A COASTAL EROSION MANAGEMENT STUDY FOR RACINE COUNTY, WISCONSIN

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SEWRPC COMMUNITY ASSISTANCE PLANNING REPORT NO. __

A COASTAL EROSION MANAGEMENT STUDY FOR RACINE COUNTY, WISCONSIN

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Racine County Planning and Zoning Department

and the

Southeastern Wisconsin Regional Planning Commission

September 7, 1982

TC224.W6C6 1982

A COASTAL EROSION MANAGEMENT STUDY FOR
RACINE COUNTY, WISCONSIN

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RACINE COUNTY COASTAL EROSION MANAGEMENT STUDY

Chapter I

INTRODUCTION

BACKGROUND

In response to increasing public concern over the many competing and frequently conflicting land uses within the unique and limited Lake Michigan shoreland area, Racine County recently completed a shoreland development management study.[1] The study, which was funded in part by a grant under the Wisconsin coastal management program and in part by Racine County, was intended to help shape and guide development and redevelopment in the Lake Michigan shoreland area. The study included an analysis of shoreland development problems and resulted in recommendations relating to erosion hazard abatement, recreational access, natural resource preservation, and land use regulation.

The following recommendations relating to the abatement of erosion hazards were made:

1. Racine County should undertake a mapping program to identify those Lake Michigan coastal reaches which may be expected to be subject to severe erosion hazards.

2. Racine County should incorporate erosion area setbacks into the County shoreland zoning regulations.

3. Racine County, assisted by the Racine County Coastal Management Program Technical Advisory Committee, should modify its shoreland

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[1]The findings and recommendations of this study are documented in SEWRPC Community Assistance Planning Report No. 73, Racine County Shoreland Development Management Study, January 1982.

zoning regulations to indicate, in as much detail as practicable, the design criteria considered by the County in its review of conditional use permits for shore protection activities.

4. In preparing its new subdivision control ordinance, Racine County should require the identification of shore erosion hazard areas on land division plat maps and the preparation of erosion hazard abatement plans, where applicable.

5. Racine County should continue to collect and analyze information regarding Lake Michigan shoreline erosion hazards and erosion hazard abatement strategies.

6. The City of Racine and the Villages of North Bay and Wind Point should determine whether shoreline erosion-related zoning regulations are necessary after an analysis of the results of the previously recommended County effort to identify and map existing and future erosion hazard areas.

7. The Racine County Planning and Zoning Department should serve as the "first contact" agency for all riparian landowners proposing structural shore protection or other erosion-related work.

In partial response to these recommendations concerning shoreland erosion control, Racine County, in 1981, requested and received a grant under the Wisconsin Coastal Management Program in partial support of a coastal erosion study. This study was subsequently carried out cooperatively by the staffs of the Regional Planning Commission and the Racine County Planning and Zoning Department and an Advisory Committee consisting of representatives from the University of Wisconsin Sea Grant Program, the City of Racine, the Town of Caledonia, the Racine County Coastwatch Program, the Racine Board of Realtors, Inc., the Wisconsin Department of Natural Resources, the Sierra Club, and private engineering consulting firms. A number of important studies regarding shoreline erosion and bluff recession rates, and erosion processes along the Racine County coastline have been completed, providing much of the basic

information required to prepare an erosion management plan. In addition, Racine County has established the County Coastwatch Program as a means for continuously monitoring shoreland erosion.

DEFINITION OF COASTAL EROSION MANAGEMENT

Coastal erosion management may be defined as a coordinated set of measures designed to abate coastal erosion and reduce attendant property losses, aesthetic impacts, and risks to human safety which result from such erosion. Erosion management measures include both structural measures such as the construction of revetments and bulkheads, and nonstructural measures such as land use regulations which prohibit certain types of development in erosion-prone shoreland areas. The broad goal of coastal erosion management is the preservation of the overall quality of life of the residents of an area through the selective protection of high value physical resources and those environmental values--recreational, aesthetic, ecological, and cultural--normally associated with and concentrated in coastal areas.

NEED FOR COASTAL EROSION STUDY

The erosion and subsequent recession of coastal bluffs constitute one of the most adverse impacts of coastal erosion processes. Bluff recession rates in Racine County range up to 14 feet per year.[2] This bluff recession results in the loss of approximately three acres of land each year containing 6.3 million cubic feet of shore material. This annual amount of eroded material would fill over 1,500 railroad boxcars, which, if placed end to end, would form a line 16 miles long. This extremely severe erosion is concentrated within a narrow strip of shoreline which contains valuable man-made and natural resources.

The Racine County shoreland zoning ordinance was enacted to regulate human activities in shoreland areas which could have adverse effects on those shore-

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[2] J. P. Keillor, and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, University of Wisconsin Sea Grant College Program Advisory Services, April 1, 1978.

land areas and the associated surface waters. The County's ordinance presently specifies a uniform 400 foot set back from the Lake Michigan shoreline for all structures except public utilities, public recreation facilities, and most single-family residences. In addition, tree and shrub cutting and clearing, road and trail development, earth moving activities, surface water use or discharge, and certain agricultural activities are regulated in the shoreland area. The specified setback distance and regulations may provide more than adequate protection in some shoreland areas; however, other areas may require more stringent regulations in order to provide a sufficient level of shore protection. The significant data base which has now been acquired relating to the coastal erosion problems in the County provides an opportunity to refine the County shoreland zoning ordinance and other pertinent County and local ordinances by establishing development setbacks and other use restrictions which are related specifically to existing and probable future beach and/or bluff recession rates, as well as to an expected stable slope configuration. Since the Racine County shoreland represents an extremely valuable resource, and, since competition for coastal resources is increasing, the development of setback distances and other regulations based upon careful analysis of all available pertinent data warrants attention at this time.

REVIEW OF PREVIOUS STUDIES

A major work element of this study is the collation and analysis of previously collected data relating to shoreland erosion and recession in Racine County. Data on coastal erosion have been developed under the Racine County Coastwatch Program, the Wisconsin Coastal Management Program, the University of Wisconsin Sea Grant College Program, and by the firm Owen Ayres & Associates, Inc., working under contract to Racine County. The following section briefly describes each of the past coastal studies conducted in Racine County:

1. Racine County Coastwatch Program

   The Racine County Coastwatch Program was initiated in 1978 to monitor the causes, occurrence, and extent of bluff recession and related factors. Along the coast, 16 coastwatch stations were established and volunteer coastwatchers have since 1978 observed coastal erosion conditions. Data collection sheets were completed and photographs periodically taken of

designated sections of the coastline. Data were collected on bluff erosion and recession, wave action, water level changes, precipitation, surface runoff, placement of man-made structures, and various shoreland uses. The findings of the program are set forth in the Racine County Coastwatch Program Final Report (1981). This report provides important insights into the processes affecting Lake Michigan shoreland erosion in Racine County and documents the relative bluff recession rates at several locations.

2. University of Wisconsin Sea Grant College Program

The University of Wisconsin Sea Grant College Program undertook measurements of shoreline recession along the Lake Michigan coast over a period of eight years (1968-1976) during which water levels in Lake Michigan at Milwaukee rose gradually from their lowest recorded levels in the early 1960's to their highest levels since the 1870's. Long-term recession rates were estimated. The study characterized the impacts of storm waves on recession rates. The study also characterized the general landforms along the Lake Michigan coast and discussed the causes of shoreline recession in the County. The findings of the study are documented in: Recent Recession of Lake Michigan Shoreline in Racine County, Wisconsin, J. I. Keillor and R. DeGroot, 1978.

The largest bluff recession rates were recorded along the northern reaches of the County coastline. In this area, bluff recession rates were found to average 5.8 feet per year over the period of observation, with one site averaging 14 feet per year. Recession rates measured south of the City of Racine averaged only 1.4 feet per year over the period of observation. Nearly five million cubic feet per year of bluff material, or about 80 percent of the total County loss of 6.3 million cubic feet per year, is estimated to be eroded from the northern segment of the County coastline. The most probable cause of the large land losses in the northern part of the County is a combination of high, unstable bluffs with a perched watertable, a lack of structural protection, and high exposure to storm wave action.

3. Wisconsin Coastal Management Program

An inventory of shoreline conditions was completed in 1976 under the Wisconsin Coastal Management Program. For each of four coastal reaches within the County, information assembled on short term--10-year--and long term--100-year--bluff recession rates; the physical characteristics of the bluffs, beach, and geologic formations present; observed shore damages; and known shore protection structures and boat ramps was presented. The findings of this study are presented in: Shore Erosion Study Technical Report, Appendix Two, Racine County, A. F. Schneider, T. Edil, and B. Haas, Wisconsin Coastal Management Program, 1977.

In the southern part of the County, numerous shore protection structures and artificial fill areas were noted. In unprotected areas, considerable property damage and shoreline recession were reported. Beach conditions and widths were extremely variable, depending upon the degree of structural protection provided, and bluff heights ranged from less than 10 feet to over 40 feet. Immediately north of the City of Racine, poorly protected areas were subject to severe wave erosion at the toe, or bottom, of the bluff, slumping at the top of the bluff, and material loss from the exposed face of the bluff, often due to groundwater discharge and surface water runoff. Bluff heights commonly ranged from 20 feet to 30 feet. The reach of coastline north of Wind Point is rated as the third most critical erosion area along the entire coastline of Wisconsin. The severe erosion and bluff recession along this northern section is attributed to the following factors:

1. Narrow--10 to 40 foot wide--beaches.
2. Relative lack of structural shore protection.
3. Intense wave action against the toe of the bluff.
4. A northwest-southeast orientation of the coast and its gentle concavity towards the northeast, which make the shoreline particularly vulnerable to attack by winter storm waves from the northeast.
5. Steep, high--up to 85 feet high--bluffs.
6. A high content of easily eroded, fine-grained materials in the bluff.

7. Permeable layers in the bluff which allow rapid groundwater flow-through.
8. The massive groin structure at the Wisconsin Electric Power Company Oak Creek Power Plant that probably interrupts the prevailing longshore current and leads to increased net erosion along the predominant down-current side.

4. University of Wisconsin-Extension

The University of Wisconsin-Extension developed, for the Wisconsin Coastal Management Program, proposed regulations to reduce coastal erosion losses. The report suggests methods of determining erosion hazard areas, describes ways to reduce shoreline erosion, presents the rationale for developing zoning and subdivision regulations which adjust land use and development to the erosion hazard, and includes sample ordinance provisions for zoning ordinances and subdivision ordinances which take the shoreline erosion hazard into account. The report is set forth in: Regulations to Reduce Coastal Erosion Losses, D. A. Yanggen, 1981.

5. Racine County Erosion Control Study

In 1979, Racine County retained the firm of Owen Ayres & Associates, Inc., to prepare a combined lake access, ecological management, recreational activity and management, and coastal zone erosion study, to help guide the future development of the County's Cliffside Park, the Town of Caledonia's Lake Michigan park area, and adjacent areas in the Town of Caledonia. The study area consisted of the entire coastal region north of Six Mile Road in the Town of Caledonia, an area containing the most severe coastal erosion problems in Racine County. Bluffs range from 40 to 80 feet in height and beach widths are generally less than 30 feet. Soil boring logs indicated a zone of perched groundwater lying from three to eight feet below the ground surface. Strata of permeable sand and gravel were also located along the bluff face. These conditions allow groundwater to discharge at the bluff face, causing material flows and slumps. Toe erosion of the bluffs was also very common. The report cites references which state that the long-term--110-year--recession rate ranged from one to four feet per year. During the period of 1967 to

1975, recession rates ranged up to 12.5 feet per year. An estimated 300,000 cubic yards of material is eroded into the lake annually from the study area. The study evaluated alternative structural measures to reduce shoreline erosion. It was recommended that the bluff be regraded to a stable slope, that the bluff face be revegetated, that a granular bluff drain be constructed, that armor stone revetments be provided for bluff toe protection, and that overland flow and perched groundwater flow be collected and diverted to the stone revetment.

6. Racine County Shoreland Cadastre

In 1981, Racine County completed a multi-purpose cadastre for that portion of Racine County perceived to have special Lake Michigan shoreland management needs. The cadastre file included real property boundaries, land use data, real estate tax information, parcel size, local zoning classification, and soil types. The area for which the cadastre was developed includes all real properties in Racine County abutting Lake Michigan, as well as properties between Lake Michigan and the first major man-made or natural feature west of Lake Michigan. This area ranges in width from about 200 feet to 4,800 feet, and approximates the coastal erosion study area.

