NA	Cleanup	3630C			162780	07/01/14 17:37	CTC	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162951	07/03/14 13:57	JJP	TAL SEA
Total/NA	Prep	3050B			162656	07/01/14 08:18	KJV	TAL SEA
Total/NA	Analysis	6010B		1	162805	07/01/14 21:21	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	162788	07/01/14 18:33	CTC	TAL SEA

Client Sample ID: Equipment Wash — Lab Sample ID: 580-44186-4

Date Collected: 06/18/14 12:50 — Matrix: Water
Date Received: 06/20/14 18:15

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	NWTPH-Gx		1	162739	07/01/14 21:41	CJ	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Client Sample ID: Equipment Wash — Lab Sample ID: 580-44186-4

Date Collected: 06/18/14 12:50
Date Received: 06/20/14 18:15

Matrix: Water

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	3510C			162722	07/01/14 12:04	RBL	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162821	07/03/14 03:51	JJP	TAL SEA
Total Recoverable	Prep	3005A			162407	06/27/14 11:37		TAL SEA
Total Recoverable	Analysis	6010B		1	162664	07/01/14 02:54	HJM	TAL SEA

Client Sample ID: HA-33-03 — Lab Sample ID: 580-44186-5

Date Collected: 06/18/14 13:35
Date Received: 06/20/14 18:15

Matrix: Solid
Percent Solids: 92.0

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/29/14 02:29	IWH	TAL SEA
Total/NA	Prep	3546			162630	06/30/14 16:00	LHJ	TAL SEA
Total/NA	Cleanup	3630C			162780	07/01/14 17:37	CTC	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162951	07/03/14 14:12	JJP	TAL SEA
Total/NA	Prep	3050B			162656	07/01/14 08:18	KJV	TAL SEA
Total/NA	Analysis	6010B		1	162805	07/01/14 21:25	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	162788	07/01/14 18:33	CTC	TAL SEA

Client Sample ID: HA-31-00 — Lab Sample ID: 580-44186-6

Date Collected: 06/18/14 15:25
Date Received: 06/20/14 18:15

Matrix: Solid
Percent Solids: 82.6

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/29/14 02:54	IWH	TAL SEA
Total/NA	Prep	3546			162630	06/30/14 16:00	LHJ	TAL SEA
Total/NA	Cleanup	3630C			162780	07/01/14 17:37	CTC	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162951	07/03/14 14:28	JJP	TAL SEA
Total/NA	Prep	3050B			162656	07/01/14 08:18	KJV	TAL SEA
Total/NA	Analysis	6010B		1	162805	07/01/14 21:28	HJM	TAL SEA
Total/NA	Analysis	9060_PSEP		1	162279	06/26/14 10:45	LKC	TAL SEA
Total/NA	Analysis	D 2216		1	162788	07/01/14 18:33	CTC	TAL SEA
Total/NA	Analysis	PSEP Plumb 1981		1	162831	07/02/14 10:12	HJM	TAL SEA

Client Sample ID: HA-32-0.25 — Lab Sample ID: 580-44186-7

Date Collected: 06/18/14 16:00
Date Received: 06/20/14 18:15

Matrix: Solid
Percent Solids: 95.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/29/14 03:19	IWH	TAL SEA
Total/NA	Prep	3546			162630	06/30/14 16:13	LHJ	TAL SEA

Lab Chronicle

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Client Sample ID: HA-32-0.25 — **Lab Sample ID: 580-44186-7**
Date Collected: 06/18/14 16:00 — Matrix: Solid
Date Received: 06/20/14 18:15 — Percent Solids: 95.8

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Cleanup	3630C			162780	07/01/14 17:37	CTC	TAL SEA
Total/NA	Analysis	NWTPH-Dx		1	162951	07/03/14 15:15	JJP	TAL SEA
Total/NA	Prep	3050B			162656	07/01/14 08:18	KJV	TAL SEA
Total/NA	Analysis	6010B		1	162805	07/01/14 21:31	HJM	TAL SEA
Total/NA	Analysis	D 2216		1	162788	07/01/14 18:33	CTC	TAL SEA

Client Sample ID: Trip Blank 5/30/14 — **Lab Sample ID: 580-44186-8**
Date Collected: 06/18/14 00:00 — Matrix: Solid
Date Received: 06/20/14 18:15

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Prep	5035			162481	06/28/14 13:42	ERZ	TAL SEA
Total/NA	Analysis	NWTPH-Gx		1	162483	06/28/14 18:42	IWH	TAL SEA

Client Sample ID: Trip Blank — **Lab Sample ID: 580-44186-9**
Date Collected: 06/18/14 00:00 — Matrix: Water
Date Received: 06/20/14 18:15

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	NWTPH-Gx	RA	1	162590	06/30/14 15:20	AS	TAL SEA

Laboratory References:

TAL SEA = TestAmerica Seattle, 5755 8th Street East, Tacoma, WA 98424, TEL (253)922-2310

Certification Summary

Client: Landau & Associates, Inc.
Project/Site: Skokomish GI WA

TestAmerica Job ID: 580-44186-1

Laboratory: TestAmerica Seattle

All certifications held by this laboratory are listed. Not all certifications are applicable to this report.

Authority	Program	EPA Region	Certification ID	Expiration Date
Alaska (UST)	State Program	10	UST-112	05-27-15
California	NELAP	9	01115CA	01-31-14 *
California	State Program	9	2901	01-31-15
L-A-B	DoD ELAP		L2236	01-19-16
L-A-B	ISO/IEC 17025		L2236	01-19-16
Montana (UST)	State Program	8	N/A	04-30-20
Oregon	NELAP	10	WA100007	11-06-14
USDA	Federal		P330-11-00222	04-08-17
Washington	State Program	10	C553	02-17-15

* Certification renewal pending - certification considered valid.

APPENDIX F

Survey Data

Skokomish Boring Locations

M2C Project Number: 14-204
Date: 08/19/14

Prepared By: Seth Prigge
Reviewed By: Blair Prigge

Stake Pt.	Boring Hole ID	Northing	Easting	Elevation
1006	BH-01	734023.58	961019.41	61.15
1000	BH-02	734051.27	961745.17	57.35
1008	BH-03R	733984.20	962987.83	55.58
1003	BH-04	733988.15	964705.70	53.35
1002	BH-05R	733477.10	963895.32	54.78
1012	BH-07R	735568.09	967738.10	46.60
1004	BH-08	734699.04	967096.58	47.73
1010	BH-09R	735381.34	967509.86	44.44
1011	BH-10	735606.70	967531.40	44.32
1016	BH-14R	732906.96	972671.35	32.02
1001	BH-15	734489.81	961556.76	62.90
2000	HA-01X	734512.66	961745.48	60.02
1007	TP-02R	734215.41	962703.35	56.79
1005	TP-13R	734751.13	968041.21	41.21
1009	TP-17R	735110.88	967491.95	43.97
1013	TP-19R	735018.23	967816.92	42.25
1014	TP-23R	731940.03	971414.66	31.40
1015	TP-27	733118.67	972413.85	33.56

State Plane Cordinates, South Zone NAVD88
NAD 83/91

APPENDIX G

Driller Logs

HOLOCENE DRILLING
Licensed Tel

11412 62nd Avenue East, Puyallup, WA 98373
Tel: (253) 848-6500 Fax: (253) 848-6515
info@holocenedrillinginc.com

DAILY DRILLING LOG

JOB INFORMATION

CLIENT INFORMATION				TIME		COMMENTS
CLIENT:	CANDAN			TO:	FROM:	DESCRIPTION:
PROJECT:	0621.004.010			700	800	MOBE
LOCATION:	SHELTON			800	815	SET UP
RIG:	RK			815	915	DRILL
LEVEL:				915	1015	CLEAN UP / MOVE / SET UP
DATE:	6.9.17			1015	1030	DRILL
AUGER/CASING SIZE:	4.25			1030	1045	STAND BY (SHELBY)
DRILLING FOOTAGE				1045	1145	DRILL
DESCRIPTION:	QTY. (LF):	DESCRIPTION:	QTY. (LF):	1145	1215	CLEAN UP / MOVE
HSA UNDER:	94.5	HSA OVER:		1215	1245	LUNCH
ROTARY:		CORING HQ/NQ:		1245	100	STAND BY (FLAGGER)
ODEX:		CASING ADV.:		100	130	DRILL
EXTRA SPT's:	5	SHELBY TUBES:	2	130	145	S.B. (SHELBY)
WELL INFORMATION				145	215	DRILL
B#:	FROM:	TO:	WELL DP.:	TAG#:	215	300	CLEAN UP
	0	31.5			300		DEMOBE
	0	31.5					
	0	31.5					

DRILLING TIME

DESCRIPTION:	REG.	OT:	DESCRIPTION:	REG.:	OT:	DESCRIPTION:	REG.:	OT:
STANDBY:			CASING:			TRAVEL:		
MOVING:			WELL DEVELOPMENT:			OTHER:		
DECON:			WELL ABANDONMENT:			OTHER:		
INSTALL:			ADDITIONAL MAN:			OTHER:		

MATERIALS

DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:
SHELBY TUBE:	12	WELL SIZE:		ATV GATOR:		OTHER:	
BENTONITE CHIPS:	8	WELL TYPE:		AIR COMPRESSOR:		OTHER:	
QUIK-GEL:		CASING:		CORE BOX:		OTHER:	
QUIK- GROUT:		SCREEN:		DECON TRAILER:		OTHER:	
10/20 SAND:		SLOPE CASING:		EROSION CONTROL:		OTHER:	
OTHER SAND:		CAPS/PLUGS:		GENERATOR:		OTHER:	
REDIMIX:	10	DRUMS FOR DISPOSAL:	2	OTHER:		OTHER:	
CEMENT:		DRUMS LEFT ONSITE:		PERISTALIC PUMP:		OTHER:	
EZ STREET:		MONUMENT FLUSH:		PISTON SAMPLER:		OTHER:	
JET SET:		MONUMENT STAND-UP:		PPE:		OTHER:	
PEA GRAVEL:		BOLLARDS:		VISQUEEN:		OTHER:	

CLIENT APPROVALS (Ensures Client's figures agree with Holocene Drilling, Inc. figures)

OVERTIME APPROVAL:	DRILLER'S ASSISTANT: M. RAYMOND
CLIENT SIGNATURE:	DRILLER'S ASSISTANT:
LEAD DRILLER SIGNATURE:	*Thank you for choosing Holocene Drilling, Inc.* *We appreciate your business today!* **www.holocenedrillinginc.com**

DIRECT PUSH | HOLLOW STEM AUGER | MUD ROTARY | AIR/ODEX | ROCK CORING | DEWATERING

HOLOCENE DRILLING
Licensed To Drill
11412 62nd Avenue East, Puyallup, WA 98373
Tel: (253) 848-6500 Fax: (253) 848-6515
info@holocenedrillinginc.com

DAILY DRILLING LOG

JOB INFORMATION

CLIENT INFORMATION		TIME		COMMENTS
DATE:	6-11-14	TO:	FROM:	DESCRIPTION:
CLIENT:	Landau	5:30	7:00	Mobe
PROJECT:	Skokomish	7:00	7:30	Safety, unload, set up
LOCATION:	3011 W Skokomish Valley Rd	7:30	8:30	Drill
RIG:	3" D-50	8:30	9:30	Clean, move,
AUGER/CASING SIZE:		9:30	11:15	Drill
PPE LEVEL:		11:15	12:15	Clean, move
		12:15	12:45	Lunch
		12:45	1:00	Unload, set up
		1:00	2:30	Drill
		2:30	3:00	Clean
		3:00	4:00	Site walk
		4:00		Travel

DRILLING FOOTAGE

DESCRIPTION:	QTY. (LF):	DESCRIPTION:	QTY. (LF):
HSA UNDER:		HSA OVER:	
ROTARY:		CORING HQ/NQ:	
ODEX:		CASING ADV.:	
EXTRA SPT's:	8	SHELBY TUBES:	

WELL INFORMATION

B#:	FROM:	TO:	WELL DP.:	TAG#:
B1	0	31.5		
B2	0	41		
B3	0	31.5		

DRILLING TIME

DESCRIPTION:	REG.	OT:	DESCRIPTION:	REG.:	OT:	DESCRIPTION:	REG.:	OT:
STANDBY:			CASING:			TRAVEL:		
MOVING:			WELL DEVELOPMENT:			OTHER:		
DECON:			WELL ABANDONMENT:			OTHER:		
INSTALL:			ADDITIONAL MAN:			OTHER:		

MATERIALS

DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:
SHELBY TUBE:	1	WELL SIZE:		ATV GATOR:		OTHER:	
BENTONITE CHIPS:	5	WELL TYPE:		AIR COMPRESSOR:		OTHER:	
QUIK-GEL:		CASING:		CORE BOX:		OTHER:	
QUIK- GROUT:		SCREEN:		DECON TRAILER:		OTHER:	
10/20 SAND:		SLOPE CASING:		EROSION CONTROL:		OTHER:	
OTHER SAND:		CAPS/PLUGS:		GENERATOR:		OTHER:	
REDIMIX:		MONUMENT FLUSH:		OTHER:		OTHER:	
CEMENT:		MONUMENT STAND-UP:		PERISTALIC PUMP:		OTHER:	
EZ STREET:		BOLLARDS:		PISTON SAMPLER:		OTHER:	
JET SET:		DRUMS FOR DISPOSAL:		PPE:		OTHER:	
PEA GRAVEL:		DRUMS LEFT ONSITE:		VISQUEEN:		OTHER:	

CLIENT APPROVALS (Ensures Client's figures agree with Holocene Drilling, Inc. figures)

OVERTIME APPROVAL:
CLIENT SIGNATURE:
LEAD DRILLER SIGNATURE:

DRILLER'S ASSISTANT: Nuno
DRILLER'S ASSISTANT:

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Tel: (253) 848-6500 Fax: (253) 848-6515
info@holocenedrillinginc.com

DAILY DRILLING LOG

JOB INFORMATION

CLIENT INFORMATION	
DATE:	6-12-14
CLIENT:	Landau
PROJECT:	Skokomish
LOCATION:	
RIG:	D-50
AUGER/CASING SIZE:	3"
PPE LEVEL:	

DRILLING FOOTAGE			
DESCRIPTION:	QTY. (LF):	DESCRIPTION:	QTY. (LF):
HSA UNDER:		HSA OVER:	
ROTARY:		CORING HQ/NQ:	
ODEX:		CASING ADV.:	
EXTRA SPT's:	40	SHELBY TUBES:	

WELL INFORMATION				
B#:	FROM:	TO:	WELL DP.:	TAG#:
B4	Ø	31.5		
B5	Ø	31.5		
B6	Ø	31.5		
B7	Ø	31.5		

TIME TO:	TIME FROM:	COMMENTS DESCRIPTION:
6:30	7:00	Travel
7:00	7:45	Safety, unload, set up
7:45	9:00	Drill
9:00	10:00	Clean, load, move, set up
10:00	11:15	Drill
11:15	11:45	Clean, move, set up
11:45	12:15	Lunch
12:15	2:00	Drill
2:00	2:30	Clean, move, set up
2:30	3:45	Drill
3:45	4:45	Clean, load
4:45	6:00	Travel

DRILLING TIME

DESCRIPTION:	REG.	OT:	DESCRIPTION:	REG.:	OT:	DESCRIPTION:	REG.:	OT:
STANDBY:			CASING:			TRAVEL:		
MOVING:			WELL DEVELOPMENT:			OTHER:		
DECON:			WELL ABANDONMENT:			OTHER:		
INSTALL:			ADDITIONAL MAN:			OTHER:		

MATERIALS

DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:
SHELBY TUBE:	4.5	WELL SIZE:		ATV GATOR:		OTHER:	
BENTONITE CHIPS:	9	WELL TYPE:		AIR COMPRESSOR:		OTHER:	
QUIK-GEL:		CASING:		CORE BOX:		OTHER:	
QUIK- GROUT:		SCREEN:		DECON TRAILER:		OTHER:	
10/20 SAND:		SLOPE CASING:		EROSION CONTROL:		OTHER:	
OTHER SAND:		CAPS/PLUGS:		GENERATOR:		OTHER:	
REDIMIX:		MONUMENT FLUSH:		OTHER:		OTHER:	
CEMENT:		MONUMENT STAND-UP:		PERISTALIC PUMP:		OTHER:	
EZ STREET:		BOLLARDS:		PISTON SAMPLER:		OTHER:	
JET SET:		DRUMS FOR DISPOSAL:		PPE:		OTHER:	
PEA GRAVEL:		DRUMS LEFT ONSITE:		VISQUEEN:		OTHER:	

CLIENT APPROVALS (Ensures Client's figures agree with Holocene Drilling, Inc. figures)

OVERTIME APPROVAL:	DRILLER'S ASSISTANT: Nunez
CLIENT SIGNATURE:	DRILLER'S ASSISTANT:
LEAD DRILLER SIGNATURE:	*Thank you for choosing Holocene Drilling, Inc. We appreciate your business today!* **www.holocenedrillinginc.com**

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DAILY DRILLING LOG

JOB INFORMATION

CLIENT INFORMATION		TIME TO:	TIME FROM:	COMMENTS DESCRIPTION:
DATE:	6-13-14			
CLIENT:	Ecology	5:15	7:00	Travel
PROJECT:	Skokomish	7:00	7:45	Unload set up
LOCATION:		7:45	10:00	Drill
RIG:	D-50	10:00	10:45	Clean/load
AUGER/CASING SIZE:	3"	10:45		Decmove
PPE LEVEL:				

DRILLING FOOTAGE

DESCRIPTION:	QTY. (LF):	DESCRIPTION:	QTY. (LF):
HSA UNDER:		HSA OVER:	
ROTARY:		CORING HQ/NQ:	
ODEX:		CASING ADV.:	
EXTRA SPT's:	3	SHELBY TUBES:	

WELL INFORMATION

B#:	FROM:	TO:	WELL DP.:	TAG#:
B8	0	31.5		

DRILLING TIME

DESCRIPTION:	REG.	OT:	DESCRIPTION:	REG.:	OT:	DESCRIPTION:	REG.:	OT:
STANDBY:			CASING:			TRAVEL:		
MOVING:			WELL DEVELOPMENT:			OTHER:		
DECON:			WELL ABANDONMENT:			OTHER:		
INSTALL:			ADDITIONAL MAN:			OTHER:		

MATERIALS

DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:	DESCRIPTION:	QTY.:
SHELBY TUBE:		WELL SIZE:		ATV GATOR:		OTHER:	
BENTONITE CHIPS:	3	WELL TYPE:		AIR COMPRESSOR:		OTHER:	
QUIK-GEL:		CASING:		CORE BOX:		OTHER:	
QUIK- GROUT:		SCREEN:		DECON TRAILER:		OTHER:	
10/20 SAND:		SLOPE CASING:		EROSION CONTROL:		OTHER:	
OTHER SAND:		CAPS/PLUGS:		GENERATOR:		OTHER:	
REDIMIX:		MONUMENT FLUSH:		OTHER:		OTHER:	
CEMENT:		MONUMENT STAND-UP:		PERISTALIC PUMP:		OTHER:	
EZ STREET:		BOLLARDS:		PISTON SAMPLER:		OTHER:	
JET SET:		DRUMS FOR DISPOSAL:		PPE:		OTHER:	
PEA GRAVEL:		DRUMS LEFT ONSITE:		VISQUEEN:		OTHER:	

CLIENT APPROVALS (Ensures Client's figures agree with Holocene Drilling, Inc. figures)

OVERTIME APPROVAL:
CLIENT SIGNATURE:
LEAD DRILLER SIGNATURE:

DRILLER'S ASSISTANT: Nate
DRILLER'S ASSISTANT:

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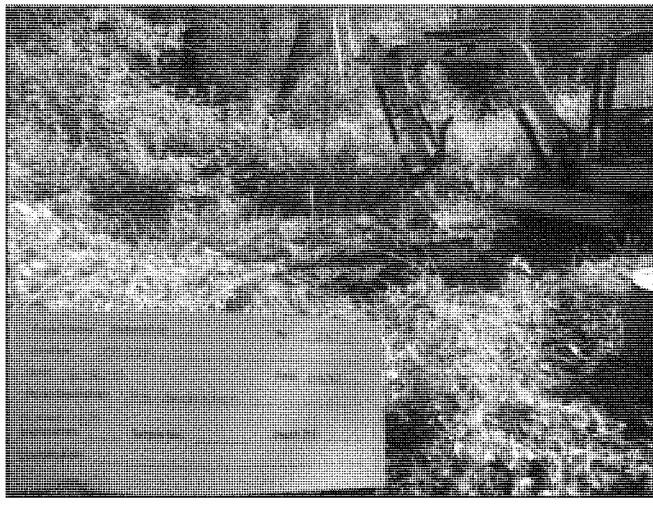
Exploration Photos



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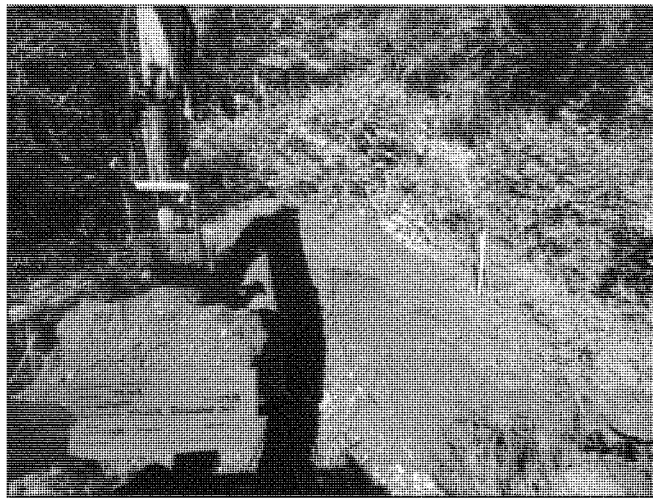
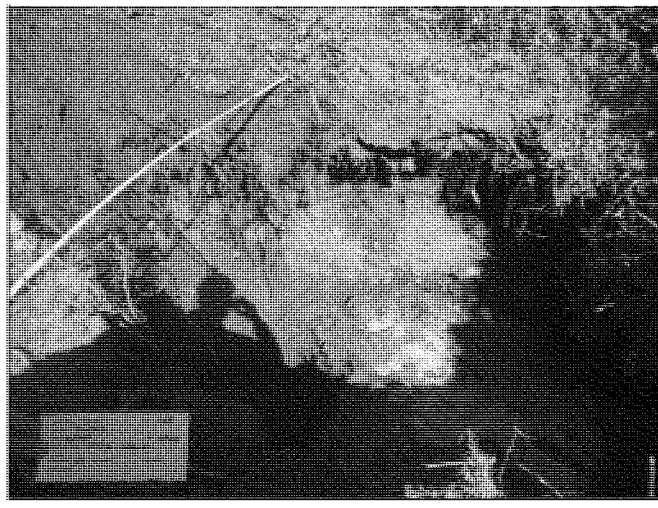
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-02R Photographs**	Figure H-1





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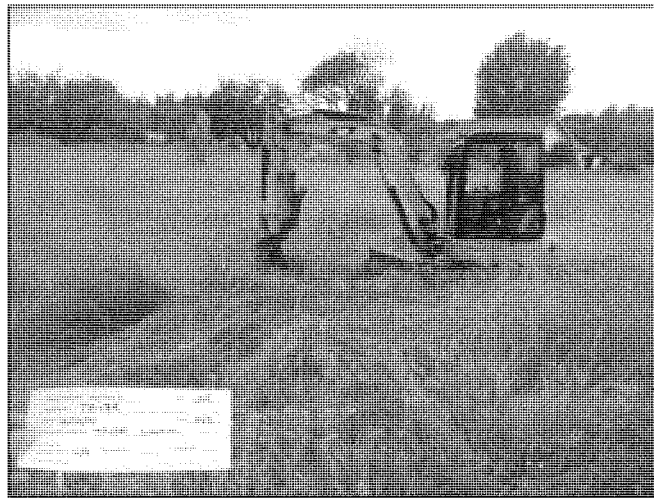
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-02R Photographs**	Figure H-1



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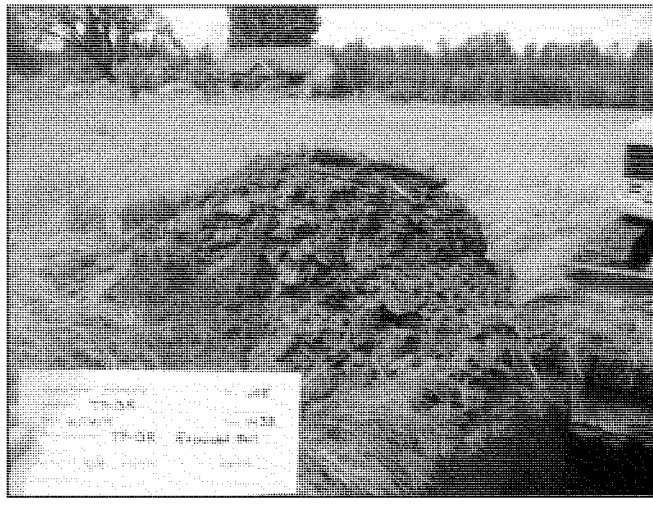
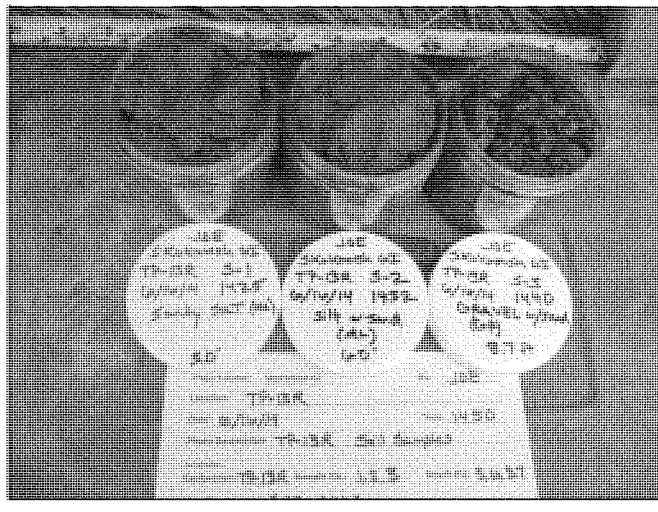
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-13R Photographs**	Figure H-2





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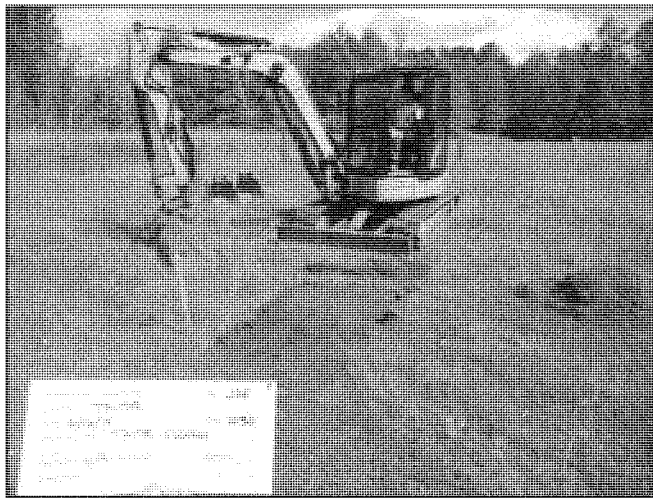
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-13R Photographs**	Figure H-2



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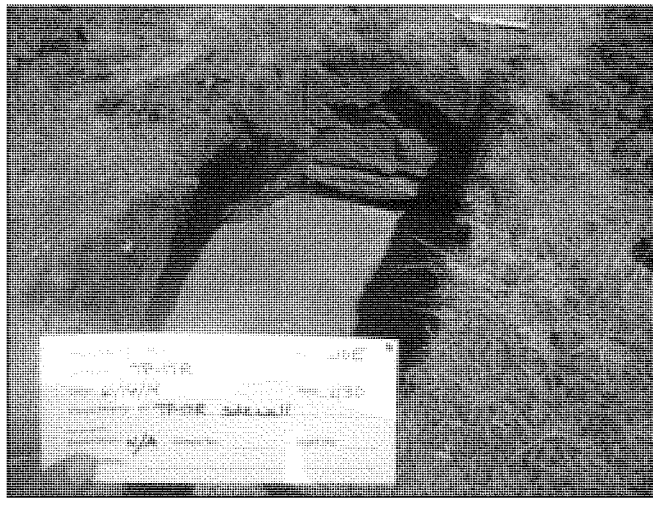
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-17R Photographs**	Figure H-3



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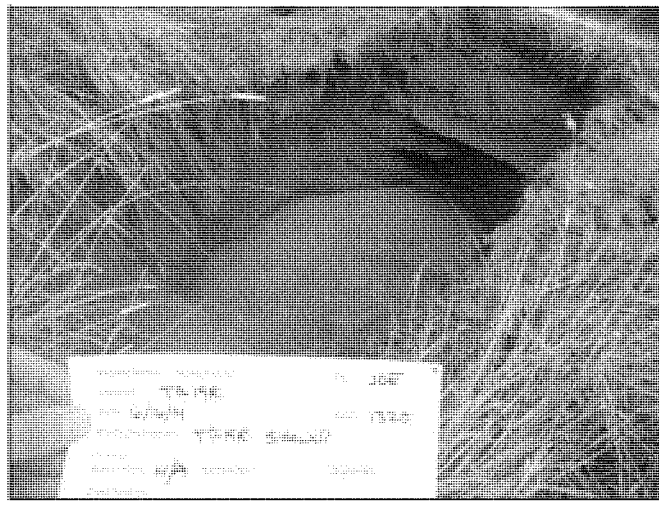
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-17R Photographs**	Figure H-3



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-19R Photographs**	Figure H-4

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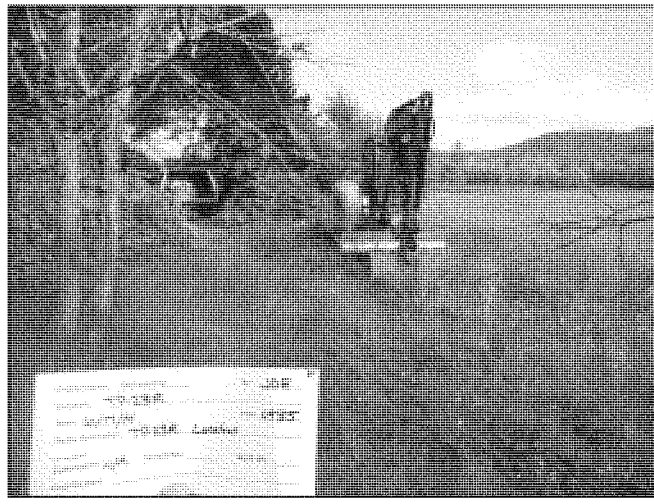
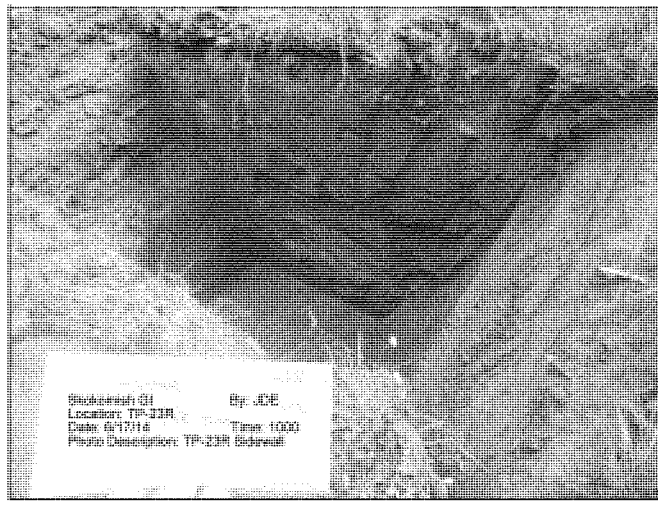
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-19R Photographs**	Figure H-4





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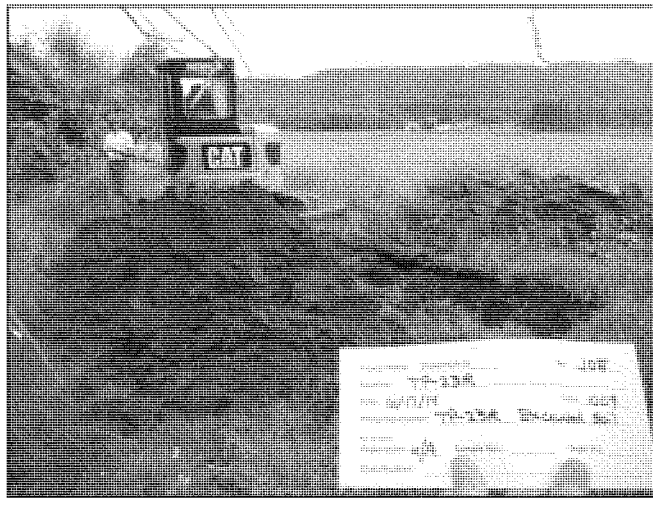
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-23R Photographs**	Figure H-5



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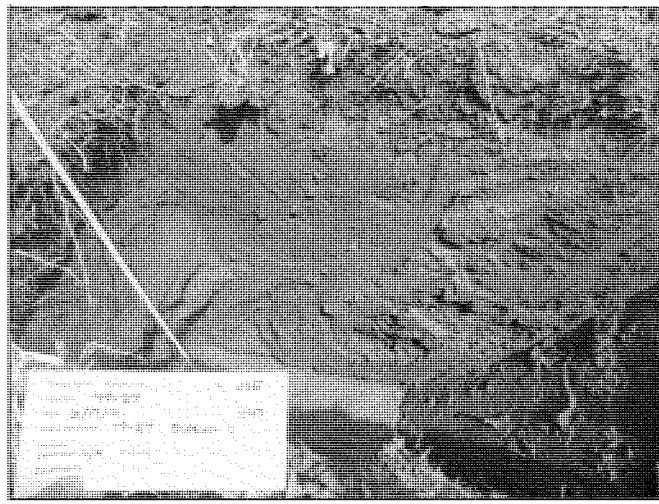
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-23R Photographs**	Figure H-5



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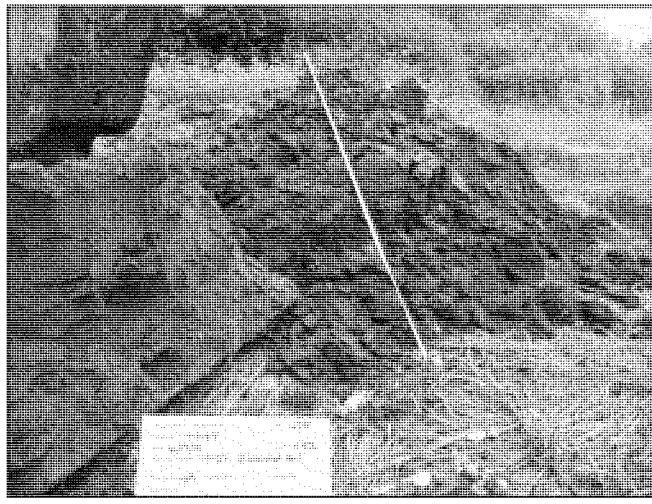
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-27 Photographs**	Figure H-6



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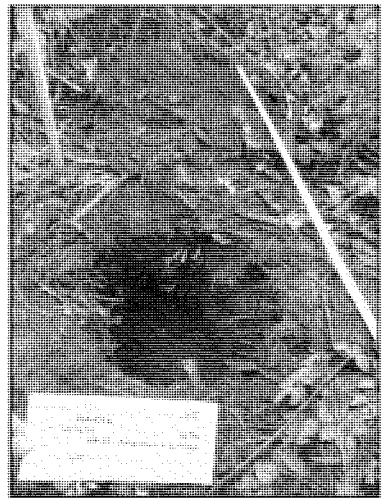
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**TP-27 Photographs**	Figure H-6



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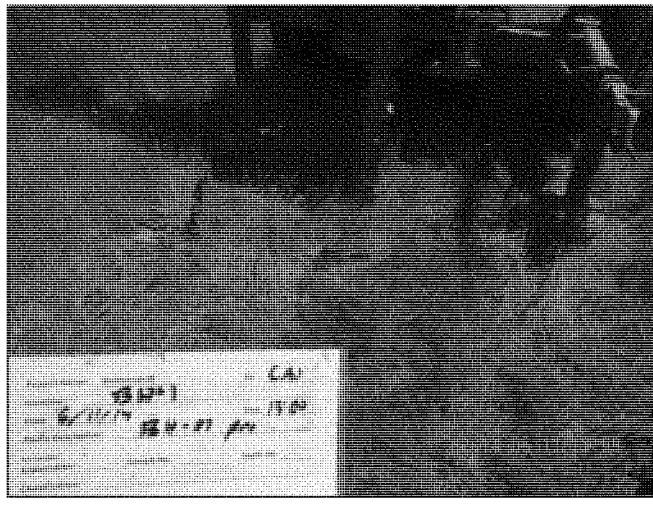
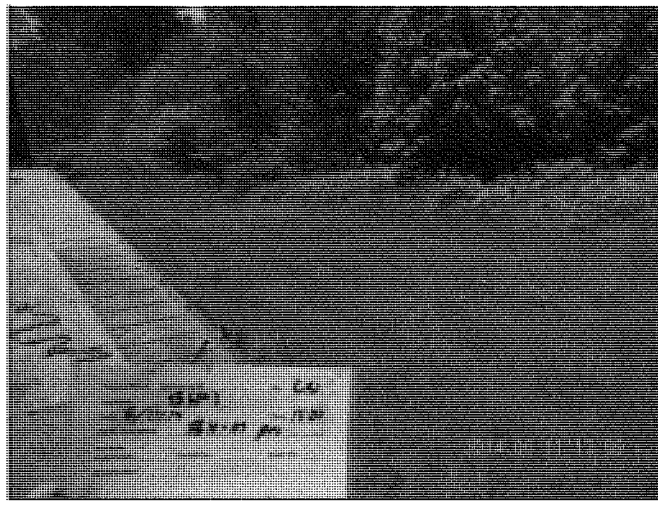
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-01X Photographs**	Figure H-7