COASTAL EROSION STUDY AREA

For the purposes of this study, the shoreland area of Lake Michigan was defined as all that area of Racine County lying with in approximately 1,000 feet of the ordinary high water mark of Lake Michigan, as well as certain lands along the Root River east of the Marquette Street bridge (see Map 1).[3] The study area thus includes lands subject to county shoreland zoning regulations, one of the most important of all shoreland development management mechanisms. In general, the study area includes those lands which most directly affect,

[3]The actual study area boundary is the man-made or natural physical feature lying closest to a line 1,000 feet from the ordinary high water mark of Lake Michigan. Along several reaches of the study area in the northern portion of the County, real property lines had to be used as the study area boundary, owing to absence of major physical features near the shoreline in this area.

Map 1

RACINE COUNTY COASTAL EROSION MANAGEMENT STUDY AREA

and are most affected by, Lake Michigan resources and processes. The Racine County cadastral map was prepared for the shoreland area covering an area ranging in width from 200 feet to 4,800 feet. The area covered by the cadastral mapping program approximates the Coastal Erosion Study Area.

SUMMARY

Several previous studies on shoreland development and shoreline erosion in Racine County have been prepared in response to increasing public concern over land use in the shoreland area and the erosion of that area. A recently completed shoreland development management study for Racine County analyzed shoreland development problems, including shore erosion, recreational access, natural resource preservation, and land use regulations.

Coastal erosion management may be defined as a coordinated set of measures--both structural and nonstructural--designed to abate shoreline erosion and reduce damages which result from such erosion. Currently, shoreland development in the unincorporated portions of Racine County is regulated by the County Shoreland Zoning Ordinance. Because of the extremely valuable resources contained within the shoreland area and the increasing demand for these coastal resources, there is a need to establish development setbacks and other use restrictions which are related specifically to existing and probable future bluff recession rates and stable slope configurations.

Previous studies pertinent to coastal erosion in Racine County have been prepared by the Racine County Coastwatch Program, the University of Wisconsin Sea Grant College Program, the Wisconsin Coastal Management Program, the University of Wisconsin-Extension, and Racine County. These studies provide much of the basic data needed to prepare an erosion management plan.

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Chapter II

PURPOSE AND SCOPE

INTRODUCTION

The purpose and scope of the Racine County coastal erosion study were developed on the basis of the knowledge and experience of persons who were well informed and intimately familiar with the coastal area of the County, as well as the knowledge of persons who possess the technical skills important to good coastal zone erosion management. To place such knowledge and experience at the disposal of the study, the Racine County Board established the Coastal Erosion Advisory Committee, the composition of which is given on the inside front cover of this report. One of the important functions of this Committee was to articulate the purpose and define the scope and content of the study, so that the findings and recommendations would be relevant to, and useful by, the public officials and private interests concerned with the development and redevelopment of the coastal area, providing a sound guide to decision making over time related to such development and redevelopment.

RELATION TO OTHER STUDIES

As noted in Chapter I, several previous studies have addressed coastal erosion in Racine County and the findings and recommendation of these studies constituted important considerations in defining the purpose and scope of this study. The recommendations for both structural and nonstructural coastal erosion control measures made by the Racine County Technical Subcommittee on Shoreland Development Standards were incorporated into this study and used to estimate potential future coastal conditions, to coordinate the nonstructural control measures developed in this study to potential structural control measures, and to reflect the coastal erosion control objectives of the local agencies of government concerned[4]. The Technical Subcommittee made recommendations for three subareas of the coastal zone: 1) the "undeveloped area",

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[4] Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards to the Racine County Land Use Committee, Draft, June 15, 1982.

that is, the subareas of the coastal zone not yet developed for intensive urban uses; 2) the "undeveloped coastal strip" located adjacent to the developed areas of the coastal zone; and 3) the "developed area"; that is, the subareas of the coastal zone developed for intensive urban uses. The recommendations made by the Technical Subcommittee are summarized in the following paragraphs.

The "undeveloped area" was defined as the coastal area from the northern county boundary to the southern boundary of Cliffside Park. This area consists of about 1.8 miles of coastline not yet developed for intensive urban use. For this area nonstructural measures were generally recommended to reduce losses by shore erosion. These measures included: beach nourishment; sand bypassing at the Oak Creek power plant; acquisition of additional land for Cliffside Park; setback restrictions on new buildings and public roads; and, the use of relocatable structures for any planned development in this subarea of the coastal zone. These measures recognized and sought to protect the natural resource related values and use opportunities in the coastal areas, and recognize that structural shore protection measures and bluff stabilization efforts are generally very costly.

The "undeveloped coastal strip" located adjacent to developed areas was defined as the coastal area from the southern edge of Cliffside Park to Six Mile Road. This area is generally undeveloped except for a few residences. Recommended measures to reduce losses by shore erosion in this area included bluff stabilization and structural shore protection measures to reduce the erosion hazard; private relocation, or public acquisition and removal of existing structures; application of minimum setback distances to proposed new structures where predictable; and adequate shore protection measures for proposed new facilities which are not relocatable and do not meet minimum setback distances.

The "developed area" was defined as the coastal area from Six Mile Road to the southern County line. The coastline in this area is generally developed for intensive urban uses except for occasional vacant lots and municipal parkland. In this area structural measures were considered the only feasible means of

reducing losses by shore erosion. The recommended measures for this area include structural protection; prohibition of new structures vulnerable to erosion damage in the erosion hazard area; special public review procedures for proposed bluff stabilization and shore protection measures to ensure proper design, sound land management practices to reduce erosion potential; continued use of conditional use permit application procedures; encouragement of cooperative structural protection and bank stabilization measures; use of minimum setback requirements with a required justification by the owners concerned of the use of subminimal setback distances; and the provision of shore protection measures for all new structures which are not relocatable.

PURPOSE AND SCOPE

The primary purpose of the Racine County coastal erosion management study is to identify and map high erosion risk areas along the Lake Michigan shoreline of Racine County and to develop a coordinated set of land use regulations properly related to existing and probable future bluff recession rates within the identified high risk areas. The study is thus intended to provide a sound technical basis for amending the County shoreland zoning ordinance and other local land use regulations in order to more effectively reduce erosion hazards, and to guide and shape future coastal development in the public interest. To accomplish this purpose, the following specific work elements were undertaken as part of the coastal erosion management study:

1. The collation of all existing pertinent data on Lake Michigan coastal erosion processes, problems, and rates in Racine County; pertinent land use regulations; and structural and nonstructural erosion control measures;

2. The collection of additional data, as necessary, to verify or update the results of previous studies;

3. The identification and mapping of high erosion risk areas and the establishment of coastal recession rates, stable slope angles, and areas of impact;

4. The formulation of recommendations to amend the County shoreland zoning ordinance and other applicable local land use regulations to better meet the agreed-upon coastal management objectives;

5. The conduct of special evaluations of critical high erosion risk areas to provide additional data needed to define alternative erosion control measures.

The results of this study represent an important step towards the development of a total coastal erosion management program for Racine County. Control of coastal erosion in Racine County requires an integrated approach involving both structural and nonstructural measures. The degree of erosion and the effectiveness of erosion abatement measures are highly site-specific and may vary over time. Factors such as Lake Michigan water elevations, up-current erosion control measures, and changing wind and wave characteristics contribute to and complicate this variability. Therefore, structural erosion control measures as well as a continuing program of data collection and refinement will be needed in addition to nonstructural measures to fully attain an effective coastal erosion control program in Racine County.

SUMMARY

The purpose and scope of the Racine County coastal erosion study was developed under the guidance of the Coastal Erosion Advisory Committee established by the Racine County Board. As a basis for estimating future coastal conditions and to coordinate the nonstructural control measures developed in this study to potential structural control measures, recommendations for structural measures made by the Racine County Technical Subcommittee on Shoreland Development Standards were incorporated into this study. These structural control recommendations were prepared for developed and undeveloped areas of the coast. Generally, structural control measures were not found cost-effective for undeveloped coastal areas, with the exception of a small area south of Cliffside Park adjacent to an urban development. For the remaining coastal area developed for intensive urban uses, the consideration of structural control measures was recommended.

The primary purpose and scope of this study is to identify and map high erosion risk areas along the Lake Michigan shoreline of Racine County and to develop a coordinated set of land use regulations properly related to existing and probable future bluff recession rates within the identified high risk areas. Work elements undertaken as part of this study include the collection, verification, and updating of existing coastal erosion data, the mapping of high erosion risk areas based on coastal recession rates and stable slope angles, the formulation of recommendations to amend the County shoreland zoning ordinance and other applicable local land use regulations, and the conduct of special evaluations of critical high risk areas.

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RACINE COUNTY COASTAL EROSION MANAGEMENT STUDY

Chapter III

INVENTORY FINDINGS

INTRODUCTION

The formulation and application of land use regulations to reduce existing and probable future losses due to shoreline erosion requires the delineation of high-risk erosion areas; and careful consideration of the existing land use pattern, of the natural resource base of the shoreland area, and of coastal erosion processes, rates, and control measures. Accordingly, this chapter provides a description of the shoreland study area, pertinent information on the natural resource base elements relevant to coastal erosion management, a summary of existing land use and zoning patterns, and information specific to coastal erosion in Racine County.

Much of the data presented herein--including most of the specific coastal erosion data--were originally collected in the previous studies referenced in Chapter I. Other data were collected specifically for this study; these data being used to verify and extend the results of previous studies. Full use was also made of the findings of the recently completed Racine County shoreland development management study.[5]

The study area was defined in Chapter I and shown on Map 1. Some of the inventory data, such as land use, surface water drainage, and soils, are presented for the entire study area. Other inventory information, particularly that specifically related to coastal erosion processes, rates, problems, and control measures, is presented only for the immediate shoreland area. As appropriate, other data, such as climatic and groundwater data are presented for adjacent inland portions of Racine County as well as for the shoreland area.

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[5]See SEWRPC Community Assistance Planning Report No. 73, A Shoreland Development Management Study for Racine County, Wisconsin, 1982.

This chapter consists of six sections. The first section presents data on the natural resource base pertinent to coastal erosion management. The second section concerns the existing land use pattern and zoning district regulations and boundaries within the study area. The third section addresses coastal erosion processes. The fourth section concerns shoreland development regulations. Structural shore protection measures are discussed in the fifth section, and the sixth section addresses coastal erosion problems.

NATURAL RESOURCE BASE

This section presents data on those aspects of the natural resource base which affect, or may be affected by, coastal erosion management. Data are presented on the geology, soils, beach and bluff characteristics, surface water resources, groundwater resources, and climate of the shoreland and related areas.

Geology

The consolidated bedrock underlying Racine County generally dips eastward at a rate of 10 to 15 feet per mile. Precambrian age crystalline rock formations generally lies between 2,000 to 3,000 feet below the surface. Cambrian age, sandstone rock formations imbedded with shale and dolomite lie above the crystalline rock formations and generally range in thickness up to 2,000 feet. Above the Cambrian rock formations lie Ordivician-aged sandstone, dolomite, and shale formations which vary in thickness from 500 to 850 feet. The bedrock closest to the surface is comprised of Silurian-aged rock formations, primarily Niagara dolomite, which ranges up to 350 feet in thickness.

The Niagara dolomite formations are covered by unconsolidated glacial deposits which range up to 300 feet in thickness in the extreme northern end of the County. Glacial deposits in other portions of the County generally range from 20 to 100 feet in thickness in the northern part of the County, and from 100 to 200 feet thick in the southern part of the County.

Materials directly deposited by glacial ice are called till. Although unconsolidated, the till deposited over Racine County is relatively uniform in terms of physical and engineering properties. The till present in Racine County, called the Wadsworth till, is relatively fine-grained and interspersed with lake sediment deposits. The Wadsworth till is the most predominant material comprising the eroding bluff faces along the Lake Michigan shoreline in Racine County. Following the retreat of the glacier which deposited the Wadsworth till, a lake--called Glacial Lake Chicago--filled the southern part of the now Lake Michigan basin at an elevation of about 640 feet above National Geodetic Vertical Datum (NGVD), or about 60 feet above the present level of Lake Michigan. The remnants of this lake in Racine County consist of ridges of sand and other lake sediments which cover the Wadsworth till at an elevation of about 640 feet NGVD.

Soils

Soil properties influence the rate and amount of stormwater runoff, thereby affecting the severity of surface erosion at the top of the lake bluffs. Soil properties also are an important consideration in the evaluation of shallow groundwater seepage from the bluff face. Soil properties are also an important determinant of the angle of stable slope and the type of vegetative cover which can be supported along the shoreline.

In order to assess the significance of the diverse soils found in southeastern Wisconsin, the Southeastern Wisconsin Regional Planning Commission, in 1963, negotiated a cooperative agreement with the U. S. Soil Conservation Service under which detailed operational soil surveys were completed for the entire planning Region. The results of the soil surveys have been published in SEWRPC Planning Report No. 8, Soils of Southeastern Wisconsin. The regional soil surveys have resulted in the mapping of the soils within the Region in great detail. At the same time, the surveys have provided data on the physical, chemical, and biological properties of the soils and, more importantly, have provided interpretations of the soil properties for planning, engineering, agricultural, and resource conservation purposes. Detailed soils maps are thus available for the entire shoreland area for use in coastal erosion management.

With respect to surface stormwater runoff, which is a contributing factor to bluff erosion, the most significant soil interpretation is the categorization of soils into four hydrologic soils groups: A, B, C, and D. In terms of runoff characteristics, these four hydrologic soil groups are defined as follows:

Hydrologic Soil Group A: Very little runoff because of high infiltration capacity, high permeability, and good drainage. Covers 180 acres, or about 7 percent of study area.

Hydrologic Soil Group B: Moderate amounts of runoff because of moderate infiltration capacity, moderate permeability, and good drainage. Covers 535 acres, or about 21 percent of study area.

Hydrologic soil Group C: Large amounts of runoff because of low infiltration capacity, low permeability, and poor drainage. Covers 1,041 acres, or about 41 percent of study area.

Hydrologic soil Group D: Very large amounts of runoff because of very low infiltration capacity, low permeability, and poor drainage. Covers 362 acres, or about 14 percent of study area.

The remaining 434 acres, or about 17 percent is covered by disturbed soils and man-made features.

The spatial distribution of the four hydrologic soil groups within the study area is shown on Map 2. Hydrologic soil group C and D soils may contribute substantial surface runoff from the top edge of the bluff and over the bluff face, causing severe erosion. Soil groups A and B, due to increased infiltration capacity, may produce higher levels of groundwater seepage, which also may cause severe bluff erosion.

Bluff Characteristics

The bluffs along the Racine County shoreline of Lake Michigan exhibit a range of height, composition, vegetative cover, level of structural protection, and recession rates. This section describes the physical characteristics--the height and composition--of the bluffs. Bluff erosion processes, structural protection measures, and bluff recession rates are described in later sections of this chapter.

Map 2

HYDROLOGIC SOIL GROUPS IN THE
COASTAL EROSION STUDY AREA OF RACINE COUNTY

Table 1 summarizes the length of shoreline within various bluff height ranges. Bluff heights are also shown on Map 3 and on Figure 1. Along the shoreline south of Pershing Park, the bluffs generally range in height from 30 to 40 feet. Between the northern breakwater of the Racine harbor and Six Mile Road in the Town of Caledonia, the height of the coastal bluffs varies considerably, but is generally less than 40 feet. North of Six Mile Road the bluff heights increase with bluffs of more than 80 feet in height found along the shoreline north of Cliffside Park. Typically, the coastal bluffs in Racine County extend to the water's edge or to the edge of a narrow beach area parallel to the water's edge. Notable exceptions occur at Pershing Park, North Beach, the Racine sewage treatement plant, and the Wisconisn Electric Company site, where extensive areas of natural or man-made land exist between the base of the bluff and the water's edge. Only about 21 percent of the shoreline has bluffs equal to or less than 21 feet in height. Nearly 56 percent of the shoreline has bluff heights ranging from 21 through 40 feet in height and about 22 percent of the shoreline has bluff heights ranging from over 40 to 80 feet in height. Less than 2 percent of the shoreline has bluffs in excess of 80 feet in height.

The Racine County bluffs are composed of a large variety of materials. Table 2 indicates the predominance of various materials, and Figure 1 and Map 3 show the distribution of various types and combinations of materials along the shoreline. Till is the most predominant bluff material, comprising at least a portion of the bluff along approximately 90 percent of the shoreline. Silt and clay are the second most predominant bluff materials, occurring in about 69 percent of the bluff shoreline length, with the next most common material being sand, present within about 49 percent of the bluff shoreline length. Nearly one third of the bluffs contained portions, or strata, of an unknown composition. Some of these unknown strata may be composed of artificial fill containing gravel, stone, concrete, iron, glass, slag, asphalt, and solid waste.

Beach Characteristics

A beach may be defined as an area of unconsolidated material which extends landward from the ordinary low-water line to the line marking a distinct

Table 1

SUMMARY OF BLUFF HEIGHTS
IN RACINE COUNTY: 1978

Bluff Height (feet)	Length of Shoreline (feet)	Percent of Total Shoreline Length
0-10	7,280	9.3
11-20	9,070	11.6
21-30	12,790	16.4
31-40	30,810	39.5
41-50	6,020	7.7
51-60	4,620	5.9
61-70	4,160	5.3
71-80	2,180	2.8
81-90	680	0.9
91-100	480	0.6
Total	78,090	100.0

Source: Keillor and DeGroot (1979) and SEWRPC.

Map III-3

BLUFF HEIGHTS AND COMPOSITION ALONG THE
RACINE COUNTY SHORELINE OF LAKE MICHIGAN: 1978

Figure 1

LONGITUDINAL SECTION THROUGH RACINE COUNTY SHORELINE
OF LAKE MICHIGAN SHOWING BLUFF HEIGHT AND COMPOSITION: 1977

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Table 2

PREDOMINANCE OF BLUFF COMPOSITION MATERIALS

Material	Shoreline Length Which Contains Material in Bluff (feet[a])	Percent of Total Shoreline Length
Till.....	70,530	90.3
Silt and Clay.....	53,520	68.5
Sand.....	38,580	49.4
Sand and Gravel.....	11,480	14.7
Unknown[b].....	25,210	32.3

[a]The shoreline length shown is the length of the bluff which is at least partially composed of the stated material. Most bluffs are composed of more than one material. Therefore, the totals exceed 100 percent of the County shoreline.

[b]Usually only certain portions, or strata, of a bluff are of unknown composition.

Source: Schneider, et al (1977); and SEWRPC.

change in physiographic form or the beginning of permanent terrestrial vegetation. The width of a beach and the size and character of the sediments found on beaches vary widely in response to the degree of wave action affecting the beach, the slope of the beach face and the nearshore lake bottom, the kinds of material available near the shore for the formation of beaches, and man-made structures. Table 3 sets forth beach chacteristics for the Racine County shoreline of Lake Michigan.

The table indicates that the beaches in the County are composed primarily of sand, gravel, cobbles, and pebbles; smaller particles like silt and clay do not usually remain on the beach as do the larger-size materials, since clay and silt are more readily kept in suspension and carried out into the lake. These finer-size materials tend to ultimately settle out in calmer, deeper, offshore waters. In 1977, about 32 percent of the County shoreline contained no beach--the lake water reaches the bluff toe or, in some cases, a shore protective structure. Less than 3 percent of the beach length was composed of artificial fill.

Map-4 shows the distribution of various beach materials along the County coast. Sand and gravel are predominant along the far northern and southern coastal reaches in the County. The larger cobble and pebble-size materials are primarily located near Wind Point--south of the Crestview subdivision and north of the Village of North Bay. The greatest sand deposits are found adjacent to the northern section of the City of Racine. Much of the remainder of the coastal area through the City of Racine contains no beach, largely a result of the protective structures present. Beach materials are supplied by littoral drift transporting particles contributed to the lake by watershed drainage and up-current shoreline erosion and bluff recession.

Table 3 and Map 4 also indicate the beach widths along the coast. About 54 percent of the shoreline has a beach width equal to or less than 10 feet. About 25 percent of the shoreline has a beach width ranging from 11 feet through 30 feet, and about 15 percent has a beach width ranging from 31 feet through 75 feet. Only about 6 percent of the shoreline, all located just north of the Racine harbor breakwater, has a beach over 75 feet wide, and this beach is composed entirely of sand.

Table 3

BEACH CHARACTERISTICS OF THE RACINE COUNTY
LAKE MICHIGAN SHORELINE: 1977

Composition	Shoreline Length (Feet)	Percent of Total Shoreline Length	Beach Width Ranges (Feet) 1-10	Percent of Total Shoreline Length	11-30	Percent of Total Shoreline Length	31-75	Percent of Total Shoreline Length	76-125	Percent of Total Shoreline Length
Sand	9,145	11.7	1,460	1.9	3,185	4.1	0	0.0	4,500	5.7
Gravel	2,230	2.9	1,710	2.2	0	0.0	520	0.7	0	0.0
Gravel and Sand	20,515	26.3	8,610	11.0	9,855	12.6	2,050	2.7	0	0.0
Cobbles and Pebbles	3,260	4.2	3,260	4.2	0	0.0	0	0.0	0	0.0
Sand, Cobbles and Pebbles	16,160	20.7	355	0.5	0	8.5	9,130	11.7	0	0.0
Artifical Fill	1,940	2.5	1,940	2.5	0	0.0	0	0.0	0	0.0
No Beach Area	24,840	31.7	--	--	--	--	--	--	--	--
Total	78,090	100.0	17,335	22.3	19,715	25.2	11,700	15.1	4,500	5.7

Source: Schneider, et al. (1977).

Map 4

BEACH WIDTH AND COMPOSITION ALONG THE RACINE COUNTY SHORELINE OF LAKE MICHIGAN: 1977

Surface Water Resources

Surface water resources in the coastal zone of Racine County consist primarily of Lake Michigan but also include the Root River and certain minor streams tributary to Lake Michigan, and form a particularly important element of the natural resource base of the study area. In some areas, surface runoff has an important effect on bluff recession by eroding material from the face of the bluff and by forming gullies and ravines at the edge of the bluff. The Lake Michigan shoreline through Racine County measures 14.8 miles in length. The shoreland area also contains a portion of the Root River estuary as well as all or portions of two unnamed perennial streams and seven unnamed intermittent streams (see Map 5). Within the study area, there are a total of 1.6 miles of perennial streams and 5.1 miles of intermittent streams. There are also a few small ponds within the study area.

The quality of both the inland surface waters and of Lake Michigan are susceptible to deterioration as a result of the activities of man. The quality of surface waters is influenced by pollutant contributions from sewage treatment plant outfalls, separate and combined sewer flow relief devices, storm sewer outfalls, direct surface runoff from adjacent lands, and coastal beach and bluff erosion. Coastal bluff erosion contributes a substantial amount of sediment to the lake; about 6.3 million cubic feet of shore material is estimated to be eroded into the Lake each year within Racine County. By comparison, less than 0.8 million cubic feet of sediment is transported annually by the Root River at the City of Racine.[6] A more detailed discussion of the water quality and sources of pollution of Lake Michigan and of the streams and rivers tributary to the Lake is found in the Lake Michigan Estuary and Direct Drainage Area Subwatersheds Planning Programs Prospectus, published by the Regional Planning Commission in 1978.

Groundwater Resources

The occurrence, distribution, direction, and quantity of flow of groundwater resources have important impacts on the stability of bluff slopes. Along the

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[6]See SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, 1978, p. 663.

Map 5

PERENNIAL AND INTERMITTENT STREAMS IN THE
RACINE COUNTY COASTAL EROSION STUDY AREA: 1982

Racine County shoreline, groundwater generally flows towards the Lake and discharges either at, or below, the base of the bluff into the lake, or seeps out of the bluff slope at some elevation above the lake level. The presence of groundwater reduces the frictional resistance to stress, creates a seepage pressure in the direction of water flow, adds weight to the bluff, and causes undercutting of bluff materials. A U. S. Geological Survey report noted that within Racine and Kenosha Counties, surface water runoff contributes about 125 cubic feet per second to Lake Michigan, while groundwater contributes only about 5 cubic feet per second to the lake[7].

Three major aquifers underlying the study area yield water to wells, springs, lakes, and streams. These aquifers are commonly called the deep sandstone aquifer, the shallow Niagara dolomite aquifer, and the shallow sand and gravel aquifer. The sandstone aquifer underlying the entire County and comprised of the Cambrian and Ordivician aged strata is used primarily as an industrial water supply in the study area. About 80 percent of the recharge of the sandstone aquifer occurs in a corridor through western Washington, Waukesha, and Walworth Counties. Wherever the water table level of the sandstone aquifer lies beneath the level of Lake Michigan, some recharge from the Lake is induced.

The Niagara dolomite, of Silurian age, is the principal shallow aquifer in the area. This aquifer, which underlies the entire study area, produces water yields which are somewhat erratic, depending on the size and number of crevices and solution cavities in the portion of the aquifer contributing to the well. Recharge of the aquifer is by the downward seepage of precipitation which falls in the immediate area. Some recharge is also induced from Lake Michigan.