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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8

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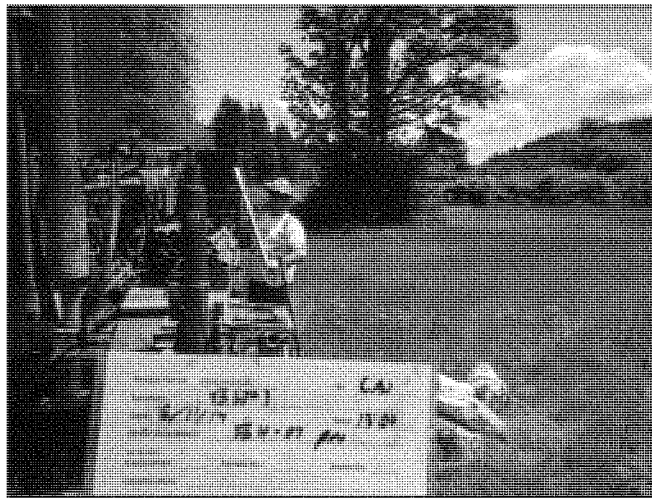
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8

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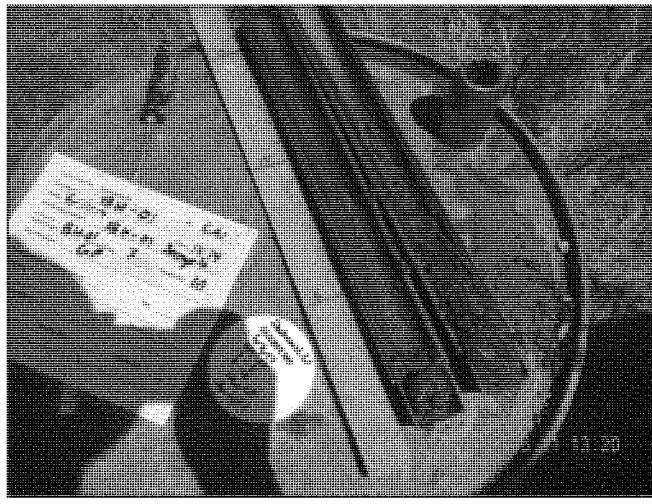
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8

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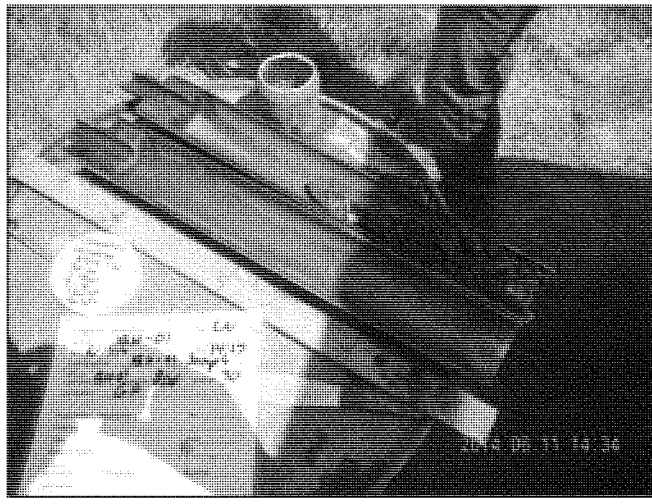
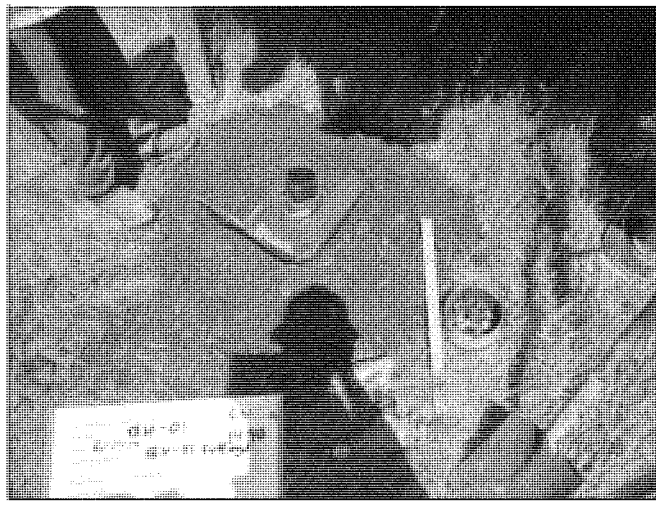
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8





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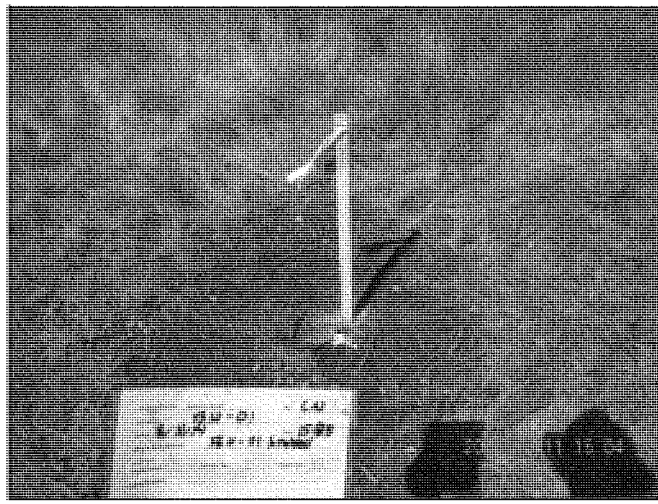
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

BH-01 Photographs

Figure
H-8



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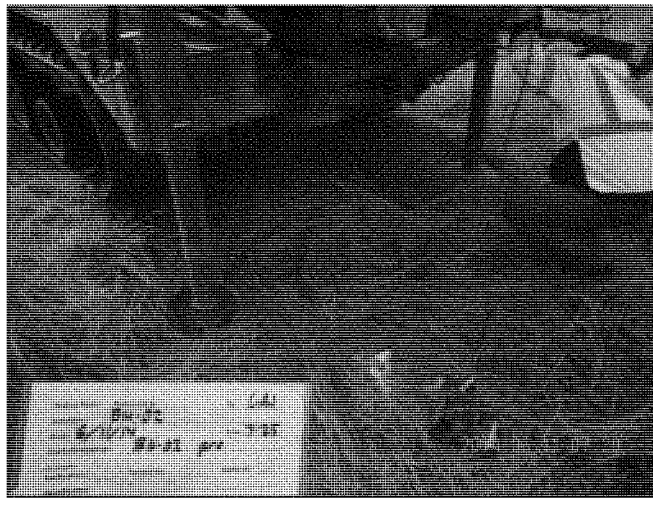
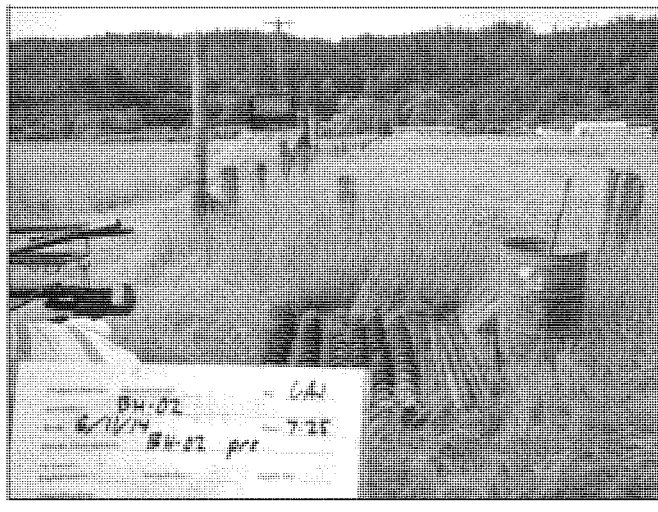
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-01 Photographs**	Figure H-8





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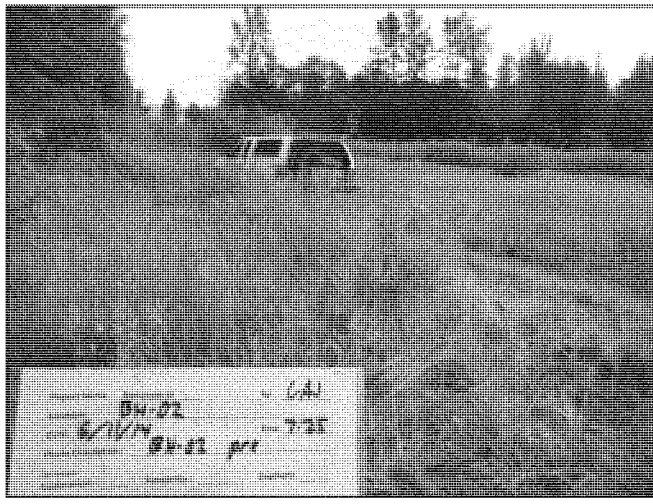
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9



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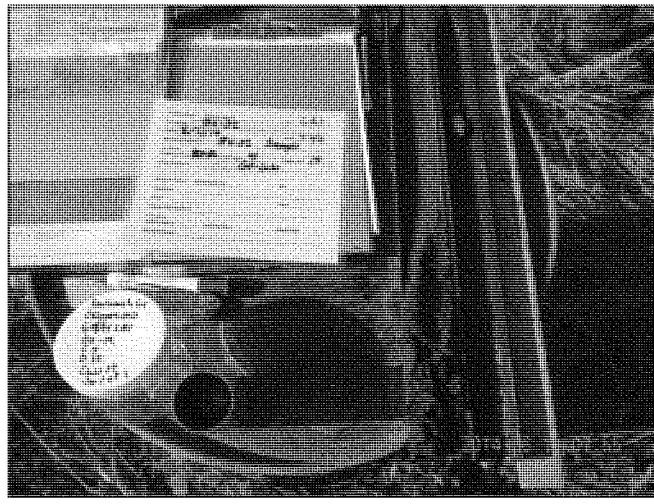
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9

Y:\06211\041\RG\DR\Appendix H - Exploration Photos\H-9 BH-02 01.docx

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9

Y:\06211\004\RG\DR\Appendix H - Exploration Photos\H-9 BH-02 01.docx

LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9

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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

BH-02 Photographs

Figure
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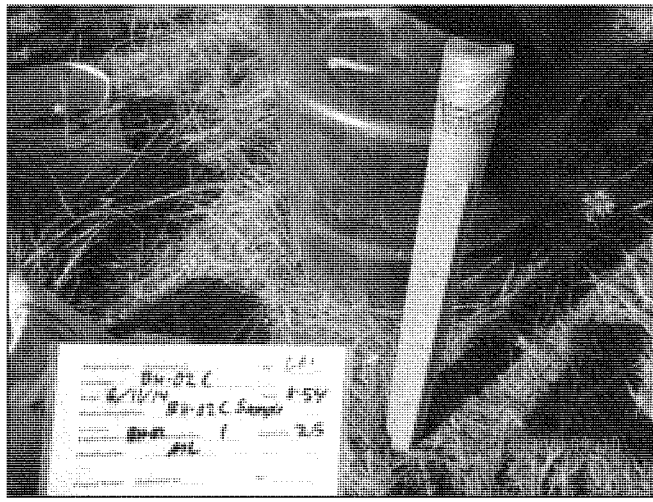

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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9

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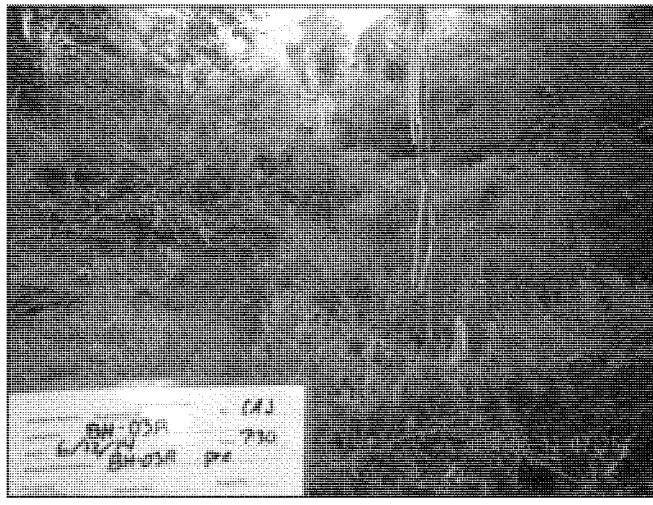
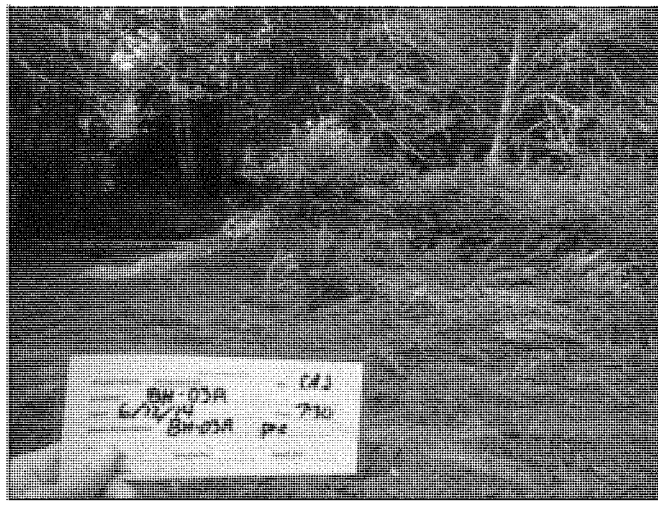
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-02 Photographs**	Figure H-9





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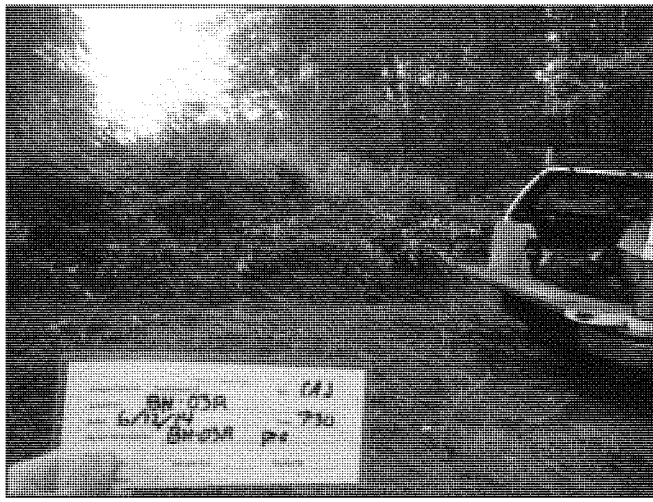
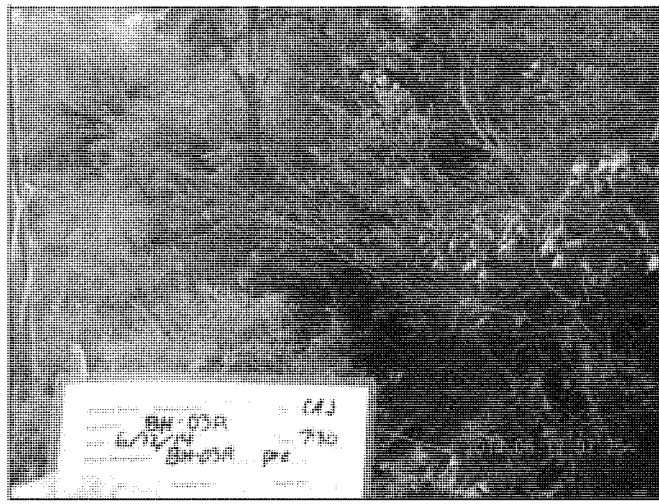
LANDAU ASSOCIATES	Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-03R Photographs**	Figure H-10





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-03R Photographs**	Figure H-10

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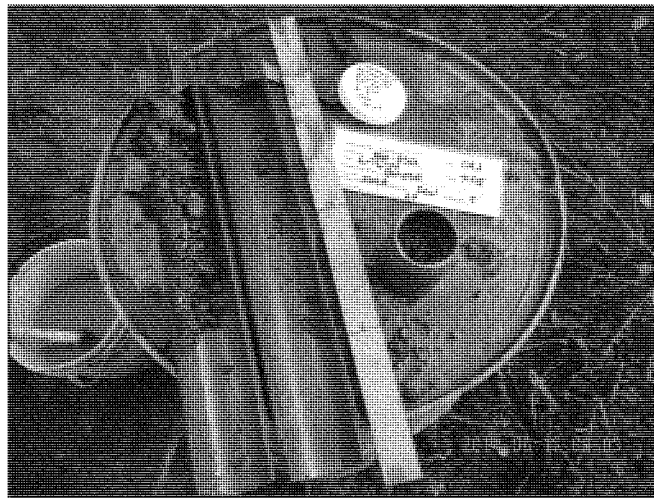
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-03R Photographs**	Figure H-10



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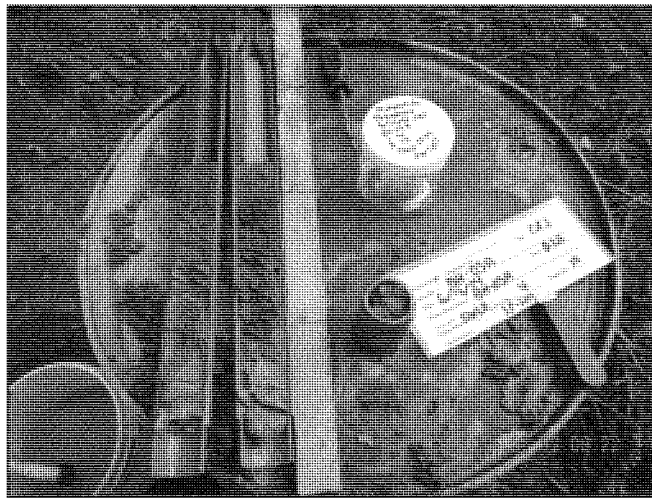

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LANDAU ASSOCIATES

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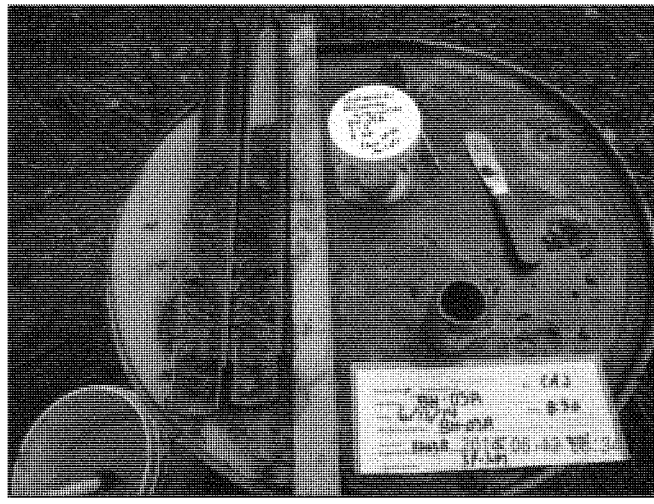

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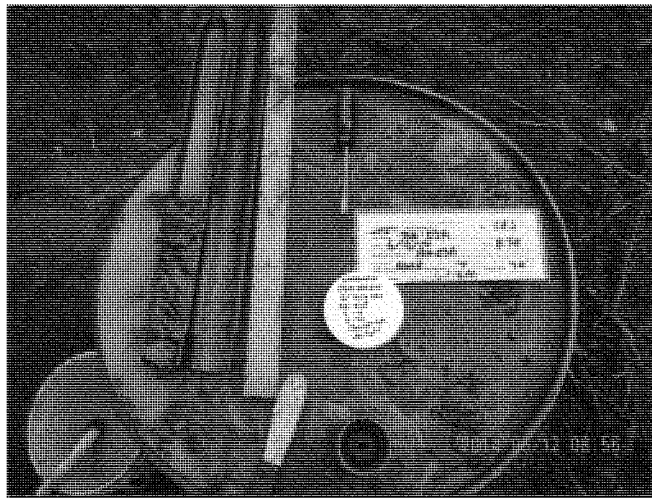
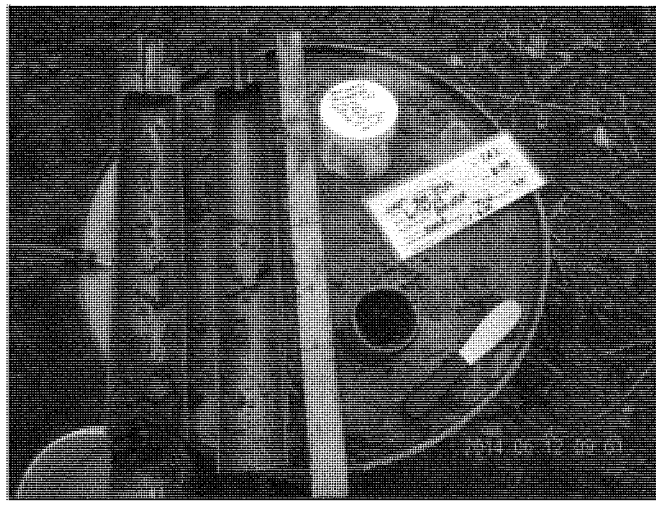
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-03R Photographs**	Figure H-10





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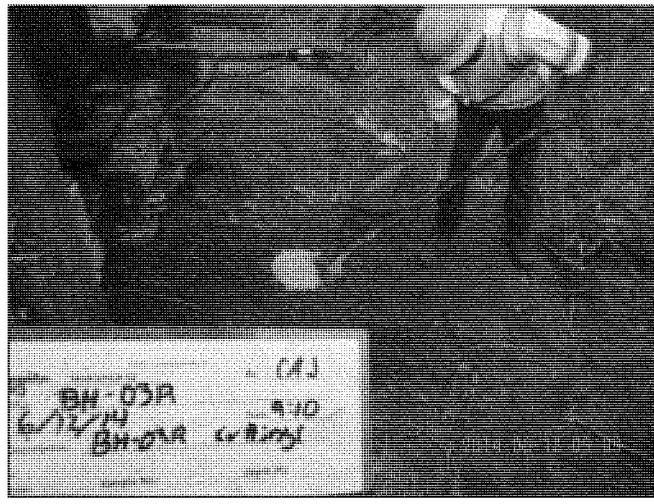
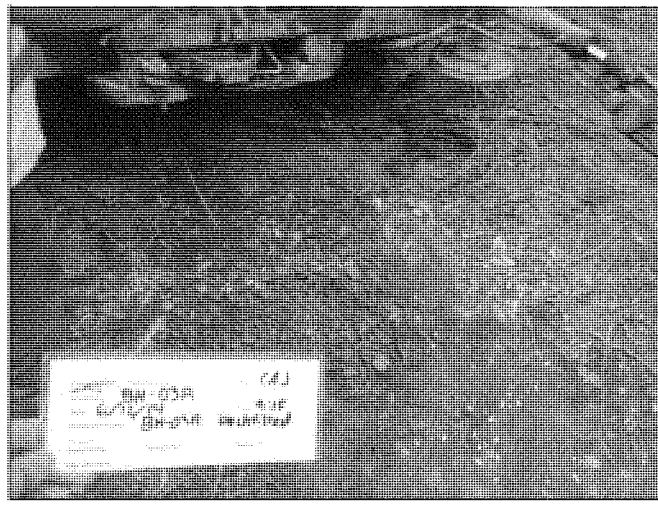
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-03R Photographs**	Figure H-10





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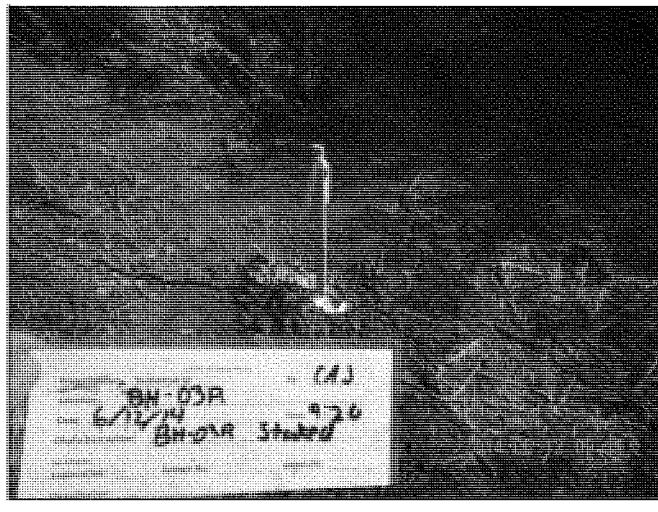

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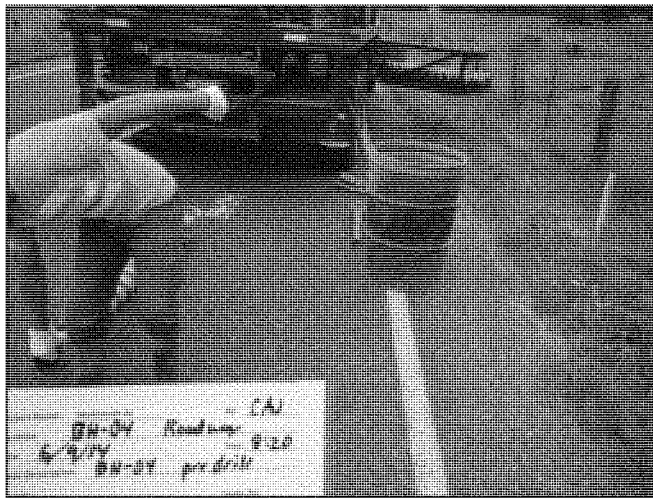
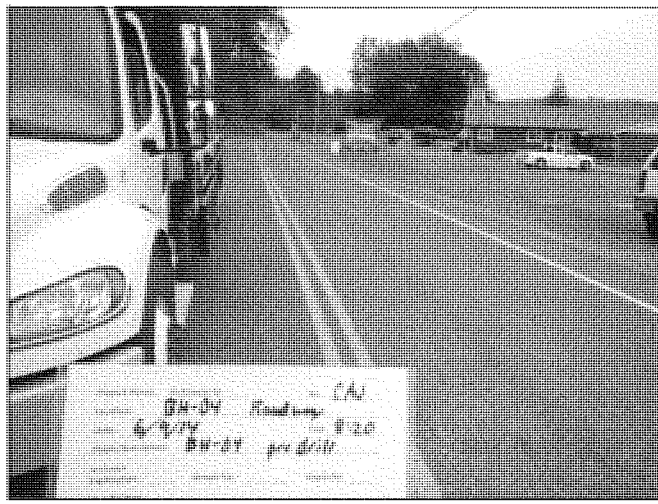
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-03R Photographs**	Figure H-10





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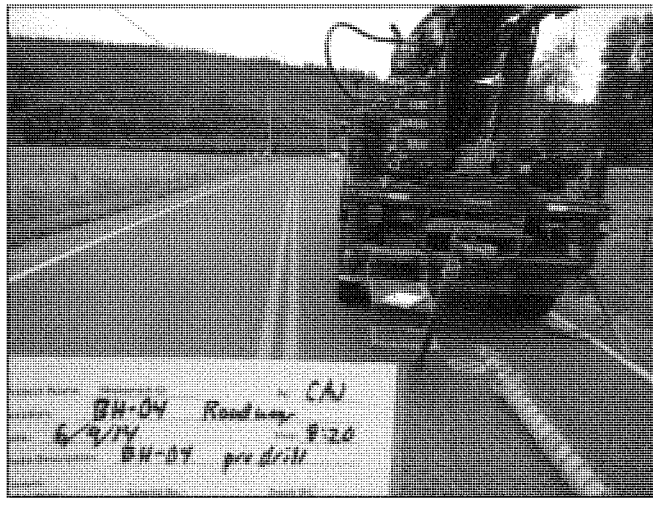
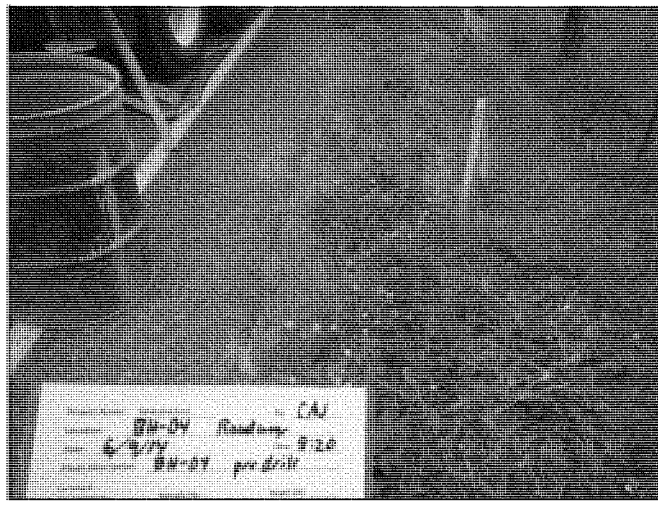
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11





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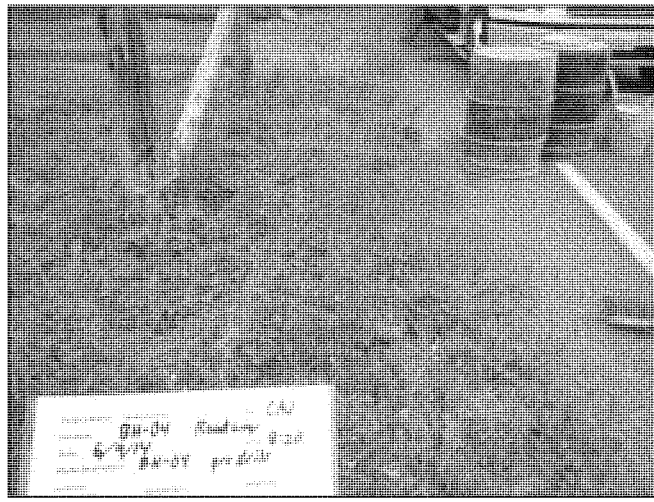
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11



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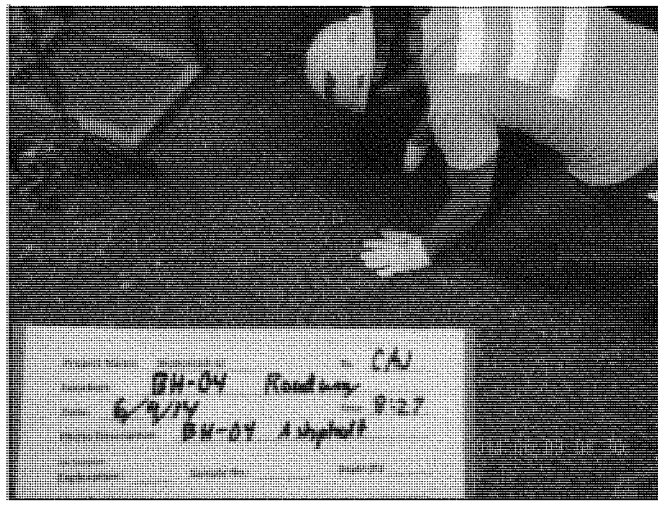
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11

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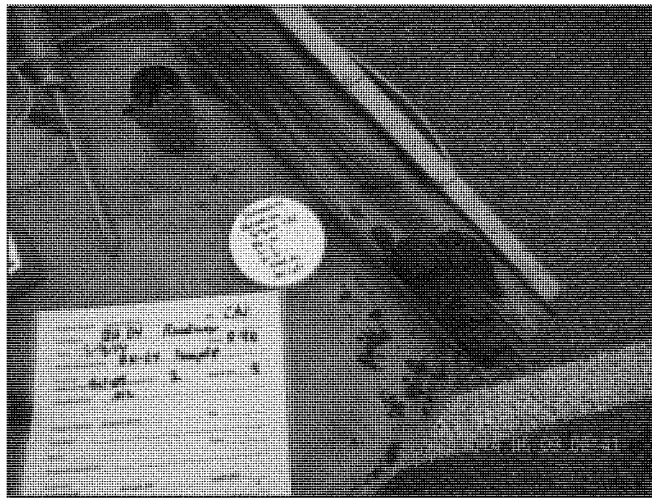
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11



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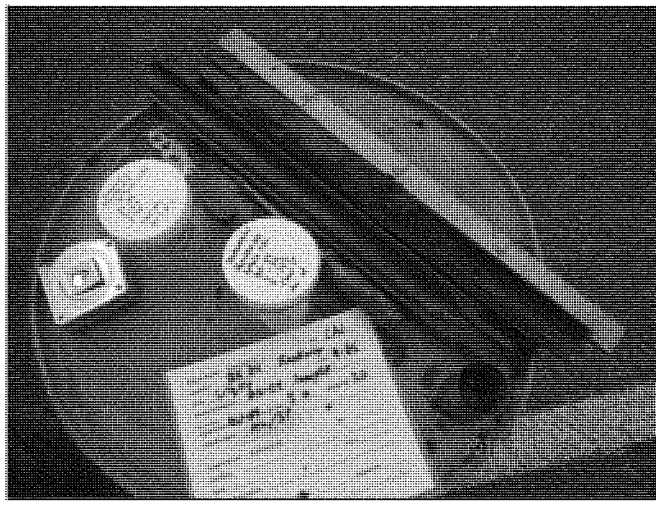
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11



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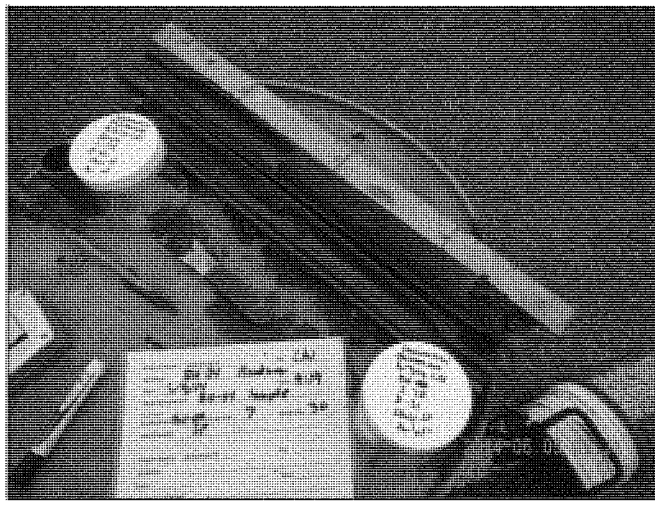
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11



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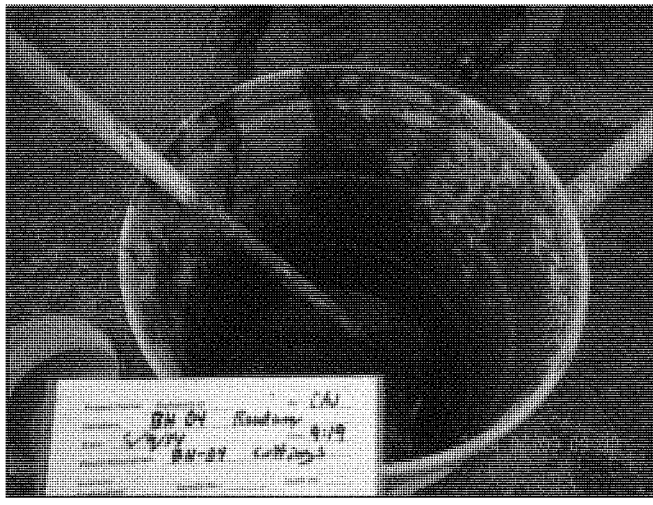
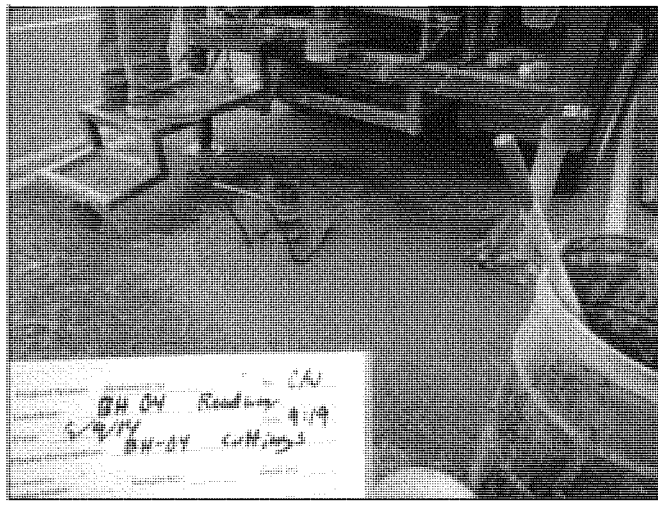
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11