Water-saturated sand and gravel deposits above the bedrock form a third source of groundwater in Racine County. The sand and gravel aquifer is discontinuous. Where the sand and gravel deposits are deep and overlie the Niagara dolomite, the two aquifers are hydraulically connected, and the lateral movement of water within the two aquifers is similar. The recharge of the sand and

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[7]R. D. Hutchinson, Water Resources of Racine and Kenosha Counties, Southeastern Wisconsin, U. S. Geological Survey Water Supply Paper, 1878, 1970.

gravel aquifer is by local downward percolation of precipitation. The groundwater discharges and seepages from the bluff slopes are primarily contained within the sand and gravel aquifer.

Climate

Air temperature and the type, intensity, and duration of precipitation events affect the degree and extent of erosion. Climate impacts on coastal erosion include freeze-thaw actions caused by water contained within the bluff material, high surface runoff from frozen soils in early spring, the reduction of wave action due to ice formation on the lake, high levels of surface runoff and soil erosion following periods of heavy rainfall.

Air temperature impacts are primarily related to the formation of ice on the lake, the initiation of freeze-thaw actions on soils, and the high runoff rates from frozen soils. Table 4 presents average monthly air temperature variations at the Racine National Weather Service Station. As shown in the table, winter temperatures, as measured by the monthly means for December, January, and February, range from 17°F to 26°F. Summer temperatures, as measured by the monthly means for June, July, and August, average from 66°F to 77°F.

The depth and duration of ground frost, or frozen ground, influences hydrologic and soil erosion processes, particularly the proportion of rainfall or snowmelt that will run off the land and freeze-thaw activity. The amount of snow cover is a major determinant of frost depth. Since the thermal conductivity of snow cover is less than one-fifth that of moist soil, heat loss from the soil to the colder atmosphere is greatly inhibited by the insulating snow cover. Snow cover is most likely during the months of December, January, and February, during which at least a 40 percent probability exists of having one inch or more of snow cover, as measured at the Milwaukee weather station. Frozen ground is likely to exist throughout the study area for approximately four months each winter season, extending from late November through March, with more than six inches of frost occurring in January, February, and the first half of March. As frozen ground on the slopes thaws, it frequesntly is susceptible to active slumping of the bluff, as observed by Racine County Coastwatchers. Streams and lakes begin to freeze over in late November, and ice breakup normally occurs in late March or early April.

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Table 4

AVERAGE MONTHLY AIR TEMPERATURE
AT RACINE: 1970 THROUGH 1980

	Average Daily Maximum	Average Daily Minimum	Mean
January.....	25	8	17
February.....	31	15	23
March.....	41	26	34
April.....	54	36	45
May.....	66	46	56
June.....	76	56	66
July.....	82	72	77
August.....	80	61	71
September.....	72	54	63
October.....	61	44	52
November.....	46	31	39
December.....	33	18	26
Yearly Average	55.5	38.9	46.2

Source: National Weather Service and SEWRPC.

Precipitation within the study area takes the form of rain, sleet, hail, and snow, and ranges from gentle showers of trace quantities to brief but intense and potentially destructive thunderstorms or major rainfall-snowmelt events causing severe bluff and beach erosion. Average monthly and annual total precipitation and snowfall for the Racine National Weather Service Station, are presented in Table 5. The average annual total precipitation in the Racine area is 34.19 inches over the period of 1970 through 1980. The average annual snowfall and sleet measured as snow and sleet also over the period of 1970 through 1980 is 43.43 inches. Assuming the 10 inches of measured snowfall and sleet are equivalent to one inch of water, the average annual snowfall of 43.43 inches is equivalent to 4.34 inches of water and, therefore, only about 13 percent of the average annual total precipitation occurs as snowfall and sleet. Average total monthly precipitation for the Racine area ranges from 1.07 inches in February to 4.22 inches in April. The principal snowfall months are December, January, February, and March, during which 90 percent of the average annual snowfall may be expected to occur.

Extreme precipitation events may result in massive coastal losses due to high levels of erosion, seepage, and slumping. A one-hour storm with an expected average recurrence interval of once every two years would have a total rainfall of about 1.2 inches.[8] A 1-hour, 10-year recurrence interval storm would have a total rainfall of about 1.8 inches and a 24-hour, 10-year recurrence interval storm would have a total rainfall of about 3.7 inches. Extended wet periods may also result in unusually high coastal losses. Over the period 1895 to 1980, the maximum annual amount of precipitation at Racine was 48.33 inches in 1954, or 41 percent above the 1970 to 1980 annual average.[9] The maximum monthly precipitation amount was 10.98 inches, which occurred in May 1933.

MAN-MADE FEATURES

An understanding of the existing civil divisions, land use patterns, and zoning is essential to the sound formulation of practical development guidelines based on anticipated bluff recession rates. Accordingly, this section describes the existing civil divisions, land use, and zoning within the study area.

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[8] K.W. Bauer, Determination of Runoff for Urban Stormwater Drainage System Design, SEWRPC Technical Record, Volume Two, Number Four, April-May 1965.

[9] National Weather Service, Wisconsin Statistical Reporting Service, and SEWRPC.

H0116A/J

Table 5

AVERAGE MONTHLY PRECIPITATION AND SNOW AND SLEET AT RACINE: 1970 THROUGH 1980

	Average Total Precipitation	Average Snow and Sleet
January.....	1.34	14.39
February.....	1.07	8.50
March.....	2.98	7.60
April.....	4.22	1.63
May.....	2.79	0.00
June.....	3.73	0.00
July.....	3.81	0.00
August.....	3.71	0.00
September....	4.13	0.00
October.....	2.19	0.38
November.....	1.98	2.46
December.....	2.24	8.47
Year	34.19 Inches	43.43 Inches

Source: National Weather Service and SEWRPC.

Civil Divisions

Local civil division boundaries within the study area are shown on Map 6. The study area, which lies entirely within Racine County, contains portions of the City of Racine, the Villages of North Bay and Wind Point, and the Towns of Caledonia and Mt. Pleasant. The area and proportion of the study area, as well as the length of Lake Michigan lying within the jurisdiction of each of these general purpose local units of government, are shown on Table 6.

Existing Land Use

The type and spatial distribution of major categories of land use existing within the coastal erosion study area of Racine County in 1980 are summarized on Map 7. The areal extent of the land use categories within the shoreland study area, which encompasses a total of 2,552 acres, is presented in Table 7. As shown on Map 7, and indicated in Table 7, a significant portion of the study area, 1,429 acres, or 56 percent of the total area--was devoted to urban uses in 1980, including residential; commercial; industrial; transportation, communication, and utility; and governmental and institutional uses. Of these urban land uses, residential comprises the largest proportion--695 acres, or 49 percent of the developed urban area. Recreational uses comprised an additional 414 acres, or 16 percent of the total area. Of this recreational use total, 396 acres, or 96 percent, are in public ownership, while the remainder are in private ownership. Remaining undeveloped lands, including wetlands, woodlands, and agricultural and other open lands, encompassed 672 acres, or 26 percent of the total area. Surface water, consisting primarily of the Root River, accounted for the balance--37 acres, or 1 percent of the total study area.

Existing Zoning

Zoning ordinances and attendant zoning district maps provide an important expression of community land use development objectives. Zoning ordinances are presently in effect in each of the five minor civil divisions which have jurisdiction in the Lake Michigan coastal erosion study area of Racine County. The City of Racine, the Villages of North Bay and Wind Point, and the Town of Mt. Pleasant have adopted and currently administer their own zoning ordinances. The Town of Caledonia has adopted the Racine County zoning ordinance, which is administered for the Town of Caledonia by the Racine County Planning and Zoning

Map 6

CIVIL DIVISION BOUNDARIES IN THE RACINE COUNTY
LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1982

Table 6

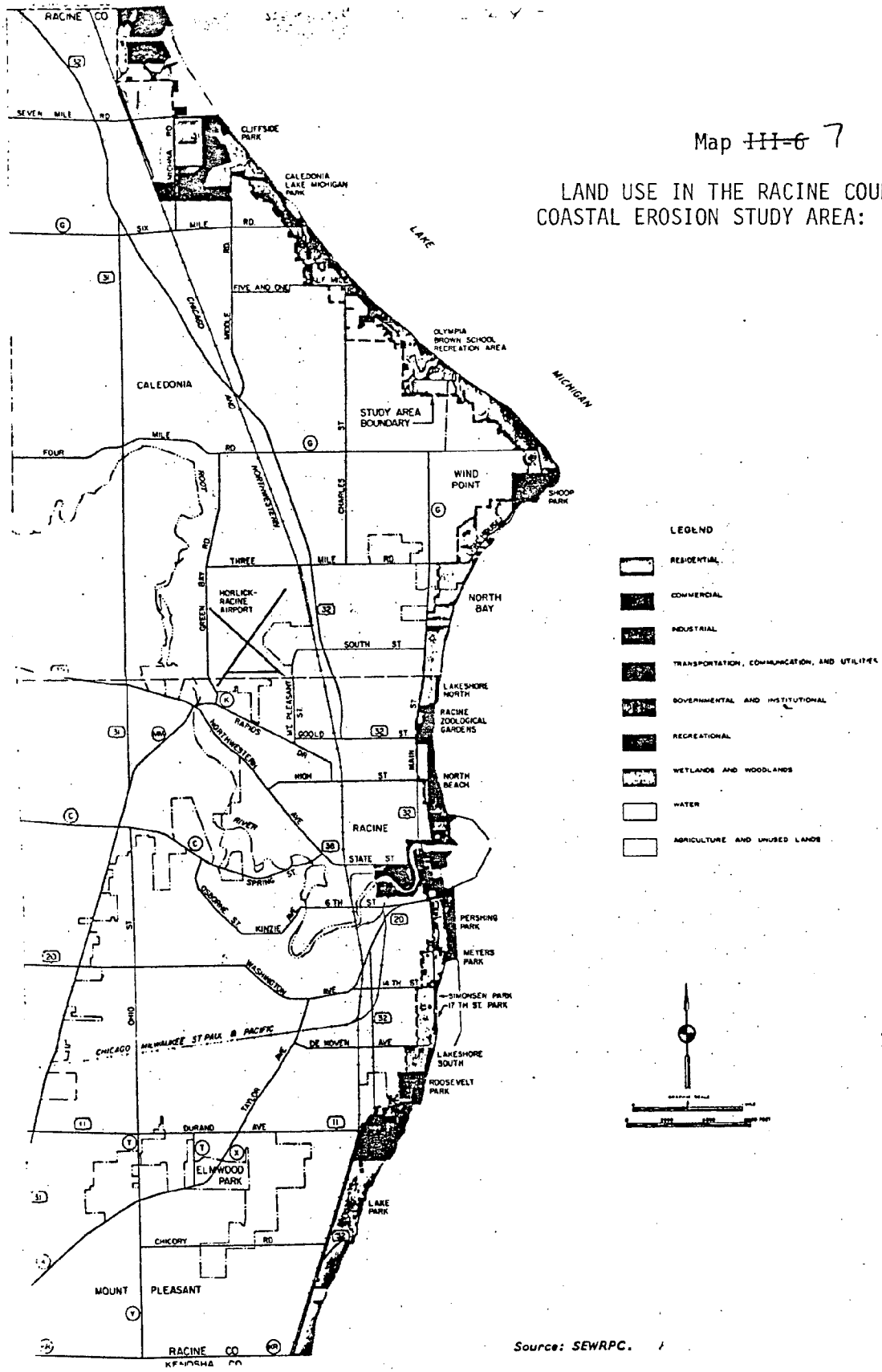
AREA AND SHORELINE LENGTH OF CIVIL DIVISIONS WITHIN THE RACINE COUNTY LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1982

Civil Division	Area (square miles)	Percent of Study Area	Lake Michigan Shoreline Length (feet)	Percent of County Total
Town of Caledonia.....	1.8	43.7	23,600	30.2
Town of Mt. Pleasant....	0.5	11.9	13,360	17.1
Village of Wind Point...	0.6	15.8	12,690	16.3
Village of North Bay....	0.1	3.3	3,300	4.2
City of Racine.....	1.0	25.3	25,140	32.2
Study Area Total	4.0	100.0	78,090	100.0

Source: SEWRPC.

Map ~~III-6~~ 7

LAND USE IN THE RACINE COUNTY
COASTAL EROSION STUDY AREA: 1980



Source: SEWRPC.

Table -7

EXISTING LAND USE IN THE RACINE COUNTY LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1980

Land Use Category	Land Use			
	Acres	Percent of Urban Subtotal	Percent of Rural Subtotal	Percent of Total
Residential	695	48.6	--	27.3
Commercial	47	3.3	--	1.8
Industrial	130	9.1	--	5.1
Transportation, Communication, and Utilities[a]	373	26.1	--	14.6
Governmental and Institutional	184	12.9	--	7.2
Subtotal Urban	1,429	100.0	--	56.0
Recreational[b]	414	--	36.9	16.2
Wetlands	50	--	4.5	2.0
Woodlands	146	--	13.0	5.7
Agricultural and Other Open Lands	476	--	42.4	18.7
Water	37	--	3.2	1.4
Subtotal Rural	1,123	--	100.0	44.0
Total	2,552	--	--	100.0

[a]Includes off-street parking, terminals, communication facilities, and utilities.

[b]Excludes wetlands, woodlands, and off-street parking within existing park and outdoor recreation sites.

Source: SEWRPC.

Department. The Village of Wind Point is currently in the process of preparing a new zoning ordinance and zoning district map. Generalized existing zoning districts within the study area are shown on Map 8. Table 8 presents the areas placed in various zoning districts.

A large portion of the study area has been placed in zoning districts which permit urban development--a finding which is not surprising, given the highly urbanized character of the study area. As indicated in Table 8, a total of 2,331 acres, or 91 percent of the study area, have been placed in zoning districts which permit residential, commercial, industrial, and governmetnal and institutional development. The largest single zoning category is residential which accounts for 1,094 acres, or 43 percent of the study area. Lands placed in districts which allow urban development account for 13.6 linear miles, or 95 percent of the total Lake Michigan shoreline in Racine County.

COASTAL EROSION PROCESSES

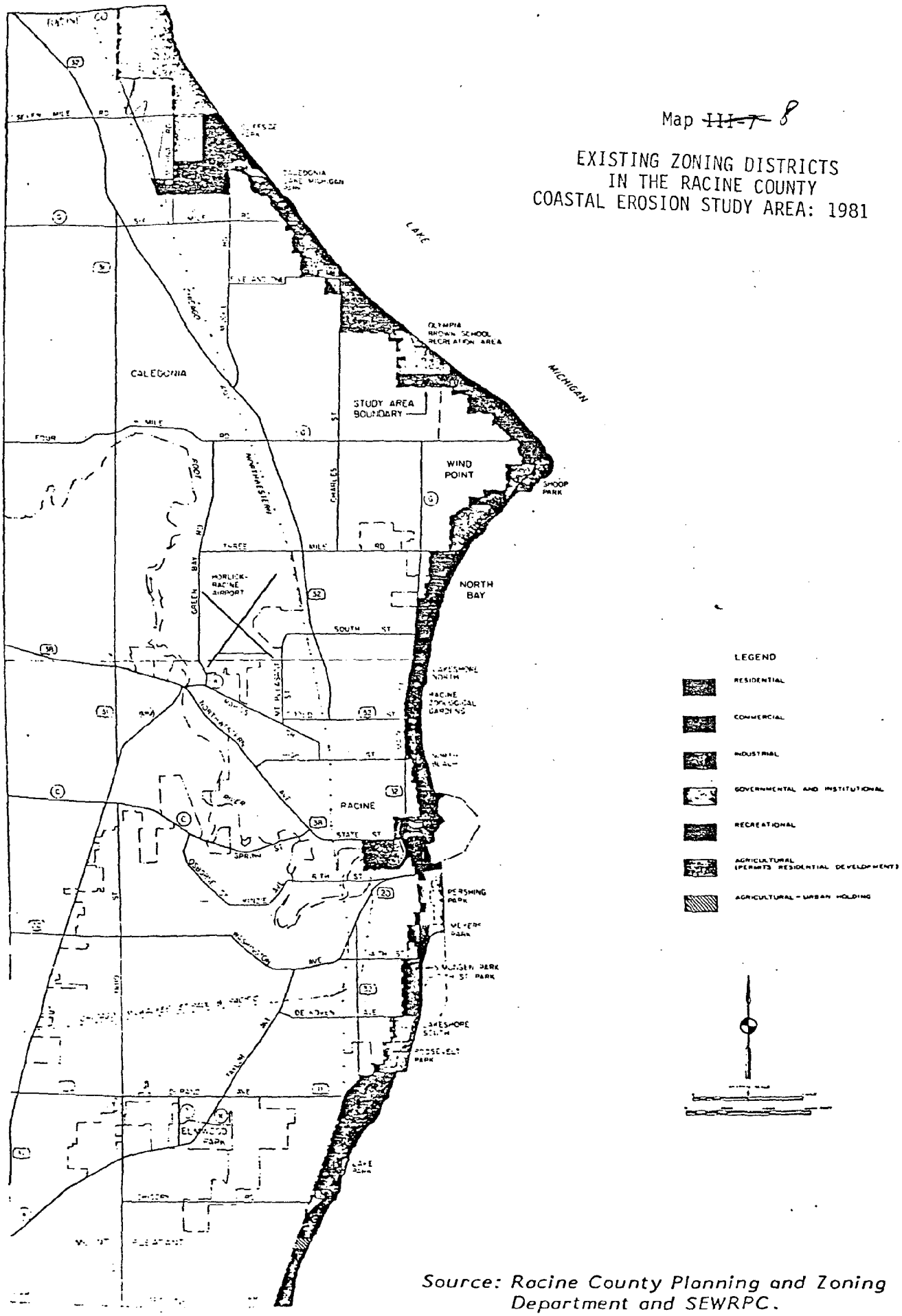
Erosion of the Racine County Lake Michigan coast is a natural process which can be accelerated or decelerated by human activities. Coastal erosion includes two processes, bluff erosion and beach erosion, but bluff erosion is of particular concern because of the threat to human life and property it poses. Various factors contribute to bluff erosion and beach erosion. These factors include: wave action, groundwater seepage, precipitation runoff, lake level elevation, freeze and thaw actions, lake ice movement, and the type of vegetative cover.

Bluff Erosion

Bluff erosion occurs in the form of toe erosion, slumping, sliding, flow, surface erosion, and solifluction, and results in the intermittent, sometimes massive, recession of the bluff. On all slopes gravity acts to move material on the slope to a lower elevation. On most slopes which are undisturbed by man, and where waves are not eroding the base of the slope, an equilibrium is established over a relatively long period of time between the stresses acting to move material down the slope and the resistance of the materials in the slope to those stresses. The shear stress of the materials in the bluffs is primarily determined by the weight of the soil and water mass in the bluff,

Map ~~III-7~~ 8

EXISTING ZONING DISTRICTS
IN THE RACINE COUNTY
COASTAL EROSION STUDY AREA: 1981



Source: Racine County Planning and Zoning Department and SEWRPC.

Table 8

EXISTING ZONING IN THE RACINE COUNTY LAKE MICHIGAN COASTAL EROSION STUDY AREA: 1981

General Zoning District[a]	Town of Caledonia				Town of Mt. Pleasant				City of Racine			
	Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan	
	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent
Districts Which Permit Urban Development												
Residential	343	29.0	1.91	45.8	179	57.2	1.64	66.1	321	48.2	2.82	57.0
Commercial	6	0.5	--	--	7	2.2	--	--	64	9.6	0.28	5.7
Industrial	--	--	--	--	106	33.9	0.61	24.6	136	20.4	0.66	13.3
Governmental and Institutional	77	6.5	0.45	10.8	14	4.5	0.15	6.1	145	21.8	1.19	24.0
Agricultural	546	46.0	1.10	26.4	--	--	--	--	--	--	--	--
Subtotal	972	82.0	3.46	83.0	306	97.8	2.40	96.8	666	100.0	4.95	100.0
Districts Which Prohibit Urban Development												
Agricultural-Urban Holding District	--	--	--	--	7	2.2	0.08	3.2	--	--	--	--
Recreational	214	18.0	0.71	17.0	--	--	--	--	--	--	--	--
Subtotal	214	18.0	0.71	17.0	7	2.2	0.08	3.2	--	--	--	--
Total	1,186	100.0	4.17	100.0	313	100.0	2.48	100.0	666	100.0	4.95	100.0

General Zoning District[a]	Village of Wind Point				Village of North Bay				Study Area Total			
	Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan		Area		Frontage on Lake Michigan	
	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent	Acres	Percent	Linear Miles	Percent
Districts Which Permit Urban Development												
Residential	210	60.7	1.48	60.7	41	100.0	0.10	100.0	1,094	42.9	8.15	56.8
Commercial	--	--	--	--	--	--	--	--	77	3.0	0.28	1.9
Industrial	--	--	--	--	--	--	--	--	242	9.5	1.27	8.8
Governmental and Institutional	--	--	--	--	--	--	--	--	236	9.2	1.79	12.5
Agricultural	136	39.3	0.98	39.8	--	--	--	--	682	26.7	2.08	14.5
Subtotal	346	100.0	2.46	100.0	41	100.0	0.30	100.0	2,331	91.3	13.57	94.5
Districts Which Prohibit Urban Development												
Agricultural-Urban Holding District	--	--	--	--	--	--	--	--	7	0.3	0.08	0.6
Recreational	--	--	--	--	--	--	--	--	214	8.4	0.71	4.9
Subtotal	--	--	--	--	--	--	--	--	221	8.7	0.79	5.5
Total	346	100.0	2.46	100.0	41	100.0	0.30	100.0	2,552	100.0	14.36	100.0

[a]The zoning district categories are generalized categories. The residential category on Map 8 includes the R1, R2, R3, R4, and R5 Districts of the City of Racine zoning ordinance; the R2, R3, R4, R5, R7, and R8 Districts of the Racine County zoning ordinance; the R40E, R100, and RM2 Districts of the Town of Mt. Pleasant zoning ordinance; and the residential districts of the zoning ordinance of the Villages of North Bay and Wind Point. The commercial category on Map 8 includes the B1, B2, B3, B4, B5, and O Districts of the City of Racine zoning ordinance; the B1 District of the Racine County zoning ordinance; and the B1, B2, and B3 Districts of the Town of Mt. Pleasant zoning ordinance. The industrial category on Map 8 includes the I2 District of the City of Racine zoning ordinance; and the M1 and ME Districts of the Town of Mt. Pleasant zoning ordinance. The governmental and institutional category on Map 8 includes the O/I District of the City of Racine zoning ordinance; the P1 District of the Racine County zoning ordinance; and the PUL District of the Town of Mt. Pleasant zoning ordinance. The recreational category on Map 8 includes the P2 District of the Racine County zoning ordinance. The agricultural category on Map 8 includes the A2 District of the Racine County zoning ordinance and the agricultural district of the Village of Wind Point zoning ordinance. The agricultural-urban holding category on Map 8 includes the AUH District of the Town of Mt. Pleasant zoning ordinance.

Source: Racine County Planning and Zoning Department and SEWRPC.

water pressures in the bluff, external loads such as buildings, vibrations, and the degree of lateral support from the bluff slope. Bluff materials have a shear strength which is normally greater than these stresses. Shear strength depends on the properties of the soil, the loading on the soil, and the moisture content, which is in part determined by the degree of soil drainage. Bluffs erode when either the shear stress is increased or the shear strength decreased, altering the balance of forces until the stresses exceed the resisting soil strength. Undercutting at the toe of the slope by waves steepens the slope and increases the shear stress.

One major type of slope failure is sliding. In this type of failure the material generally moves along a single slide plane. The two forms of slides common along the Racine County coast are translational sliding and slumping. On many slopes which have very little or no vegetation, translational sliding occurs. This type of failure involves a surface layer several inches to one or two feet thick sliding either rapidly or fairly slowly down the bluff. The term slump is used when sliding of a fairly large mass takes place along a curved surface. The slide mass is actually rotated and often the top of the slump block is tilted back and toward the hill slope. Slumping usually takes place fairly rapidly and can cause extensive damage.

A second major type of slope failure is flow. With this kind of slope failure large amounts of water are present and the soil mass actually liquifies and moves like a fluid. Some flow commonly occurs at the toe of slump blocks during and relatively soon after failure. Since slump blocks undergo rotation and the top of the block is often tilted back toward the bluff, surface water can accumulate in these depressions and saturate the underlying soil. Flows also occur when intense rains saturate the surface layer of soil or in the spring as intergranular ice melts near the soil surface and very wet conditions occur. Flows can also occur where groundwater discharges along the bluff face through silts or fine sands. If these more permeable soil layers are located between less permeable clay layers, this removal of sediment by flow due to groundwater seepage is referred to as sapping, and can cause undercutting which creates an unstable slope in which slumping or sliding will occur.

A third type of slope failure, related to flow, is solifluction. Solifluction, or soil flow resulting from freeze and thaw activity occurring both in fall and spring, can reduce the stability of bluff slopes. During the thawing period, there is a buildup of excess pore pressure within the soil mass. Because of underlying impermeable frozen ground, the pore pressures cannot be dissipated and thus, shear resistance decreases. Also, the growth of ice crystals within the soil during winter months weakens the structure of the soil. The amount of moisture in a soil prior to freezing will affect the shear strength after it is thawed; the higher the moisture content before freezing the greater the reduction in shear strength after thawing. The net result is a shear resistance (or strength) which is less than the shear stress, and therefore, even gentle slopes may erode.