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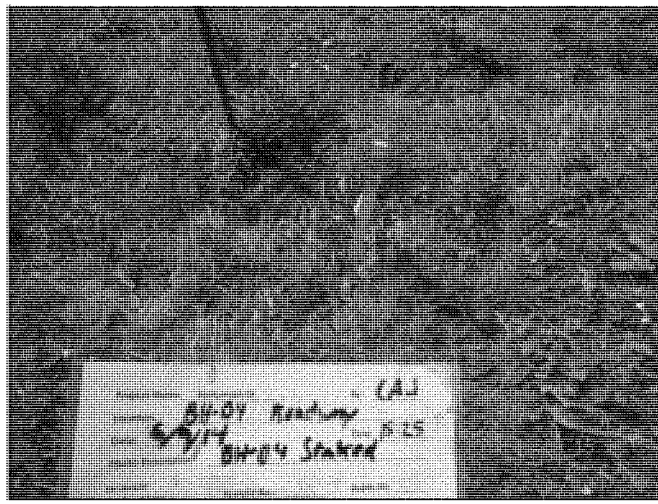
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11



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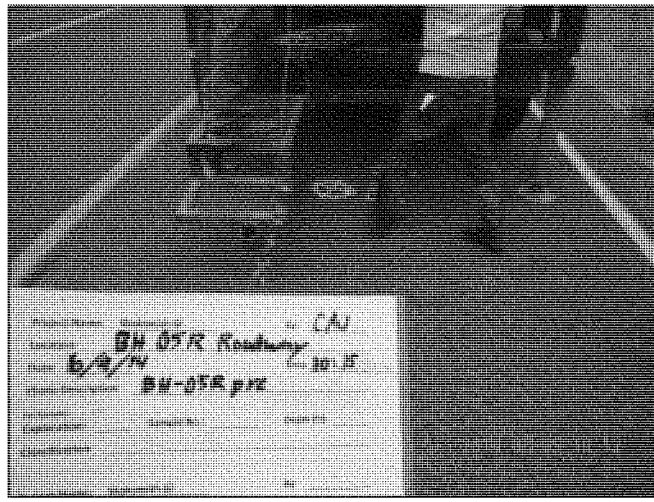
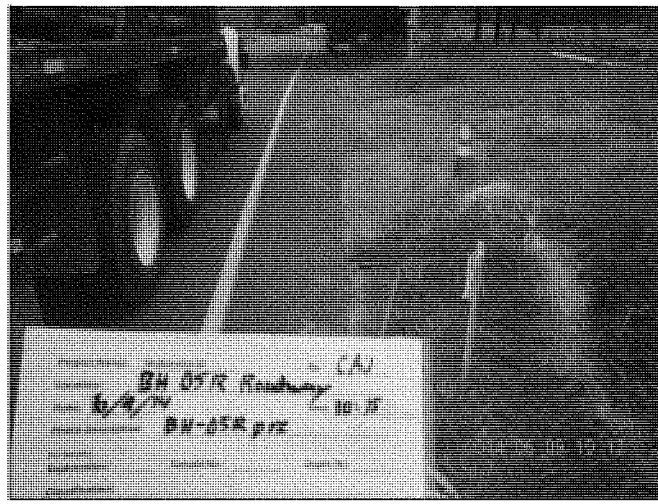
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-04 Photographs**	Figure H-11





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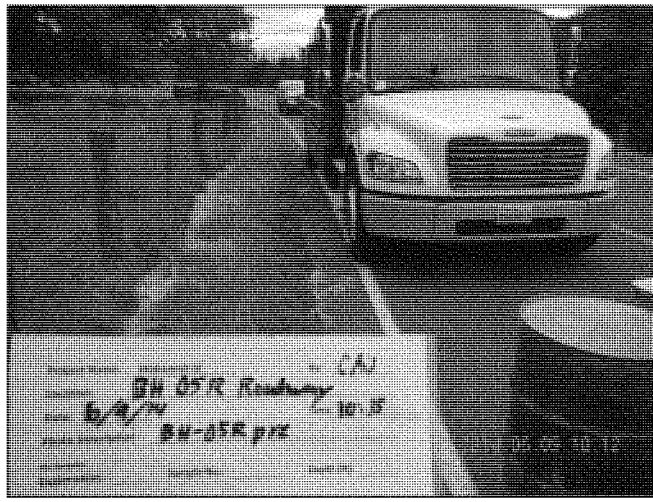
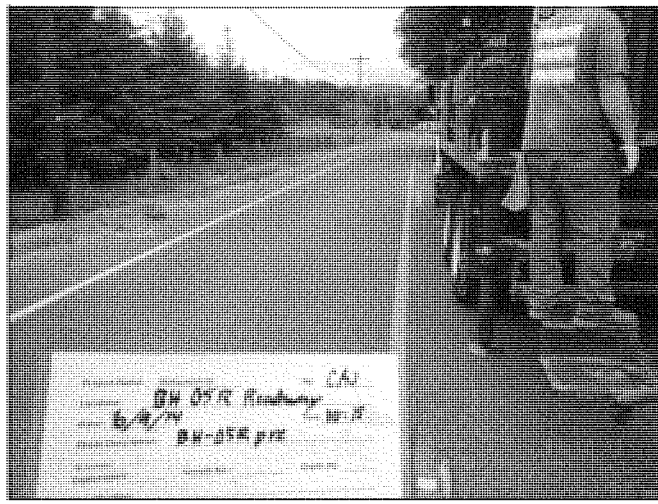
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12





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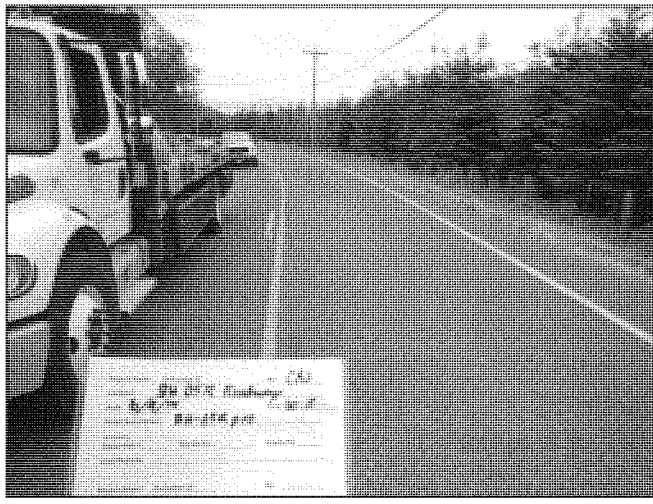
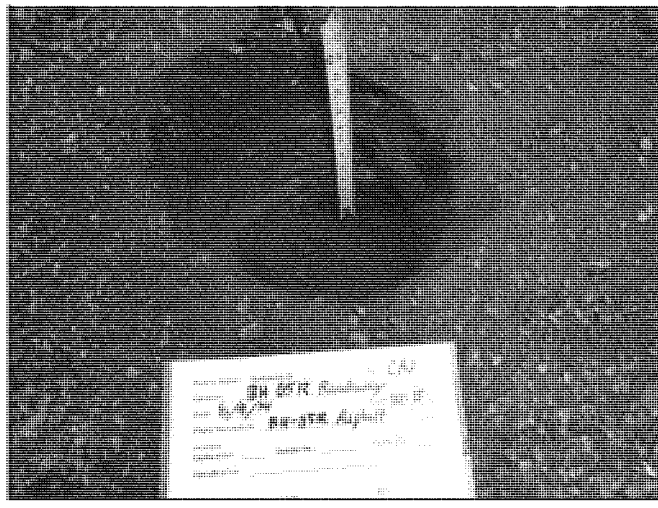
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12

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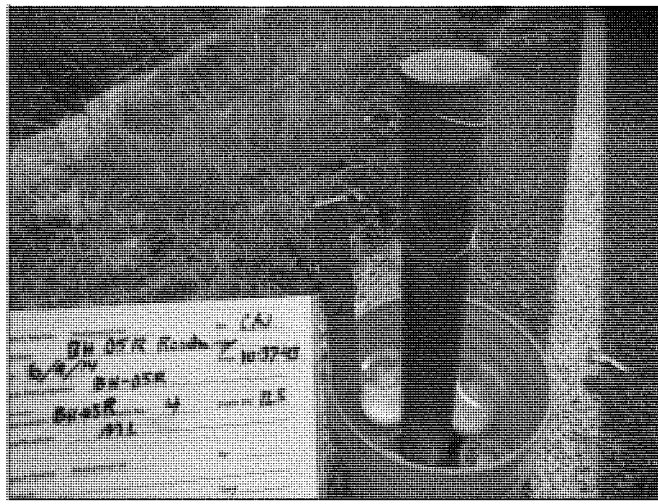
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12

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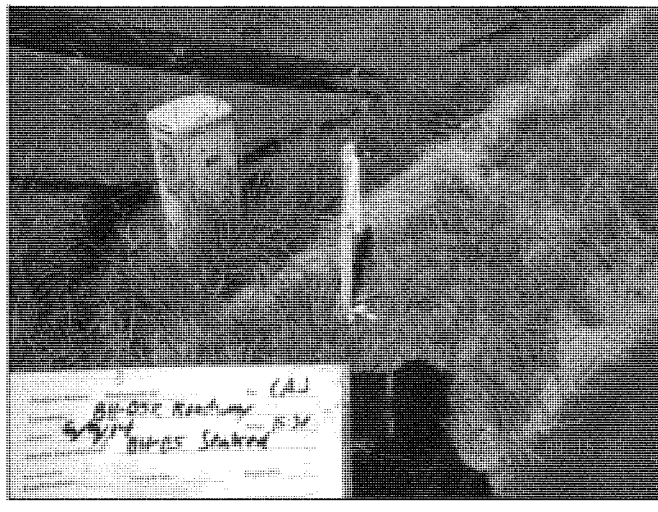
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12



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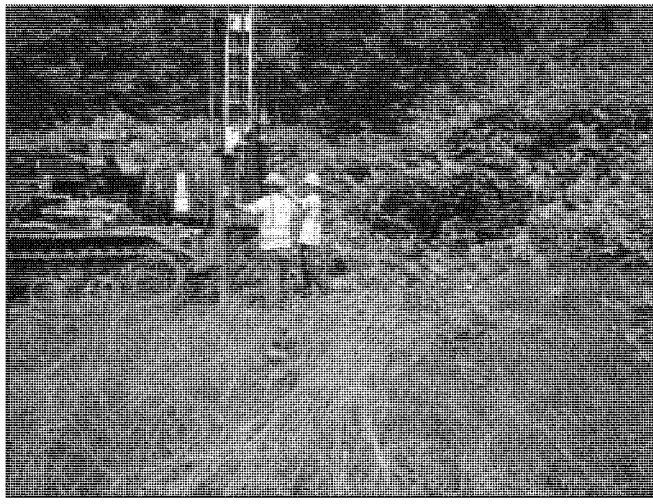
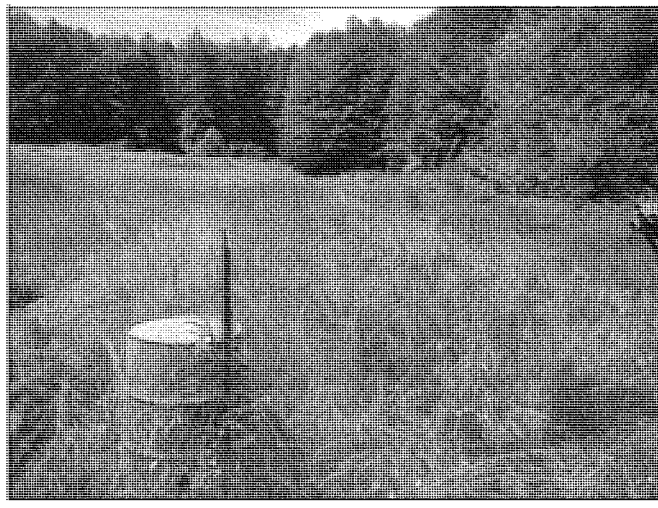
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-05R Photographs**	Figure H-12





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-07R Photographs**	Figure H-13

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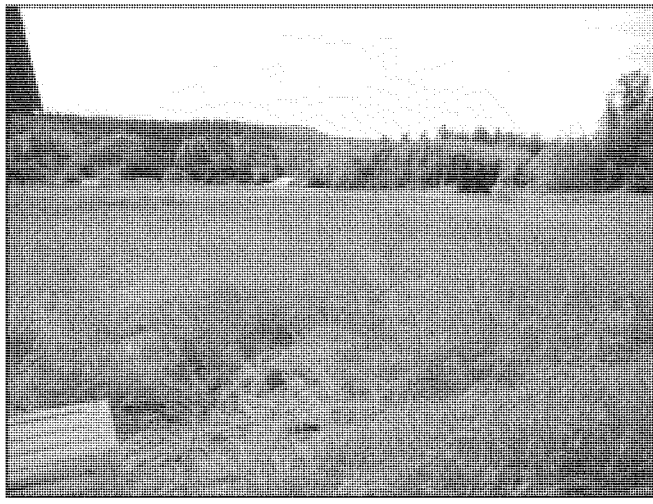

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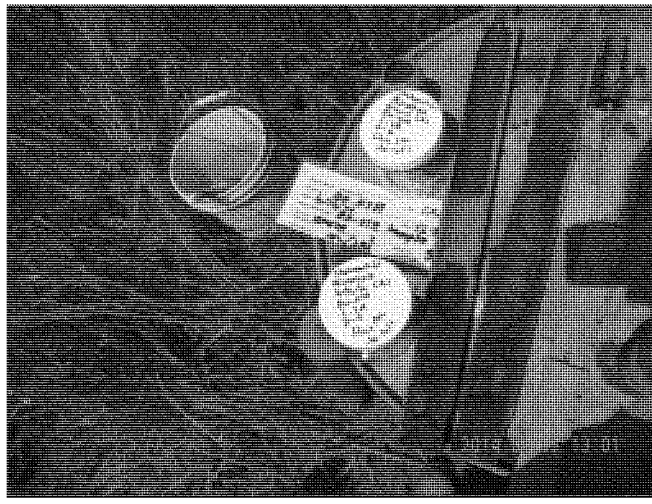

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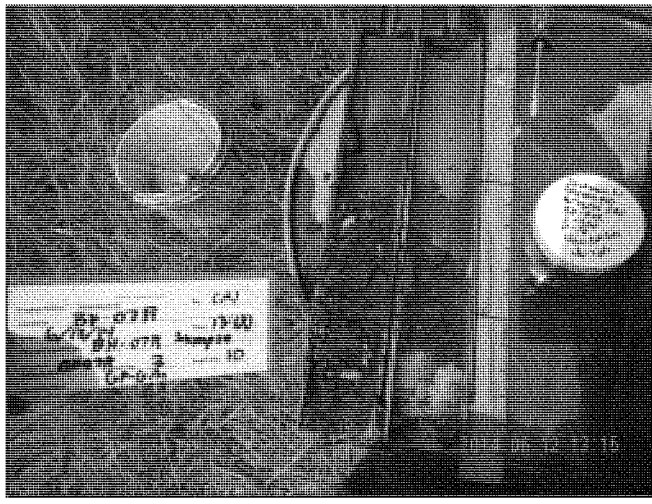
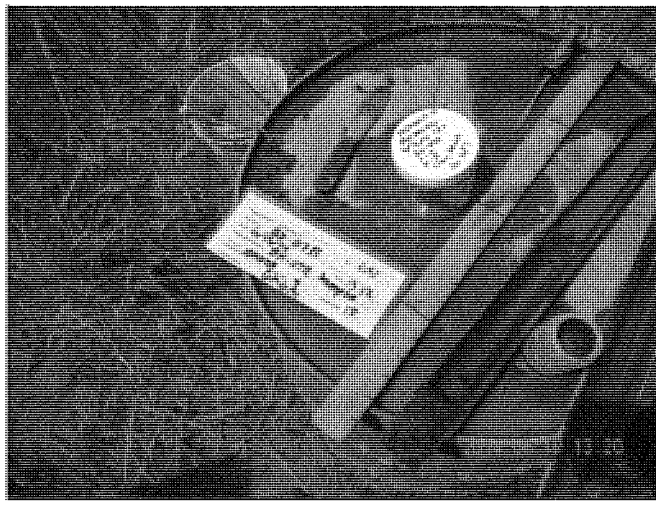
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-07R Photographs**	Figure H-13





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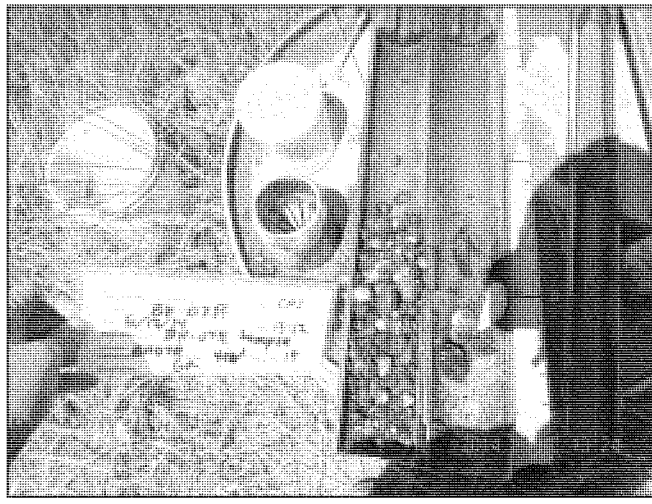
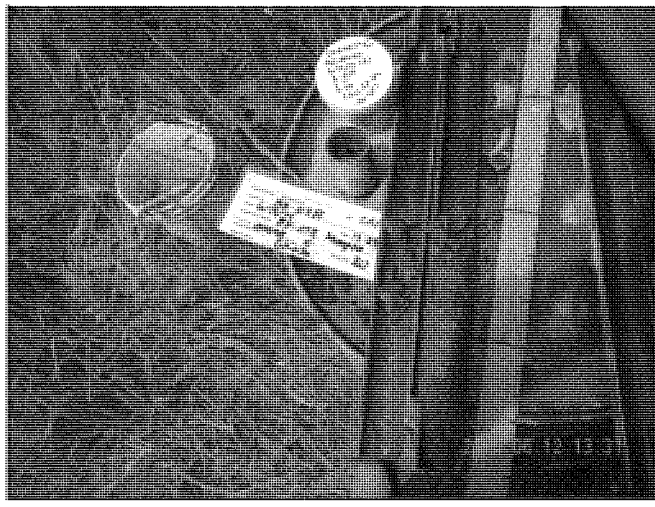
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-07R Photographs**	Figure H-13





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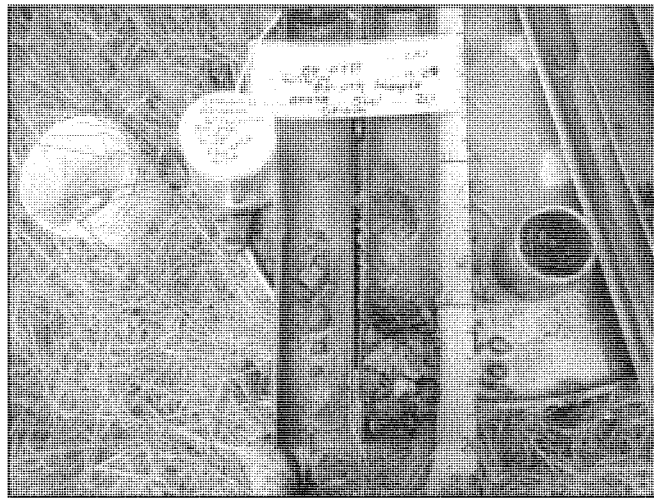
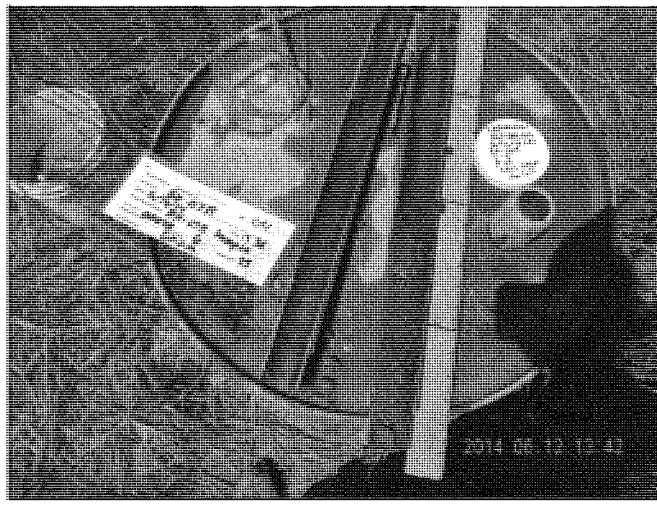
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

BH-07R Photographs

Figure
H-13





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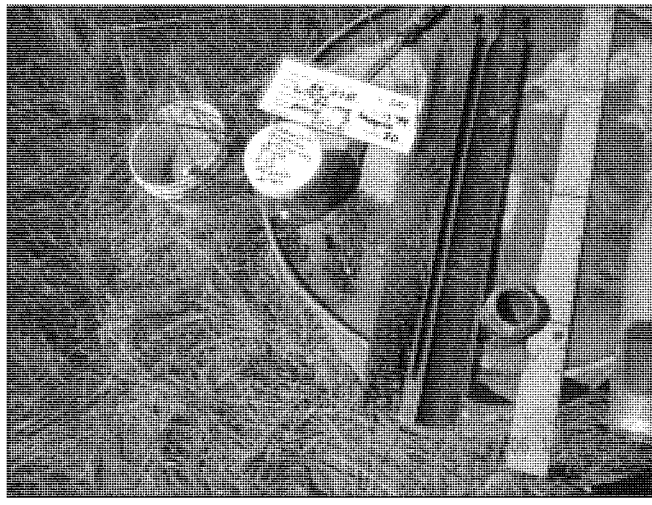
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-07R Photographs**	Figure H-13



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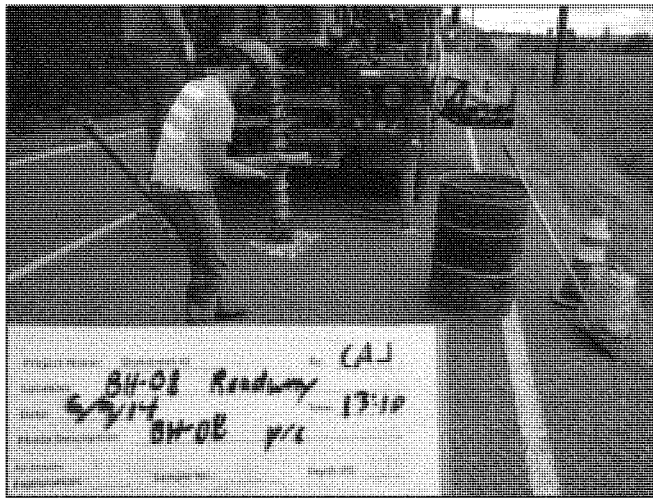
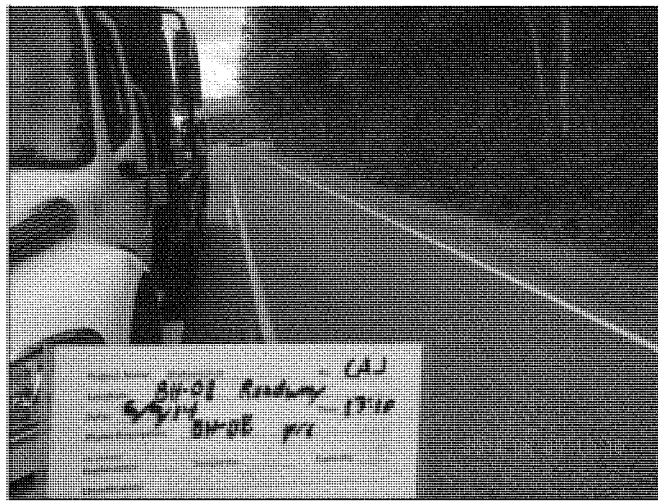
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-07R Photographs**	Figure H-13





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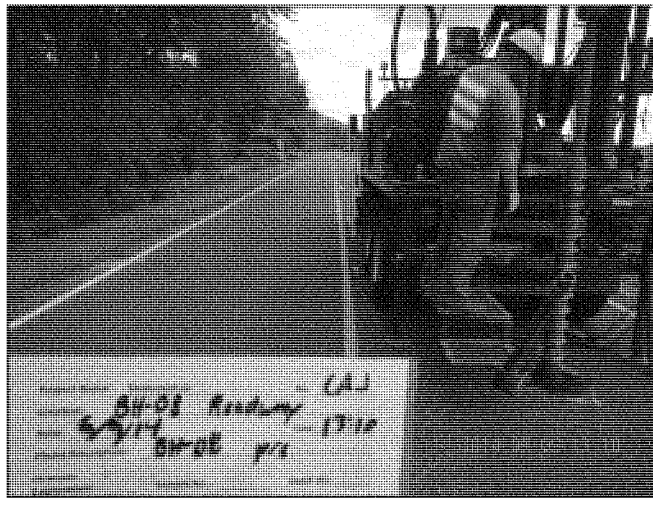
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-08 Photographs**	Figure H-14



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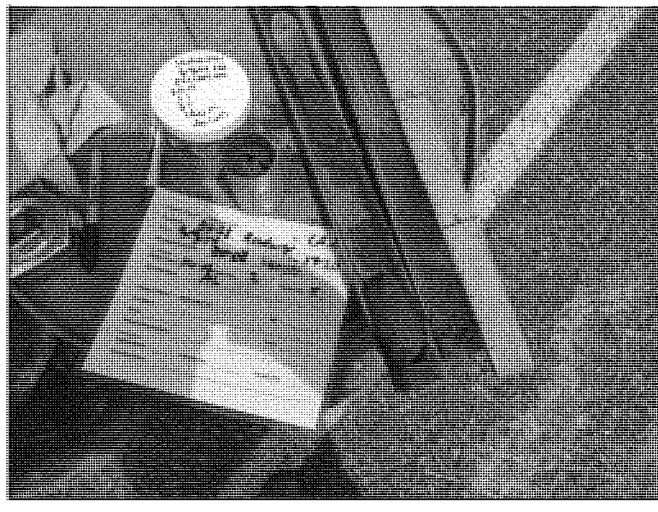
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-08 Photographs**	Figure H-14



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LANDAU ASSOCIATES

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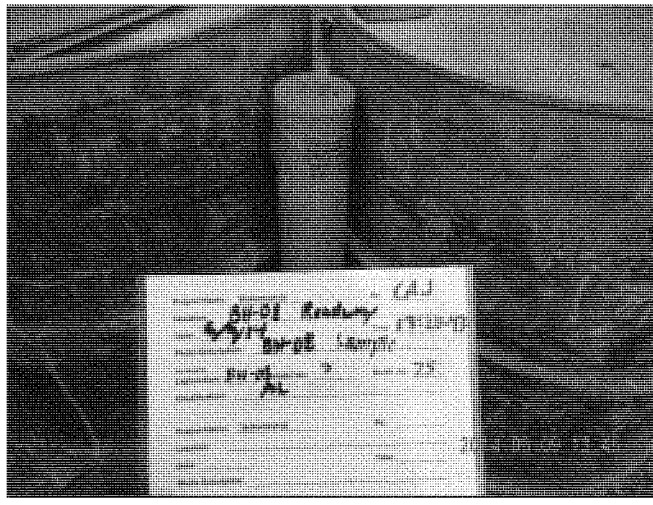

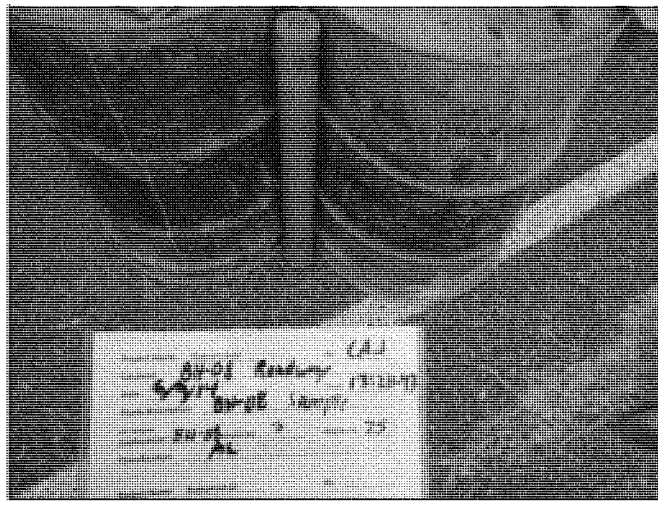

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-08 Photographs**	Figure H-14

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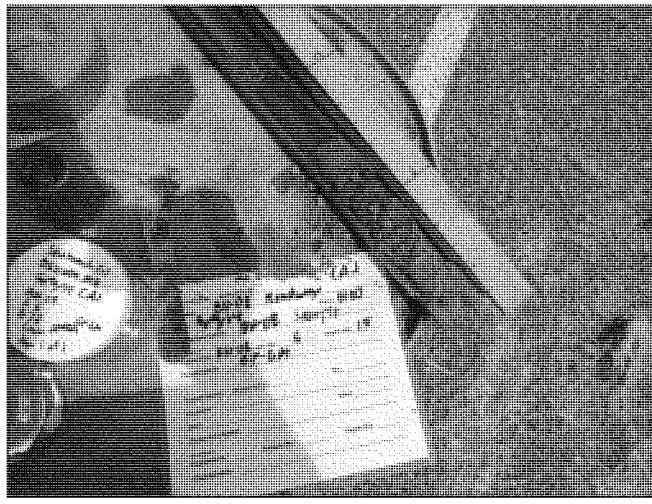
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-08 Photographs**	Figure H-14



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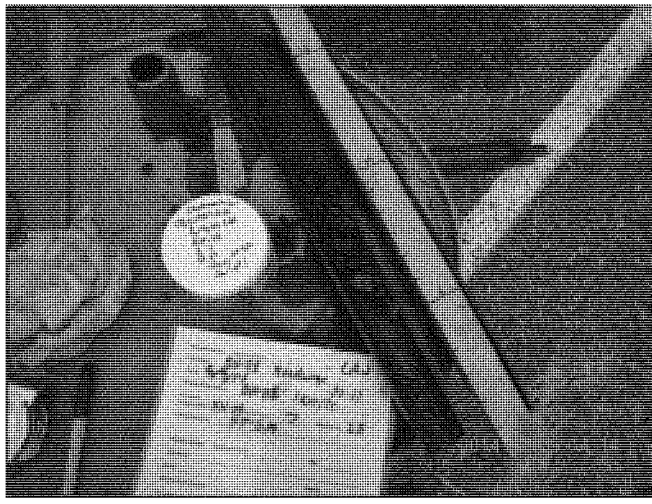

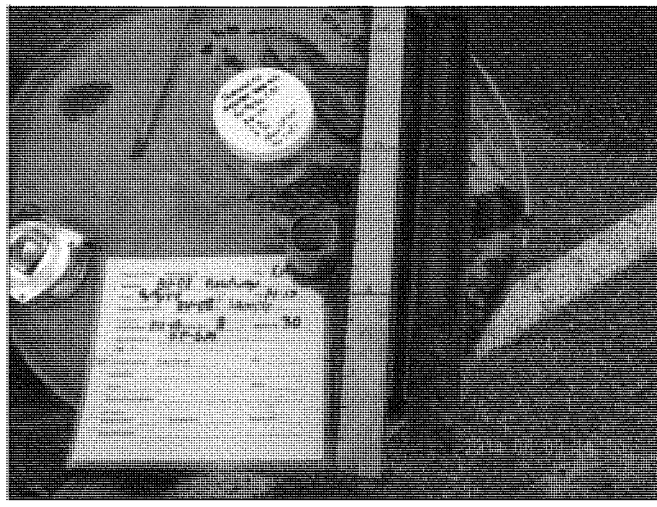

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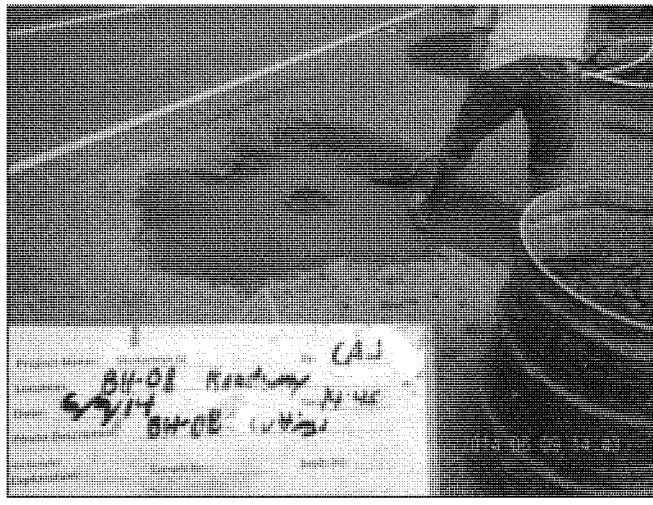
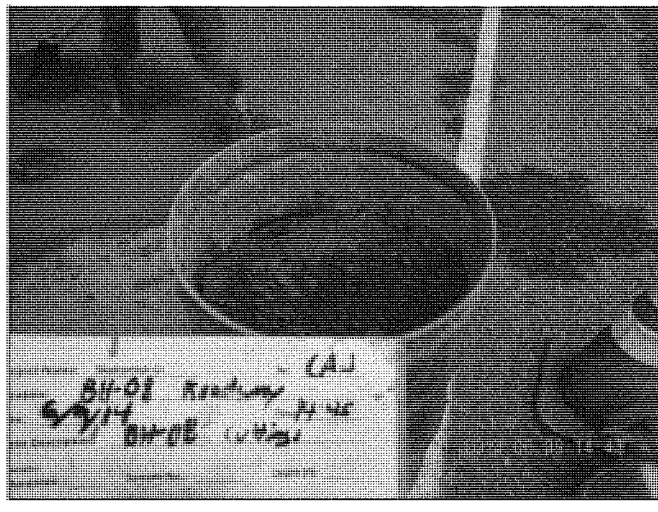
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-08 Photographs**	Figure H-14





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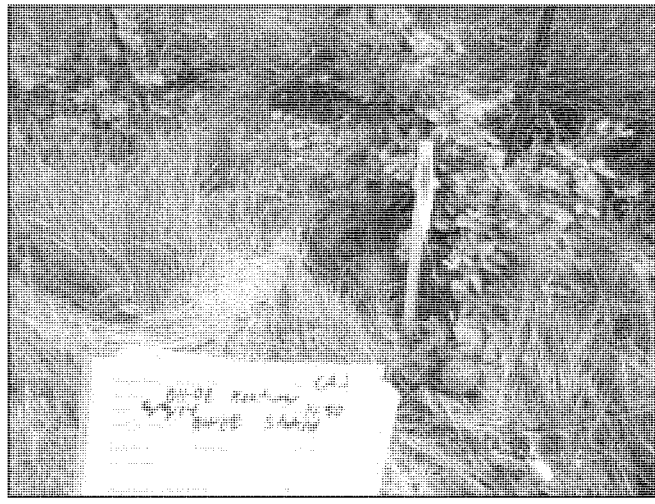

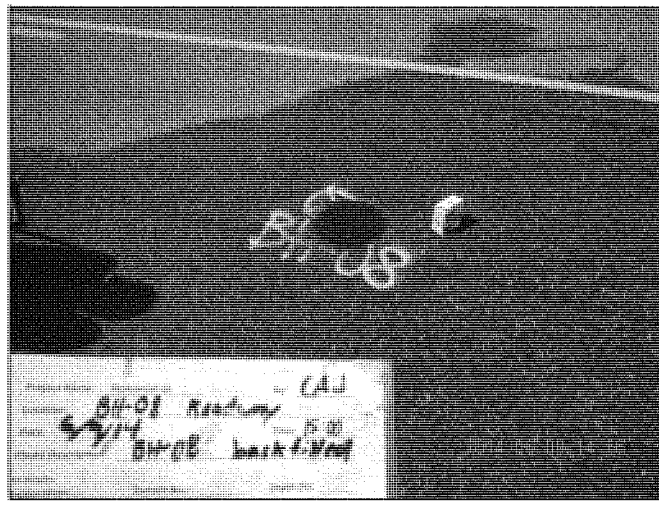

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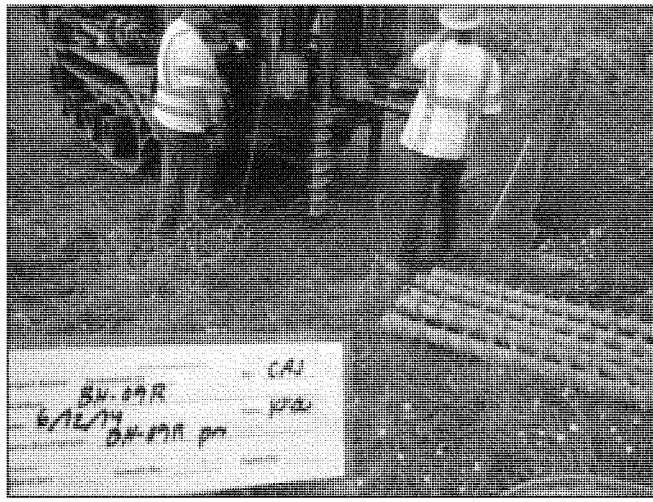
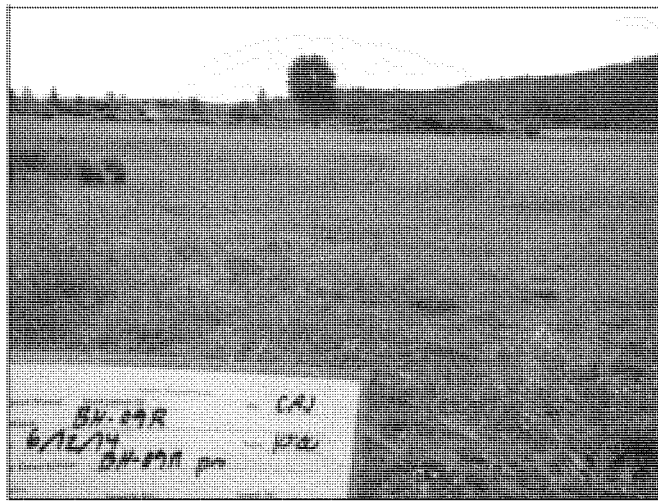
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-08 Photographs**	Figure H-14