A fourth type of slope failure is sheetwash and rill and gully erosion. Both sheetwash and rill and gully erosion result from surface water runoff flowing over the top of the bluff, and over the slope face itself. Sheetwash is the unconfined flow of water over the soil surface during and following a rainfall. Depths of flow are generally only a few millimeters. Raindrop impact is the dominant factor in the detachment of soil particles and once the particles are detached, they are transported downslope at a rate determined by the water runoff rate, slope steepness, vegetative cover, roughness of the surface, and the transportability of the detached soil particles. Rills and gullies are formed by the concentrated, channelized, flow of water on the surface. Rill and gully formation tends to follow zones of weaknesses established by desiccation cracking and differences in soil expansion due to freeze-thaw and wetting and drying. On the lake bluffs the rills are generally destroyed over the winter months by freeze-thaw activity and solifluction, whereas, gullies may exist for years.

A fifth type of slope failure is rock or soil fall. This type of failure takes place when undercutting is extreme and near vertical cliffs are produced. Even though some such segments of bluff are present along the Racine County coast, these are generally fairly small and fall from vertical faces plays only a small role in the overall coastal erosion of the County.

Because slope stability is influenced by dynamic factors, slope failure is a process that occurs in an unpredictable, abrupt fashion as opposed to a uniform, relatively continuous, fashion. After each incremental slope failure, the soil masses tend to temporarily assume a stable configuration until the net effect of the many influencing factors once again decreases slope stability, thus precipitating another incremental failure.

Several factors affect the type of slope failure which occurs and the severity of that failure. The physical characteristics of the beach and bluff, as previously discussed in this chapter, have a major influence on the resistance of the slope to failure. Numerous other factors affect the external stresses which are placed upon the slope, resulting in various types of failure.

The degree of wave energy affecting toe erosion is related to the slope of the beach and offshore areas, the orientation of the beach in relation to storm wind and waves, the lake distance over which waves can develop, and the elevation of the water surface relative to the elevation of the base of the bluff. Most of the strong lake winds over Lake Michigan near Racine County approach from a direction of 10° to 20° east of north.[9] As these wind generated waves approach the coast, wave refraction in shallow water bends the waves more perpendicular to the shore. Almost half of the major storm events approaching the Racine County coast from this direction during the period of 1968 through 1973 generated waves eastimated to be at least 10 feet in height. A wave refraction pattern analysis indicated that for the shoreline north of Wind Point, which exhibits the highest bluff recession rates in the County, storm waves were concentrated due to the alignment of the coast to the waves and to the nearshore bathymetry. South of Wind Point, the waves were dispersed, losing 40 to 75 percent of their deep water wave energy. This may partially account for the lower bluff recession rates exhibited south of Wind Point. Wave information collected under the Racine County Coastwatch Program also indicates that significant waves often approach the County shoreline from the southeast.

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[9] J.P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, April 1, 1978.

Lake water level fluctuations affect rates of wave-induced toe erosion. High water levels result in more rapid recession of the bluffs. When the water level is low, wave energy is expended as waves break along the beach. When water levels rise, waves can break directly on the toe of the bluff and erode the bluff material. The base of the bluff is then undercut, creating unstable conditions in the slope above. This is eventually followed by slope failure and the movement of material down to the base of the bluff. As water levels decrease, the beach again widens and much of the wave energy is dissipated. There is a time lag, however, between bluff recession rates and the decline in lake level because materials in the bluff take time to form a stable slope. Thus, even after water levels decline and wave erosion is decreased, bluff recession continues at a fairly high rate until the bluffs have reached a stable slope angle.

Since 1860, average annual surface elevations of Lake Michigan have ranged from a low of 577.06 feet above National Geodetic Vertical Datum (NGVD) in 1964, to a high of 584.24 feet above NGVD in 1886. (See Figure III-2) The level of Lake Michigan is a function of inflow from Lake Superior, stormwater runoff from the tributary land surface, precipitation falling directly on the Lake, outflow from Lake Michigan through the Straits of Mackinac, evaporation from the Lake surface, and changes in the storage--volume of water--in the Lake. Seasonal water level changes also occur, with generally the highest water level elevations occurring during June, July, and August, and the lowest levels occurring in January and February.[10]

The anticipated occurrence of high Lake Michigan water levels was presented in a report prepared by the U.S. Army Corps of Engineers[11]. For various reaches of the Lake Michigan coast, the report includes estimates of the highest water levels along the open coast expected to be equalled or exceeded for various recurrence intervals. Estimates were made of the highest water levels to be expected on an average of once in every 10 years, as well as once in every

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[10] C.H. Mortimer, Environmental Status of the Lake Michigan Region, Volume 2, Physical Limnology of Lake Michigan, Part 1, Physical Characteristics of Lake Michigan and its Responses to Applied Forces, 1975.

[11] U.S. Army Corps of Engineers, Report on Great Lakes Open Coast Flood Levels, February, 1977.

Figure 2

SURFACE WATER ELEVATION OF LAKE MICHIGAN AT MILWAUKEE: 1860-1980

50 years, 100 years, and 500 years. These levels were based on water level frequency curves derived by the Corps from the maximum instantaneous water levels recorded each year by the National Oceanic and Atmospheric Administration over an approximately 70-year period adjusted to current outlet conditions. Lake Michigan levels on the Racine County coast may be expected to equal or exceed maximum levels of 582.7 feet NGVD an average of once every 10 years, 583.6 feet NGVD every 50 years, 583.9 feet NGVD every 100 years, and 584.5 feet NGVD every 500 years. Even the 10-year recurrence interval maximum water level is higher than the maximum level shown on Figure 2, because the values shown on Figure III-2 are average annual surface water elevations while the predicted recurrence interval elevations are derived from maximum instantaneous levels. Prolonged storm periods of several days duration may raise water levels by a foot or more along the County coastline[12].

Ice formation influences bluff erosion and tends to contribute to a seasonal cycle in erosion. When ice develops along the shore in winter, it serves as a temporary protective barrier against wave action associated with winter storms thereby reducing the bluff erosion. When ice is not stationary against the shore, floating ice chunks can scour the beaches and the bluff toe, thereby reducing the ability of the beach to dissipate wave energy and contributing to toe erosion. Floating ice fields appear and disappear along the coast, depending on wind conditions. Ice can also cause damage to structures provided to protect the beach and bluff.

Groundwater seepage can also affect bluff stability in several ways. In most areas along the Racine County coast groundwater moves toward the Lake and, in some places, discharges either at the toe of the bluff or from the bluff face. Saturated soil conditions decrease the grain-to-grain contact pressure in the soil and reduce the frictional resistance of the material to stress. Groundwater also adds weight to the bluff, further increasing stress on the slope. In addition, groundwater seepage creates a seepage pressure in the direction of water flow. This pressure is especially important in granular soils such as sands and silts and is less important when the content of clay is fairly

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[12] J.P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, April 1, 1978.

high. If groundwater actually discharges along the bluff face, some undercutting of materials also occurs. Removal of bluff materials by groundwater is especially important when sand layers are either interbedded with fine grained materials or are present at the bluff top. When present on the top of the bluff, large amounts of water percolate through the sand until a less permeable material is reached and the water then travels laterally towards the bluff face. Sapping of material may occur at the top of this impermeable layer.

Vegetation can also have an effect on bluff stability and erosion. The aboveground portion of the vegetation physically intercepts raindrops, thereby reducing their potential to loosen particles on the bluff face, reducing the impact of wind, and serving to trap windblown sediment. The underground portion of vegetation serves to bind the unconsolidated material in place, to prevent slippage between soil layers parallel to the bluff face, and to retard surface wash and filter out the sediment carried by that wash. The roots of vegetation, however, may induce infiltration by slowing runoff and providing infiltration passages into the bluff face, thereby possibly contributing to a decrease in bluff stability as a result of increased groundwater content and level. Transpiration through vegetation can help to remove groundwater from the bluff and thereby contribute to its stability. Vegetation on the top of the bluff may serve to intercept and divert some surface runoff thus preventing it from moving down the bluff face. Probably one of the most significant aspects of the lack of vegetation on a bluff face is that it serves as an effective indicator of recent erosion.

Beach Erosion

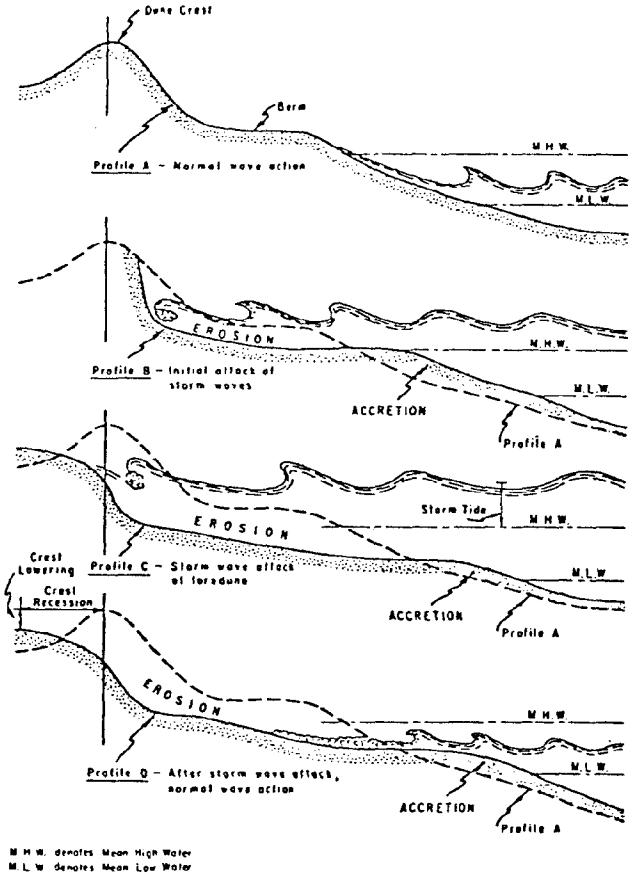
The features of a beach and the materials composing the beach are continuously in a state of flux as a result of the onshore or offshore transport of sand and gravel primarily in response to wave action. There is a constantly changing interplay between the forces that bring sand ashore and those that move it lakeward, with the position and configuration of the main mass of sand at any time serving as an index of the dominant forces. High, steep waves typical of storm events within the coastal area of southeastern Wisconsin tend to tear beaches down by removing material from them and transporting it in a lakeward direction. In contrast, the small waves characteristic of periods between

storm events tend to build beaches up through a net landward transport of sediment. Thus, the beaches exhibit a continuous cyclic pattern of erosion and accretion in response to the nature of the waves impinging on the beach. Figure 3 shows the process of beach erosion in response to the impact of high, steep waves. A beach is said to be stable, even though subject to storm and seasonal changes, when the long-term--several years or more--rates of supply and loss of material are approximately equal.

Sediment is also transported parallel to the shoreline along the beach by longshore currents. Longshore currents are currents in the breaker zone running generally parallel to the shoreline and usually caused by waves breaking at an angle to the shoreline. Longshore currents transport sediment and other particulate matter--which is suspended in the current or bounced and rolled along the lake bottom--parallel to the shore. While the longshore currents within the coastal zone of Racine County may move in either a northerly or southerly direction in response the direction of the incident waves, the net sediment transport is to the south. Evidence of this fact is the tendency for beaches to exhibit accretion on the north side of groins, piers, and other structures while erosion occurs on the southerly side of such structures. The U.S. Army Corps of Engineers has estimated that from 50,000 to 75,000 cubic yards of sediments are annually transported along the littoral area of Lake Michigan at the southern boundary of the State of Wisconsin.

Figure 10-3

BEACH EROSION IN RESPONSE TO WAVE ACTION



Source: U. S. Army Corps of Engineers.

EXISTING REGULATIONS PERTAINING TO SHORELAND DEVELOPMENT

The State of Wisconsin and the federal government have long been involved in the protection of public rights on navigable waters, while more recently water quality has become an important management concern. Of particular concern for coastal erosion managment are the means by which state and federal agencies regulate various activities affecting the protection of the Lake Michigan shoreline.

The U.S. Department of the Army, Corps of Engineers, is the primary federal agency responsible for the regulation of structures and work related to surface waters. Initial Corps authority to regulate structures or work in or affecting navigable waters stems from the River and Harbor Act of 1899. Corps regulatory authority was expanded with the passage of the Federal Water Pollution Control Act amendments of 1972. Section 404 of this act authorized the Corps to administer a permit program to regulate the deposition of dredged and fill materials into waters and related wetlands of the United States.