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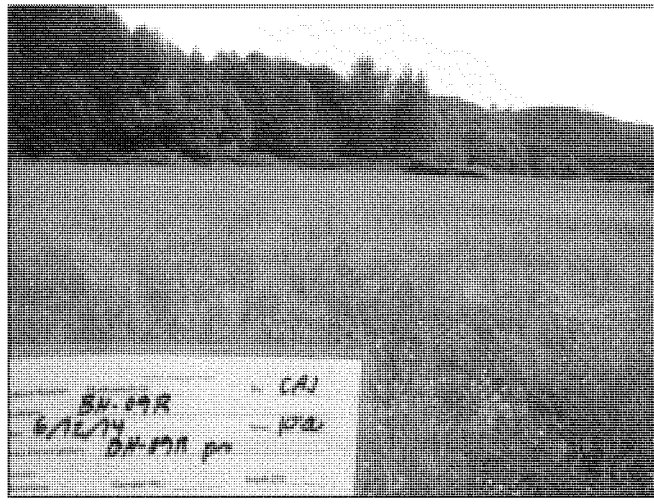
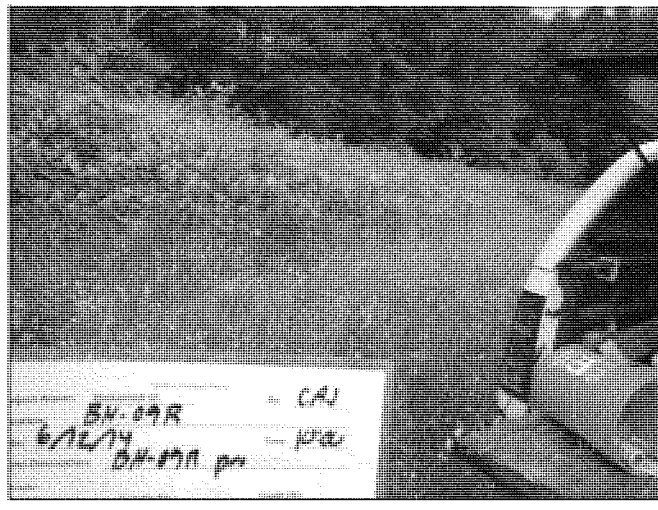
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15





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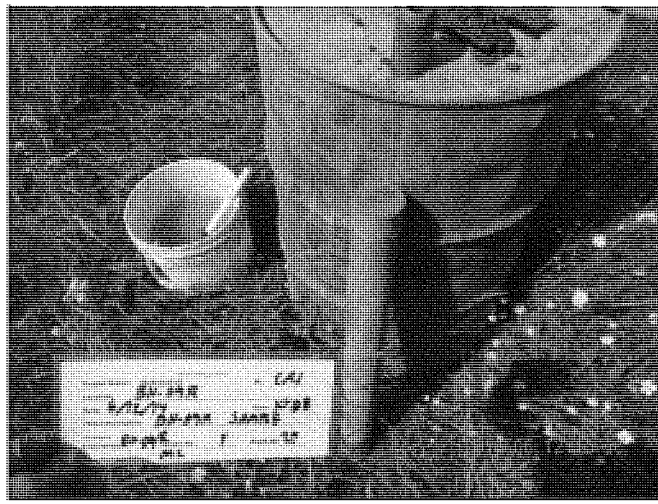
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15



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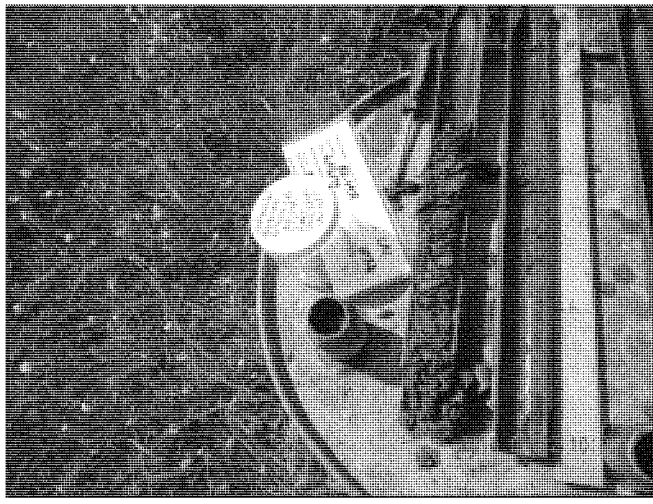
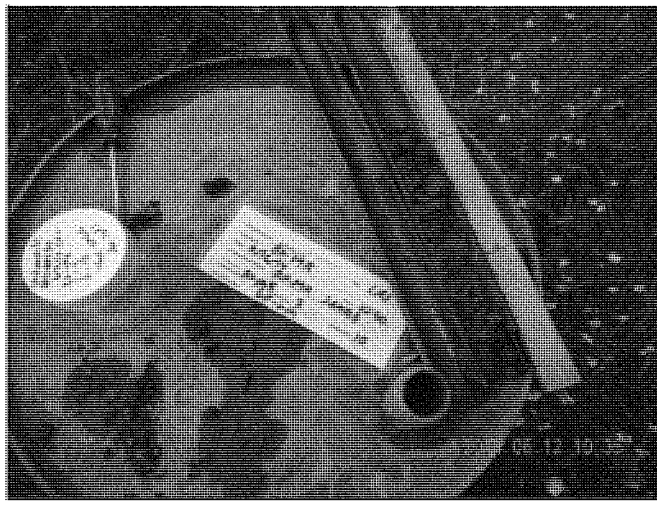
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15





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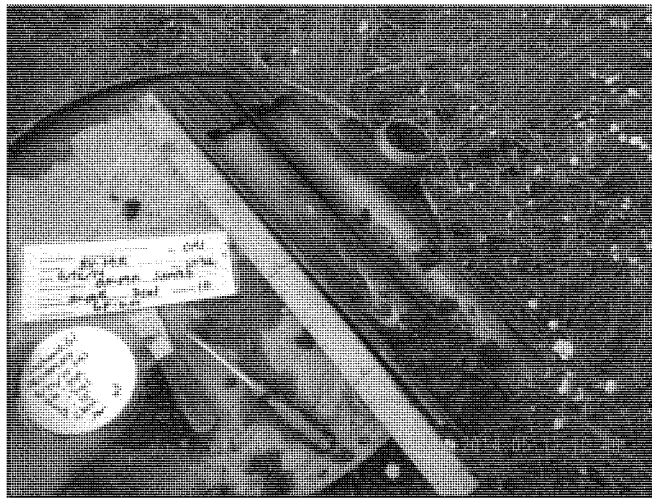
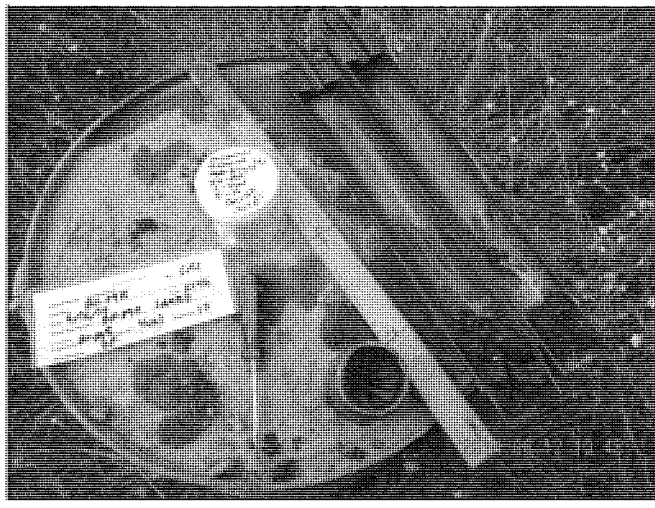
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15





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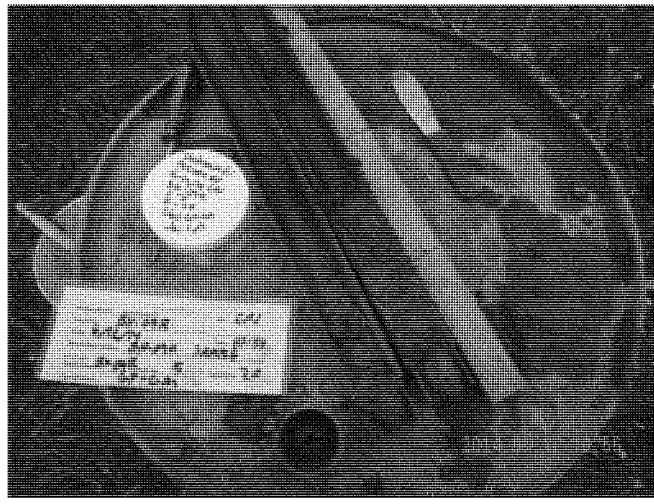
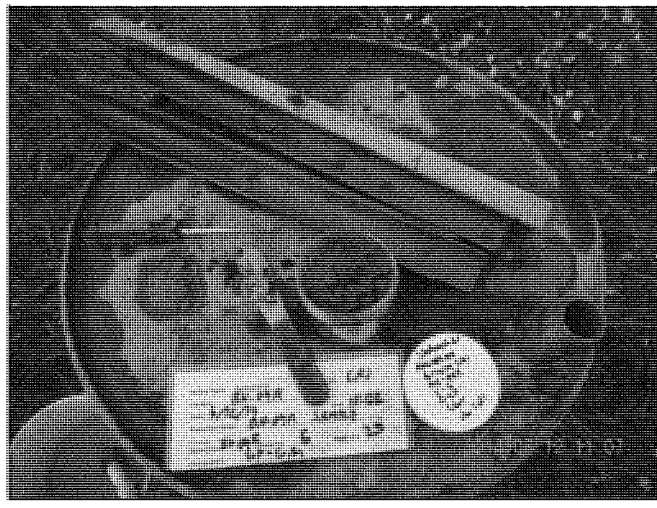
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15





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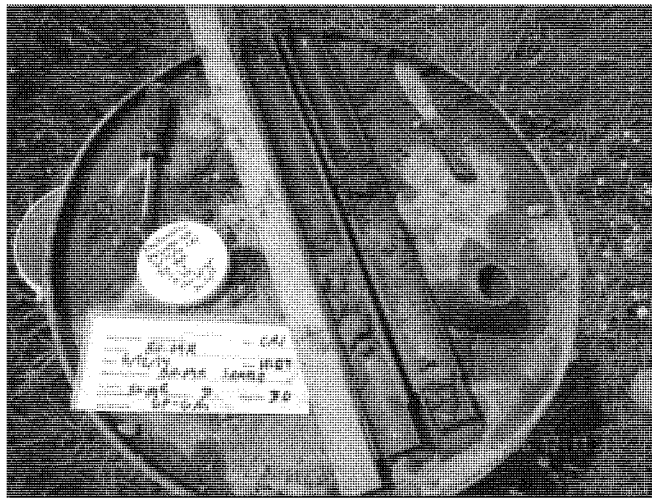
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15



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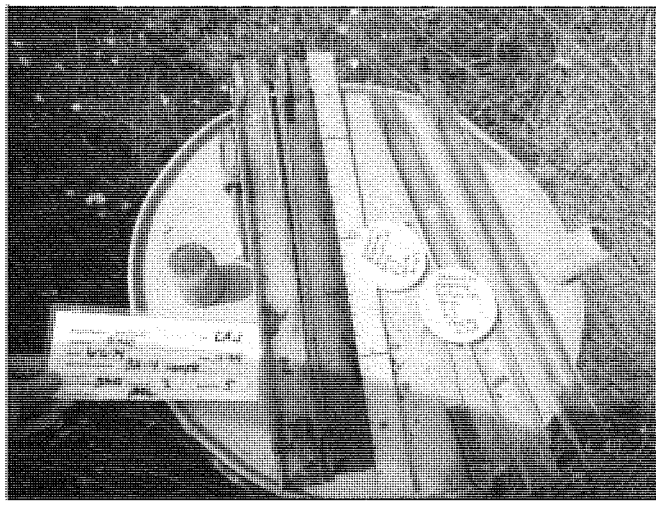
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-09R Photographs**	Figure H-15



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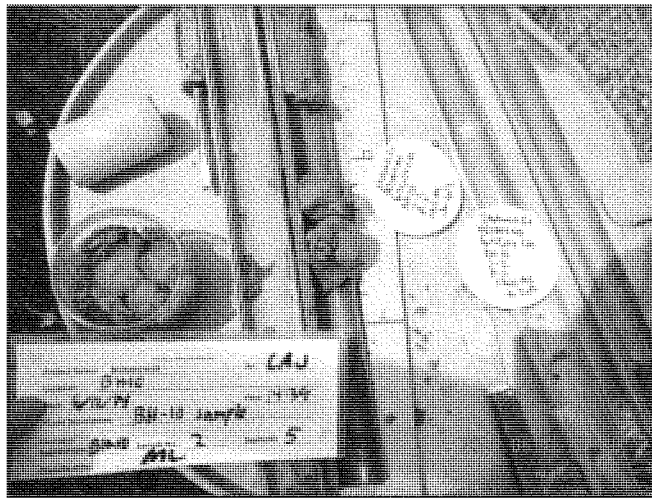
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-10 Photographs**	Figure H-16



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-10 Photographs**	Figure H-16

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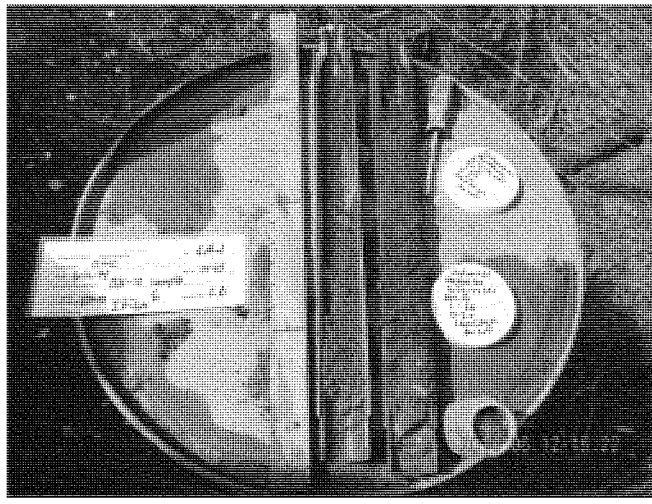
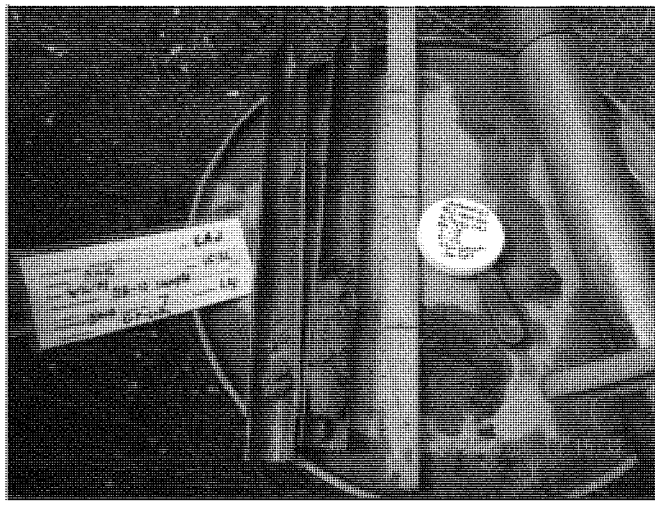
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-10 Photographs**	Figure H-16





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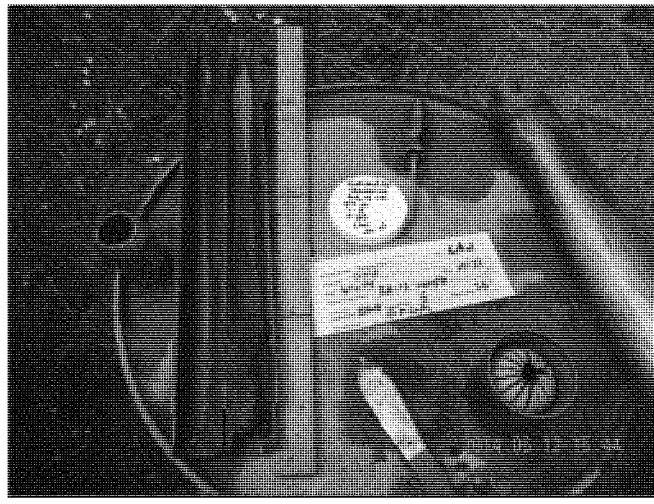
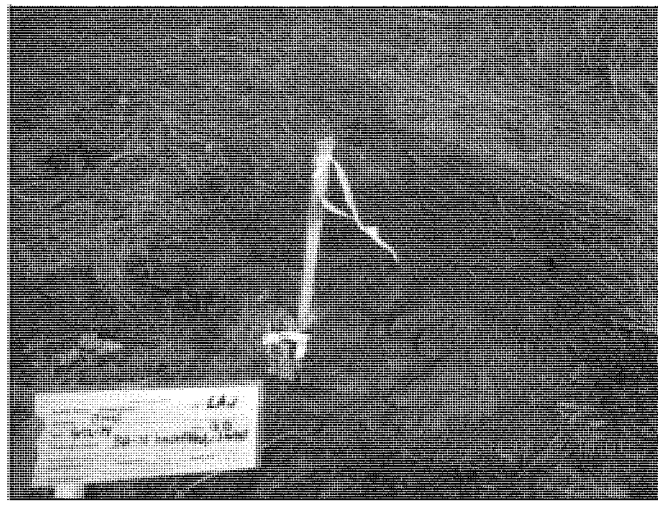
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-10 Photographs**	Figure H-16





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-10 Photographs**	Figure H-16

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17

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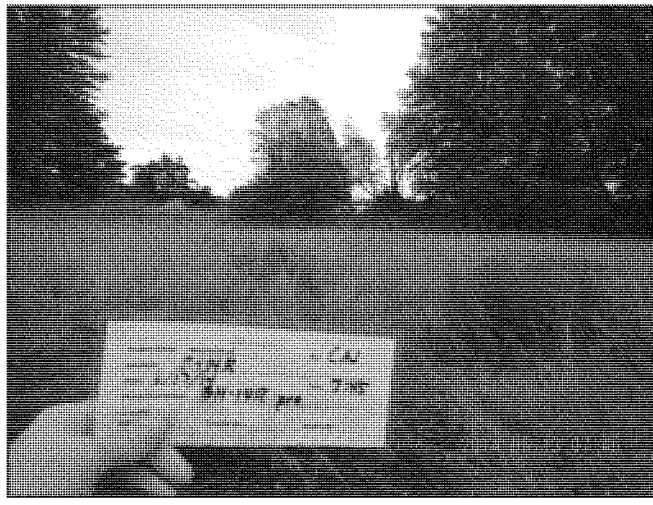
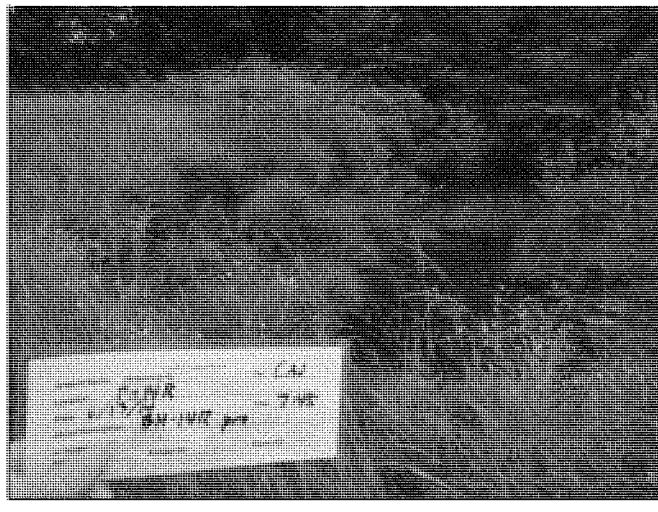
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17





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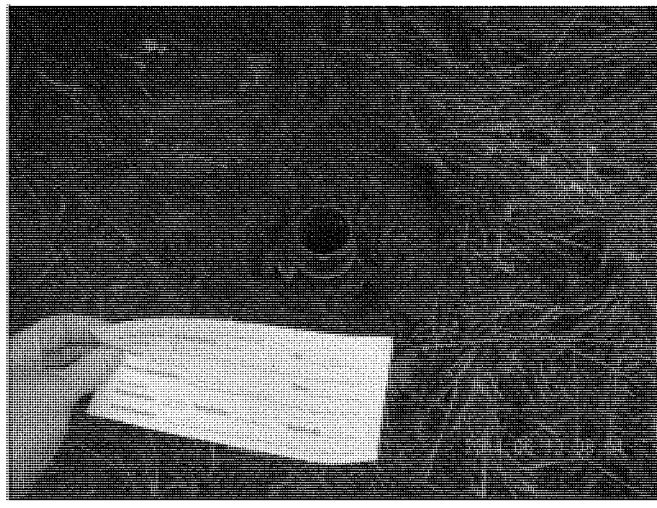
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17

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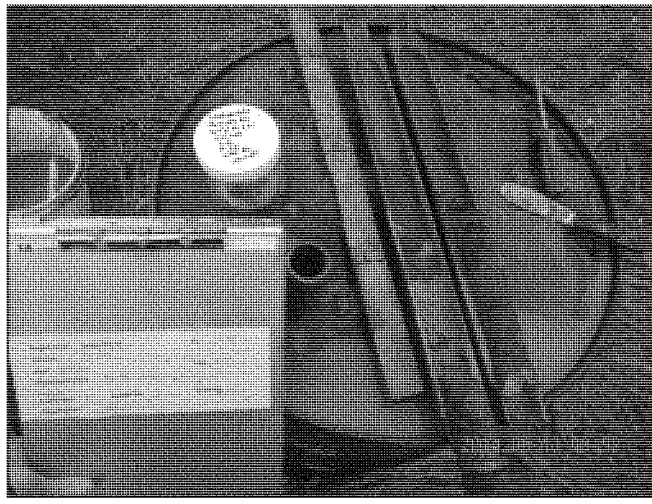
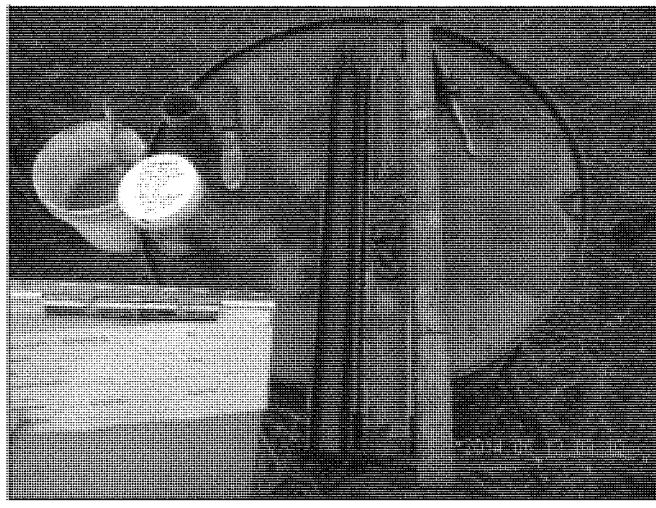
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17





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LANDAU ASSOCIATES

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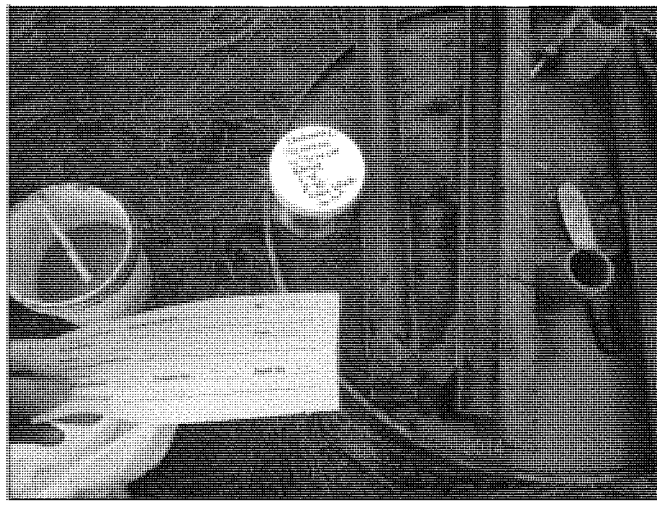

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17

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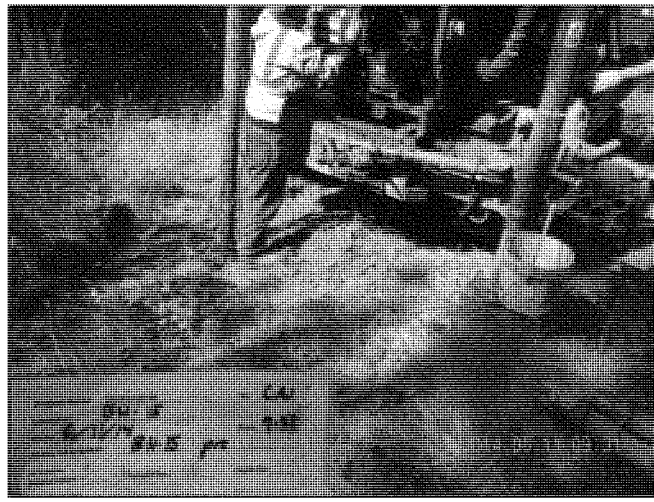
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-14R Photographs**	Figure H-17



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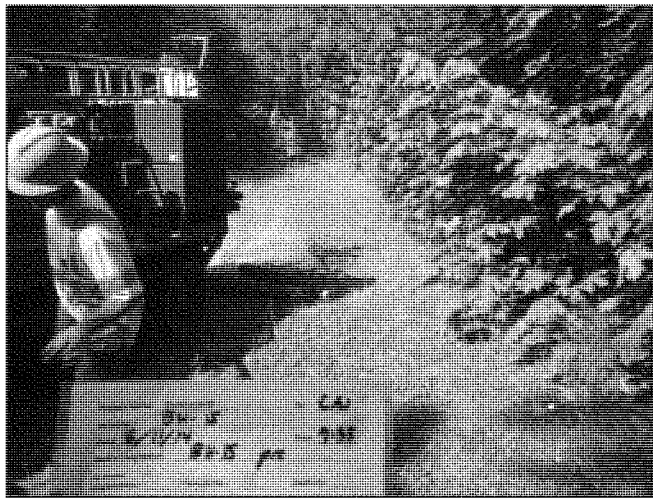
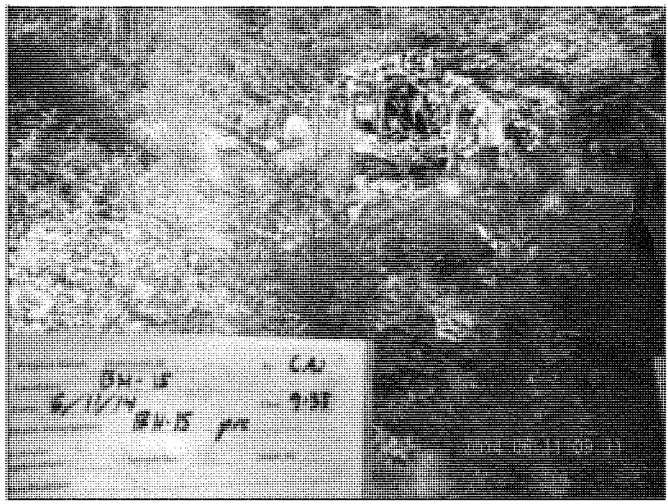
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18





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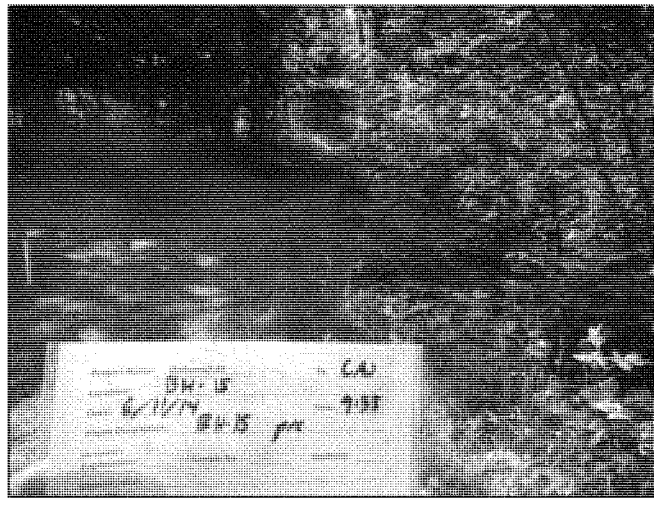
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18



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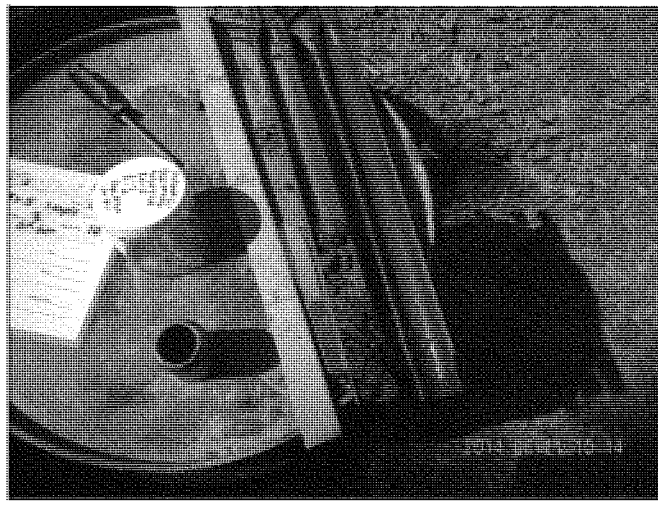
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18



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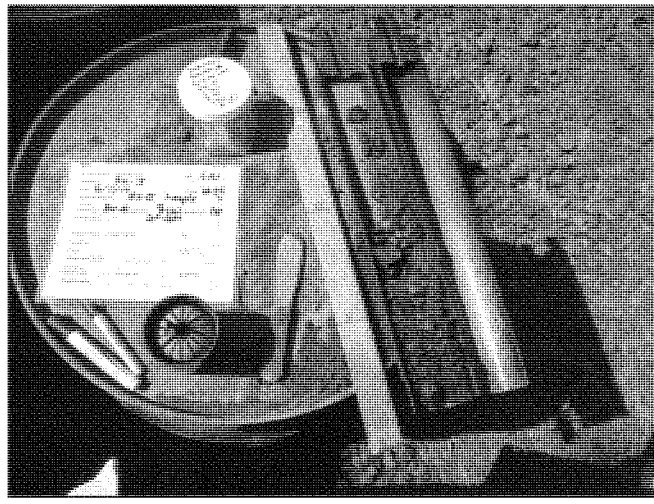
Skokomish Geotechnical and HTRW Investigation
Mason County, Washington

BH-15 Photographs

Figure
H-18



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18

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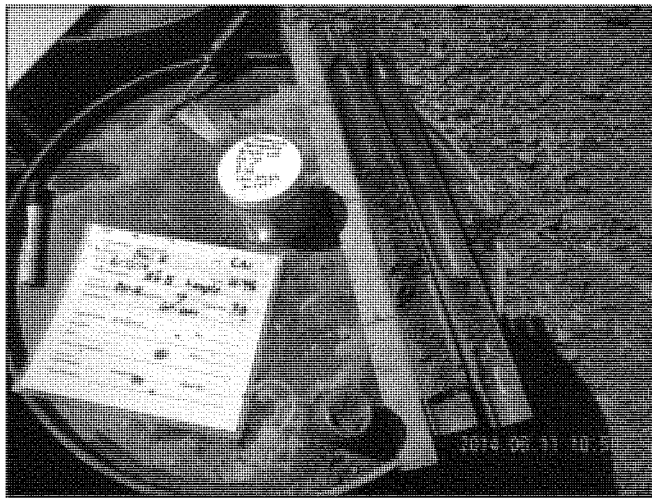
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18

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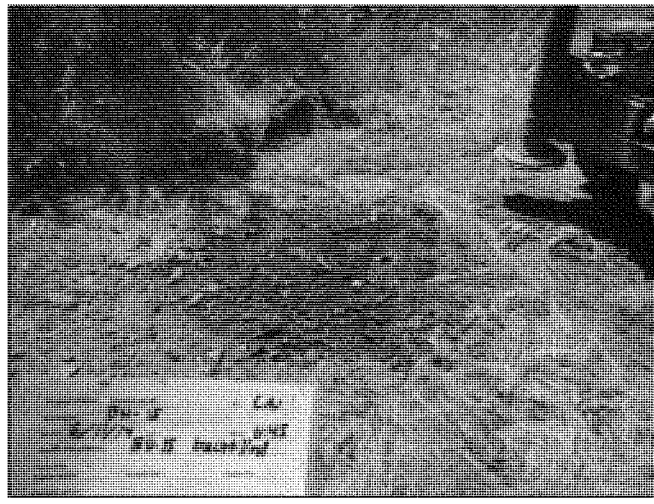
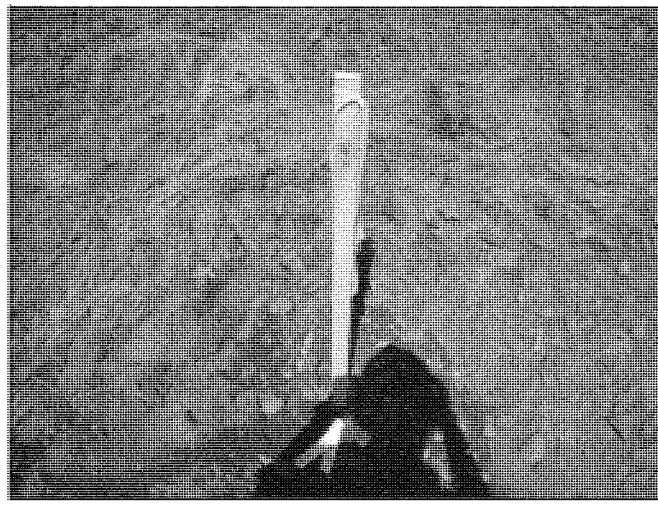
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18





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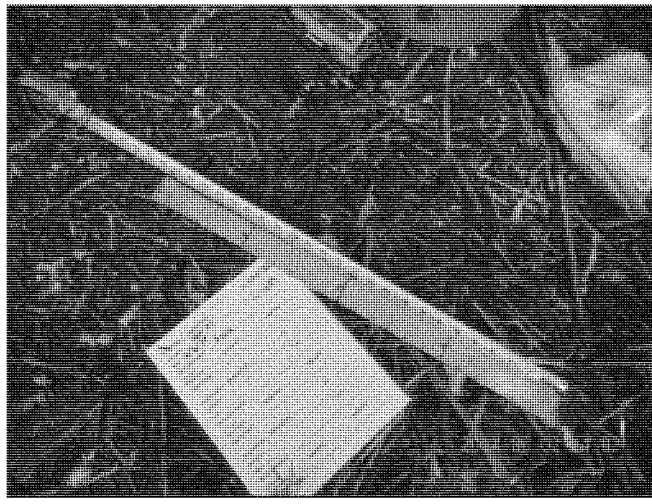
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**BH-15 Photographs**	Figure H-18



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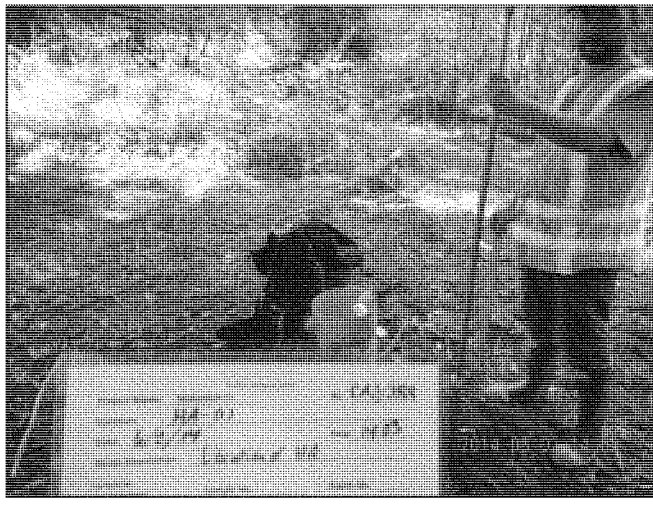
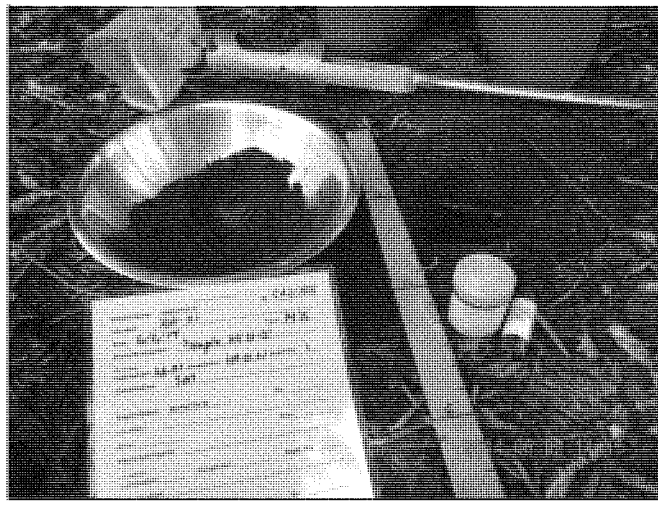
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-01 Photographs**	Figure H-19





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-01 Photographs**	Figure H-19

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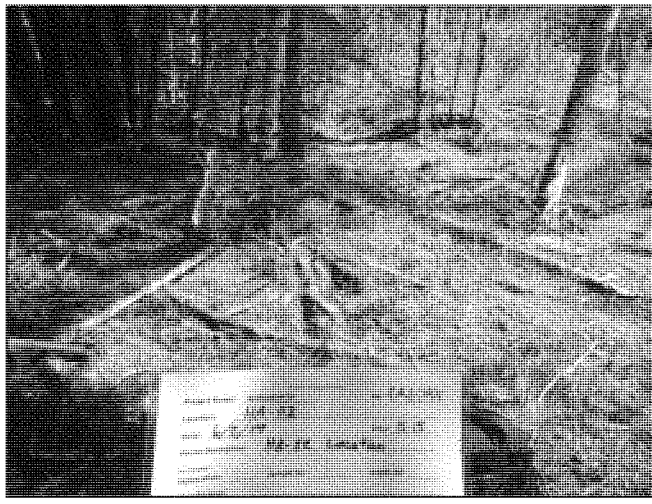
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-01 Photographs**	Figure H-19



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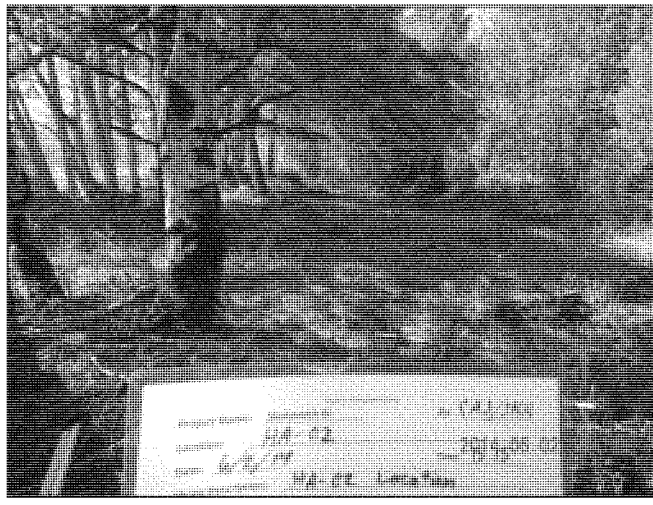
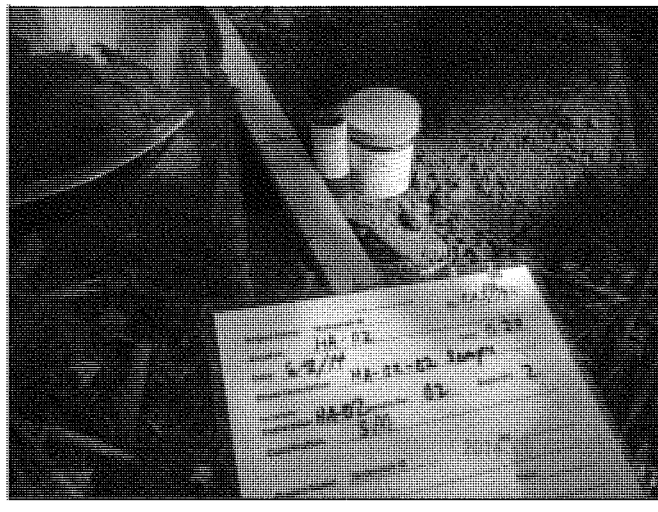
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-02 Photographs**	Figure H-20





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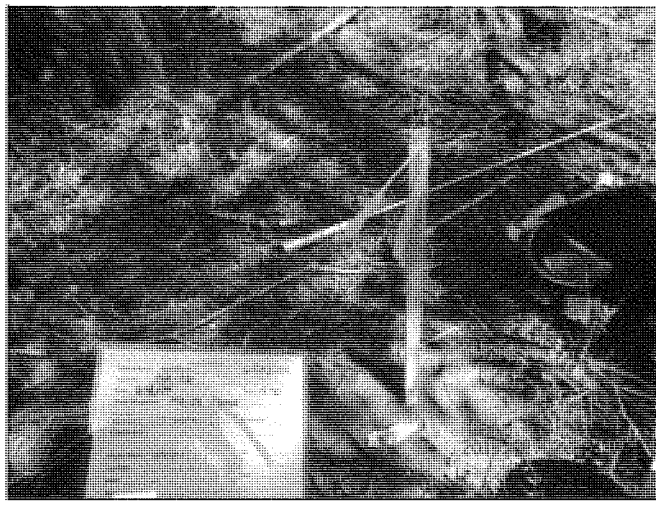
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-02 Photographs**	Figure H-20



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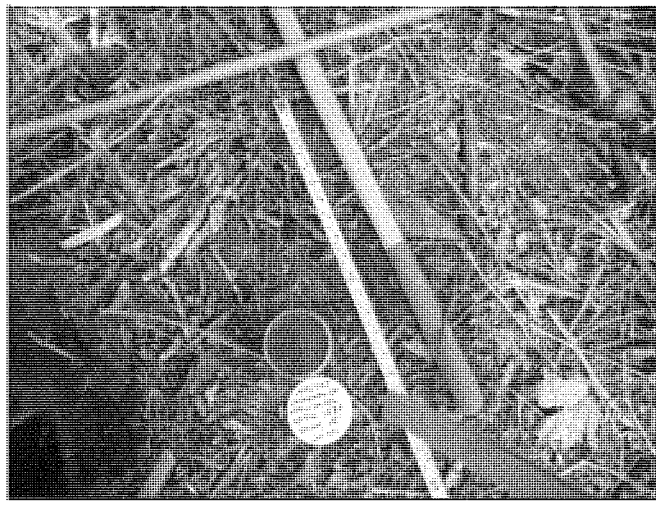
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-02 Photographs**	Figure H-20



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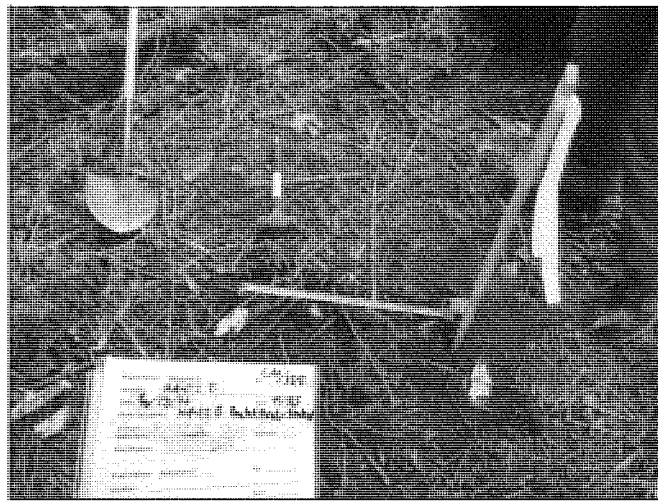
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-02B Photographs**	Figure H-21



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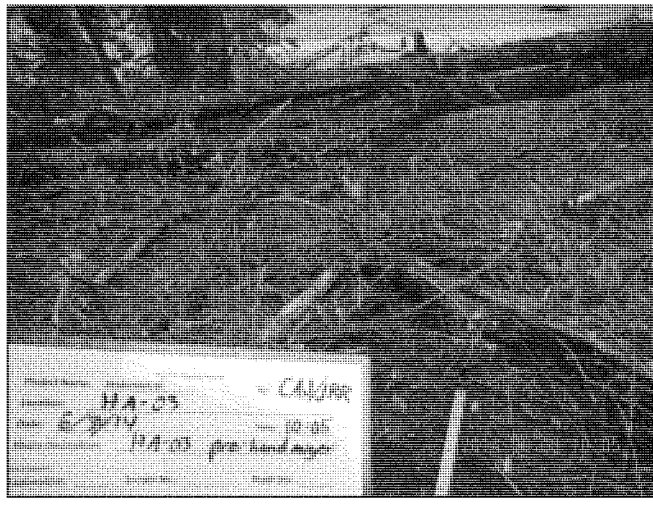
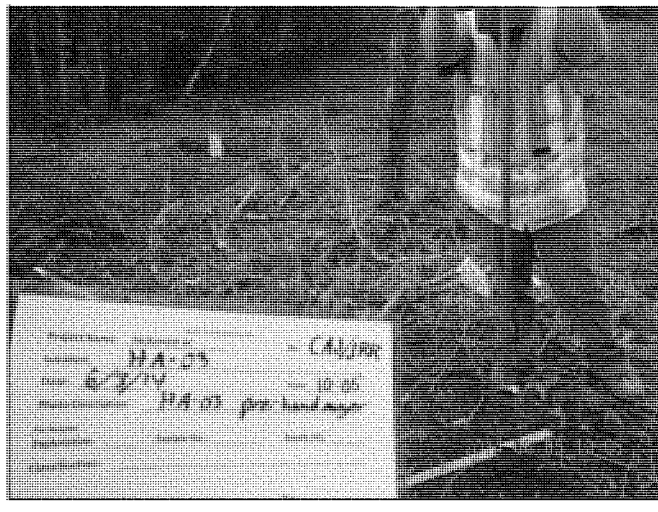
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-02B Photographs**	Figure H-21





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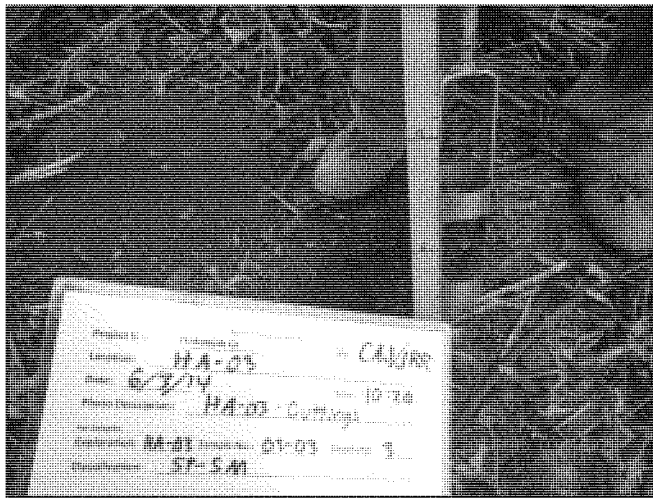
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-03 Photographs**	Figure H-22



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-03 Photographs**	Figure H-22

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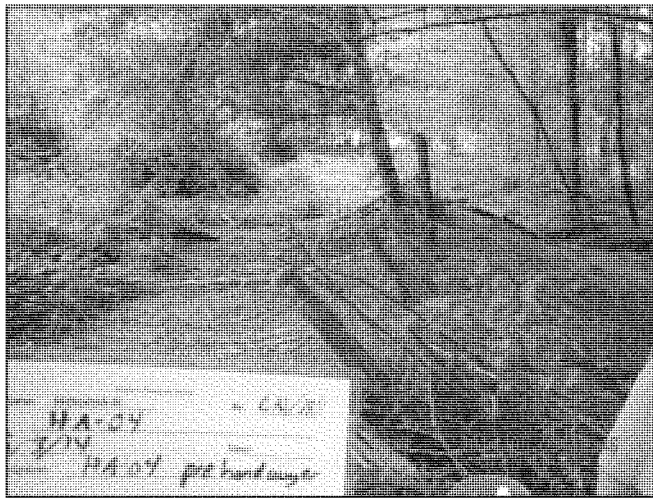
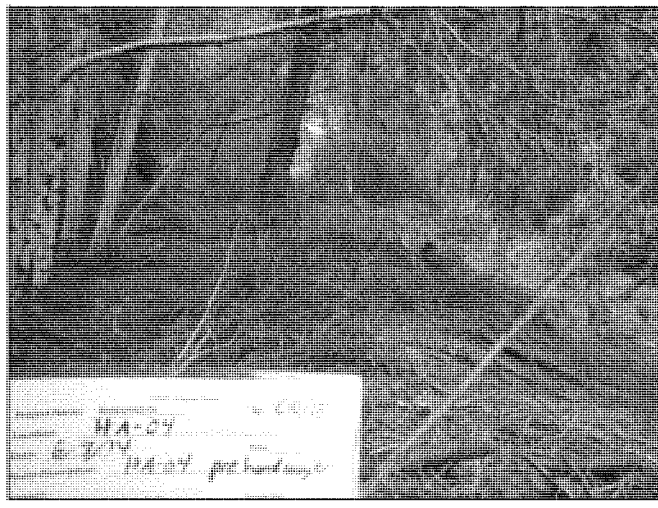
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-03 Photographs**	Figure H-22





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-04 Photographs**	Figure H-23

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-04 Photographs**	Figure H-23

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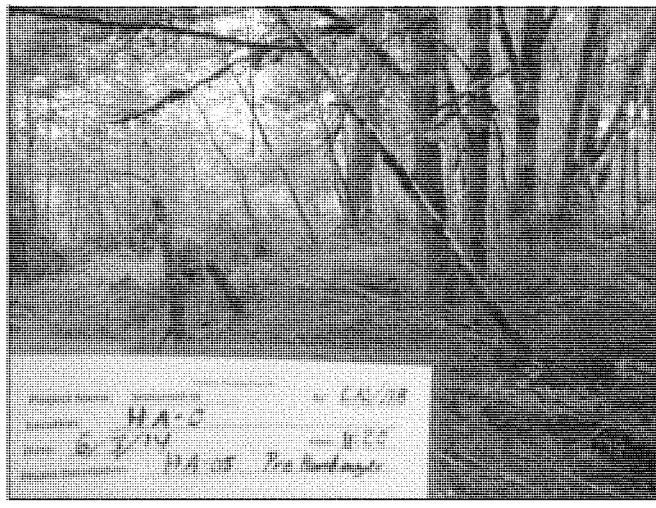
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-04 Photographs**	Figure H-23



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-05 Photographs**	Figure H-24

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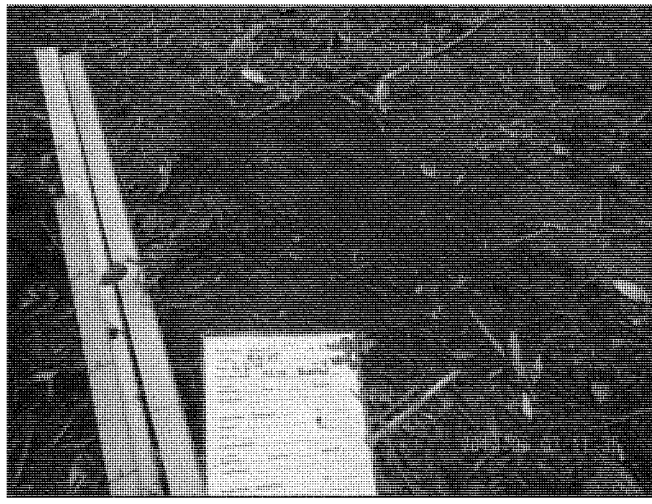
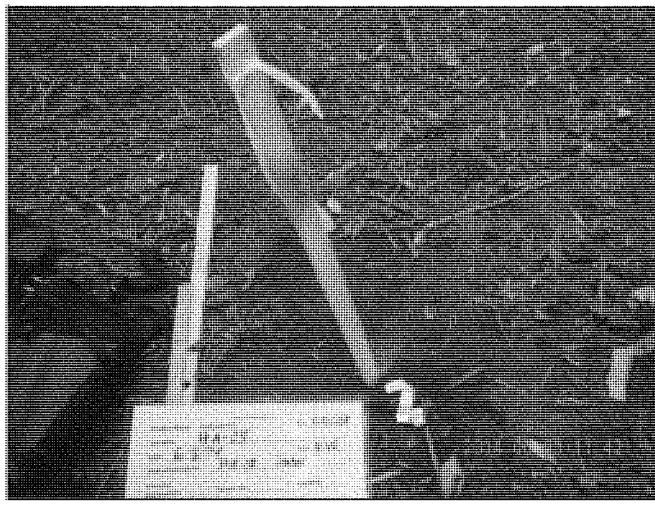
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-05 Photographs**	Figure H-24





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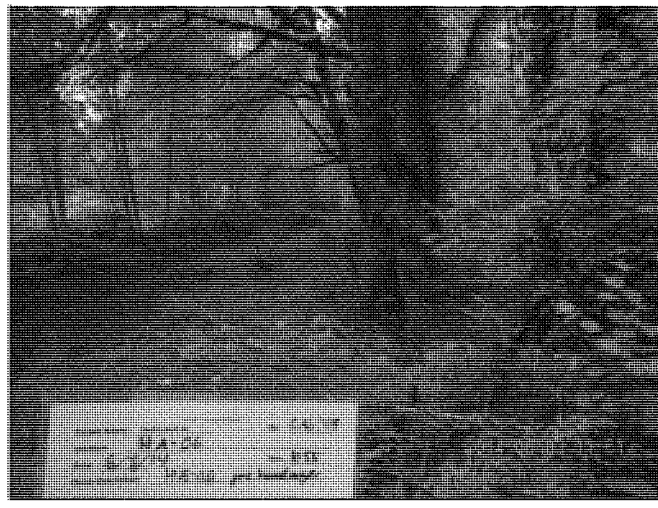
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-05 Photographs**	Figure H-24



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-06 Photographs**	Figure H-25

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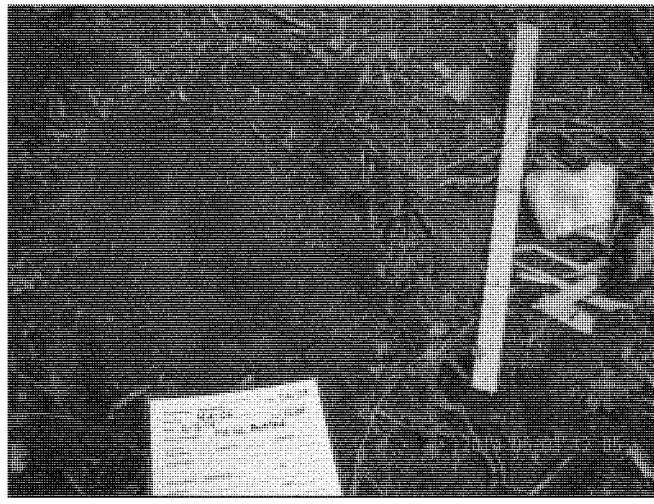
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-06 Photographs**	Figure H-25



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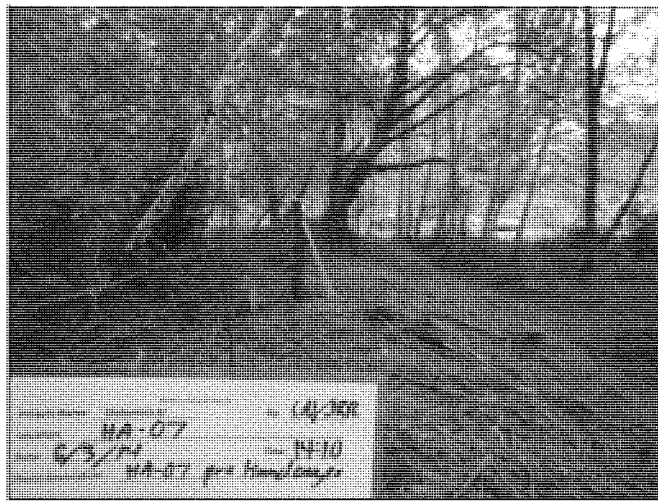
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-06 Photographs**	Figure H-25



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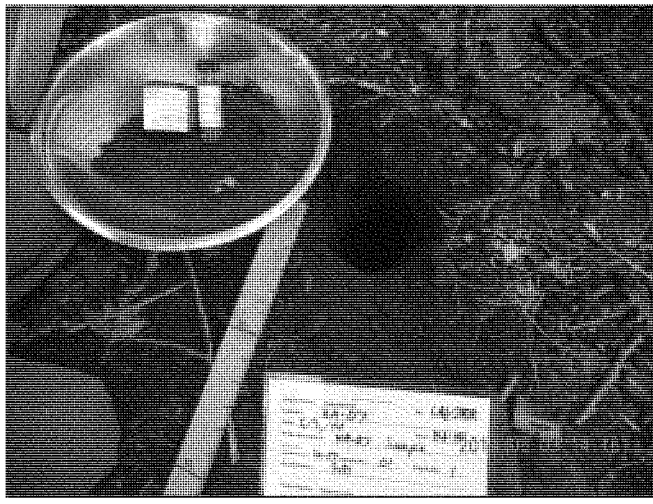
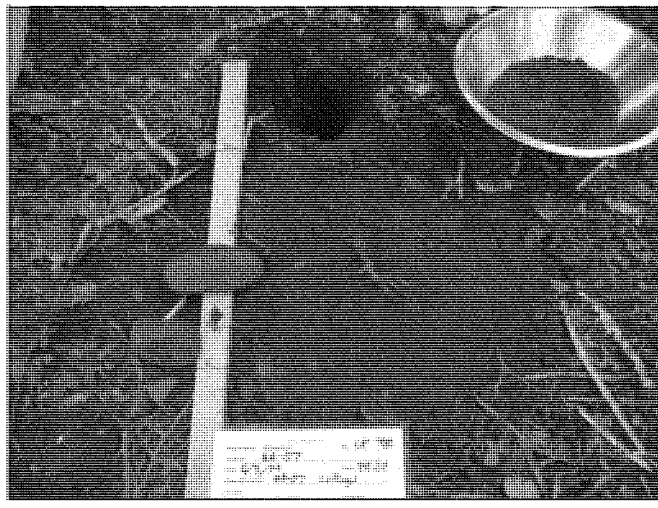
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-07 Photographs**	Figure H-26





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-07 Photographs**	Figure H-26

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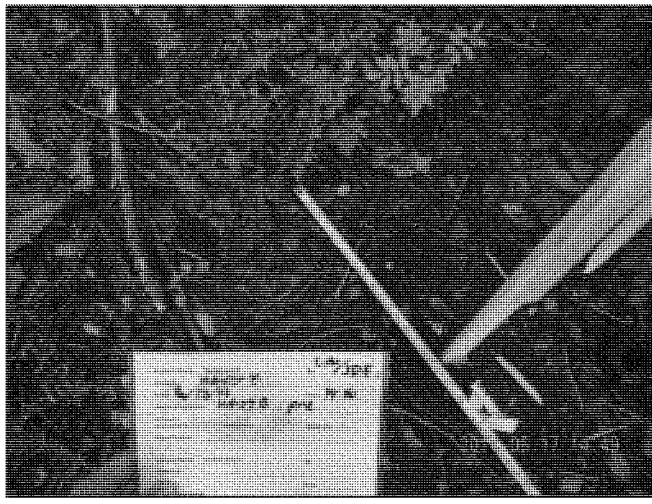
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-07 Photographs**	Figure H-26



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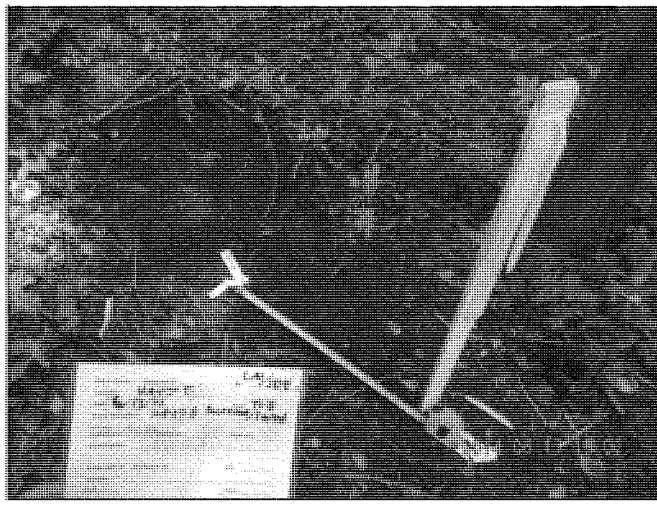
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-07B Photographs**	Figure H-27



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-07B Photographs**	Figure H-27

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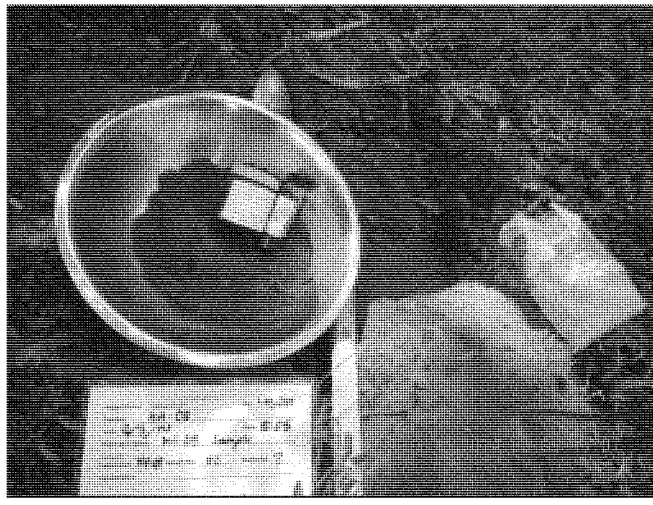
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-08 Photographs**	Figure H-28



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-08 Photographs**	Figure H-28

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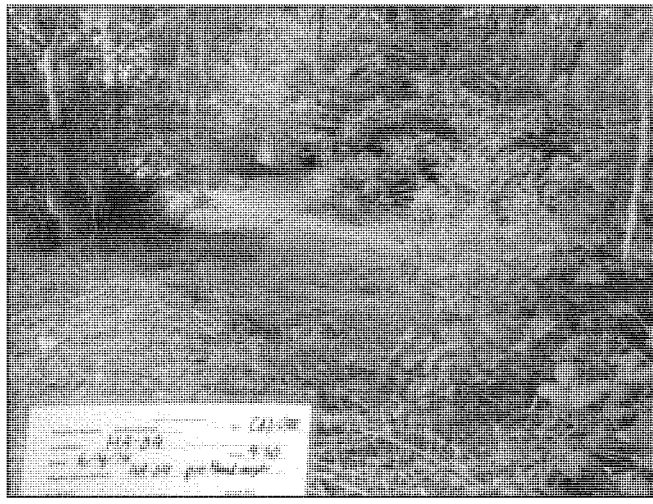
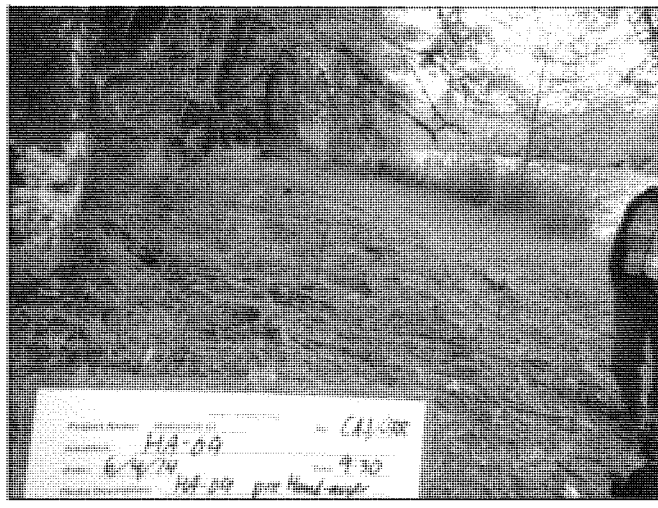
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-08 Photographs**	Figure H-28





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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-09 Photographs**	Figure H-29

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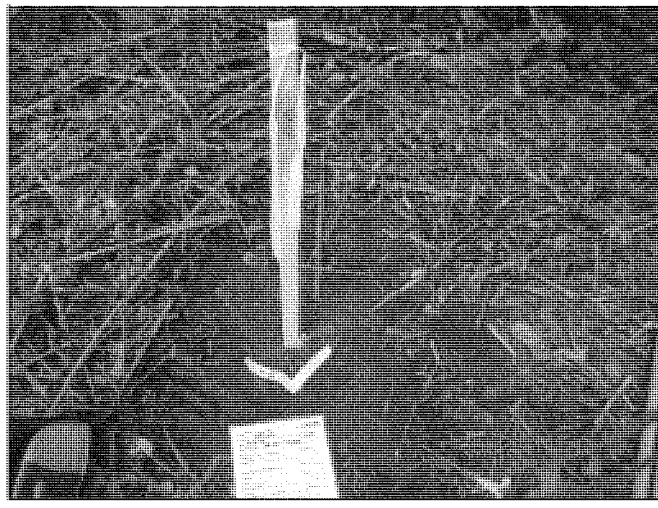
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-09 Photographs**	Figure H-29



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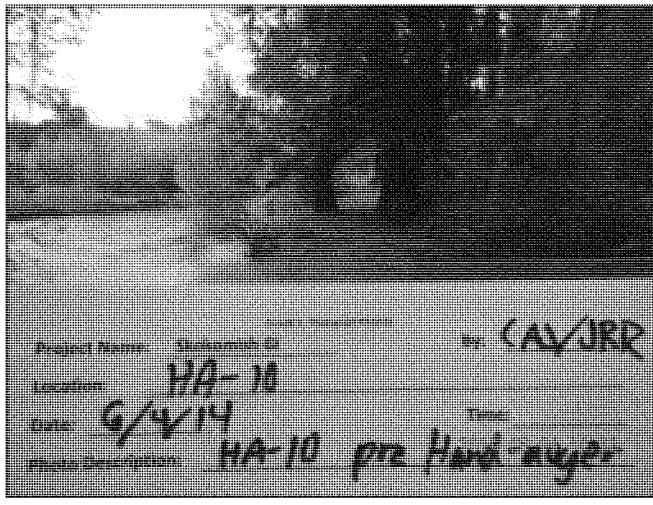
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-09 Photographs**	Figure H-29



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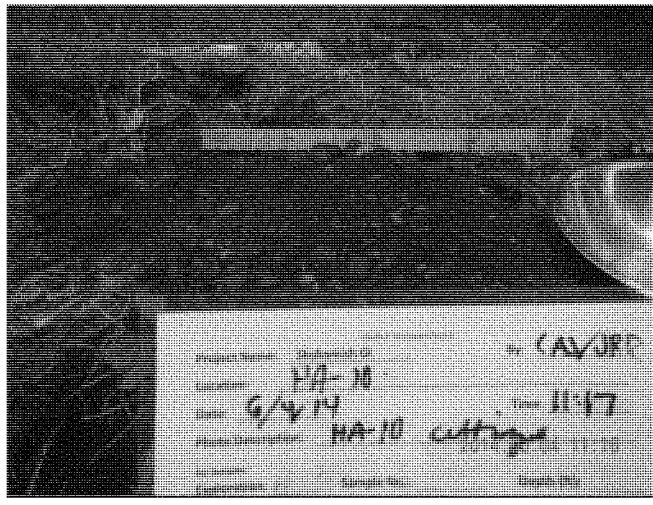
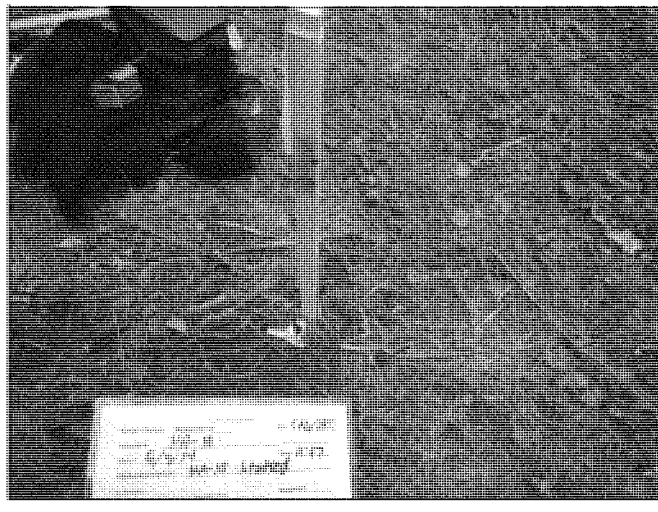
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-10 Photographs**	Figure H-30





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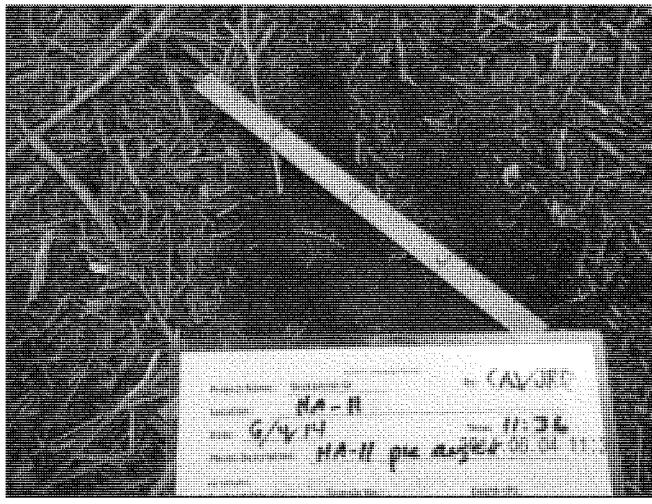
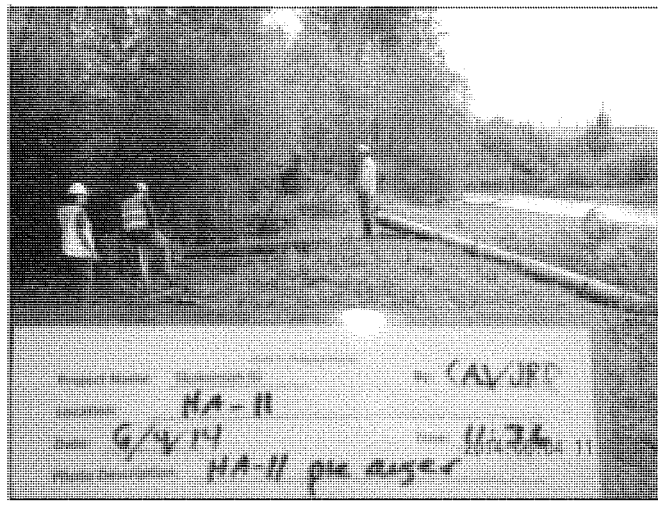
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-10 Photographs**	Figure H-30





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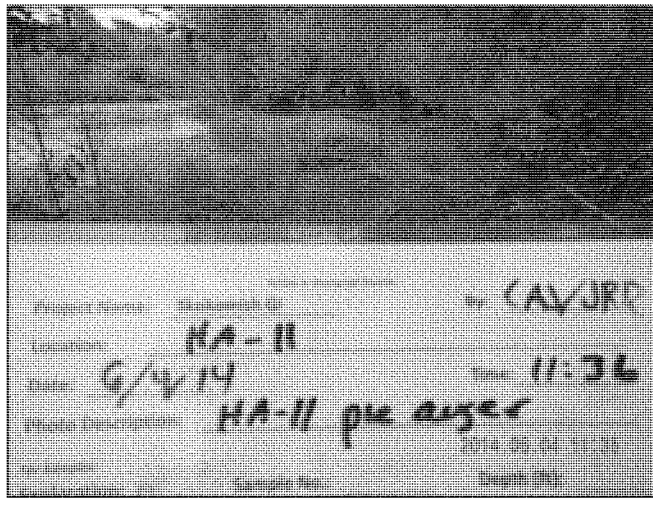
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-11 Photographs**	Figure H-31



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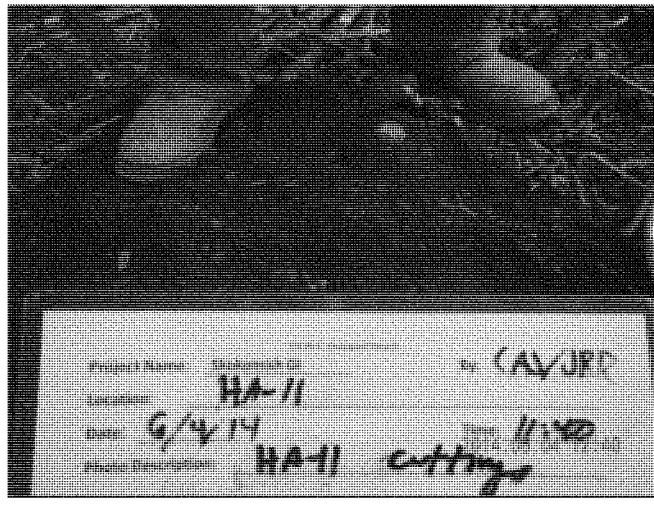
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-11 Photographs**	Figure H-31



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-11 Photographs**	Figure H-31