The State of Wisconsin, through the Wisconsin Department of Natural Resources (DNR), regulates shore protection-related activities under the provisions of Chapter 30 of the Wisconsin Statutes. State regulatory authority with respect to shore protection and erosion control projects is largely confined to projects initiated at or below the ordinary high water mark. For example, Chapter 30 provides for the establishment of bulkhead lines by local units of government and prohibits the deposit of materials or filling at or below the ordinary high water mark or beyond an established bulkhead line. Under Chapter 30, the installations of riprap and shore protection structures on the bed and bank of the water--or the unbroken slope from the ordinary high water mark--requires a DNR permit. DNR permits are also required to grade or otherwise remove soil from the bank of any navigable body of water where the area exposed will exceed 10,000 square feet; this provision, it should be noted, affects the grading of the bank below and above the ordinary high water mark and underscores the importance of county and local management of shore protection activities.

Under Wisconsin Statutes, county and local units of government also have been granted a variety of regulatory powers which can be used to guide development within the Lake Michigan shoreland area in the public interest. Among the most important of these are the shoreland zoning, comprehensive zoning, and land subdivision regulations. The existing zoning and subdivision regulations in Racine County were described previously in this chapter. This section discusses how the regulations pertain to shoreland development and erosion management.

As previously indicated, Racine County presently exercises shoreland zoning powers within statutorily-defined shoreland zoning jurisdiction areas of the Towns of Caledonia and Mt. Pleasant, including the area lying within 1,000 feet of the ordinary high water mark of Lake Michigan. Certain provisions of the county shoreland zoning ordinance serve to minimize erosion hazards along the Lake Michigan shoreline. Most importantly, the county shoreland ordinance has the effect of making virtually all man-made alterations of a shoreland zoning area a conditional use subject to county review and approval. Specifically, earth movements such as grading, top soil removal, filling, root cutting, construction, altering, or enlargement of waterways, removal of stream or lake bed materials, excavation, and soil and water conservation structures --among other activities--are designated conditional uses within the shoreland area. As a result, conditional use permits must be obtained for the construction of new buildings, the installation of shore protection structures, and most other alterations of the shoreland area. In its shoreland conditional use review process, Racine County attempts to ensure that new structures are safely sited with respect to erosion hazards, that shore protection structures are well designed and environmentally sound, and that alterations of the shoreland in general do not increase shore erosion hazards. All applications for conditional use permits within the shoreland area are referred as a matter of course to the Racine County Land Conservation Committee. In addition, Racine County may seek review comments from the Wisconsin Department of Natural Resources, the University of Wisconsin Sea Grant Institute, the U. S. Army Corps of Engineers, the Technical Subcommittee of the Racine County Coastal Management Program Technical Advisory Committee, and the Southeastern Wisconsin Regional Planning Commission.

The county shoreland zoning ordinance also establishes a setback of 400 feet from the ordinary high water mark for all structures except public utilities, recreational facilities, single-family homes, and existing water-oriented commercial uses. The residential uses and the water-oriented commercial uses allowed within this 400-foot setback are subject to the 100-foot minimum shore yard requirement of the comprehensive county zoning ordinance. The comprehensive zoning ordinance also specifies, however, that shore yards may be reduced to the average of the shore yards existing on abutting properties, but to not less than 50 feet. The 50 foot minimum also applies to shore yards on substandard lots. The shore yard is defined as the distance between the average annual high water line and the nearest part of the principal structure on a lot.

In addition to shoreland zoning regulations, Racine County has adopted special floodland regulations which serve to limit filling and development within 100-year recurrence interval flood hazard areas. Racine County floodland regulations apply to floodlands throughout the entire unincorporated area of the County. One hundred-year recurrence interval flood hazard areas along the Root River were identified by the Regional Planning Commission under the Root River watershed planning program, while flood hazard areas along other streams in the study area have been delineated under flood insurance studies conducted by private consulting firms for the Federal Emergency Management Agency for the City of Racine, the Village of Wind Point, and the unincorporated area of Racine County. These flood insurance studies also identify a narrow band along the Lake Michigan shoreline which is subject to inundation by the lake on the average of once every 100 years, and which is also subject to existing county and local floodland regulations.

The zoning ordinances of the City of Racine and the Villages of North Bay and Wind Point are generally devoid of provisions pertaining to Lake Michigan shoreline erosion hazards. These municipalities have not adopted special shoreland zoning regulations, as Racine County has done, nor have they incorporated special erosion hazard regulations into their comprehensive zoning ordinances. The City of Racine and the Village of Wind Point, however, have each adopted floodland zoning regulations which restrict filling and development within 100-year recurrence interval flood hazard areas within the respective communities. The regulations apply to the Lake Michigan shoreline below

the highest lake level elevation that may be expected during a 100-year period. These regulations provide a basis for the local regulation of filling or development--including the installation of shore protection devices such as groins or revetments--below this elevation.

There being relatively little undeveloped land within the shoreland area of the City of Racine and the Villages of Wind Point and North Bay, land subdivision regulations have, as a practical matter, little application to the control of erosion hazards in the incorporated portion of the study area. It should be noted, however, that a review of the subdivision control ordinances of the City of Racine and the Village of Wind Point indicates that there are no specific provisions in these ordinances for the minimization of Lake Michigan shoreline erosion hazards.

EXISTING STRUCTURAL EROSION CONTROL MEASURES

Shoreland structural erosion control measures are intended to reduce coastal erosion by providing an artificial protective barrier against direct wave and ice attacks on the beach and bluff toe, by increasing the extent of the beach to absorb wave energy before the water reaches the bluff, by dissipating wave energy, and/or by stabilizing bluff slopes. However, structural protective measures installed by both public agencies and by private shoreline property owners are costly and have had varying degrees of success. In addition, many structures were not properly designed nor constructed, and many are not properly maintained, resulting in severe deterioration or disappearance within a period of time much shorter than the life of the facilities they were designed to protect.

Onshore protective structures include bulkheads, revetments, and seawalls constructed at or near the base of a bluff. Bulkheads serve primarily as bluff-retaining structures and support the bluff against gravity forces. Seawalls, on the other hand, serve to support a bluff as well as effectively absorb the force of impinging waves. The most common type of on-shore protective structure is the revetment--a flattened slope surface armored with erosion-resistive materials such as concrete or natural rock riprap and underlaid by filter cloth, or gravel.

A type of onshore and nearshore protective structure is the groin, which is connected to and built perpendicular from the beach and is intended to partially obstruct the longshore current which results in the accumulation of transported sand on the beach up-current of a structure. A similar but temporary result may be able to be achieved with artificial beach nourishment, although this approach is still under study--and not generally permitted--by the Wisconsin Department of Natural Resources. The resulting beach absorbs wave energy and reduces toe erosion along the adjacent bluffs. It should be noted that the installation of groins in the coastal system of southeastern Wisconsin can lead to erosion of the beach and bluff immediately downdrift of groins or groups of groins if there is too much blocking of the littoral drift. Within the Wisconsin shoreline of Lake Michigan, the largest number of groins are located in Racine and Kenosha Counties. Groins, as well as nearly all other shore protection structures, require periodic maintenance, extension, and sometimes replacement.

Breakwaters are protective structures built out from the shore into deeper water and sometimes parallel to the shore. They provide dissipation of wave energy, thus reducing bluff toe erosion while reducing the strength of the longshore current immediately landward of the structures. Like groins, however, breakwaters may accelerate beach and bluff erosion downdrift of the protected areas, as sediments settle in the sheltered water behind the breakwater. Breakwaters currently protect the entrance to the Racine Harbor and are also located parallel to the coast south of the harbor for a distance of about 1.4 miles.

Slope stabilization can be accomplished by using earth-moving equipment to regrade the face of the slope to a flatter, more stable profile, thus accelerating the natural stabilization process. This approach is practical only if sufficient vacant land is available at the top of the bluff. Another slope stabilization procedure involves the installation of internal drains to maintain a lowered water table within the bluff face and thus reduce the likelihood of slippage along bluff surfaces. Slope stabilization can also be accomplished through maintenance of a protective cover of vegetation. Slope stabilization measures usually include a combination of these methods.

A variety of shoreline protection structures have been installed by public agencies and by private property owners, thereby reducing shoreline erosion along certain portions of the Racine County coastal area. For example, the Racine Harbor breakwater and the breakwater south of the harbor serve to minimize erosion problems relating to existing development in the Racine central business district and the portion of the City of Racine to the south. Many structures protecting individual properties have also been installed. For example, about 85 structures, including a number of groins, have been constructed along the coastal reach between the Racine Zoological Gardens and Shoop Park. In contrast, with the exception of the Wisconsin Electric Power Company bulkhead, shoreline protection structures are virtually nonexistent in the northernmost portion of the Racine County coastal area--from Cliffside Park to the Milwaukee County line--the reach which experienced the highest shoreline recession rate in the County in the recent past.[13]

The quality and effectiveness of shoreline protection structures varies considerably. An inventory of shoreline protection structures in existence in 1976 along Lake Michigan, including the Racine County coastal area, was conducted as part of the shoreline erosion study sponsored by the Wisconsin Coastal Management Program.[14] This inventory was supplemented by a Regional Planning Commission staff review of 29 approved shoreline protection structure permits filed with the Wisconsin Department of Natural Resources (DNR) between December 1977, and September 1980. The combined inventories are presented in Appendix A. It should be noted that the DNR permit files did not indicate whether proposed structures were actually constructed, but are based on the applications and plans for such structures.

Appendix A lists a total of 216 shoreline protection structures of which 78, or 36 percent are groins; 71, or about 33 percent are revetments; 39, or about 18 percent are bulkheads; 6, or less than 3 percent are piers, and 1, or less than 1 percent is a breakwater. The remaining 21 structures, or about 10 percent of the total listed as "other", include boathouses, boat launching ramps,

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[13] D. M. Mickelson, et al., Shore Erosion Study: Technical Report--Shoreline Erosion and Bluff Stability Along Lake Michigan and Lake Superior Shorelines of Wisconsin, 1977.

[14] Ibid.

slag heaps, debris, and concrete sections. Of the total, 136, or about 63 percent of the shoreline protection structures are located in the Town of Caledonia--Township 4 North, Range 23 East--and 80 structures, or about 37 percent of the shoreline protection structures are located in the Town of Mount Pleasant--Township 3 North, Range 23 East.

Bluff heights at the structure sites range up to 65 feet. The average bluff height at structure sites is 27.4 feet. Bluff slopes range up to 52° for a bluff located in Township 3 North, Range 22 East, Section 32. The average bluff slope is 29°. Beach widths at structure sites range up to 97 feet. The average beach width at structure sites is 14.0 feet.

Table 9 presents a summary of the condition of various types of shoreland protection structures and the types of failure affecting these structures. The inventory of the condition of structures and failure types was conducted in 1976 under the Wisconsin Coastal Management Program shore erosion study. Table 9 indicates that about 61 percent of the revetments, 77 percent of the groins, 94 percent of the bulkheads, 50 percent of the piers, and 35 percent of the "other" structures were classified as functional and effective.

Minor portions of many of these functional structures, however, may have been failing; about 63 percent of the functional structures exhibited some form of failure. Approximately 23 percent of the revetments, 14 percent of the groins, 6 percent of the bulkheads, 33 percent of the piers, the only inventoried breakwater, and 60 percent of the "other" structures were classified as nonfunctional. These nonfunctional structures were ineffective and/or exhibited major failures. The remaining structures, classified as failing, had major structural deficiencies, but were still providing some level of structural protection.