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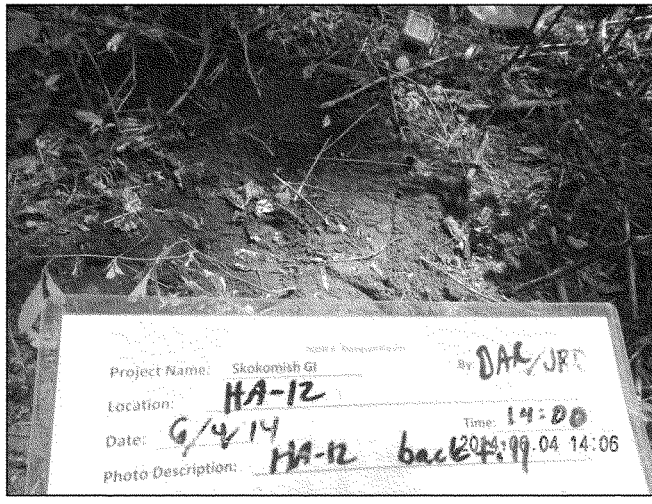
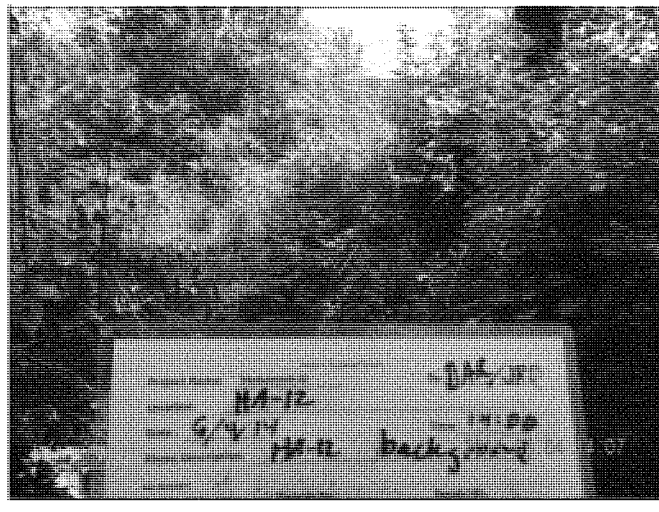
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-12 Photographs**	Figure H-32





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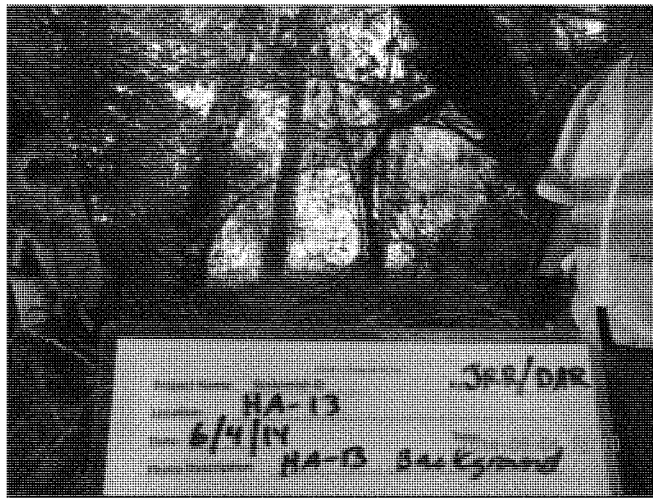
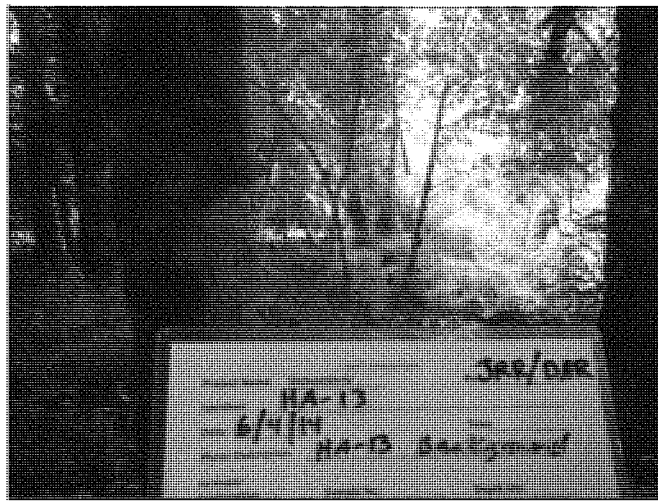
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-12 Photographs**	Figure H-32





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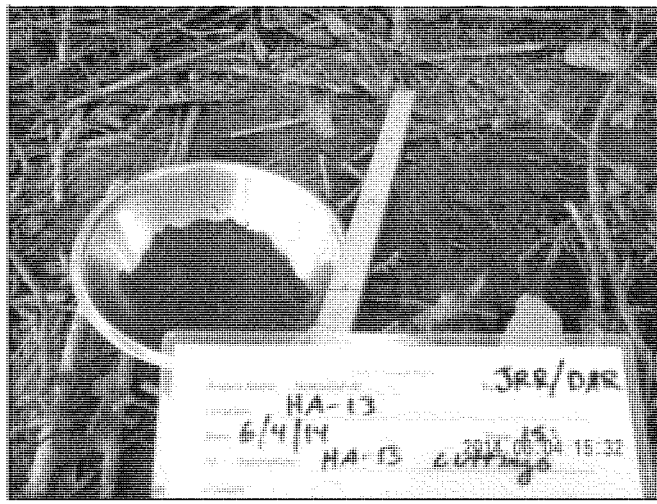
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-13 Photographs**	Figure H-33



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LANDAU ASSOCIATES	Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-13 Photographs**	Figure H-33

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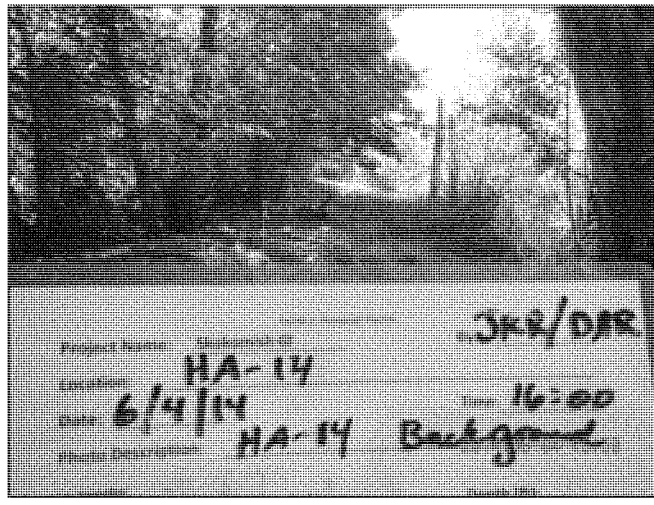
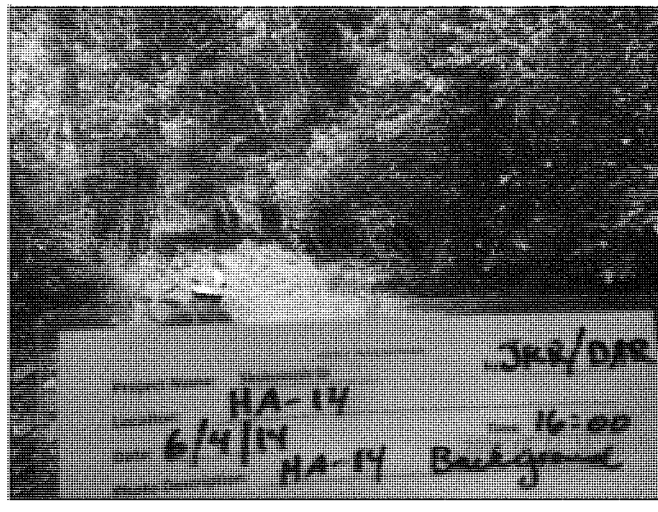
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-13 Photographs**	Figure H-33





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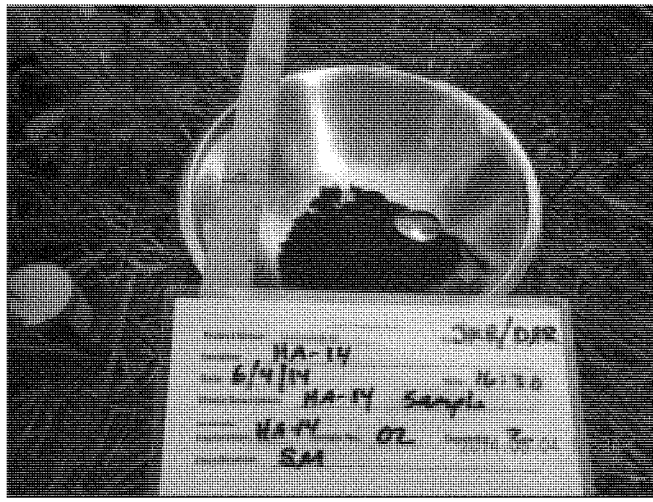
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-14 Photographs**	Figure H-34



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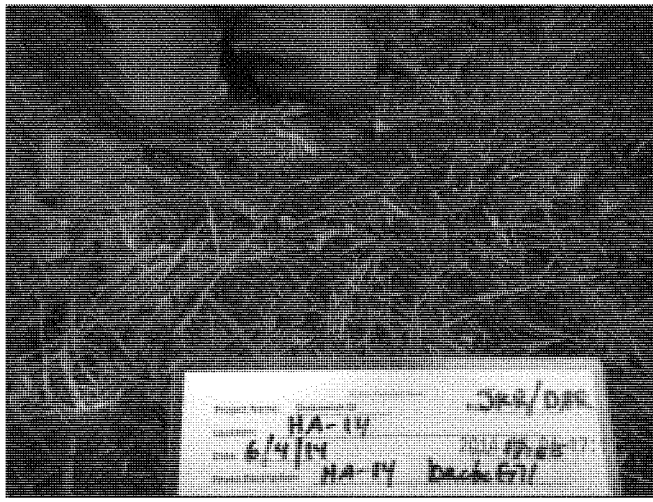
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-14 Photographs**	Figure H-34



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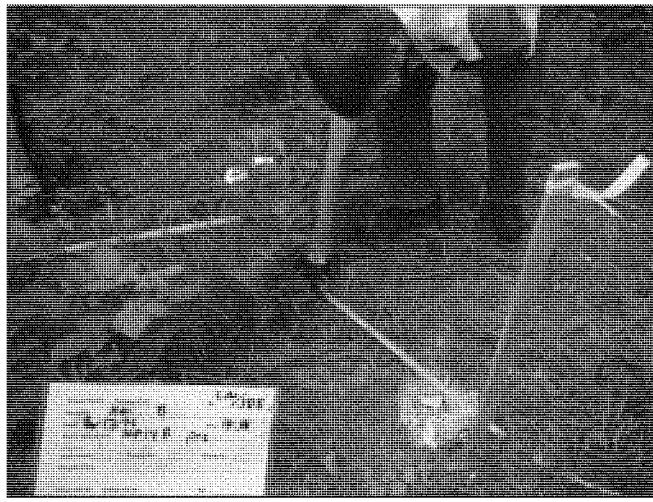
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-14 Photographs**	Figure H-34



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-14B Photographs**	Figure H-35

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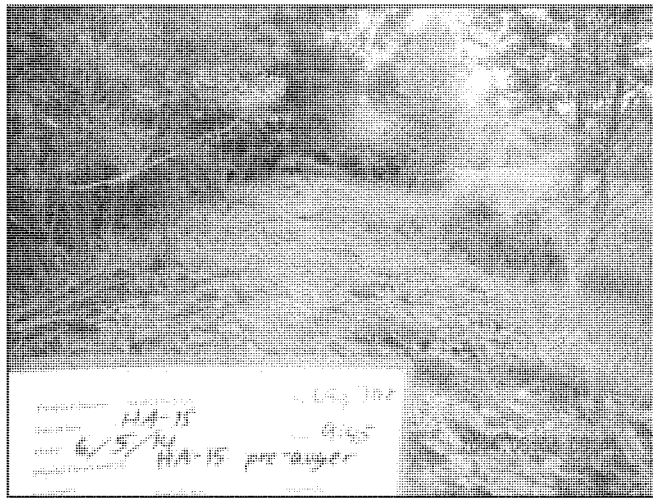
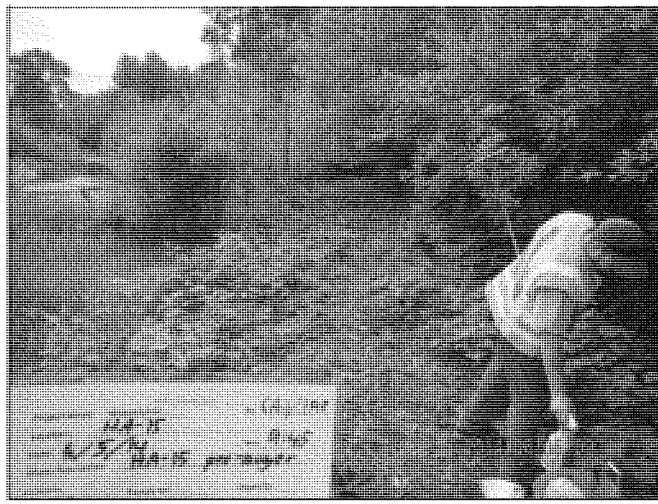
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-14B Photographs**	Figure H-35





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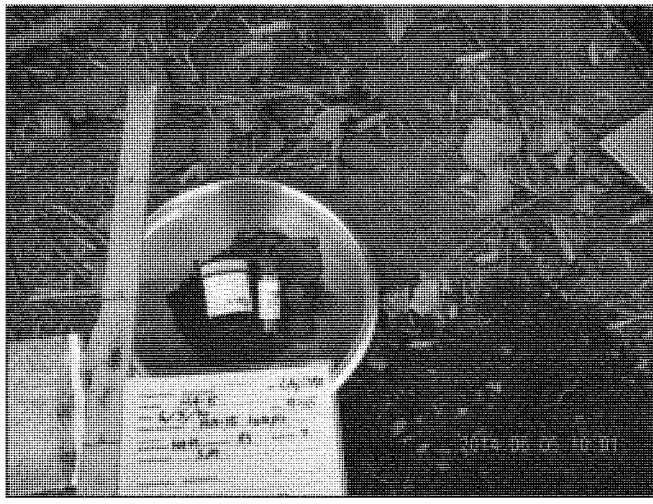
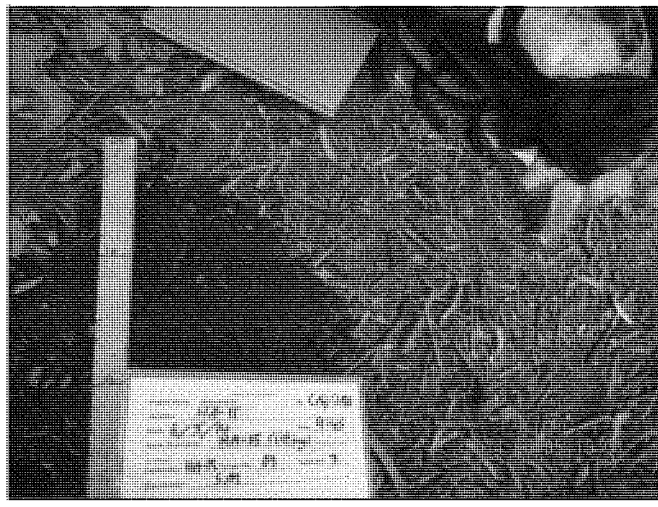
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-15 Photographs**	Figure H-36





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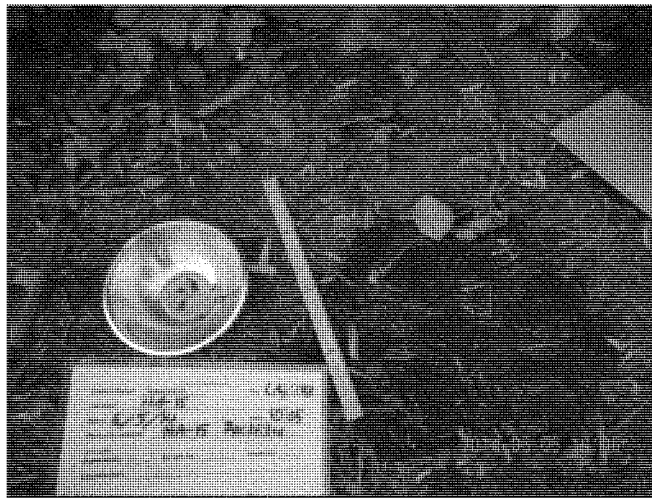
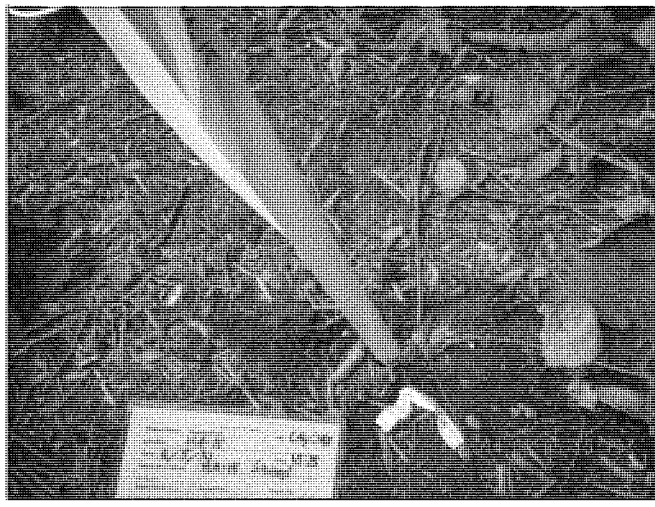
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-15 Photographs**	Figure H-36





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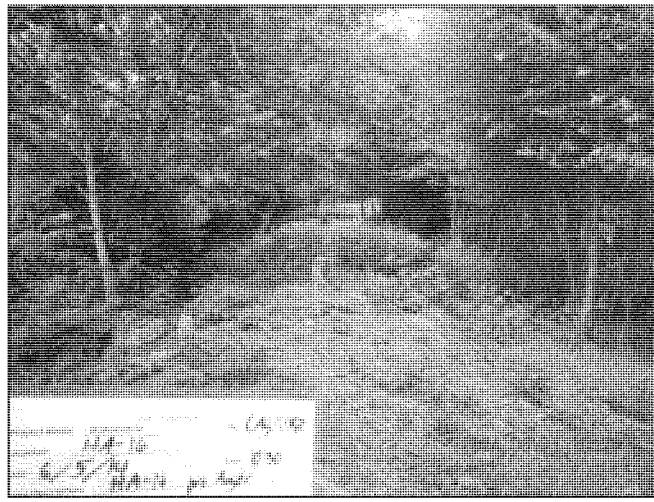
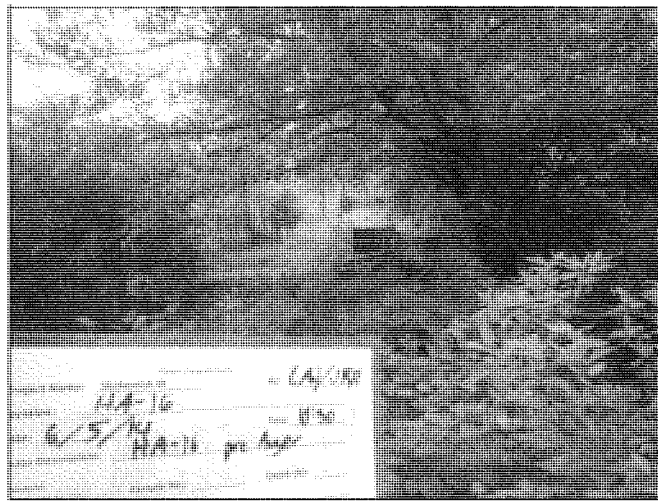
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-15 Photographs**	Figure H-36





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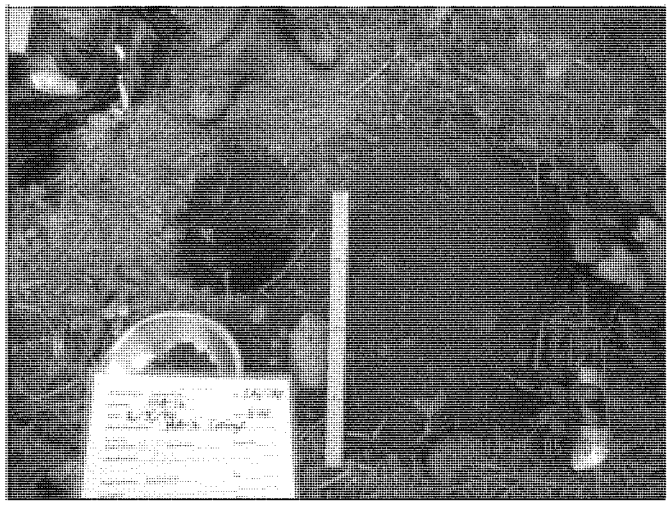
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-16 Photographs**	Figure H-37



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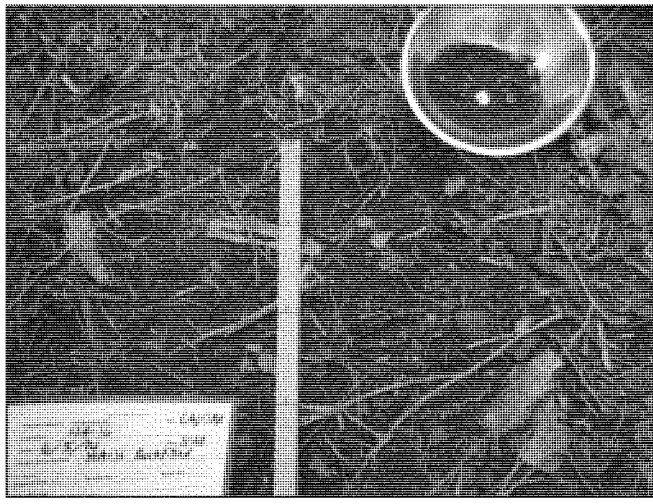
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-16 Photographs**	Figure H-37



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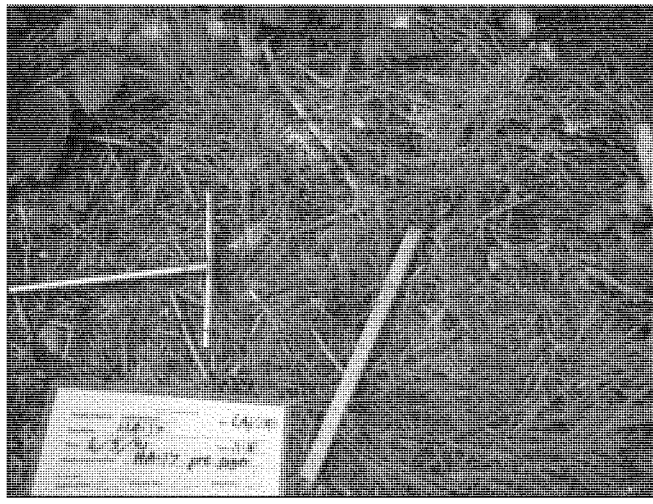
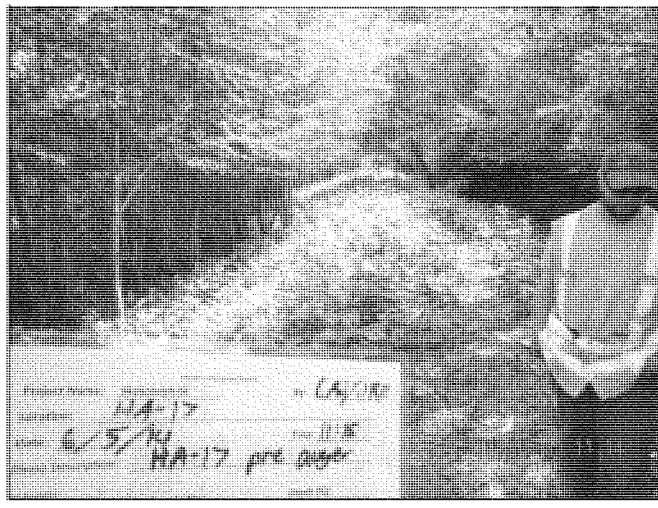
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-16 Photographs**	Figure H-37





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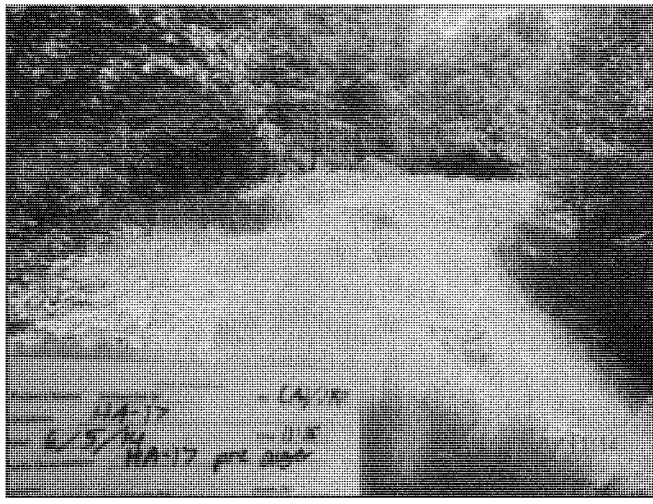
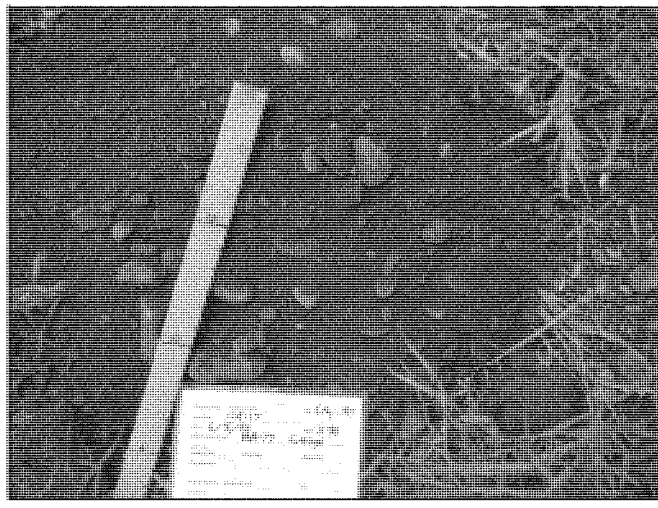
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-17 Photographs**	Figure H-38





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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-17 Photographs**	Figure H-38

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-17 Photographs**	Figure H-38

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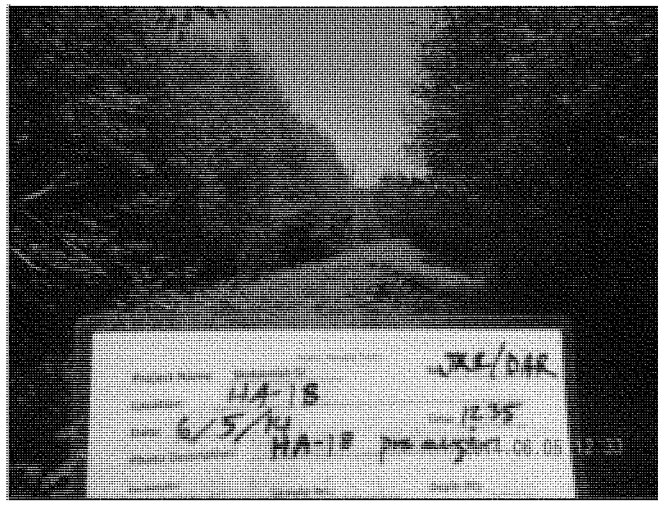
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-17 Photographs**	Figure H-38



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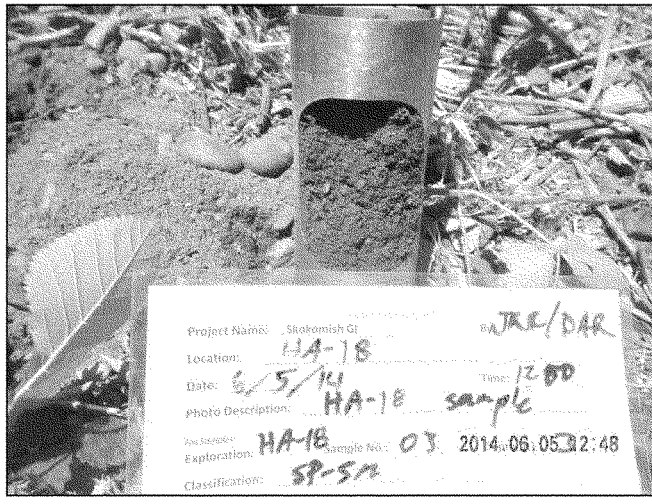
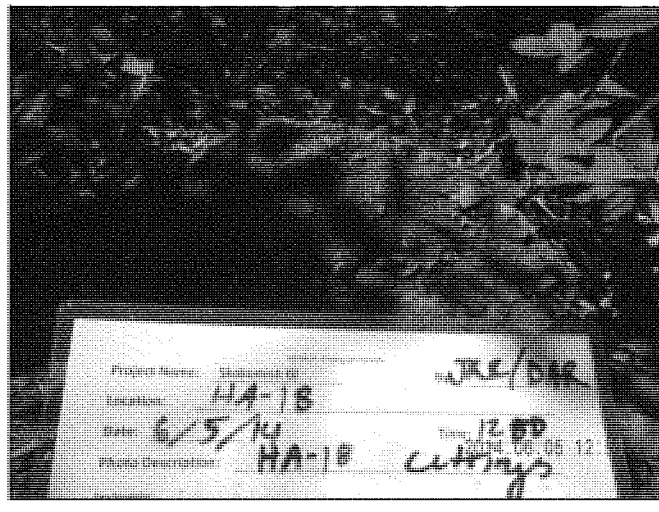
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-18 Photographs**	Figure H-39





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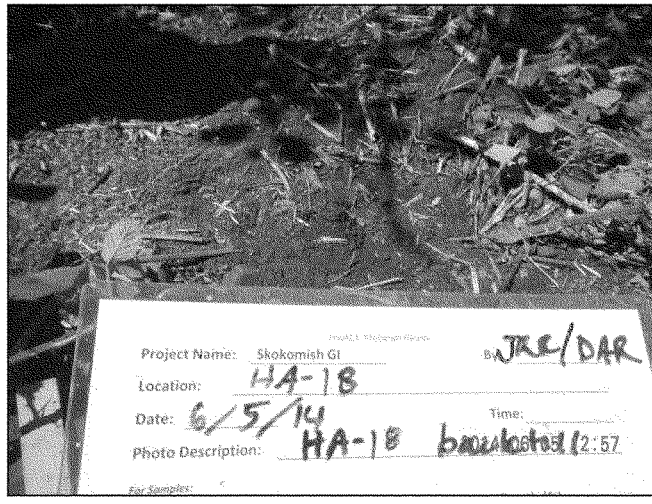
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-18 Photographs**	Figure H-39



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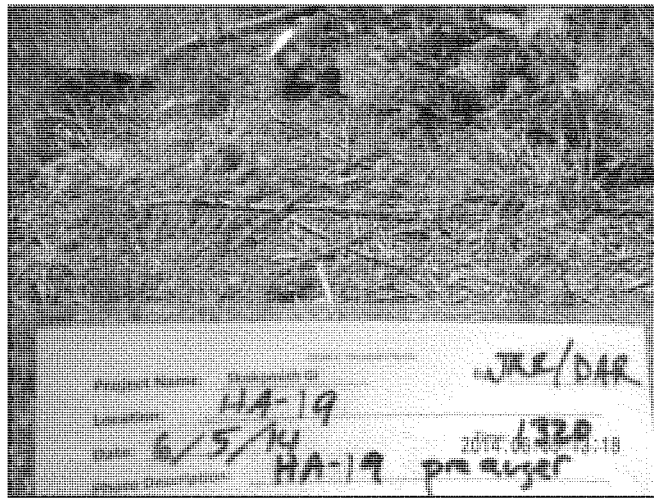
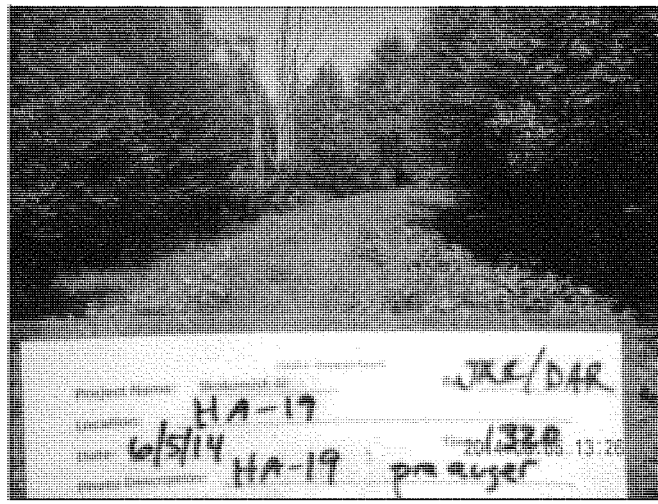
LANDAU ASSOCIATES	Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-18 Photographs**	Figure H-39





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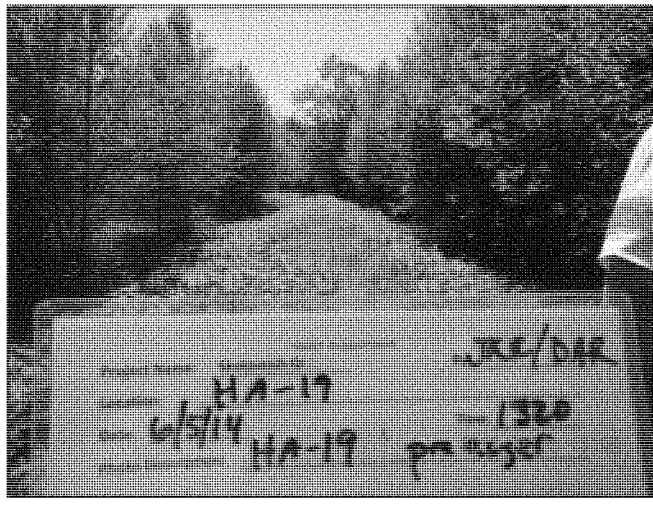
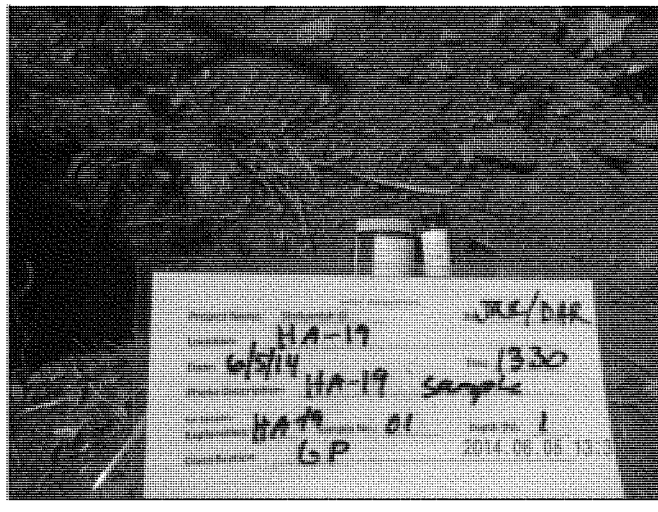
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-19 Photographs**	Figure H-40





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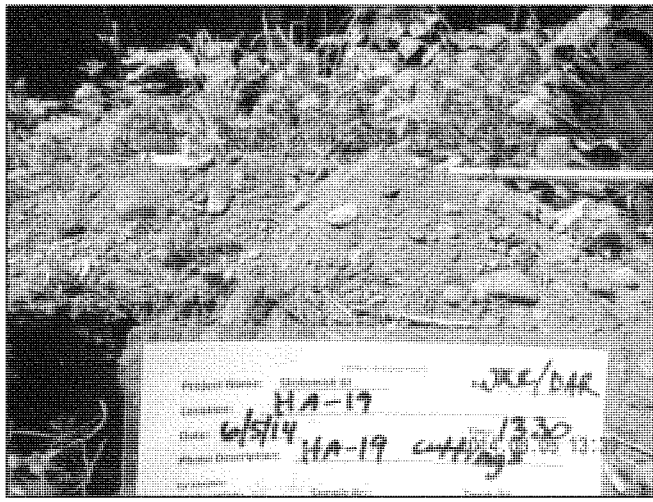
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-19 Photographs**	Figure H-40



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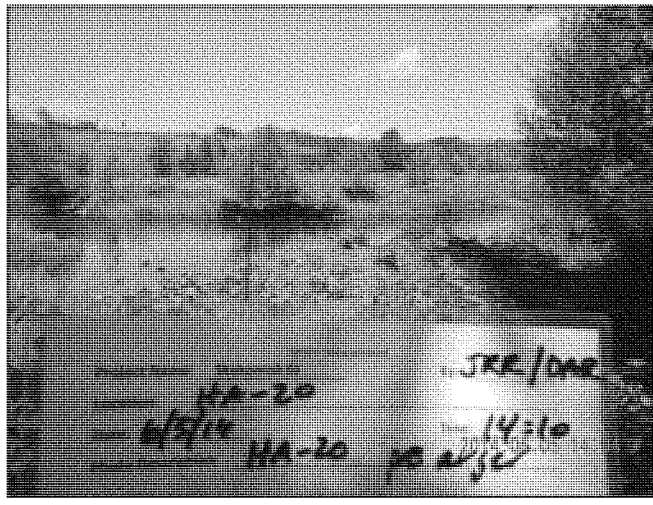
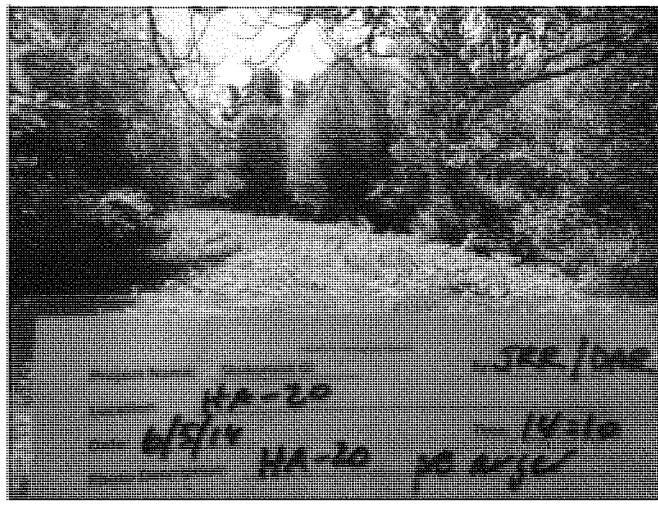
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-19 Photographs**	Figure H-40





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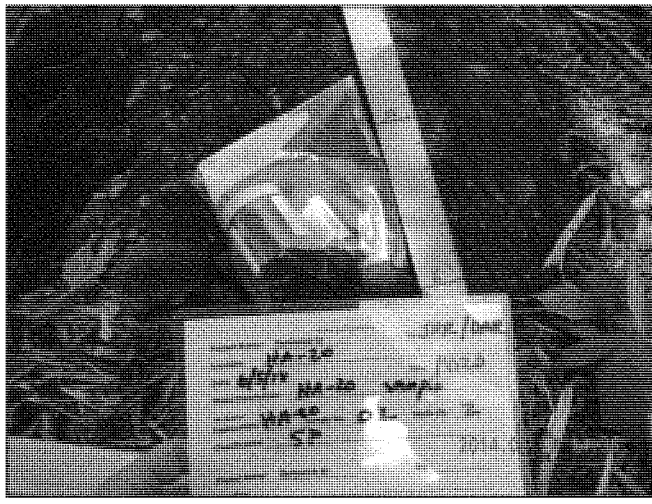
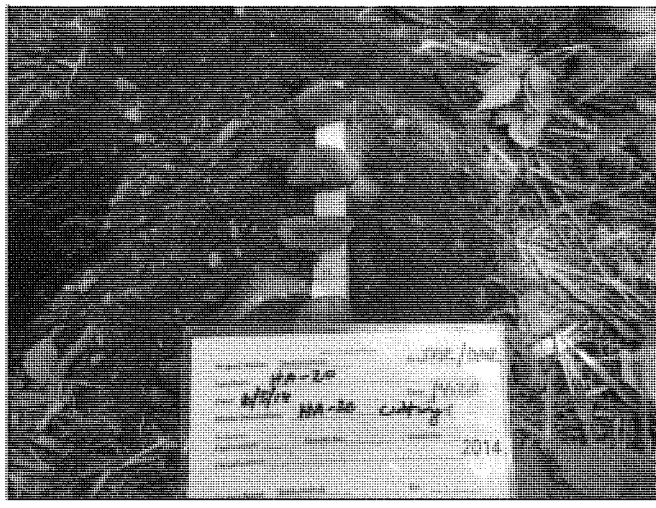
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-20 Photographs**	Figure H-41





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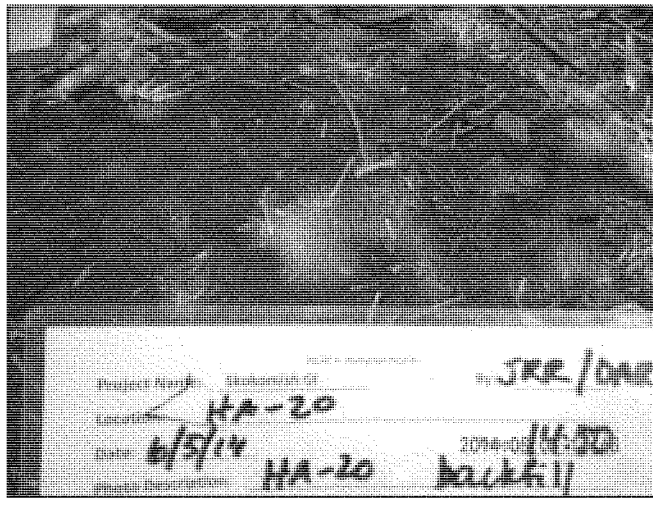
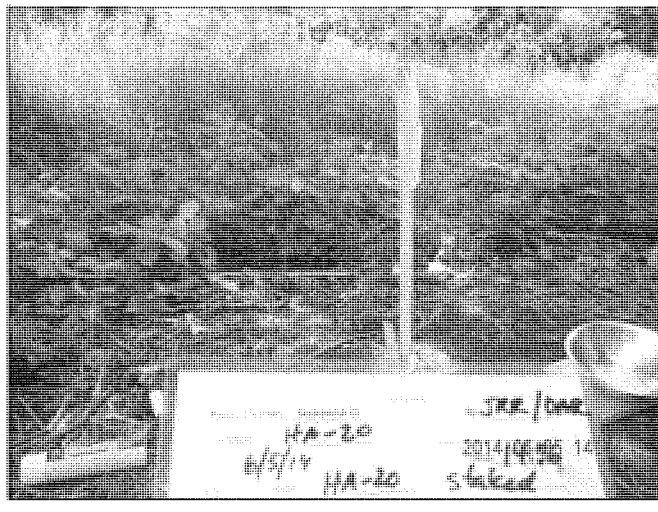
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-20 Photographs**	Figure H-41





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-20 Photographs**	Figure H-41

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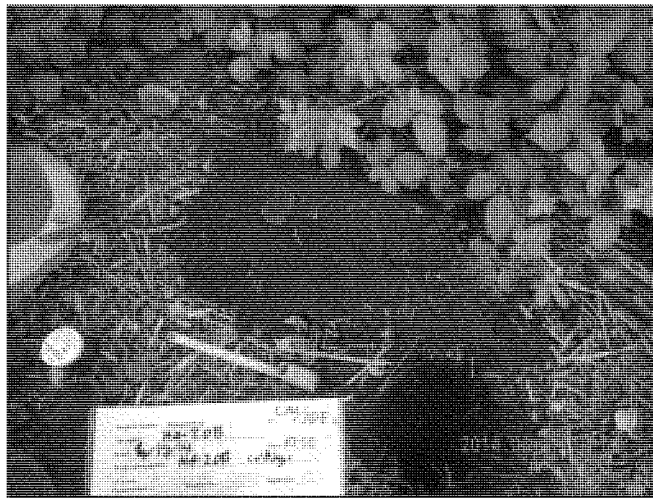
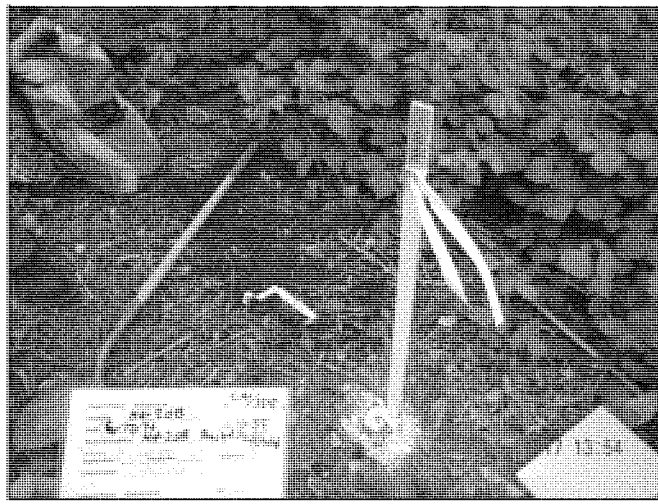
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-20B Photographs**	Figure H-42





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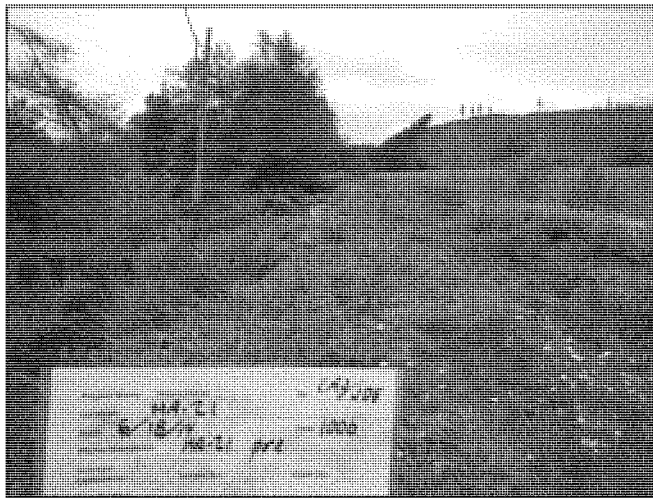
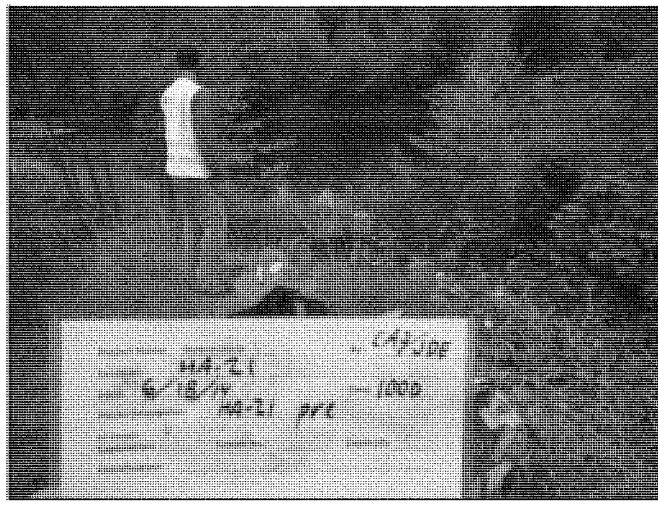
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-20B Photographs**	Figure H-42





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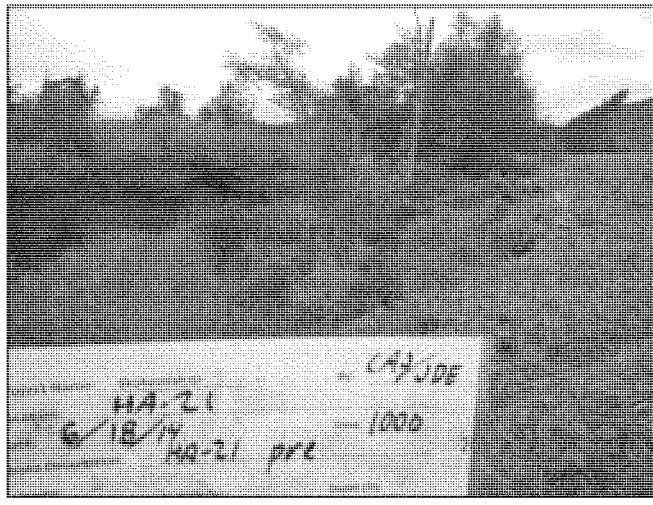
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-21 Photographs**	Figure H-43



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-21 Photographs**	Figure H-43

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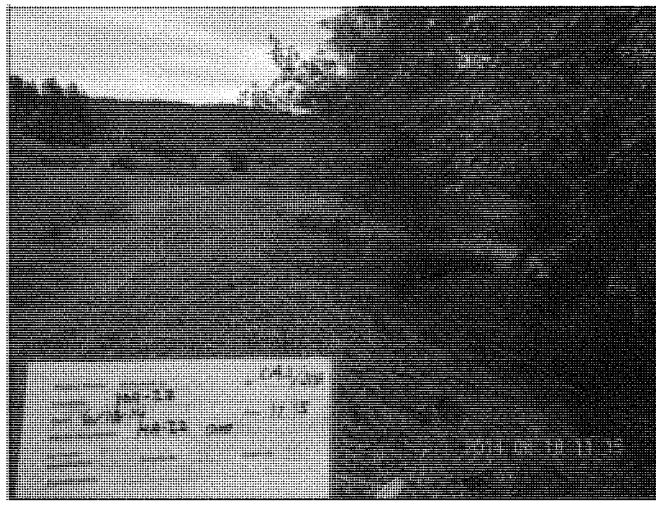
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-21 Photographs**	Figure H-43



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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-22 Photographs**	Figure H-44

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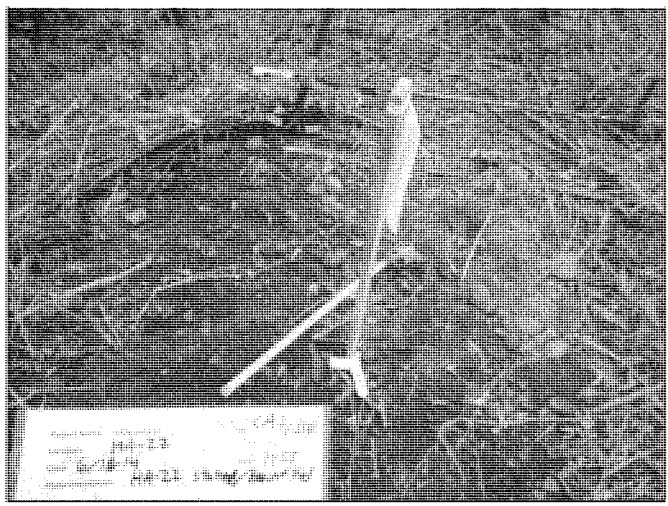
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-22 Photographs**	Figure H-44



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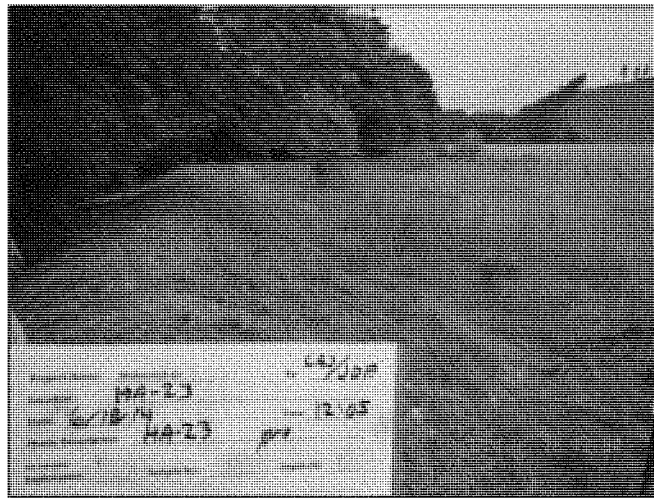
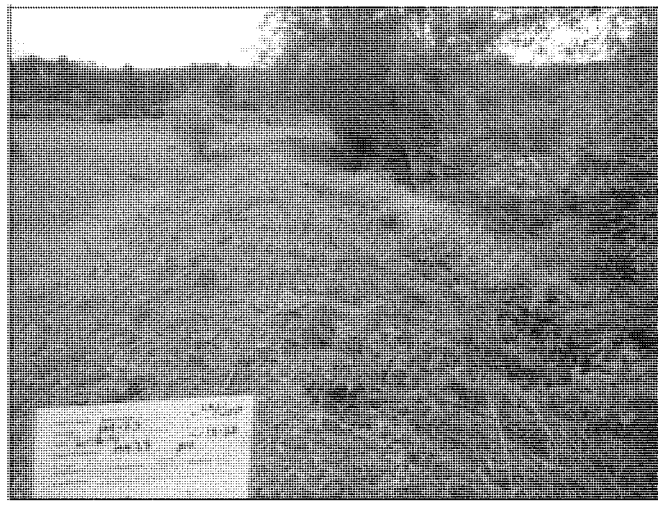
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-22 Photographs**	Figure H-44





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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-23 Photographs**	Figure H-45

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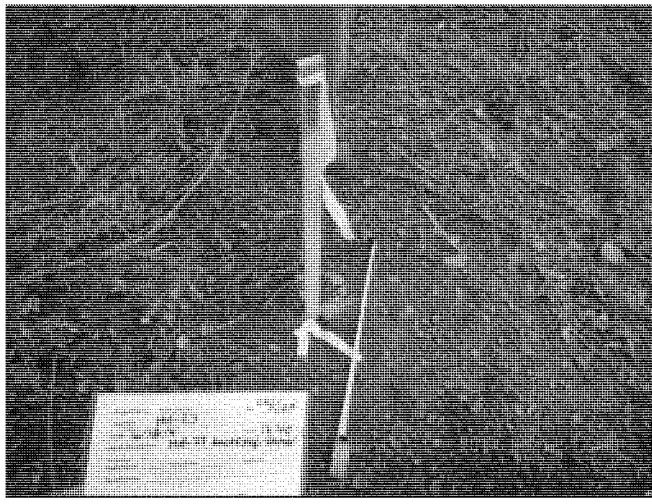
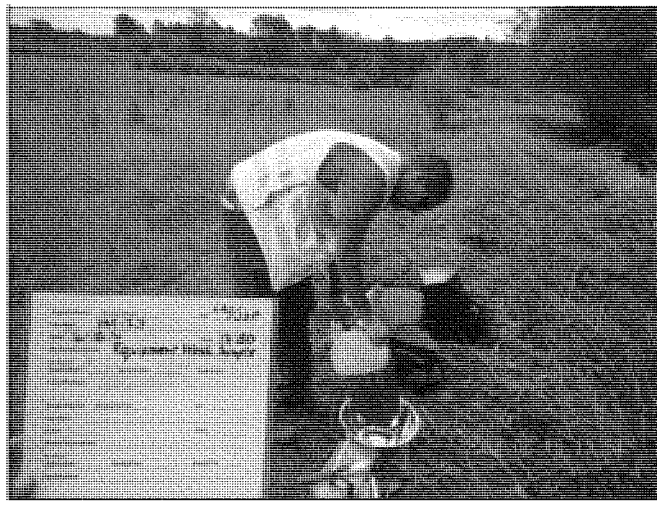
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-23 Photographs**	Figure H-45





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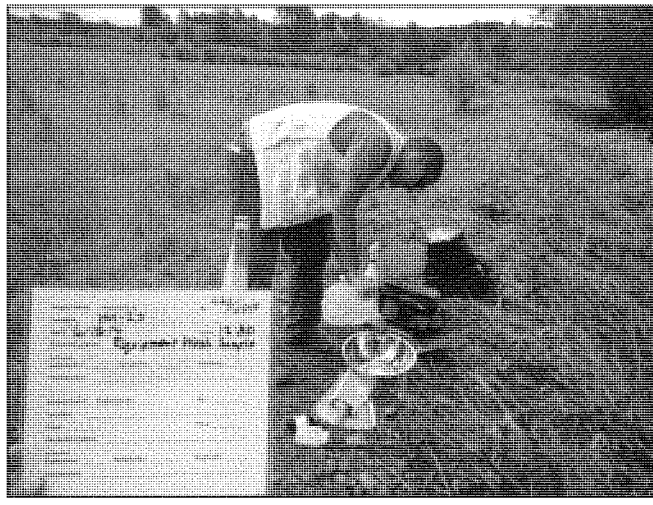
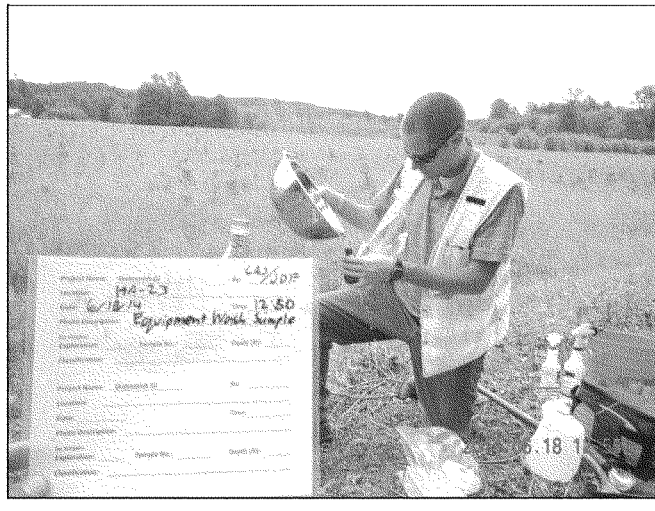
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-23 Photographs**	Figure H-45





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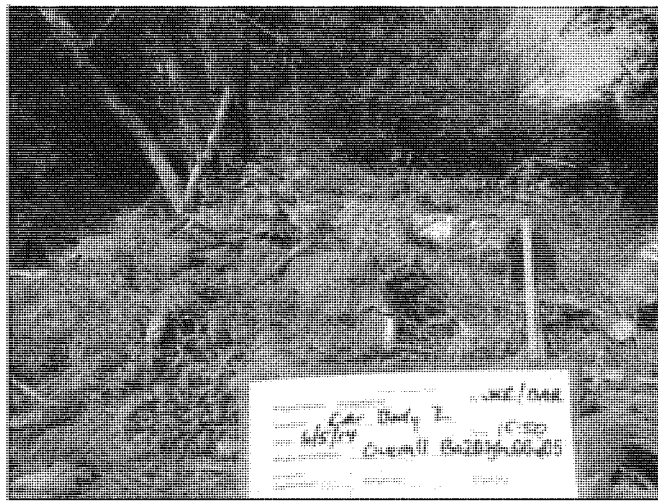
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-23 Photographs**	Figure H-45



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-24 Car Body #2 Photographs**	Figure H-46

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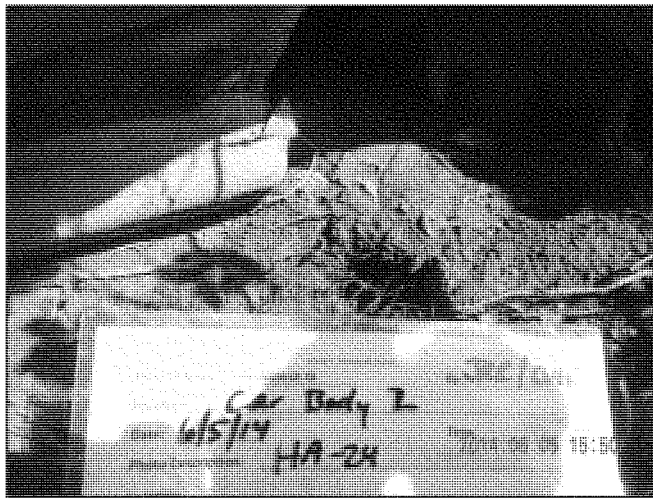
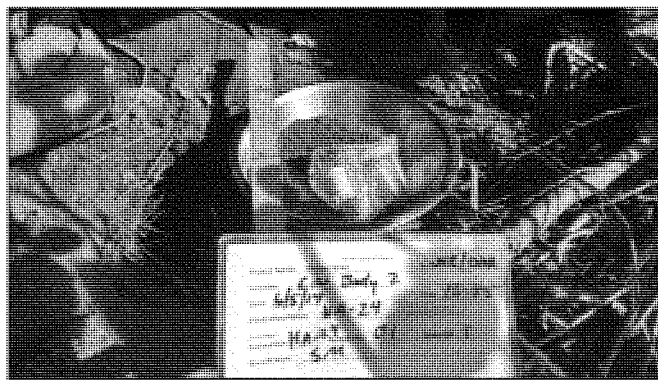
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-24 Car Body #2 Photographs**	Figure H-46





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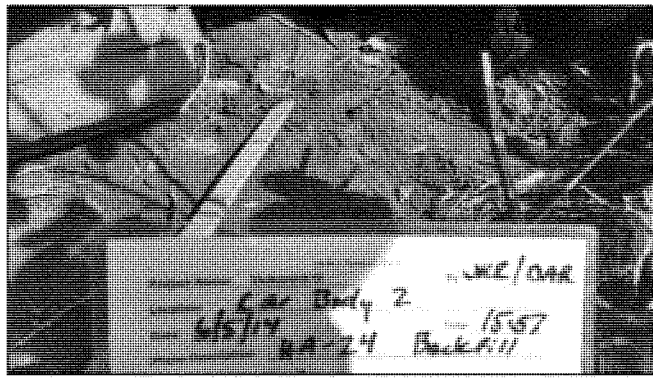
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-24 Car Body #2 Photographs**	Figure H-46



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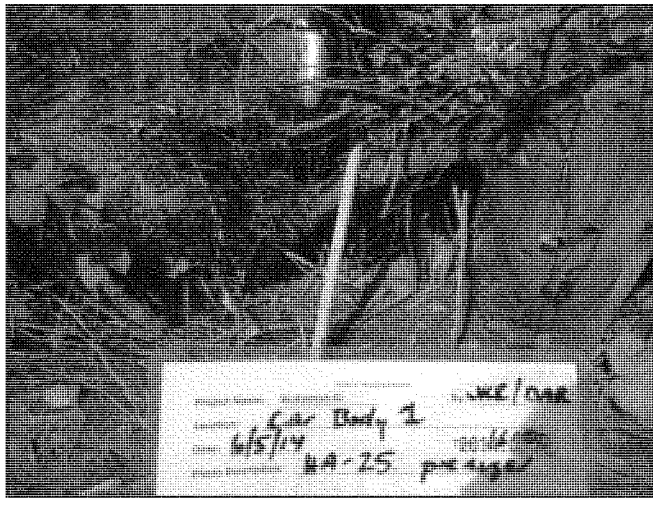
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-24 Car Body #2 Photographs**	Figure H-46



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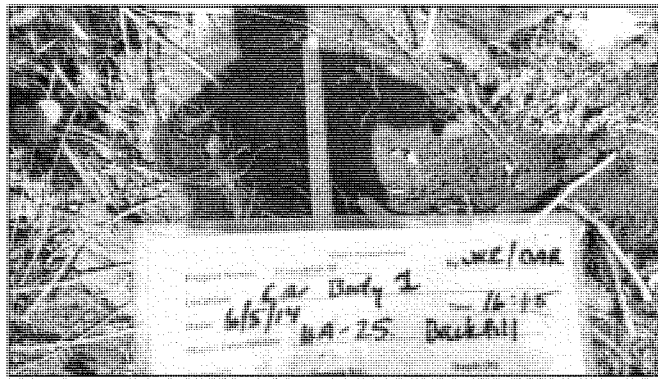
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-25 Car Body #1 Photographs**	Figure H-47



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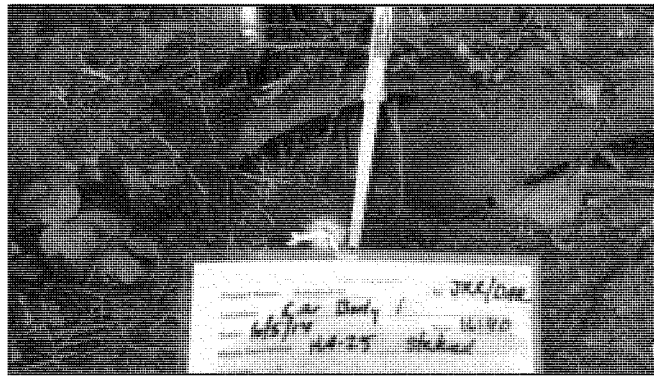
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-25 Car Body #1 Photographs**	Figure H-47



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-25 Car Body #1 Photographs**	Figure H-47

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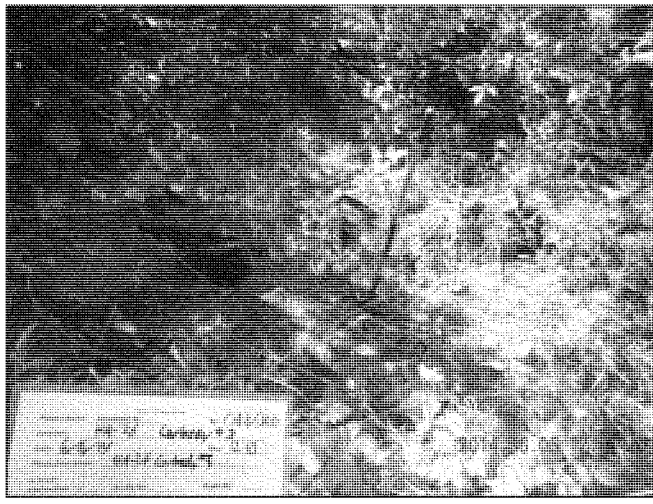
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-26 Photographs**	Figure H-48



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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-26 Photographs**	Figure H-48

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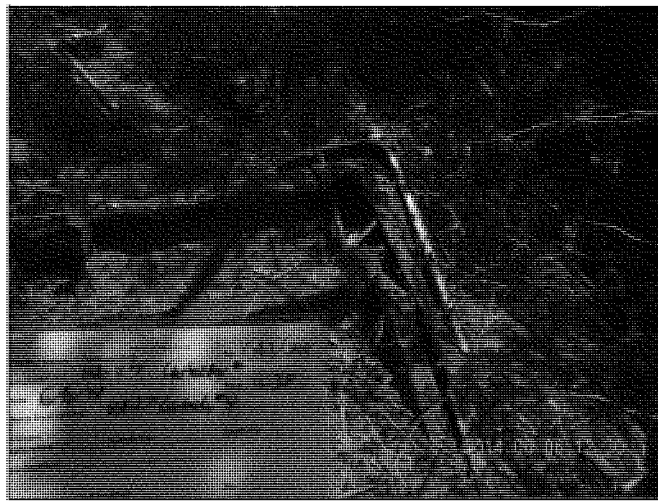
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-26 Photographs**	Figure H-48



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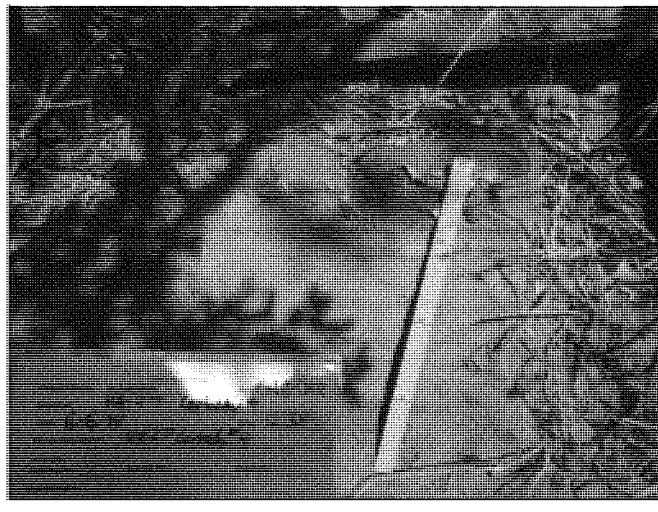
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-27 Car Body #3 Photographs**	Figure H-49



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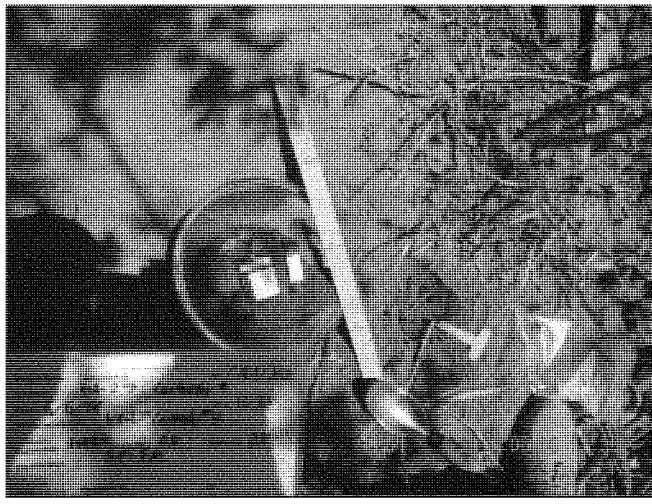
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-27 Car Body #3 Photographs**	Figure H-49



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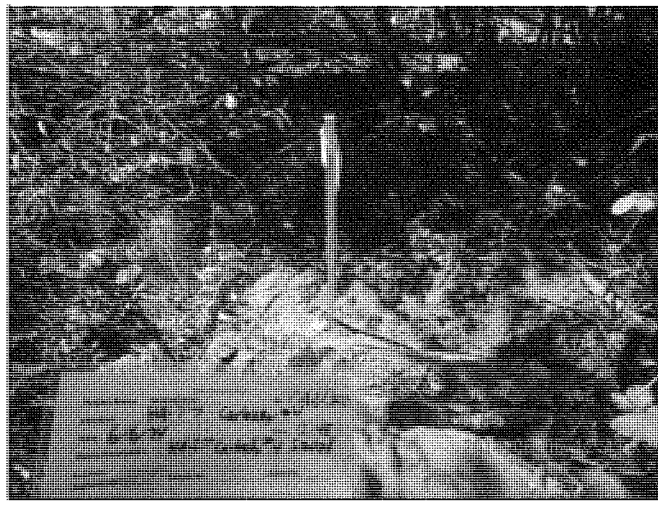
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-27 Car Body #3 Photographs**	Figure H-49



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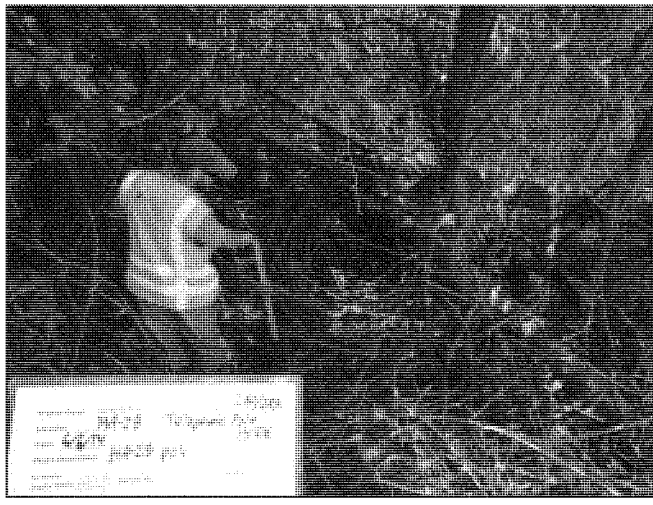
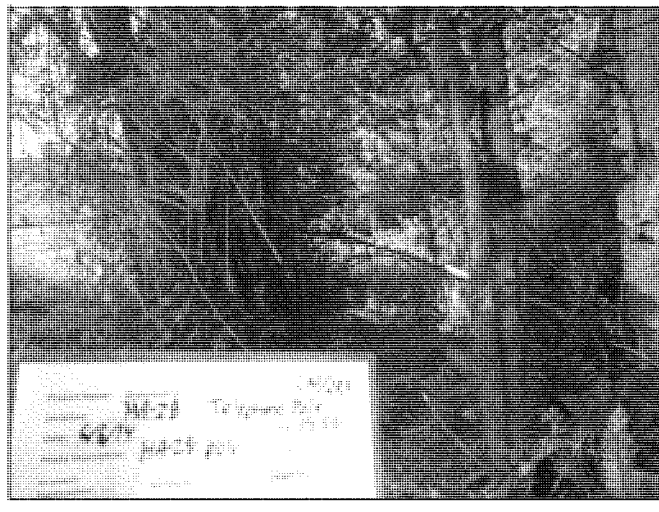
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-27 Car Body #3 Photographs**	Figure H-49





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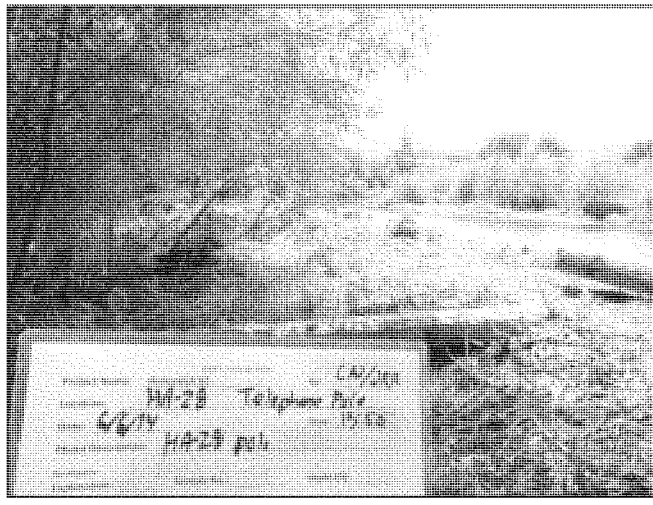
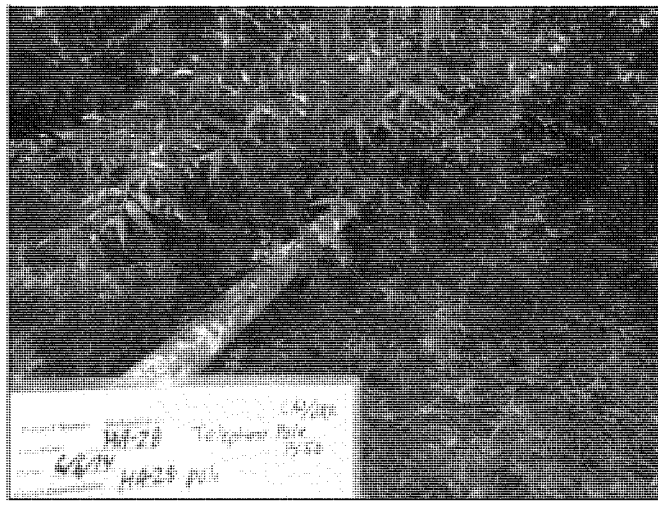
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-28 Telephone Pole Photographs**	Figure H-50





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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-28 Telephone Pole Photographs**	Figure H-50

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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-28 Telephone Pole Photographs**	Figure H-50

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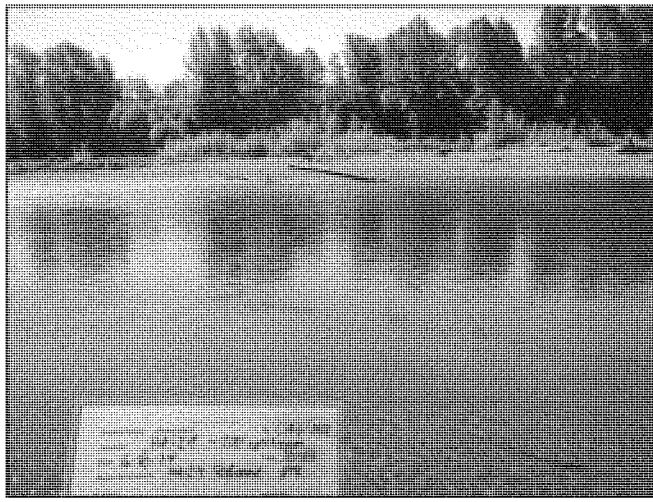
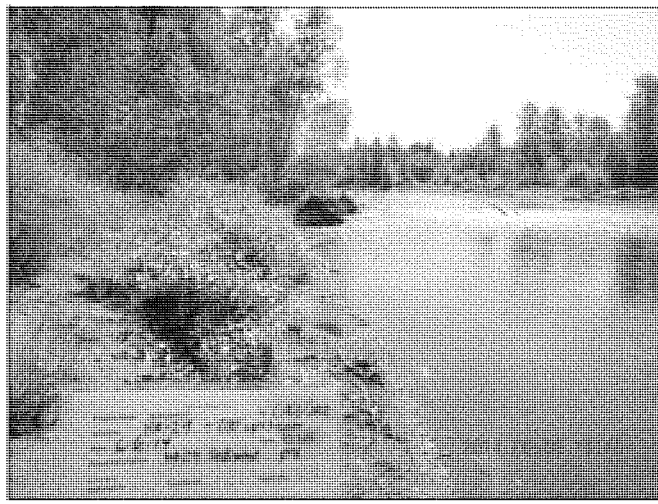
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-28 Telephone Pole Photographs**	Figure H-50





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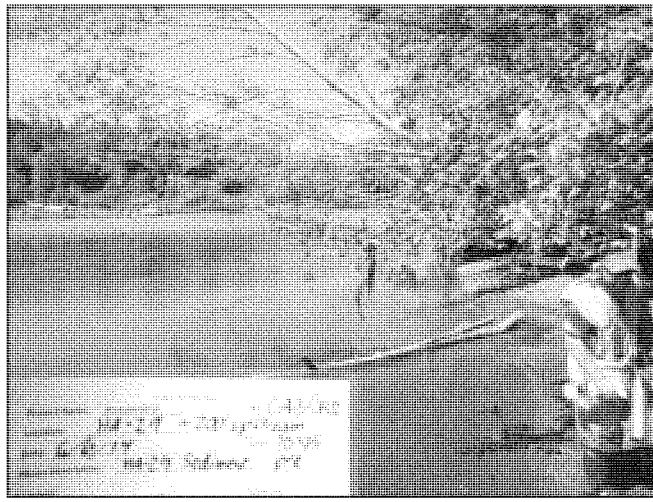
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-29 Upstream Sediment Photographs**	Figure H-51



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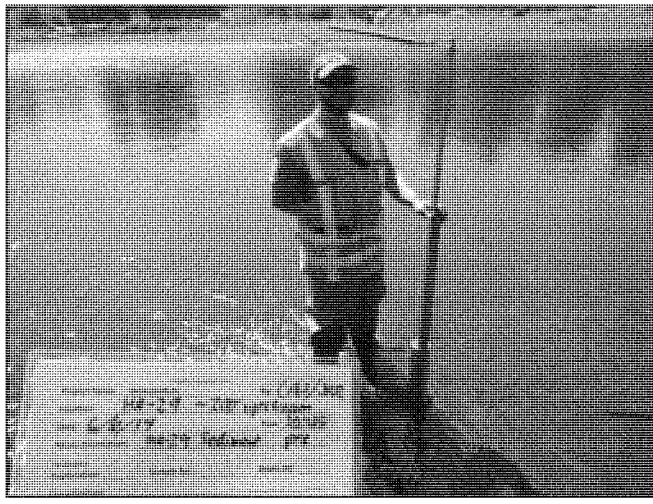
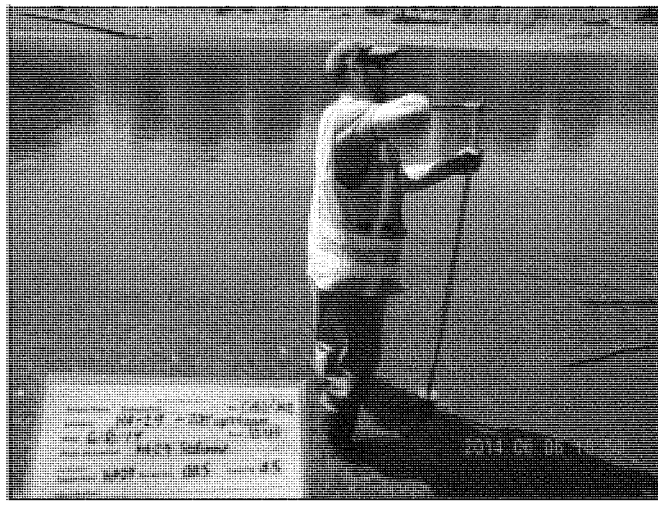
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-29 Upstream Sediment Photographs**	Figure H-51





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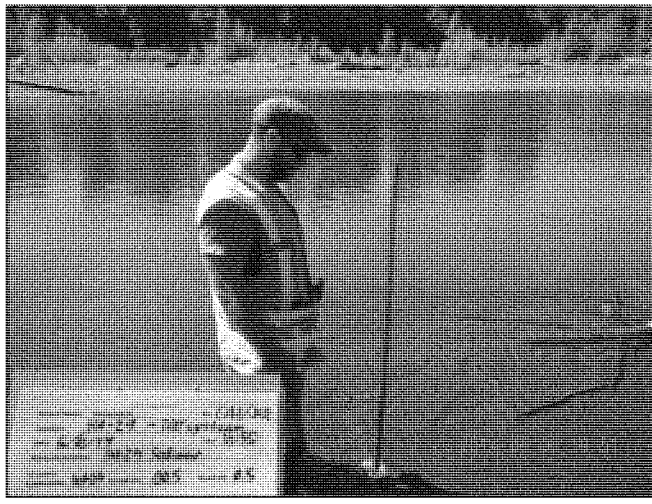
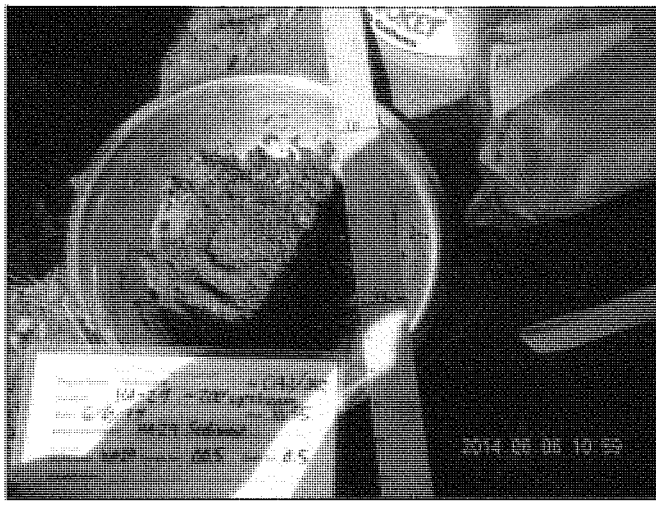
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-29 Upstream Sediment Photographs**	Figure H-51





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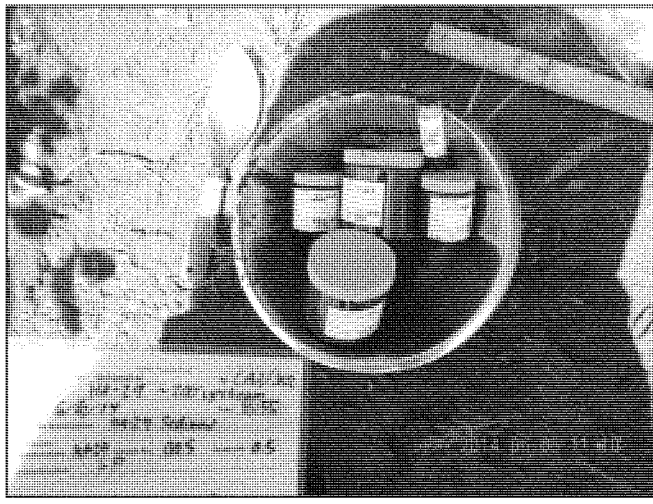
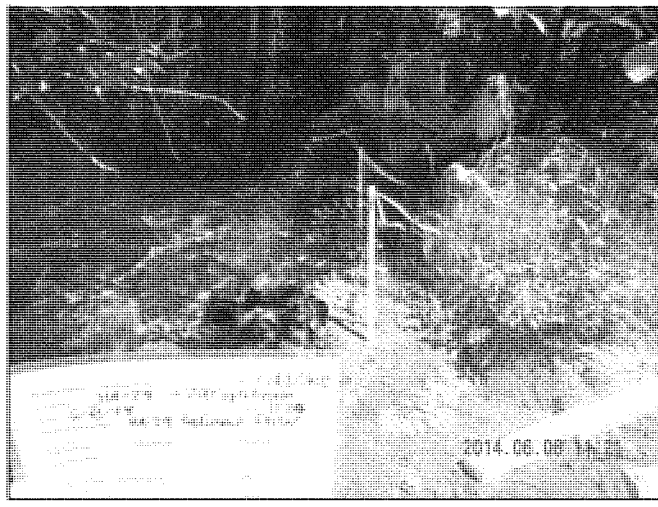
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-29 Upstream Sediment Photographs**	Figure H-51





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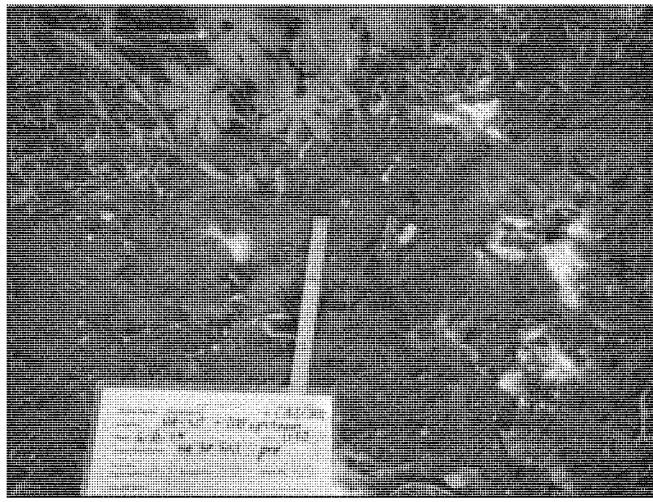
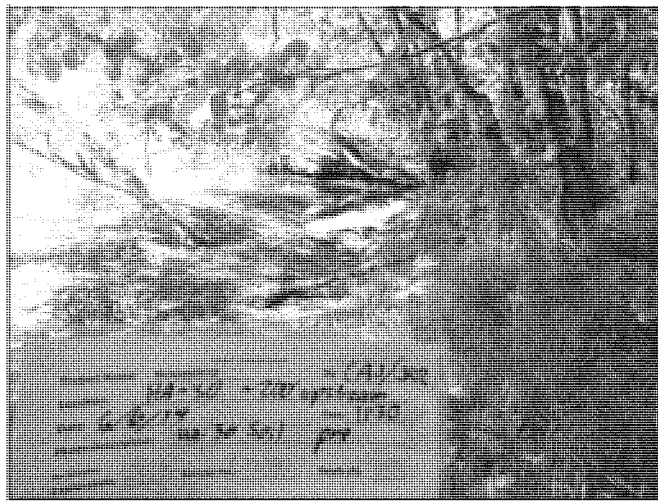
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-29 Upstream Sediment Photographs**	Figure H-51





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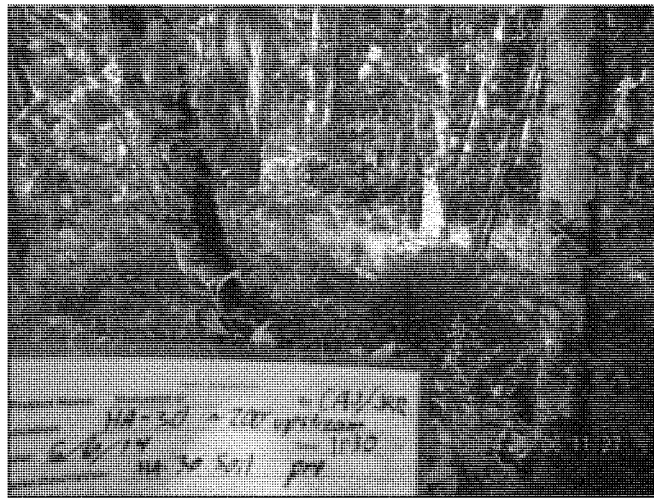
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-30 Upstream Soil Photographs**	Figure H-52



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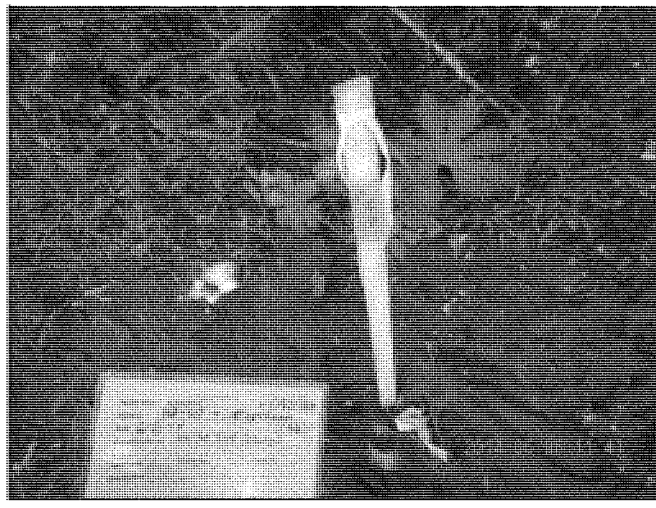
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-30 Upstream Soil Photographs**	Figure H-52



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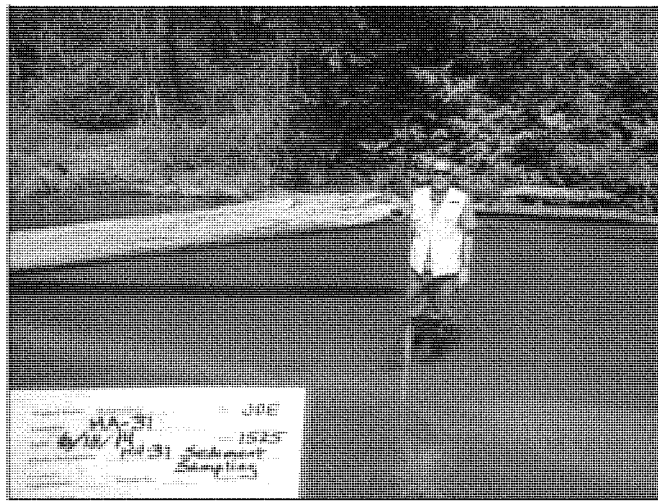
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-30 Upstream Soil Photographs**	Figure H-52



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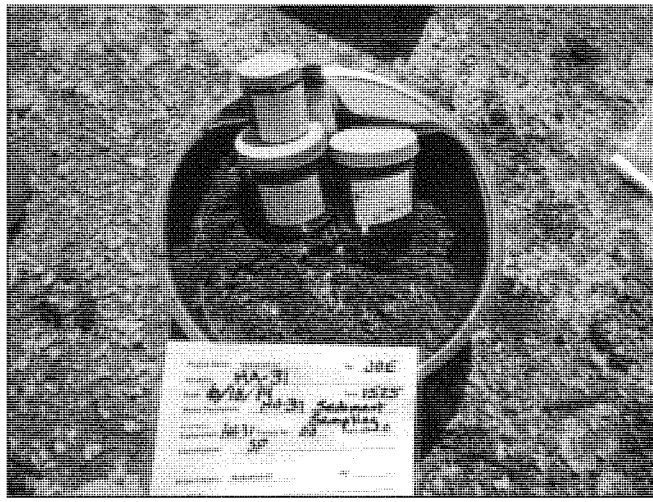
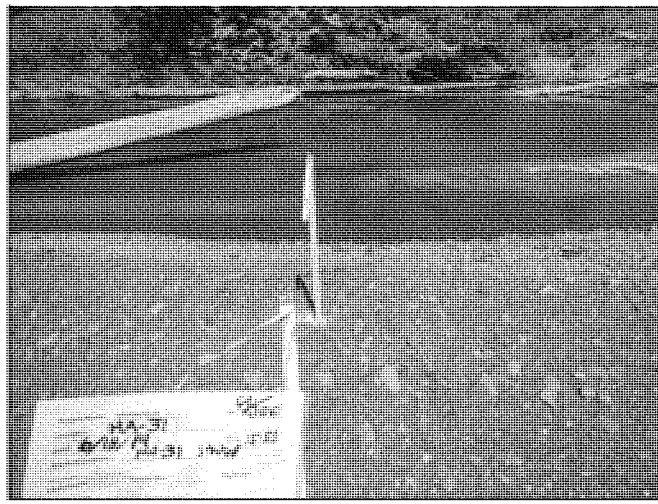
LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-31 Downstream Sediment Photographs**	Figure H-53





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LANDAU ASSOCIATES

Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-31 Downstream Sediment Photographs**	Figure H-53

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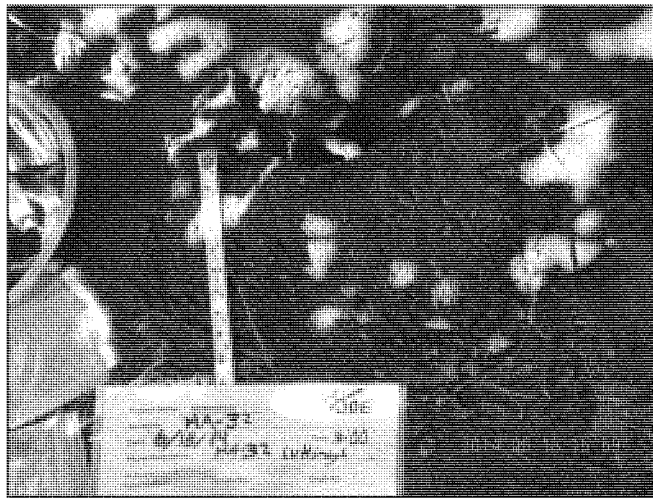
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-32 Downstream Soil Photographs**	Figure H-54



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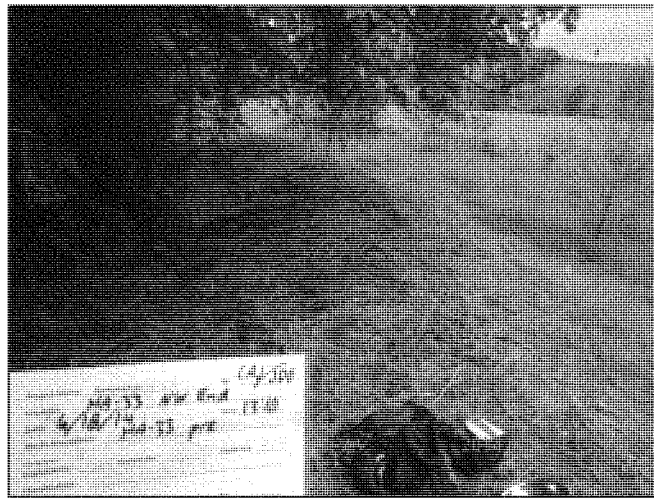
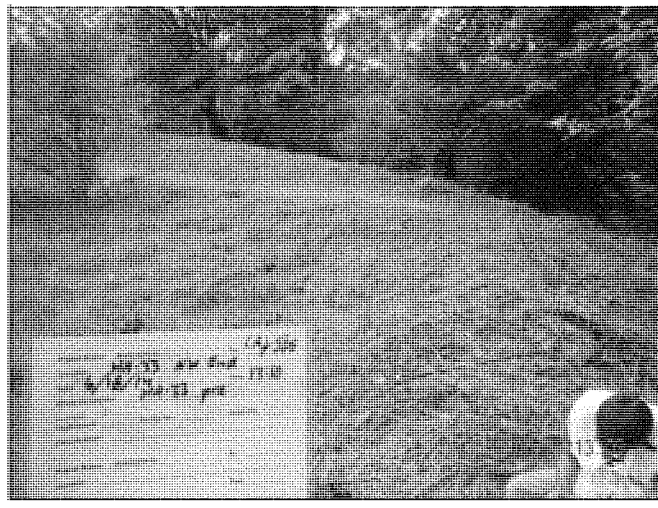
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-32 Downstream Soil Photographs**	Figure H-54





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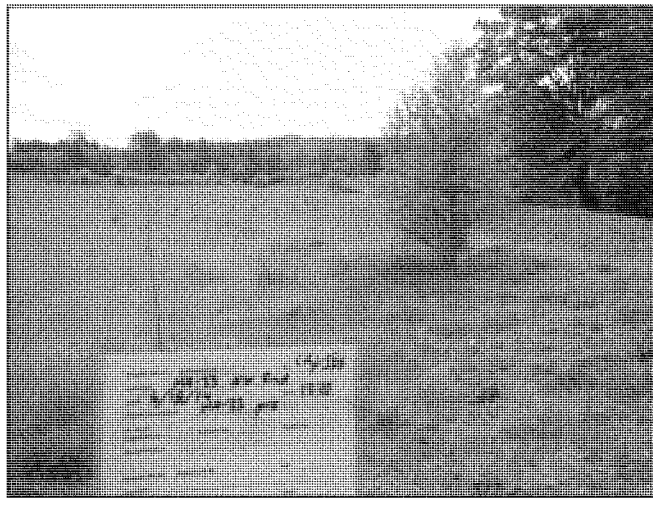
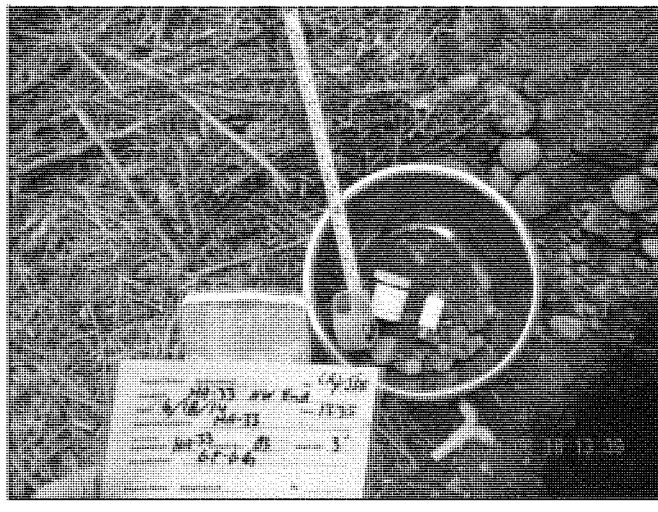
Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-33 Photographs**	Figure H-55





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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-33 Photographs**	Figure H-55

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Skokomish Geotechnical and HTRW Investigation Mason County, Washington	**HA-33 Photographs**	Figure H-55

Daily Field Reports

LANDAU ASSOCIATES

Daily Field Report

Project No.: 621004.010 Report No.: 01

Client: Mason County / USACE Date: 6/2/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Clear 70s

Prepared By: Craig Jordan SOW: HTRW Investigation - Car Body Levee

11:00 James Raspen (JRR) and Craig Jordan (CAJ) onsite
11:00 - 11:45 Onsite preparations; prep sample kits; clean tools; calibrate PID; and organize equipment
11:45 - 12:15 Lunch (Sarah onsite 12:10 - 12:15)
12:15 - 14:00 carry supplies across the river, determine location of HA-01
14:05 - 14:20 Hand-auger HA-01 and collect soil sample at 1 foot BGS (Below Ground Surface)
- decon equipment and determin location of HA-02
15:16 - 15:30 Hand-auger HA-02 and collect soil sample @ 2 feet BGS
- decon equipment / hike out,
16:15 JRR / CAJ off site

HA-01 is located near the east end of the levee and subsequently numbered to the west

Visitors: Sarah Bryan (Mason County)

Unexpected Conditions:

Resolution of Site Problems:

Attachments: Log of Exploration (2)

Signed:

LANDAU ASSOCIATES

Field Report

Project No.: 621004.010 Report No.: 02

Client: Mason County/ USACE Date: 6/3/2014

Project Name: Skokomish GI DPD Permit No.: —

Location: Skokomish River Valley, WA

Weather Conditions: Cloudy, Overcast 60°F

Prepared By: JRK (Cross Jordan) SOW: HTRW Investigations - Lar Body Levee Crest

8:20 - JRK/CAJ onsite; prep sample kits & equipment
- check span gas 451
- carry supplies across river

10:10 - Begin hand augering @ HA-3; collect sample @ 3' BGS
- Collect 4 samples w/ decon in between each

12:30 - Break for lunch

13:00 - Begin hand augering @ HA-7
- Collect 2 samples w/ decon in between each

~~13~~ 15:30 - Break for day

15:45 - JRK/CAJ offsite

Visitors: —

Unsatisfactory Conditions & Recommended Correction: —

Attachments: Log of Exploration (6)

Signed: [signature]

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Field Report

Project No.: 621004.010 Report No.: 03 6/4/14

Client: Mason County/ USACE Date: ~~6/5/14~~

Project Name: Skokomish GI DPD Permit No.: –

Location: Skokomish River Valley, WA

Weather Conditions: Sunny 60s

Prepared By: JRR/CAJ SOW: HTRW Investigation

8:20 - JRR/CAJ meet Jason O. & Dave from USACE
- Sarah from Mason county onsite for initial meet & greet
- Prep for sampling, sample kits, organize equipment
- Calibrate PID → VOCs ✓ 100 ppm

9:20 - Begin hand auging @ HA-09
- Noticed telephone pole cut down near HA-11
→ no transformers visible, no hydrocarbon staining present

12:00 - Upon starting HA-11, DAR onsite

12:45 - CAJ offsite

13:10 - Lunch Break

13:40 - Begin locating HA-12

14:30 - Cross over to west side levee (upstream from breach)

17:30 - Hike back to vehicles
- Completed 6 hand auger borings

18:00 - JRR / DAR offsite
- No car bodies found along levee during site activities

JRR = James Rasmen
CAJ = Craig Jordan
DAR = Dave Rupert

Visitors: Jason O. and Dave (USACE), Sarah (Mason County)

Unsatisfactory Conditions & Recommended Correction:

Attachments:

Signed:

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LANDAU ASSOCIATES

Field Report

Project No.: 621004.010 Report No.: 04
Client: Mason County/ USACE Date: ~~6/6/14~~ 6/5/14
Project Name: Skokomish GI DPD Permit No.:
Location: Skokomish River Valley, WA
Weather Conditions: Sunny 60-70s
Prepared By: JMR SOW: HTRW Investigation

8:00 - JMR/CAJ onsite; prep for sampling, sample kits
- Hike to west side levee
9:45 - Begin hand augering @ HA-15
11:30 - DAR onsite
12:30 - CAJ offsite
- Between HA-16 & HA-17 two car bodies were located & marked for future investigating
- Near bend in levee to the north along the west side of levee, two car bodies were located (appear to be stacked on top of each other) → marked for future investigating
14:55 - Finish levee crest augering for day as crossing to north side section of levee appears to be very deep and requires different access.
- Began investigating car bodies
- Car body 1 is the furthest to the west & car bodies will be numbered moving east
- Car body 2 is stacked on top of car body 1 or was originally, may now appear directly adjacent to car body 1.
17:15 - Hike back to vehicles
17:30 - JMR/DAR offsite
- 6 levee crest / 2 car body hand auger borings completed

Visitors:
Unsatisfactory Conditions & Recommended Correction:
Attachments:
Signed:

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Daily Field Report

Project No.: 621004.010 Report No.: 05

Client: Mason County / USACE Date: 6/6/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Clear 60s to 70s

Prepared By: Craig Jordan / James Raspen SOW: HTRW Investigation - Car Body Levee

8:30 Landau (Craig Jordan and James Raspen) On site
- prep sample kits
- hike to sample location

10:30-11:20 Obtain sediment sample from approximately 200 feet upriver (HA-29)
the sample was taken where finer soil is present in river

11:30-11:35 hand auger HA-30 on the bank above HA-29

11:45 hike to car body #3 and 4
- collect soil samples and photograph
- see HA 26 and 27 logs

13:10 Hike to power pole location
- sample below & where the top of the pole has landed
- see HA-28 log for details

14:15 Hike out

15:00 Landau off site

Visitors: -

Unexpected Conditions: -

Resolution of Site Problems: -

Attachments: Log of Explorations (5)

Signed: [signature]

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Daily Field Report

Project No.: 621004.010 Report No.: 6

Client: Mason County / USACE Date: 6/9/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Overcast/Clear 50s to Low 70s

Prepared By: Craig Jordan SOW: Roadway Borings

7:45	Craig Jordan onsite flaggers (Ken and Sandy) already on site
8:05	Holocene (Jarrod and Raymond) onsite [Drillers]
8:31-9:20	Drill BH-04 to a depth of 31.5 feet
9:20-10:15	Backfill BH-04/mobe to BH-05R
10:16-11:34	Drill BH-05R to depth of 31.5 feet
11:34-12:15	Backfill BH-05R
12:15-12:45	Lunch
12:45-13:00	Flaggers mobed to second location
13:12-14:26	Drill BH-08
14:26-15:15	Backfill BH-08 and clean site
15:15	Drillers off site
15:15-15:45	Stake boring offsets and wait for concrete to cure
15:45	Flaggers off site
16:00	Landau (Craig) off site

Visitors: —

Unexpected Conditions: Low sample recovery in BH-08

Resolution of Site Problems: Overdrove sample with California sampler (See log)

Attachments: Log of Exploration (6), Daily Drilling Log - Holocene (1)

Signed: [signature]

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Daily Field Report

Project No.: 621004.010 Report No.: 7

Client: Mason County / USACE Date: 6/11/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Clear 60s to 70s

Prepared By: Craig Jordan SOW: Track Rig Borings

6:50 LAI (Landau - Craig Jordan) on site, drillers (Holocene - Dave + Nunzio) already on site

7:30-8:30 Drill BH-02 to 31.5 feet

8:45-8:50 Drill BH-02B to 2.5 feet (no sample recovery)

8:50-9:10 Drill BH-02C to 2.5 feet (pull Shelby tube)

9:40-11:50 Drill and Backfill BH-15 to a depth of 41.5 (Michael suggested sample @ 40 feet rather than planned 42 feet)

10:25 Michael Gonia on site (USACE)

11:55-12:15 demobe

12:15-12:45 Lunch

12:45-13:00 Mobe to BH-01

13:00-14:45 Drill BH-01 to a depth of 31.5 feet and backfill

15:00-15:30 Scope additional boring locations

15:30 Holocene offsite, Michael offsite

15:45 LAI offsite

Visitors: Michael Gonia (USACE)

Unexpected Conditions: difficult sampling in gravel

Resolution of Site Problems: attempt to sample w/ california sampler with limited success

Attachments: Log of Exploration (9) Daily Drilling Log (1)

Signed:

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Daily Field Report

Project No.: 621004.010 Report No.: 8

Client: Mason County / USACE Date: 6/12/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Clear 60-70s overcast

Prepared By: Craig Jordan SOW: Track Rig Drilling

6:50	LAI (Craig Jordan - Landau) onsite drillers (Dave/Nunzio - Holocene) already on site
7:45 - 9:15	Drill and backfill BH-03R
10:05 - 11:30	Drill and backfill BH-09R
11:45 - 12:15	Lunch
12:30 - 14:05	Drill and backfill BH-07R
14:30 - 16:00	Drill and Backfill BH-10
16:45	Drillers off site
17:00	LAI off site

Visitors: —

Unexpected Conditions: —

Resolution of Site Problems: —

Attachments: Log of Exploration (8) Daily Drilling Log (1)

Signed: [signature]

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Daily Field Report

Project No.: 621004.010 Report No.: 9

Client: Mason County / USACE Date: 6/13/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Overcast/rain high 50s

Prepared By: Craig Jordan SOW: Track Rig Drilling

6:50	LAI (Landau - Craig Jordan) on site
7:05	Drillers (Halorene - Dave and Nunzio) on site
7:45 - 10:25	Drill and Backfill BH-14R
10:45	Drillers off site

Visitors: —

Unexpected Conditions: Difficult sampling @ depth in gravels

Resolution of Site Problems: attempt to clean auger and drive California sampler

Attachments: Log of Exploration (2) Daily Drilling Log (1)

Signed:

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Daily Field Report

Project No.: 621004.010
Report No.: 10
Client: Mason County / USACE
Date: 6/16/14
Project Name: Skokomish GI
Location: Skokomish River Valley, Skokomish, WA
Weather Conditions: Sunny, 60's
Prepared By: Josh Elliott SOW: Test Pits + Hand Augers

0730 JDE + Howard onsite - begin access to TP-02R
0835 Begin TP-02R
0945 Finish TP-02R, begin move to TP-
1030 Begin TP-17R
1200 Begin move to TP-19R
1225 Begin excavating TP-19R
1235-1255 Thunderstorm delay
1340 Finish backfilling TP-19R, begin move to TP-13R
1412 Begin TP-13R
1510 Finish backfilling TP-13R, move to HA-01
1535 Begin HA-01X
1645 Finish HA-01X
1710 JDE offsite

Test pits TP-17R, TP-19R, and TP-13R were all very soft after backfilling due to the relatively high groundwater table. We marked their boundaries with flagging and plan to return tomorrow morning to these locations and employ the following method:
- apply grass seed
- cover with jute net, extending at least 2 ft beyond extents of soft area
- cover jute net with straw

Visitors: Owner, Nick, of TP-17R parcel
Unexpected Conditions: None
Resolution of Site Problems: See above
Attachments: Logs for HA-01, TP-13R, TP-17R, and TP-19R
Signed: [signature] TP-02R

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Daily Field Report

Project No.: 621004.010 Report No.: 11

Client: Mason County / USACE Date: 6/17/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: AM: overcast, 60-s

Prepared By: J. Elliott SOW: HTRW sampling and Test Pits

0730 JDE + Howard onsite, begin final backfilling/ cleanup of TP-13R, TP-17R, and TP-19R

0845 Finish restoration of above test pits, begin move to TP-23R

0935 Begin TP-23R

1055 Finish TP-23R, move to TP-27

1120 Begin TP-27

1205 Finish backfilling TP-27

1220 Finish surface restoration at TP-27

1245 Meet with Craig Jordan to resume HTRW investigation

1345 Begin geotech sampling @ HA-20b

1400 Finish " " @ HA-20b

1410 Begin " " @ HA-14b

1425 Finish " " @ HA-14b

1450 Begin " " @ HA-07b

1502 Finish " " @ HA-07b

1520 Begin " " @ HA-02b

1550 Finish " " @ HA-02b

1616 Check in w/ Michael Goria via cell phone to update on progress

1620 JDE and CAJ offsite

Visitors: none

Unexpected Conditions: none

Resolution of Site Problems: N/A

Attachments: Logs for TP-23R, TP-27, HA-02b, HA-07b, HA-14b, HA-20b

Signed: [signature]

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Daily Field Report

Project No.: 621004.010 Report No.: 12

Client: Mason County / USACE Date: 6/18/14

Project Name: Skokomish GI

Location: Skokomish River Valley, Skokomish, WA

Weather Conditions: Overcast, 60's

Prepared By: J. Elliott SOW: HTRW samplings of Cow Body Levee

0800 JDE + CAJ onsite, prep for HTRW samplings
1003 Begin HA-21 (Break from 1020 to 1040 to retrieve digging bar)
1110 Complete HA-21, move to HA-~~23~~22
1120 Begin HA-22
1200 Finish HA-22, move to HA-23
1207 Begin HA-23
1245 Finish HA-23, begin equipment wash sample
1307 Finish equipment wash
1310 Begin HA-33
1350 Finish HA-33, move to downstream sediment sample
1525 Begin HA-31 (sediment sample location - downstream)
1550 Finish HA-31, move to HA-32
1555 Begin HA-32 (downstream soil sample)
1615 Finish HA-32, return to truck
1630 LAI offsite

Visitors: Skokomish Farm Rep (Ed?)

Unexpected Conditions:

Resolution of Site Problems:

Attachments: Logs for HA-21, HA-22, HA-23, HA-33, HA-31, HA-32

Signed:

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FOR CONTINUATION OF HOUSE DOCUMENT 114-139

SKOKOMISH RIVER BASIN ECOSYSTEM RESTORATION, MASON COUNTY, WASHINGTON

SEE PART 2