Only about 12 percent of the revetments, 23 percent of the groins, 61 percent of the bulkheads, none of the piers and breakwaters, and 20 percent of the other structures exhibited no failure of any kind. The predominant type of structural failure was overtopping, where the water level, or at least wave heights, exceeded the top of the structure. Overtopping affected nearly half of the structures inventoried, including about 63 percent of the revetments,

Table 9

Survey of Shore Protection Structure Type, Condition, and Failure Type in Racine County: 1976-1980

Structure Type	Condition[b]						Failure Type[a]											
	Functional		Failing		Nonfunctional		None		Overtopped		Flanked		Collapsed		Faulty Material		Other	
	Number	Percent Total	Number	Percent Total	Number	Percent Total	Number	Percent Total	Number	Percent Total	Number	Percent Total	Number	Percent Total	Number	Percent Total	Number	Percent Total
Revetment..	35	61.4	9	15.8	13	22.8	7	12.3	36	63.2	21	36.8	13	22.8	14	24.6	7	12.3
Groin.....	50	77.0	6	9.2	9	13.8	15	23.1	33	50.8	23	35.4	13	20.0	0	0.0	15	23.1
Bulkhead...	34	94.4	0	0.0	2	5.6	22	61.1	8	22.2	1	2.8	0	0.0	1	2.8	3	8.3
Pier.....	3	50.0	1	16.7	2	33.3	0	0.0	2	33.3	0	0.0	2	33.3	1	16.7	1	16.7
Breakwater.	0	0.0	0	0.0	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0
Other.....	7	35.0	1	5.0	12	60.0	4	20.0	7	35.0	6	30.0	2	10.0	4	20.0	8	40.0
Total	129	69.7	17	9.2	39	21.1	48	25.9	86	46.5	51	27.6	30	16.2	20	10.8	35	18.9

[a]The failure type percents are calculated from the total number of structures evaluated. Percents may add up to more than 100 percent because many structures exhibited more than one type of failure.

[b]Functional structures are operational and effective, but some portions may be failing. Failing structures are of questionable effectiveness and have major structural deficiencies. Nonfunctional structures are ineffective and have major structural deficiencies.

Source: Wisconsin Coastal Management Program, Wisconsin Department of Natural Resources, and SEWRPC.

51 percent of the groins, 22 percent of the bulkheads, 33 percent of the piers, and 35 percent of the other structures. This indicates that many structures have either not been constructed large enough for their intended purpose, or that the structures have settled or partially collapsed. As overtopping occurs, small particles from the structure or its foundation are removed, and the foundation may eventually fail. Other failure types inventoried included flanking--where the sides of the structure are eroded, collapsing, and faulty design and selection of materials.

EXISTING COASTAL EROSION PROBLEMS

The most important Lake Michigan coastal erosion problem existing in Racine County is recession of the bluffs. Of foremost concern regarding bluff recession is the danger to the life of residents of homes located in close proximity to the bluff edge and, therefore, subject to the consequences of major, unexpected, rapid slope failure by sliding or slumping. In addition, bluff recession has, and will continue to, damage or threaten private residences, commercial buildings, streets, parkland, and open natural areas, thereby depreciating or destroying real property values. The erosion or accretion of the beaches is a related process in that the extent of the beach affects the degree of wave erosion at the bluff toe. The failing or nonfunctional status of approximately 30 percent of the existing shoreline protection structures, previously noted in this chapter, is another factor affecting bluff recession rates.

Bluff Recession Rates

The rate of bluff recession in Racine County has been documented in several studies. In particular, a shore erosion study by Schneider, et al.[15], and a recent study by Keillor and DeGroot[16] of the University of Wisconsin Sea Grant Institute have presented detailed bluff recession rates. Schneider's study

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[15] A.F. Schneider, T.Edil, and B. Haas, Shore Erosion Study, Technical Report, Appendix 2, Racine County, February, 1977.

[16] J.P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, Text, and Volume 2, Appendix, 1978.

presented short-term--10 to 15 year--recession rates and long-term--about 110 year--rates. The Keillor-DeGroot study documents bluff recession over the period from 1968 through 1971 to 1976. It should be noted that the Keillor-DeGroot study period included the early and mid-1970's when Lake Michigan water levels rose to near record heights. As previously discussed, high Lake water levels result in the bluff toes being increasingly susceptible to wave attack. Moreover, the Lake level was increasing between 1968 and 1971--the span of the baseline data--and, therefore, several coastal reaches in the County were not observed under identical conditions.

In order to assess the impact of high water levels on bluff recession rates and to verify the Keillor-DeGroot rates, the Regional Planning Commission measured bluff recession rates in Racine County at the specific Keillor-DeGroot measurement sites for the period of 1975 through 1980--generally after the Keiller-DeGroot study period--and for the period of 1963 through 1980--thereby including the Keillor-DeGroot study period. A description of the methodologies use to measure bluff recession rates is presented in Appendix B.

Both the Keillor-DeGroot and the Commission studies presented measured recession rates at 101 locations along the County coastline. The midpoints between each measurement site were used to define the boundaries of "analysis reaches". Thus, recession rate data are presented for a total of 101 analysis reaches which cover all but two areas of the coast. These two areas are the southernmost portion of the City of Racine and the northernmost approximately 1,300 feet of the Town of Caledonia shoreline. Recession rates were not measured in these areas because the portion of the City of Racine shore concerned is heavily protected by shore protection measures, and the northernmost shore of the Town of Caledonia is covered by flyash. The shoreline length of the analysis reaches range from 220 feet to 1,160 feet and the combined length of the analysis reaches totals 58,150 feet, or 74 percent of the total Racine County shoreline length of 78,090 feet. The analysis reaches are numbered according to the U.S. Public Land Survey section number and the distance between the measurement site within each analysis reach and the south section line. For example, analysis reach 32:05 is located in Section 32 and the measurement site for that reach is located 500 feet north of the southern boundary of Section 32.

Table 10 sets forth the measured recession rates for each analysis reach as determined by Schneider et al, Keiller-DeGroot, and the Regional Planning Commission. Shoreline length and the volume of material lost for each reach are also presented. The recession rates are graphically illustrated in Figure 4. The Schneider long-term recession rates range from 0.8 feet per year to 5.0 feet per year, with a shoreline length-weighted mean of 2.1 feet per year. The Schneider short-term recession rates range from 1.0 foot per year to 9.0 feet per year, with a mean of 5.0 feet per year. The highest recession rates reported by Schneider were located within the City of Racine.

The Keillor-DeGroot recession rates range from 3.1 feet per year of accretion to 14.2 feet per year of recession, with a length-weighted mean recession rate of 2.5 feet per year. The highest recession rates measured by Keillor-DeGroot were for analysis reaches located in Section 6 of the Town of Caledonia, Township 4 North, Range 23 East. Reaches with consistently low recession rates were located between the City of Racine and Wind Point. The Keillor-DeGroot study indicated that 21 analysis reaches, or 21 percent of the total, apparently exhibited accretion of the bluff over the study period. These apparent accretion areas may represent areas of artifical fill or may indicate errors in the measurements.

The Commission recession rate measurements for the period of 1975 through 1980 ranged from 2.8 feet per year of accretion to 10.2 feet per year of recession, with a mean recession rate of 2.1 feet per year. For the period of 1963 through 1980, the recession rates ranged from 2.3 feet per year of accretion to 8.8 feet per year of recessions with a mean recession rate of 1.7 feet per year. Similar to the Keillor-DeGroot results, the highest recession rates measured by the Commission occurred in Section 6 of the Town of Caledonia, Township 4 North, Range 23 East.

The Commission results are generally consistent with the Keillor-DeGroot measured rates. The values derived in the two studies are similar throughout the coast, except in Township 4 North, Range 23 East, Section 6, where Keillor-DeGroot's rates are somewhat higher than those of the Commission. This is to be expected since Section 6 exhibits the most severe bluff erosion, and the

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Table 9-10

RACINE COUNTY BLUFF RECESSION RATES

Analysis Reach	Shoreline Length (Ft.)	Annual Recession Rates (Ft/yr)					Annual Volume of Material Loss (Ft^3/yr)[b]
		Schneider et al Short Term[a] (10-15 yrs)	Schneider et al Long Term[a] (110 yrs)	Keillor and DeGroot (1968-1971 to 1975)	SEWRPC (1975 to 1980)	SEWRPC (1963 to 1980)	
6:41	240	4	4	4.1	4.19	3.49	50,400
6:39	220	4	4	0.9	2.07	1.91	14,400
6:37	360	4	4	8.1	6.47	5.71	137,600
6:35	300	4	4	6.0	5.73	5.29	99,200
6:33	220	4	4	4.4	4.96	3.00	65,800
6:31	220	4	4	7.4	7.91	6.60	126,400
6:29	480	4	4	13.4	8.98	7.58	551,250
6:23.5	680	6	3	14.2	10.16	8.81	638,370
6:20	480	6	3	10.0	7.07	7.98	391,000
6:15	600	6	3	11.5	7.19	7.36	457,200
6:10	600	6	3	9.8	7.69	7.53	384,200
6:05	820	6	0.8	2.5	2.42	2.84	92,400
6:00	1160	6	0.8	6.8	4.94	2.62	452,480
8:40	1100	6	0.8	8.2	5.71	4.06	566,040
8:35	600	6	0.8	5.7	3.75	2.22	222,000
8:30	540	6	2	3.0	0.86	2.68	96,720
8:27	680	6	2	4.0	3.52	2.47	145,600
8:20	820	6	2	4.1	3.90	2.22	249,480
8:15	700	6	2	1.0	4.07	1.53	37,800
8:10	700	6	2	0.7	0.49	0.57	20,700
8:05	640	6	2	0.5	1.03	0.21	12,000
8:00	460	6	2	0.2	0.00	0.56	3,120
17:50	500	6	2	0.0	0.00	0.21	0
17:45	600	6	1	+1.5	+0.34	+0.70	--
17:40	740	6	1	0.8	0.55	0.35	22,500
17:35	860	6	1	0.6	0.73	0.28	20,800
16:27	700	6	1	4.7	3.93	2.30	127,300

-Continued-

Analysis Reach	Shore-line Length (Ft.)	Annual Recession Rates (Ft/yr)					Annual Volume of Material Loss (Ft^3/yr)[b]
		Schneider et al Short Term[a] (10-15 yrs)	Schneider et al Long Term[a] (110 yrs)	Keillor and DeGroot (1968-1971 to 1975)	SEWRPC (1975 to 1980)	SEWRPC (1963 to 1980)	
16:25	510	6	1	3.4	3.42	2.16	65,170
16:20	680	6	1	1.5	1.00	1.42	45,600
16:15	740	6	2	3.3	2.01	1.26	88,400
16:10	800	4	2	4.3	2.13	3.29	121,600
16:05	780	4	2	1.4	1.11	1.84	24,000
16:00	450	4	2	0.1	0.94	0.59	780
21:50	480	4	2	0.0	0.00	0.46	0
21:45	740	4	2	0.4	0.77	0.45	7,200
21:40	1100	4	2	+0.2	+0.07	+0.50	--
22:30	1100	4	2	0.7	0.95	0.36	42,000
22:25	840	3	2	0.1	0.66	0.15	3,200
22:20	800	3	0.9	0.4	0.97	0.38	21,600
22:15	780	3	0.9	0.7	0.84	0.50	--
22:10	630	3	0.9	+0.8	+0.29	0.17	--
22:05	640	3	0.9	0.0	+0.51	0.33	0
22:00	500	3	0.9	1.6	1.16	0.99	21,500
27:50	490	3	0.9	+0.6	0.87	0.36	--
27:45	630	3	0.9	3.8	2.69	0.52	23,040
27:40	560	4	0.9	1.0	0.72	1.71	5,000
27:35	820	4	0.9	1.3	1.34	1.98	13,500
27:30	480	4	0.9	0.1	0.51	0.06	500
27:27	980	4	0.9	+0.1	0.39	0.15	--
27:25	530	4	1	0.2	0.00	0.48	--
27:20	690	4	1	+0.5	+0.67	+0.02	--
27:15	700	4	1	+0.2	+0.69	+0.04	--
27:10	680	4	1	1.4	1.18	0.44	84,000
27:05	600	4	1	+0.4	+0.67	+2.30	--
27:00	480	3	1	+0.3	0.44	0.59	0
33:50	490	3	1	+0.9	+0.68	+0.42	--
33:45	630	3	3	1.2	0.55	0.71	25,200

-Continued-

Analysis Reach	Shore-line Length (Ft.)	Annual Recession Rates (Ft/yr)					Annual Volume of Material Loss (Ft^3/yr)[b]
		Schneider et al Short Term[a] (10-15 yrs)	Schneider et al Long Term[a] (110 yrs)	Keillor and DeGroot (1968-1971 to 1975)	SEWRPC (1975 to 1980)	SEWRPC (1963 to 1980)	
33:40	930	3	3	+0.8	0.34	+0.10	--
33:30	730	4	3	0.4	0.25	0.26	8,000
33:27	280	4	3	+2.1	+2.66	0.01	--
33:25	380	4	3	1.6	0.79	1.45	36,000
33:20	530	4	1	+0.5	+0.43	0.14	--
33:15	520	4	1	5.6	5.12	0.42	171,000
33:10	530	4	1	+0.8	0.87	+0.32	--
33:05	530	4	1	0.7	0.71	0.41	16,800
33:00	510	4	1	1.4	0.96	0.33	30,460
4:50	490	4	1	+0.8	0.18	0.00	--
4:45	530	4	1	0.0	0.00	0.19	0
4:40	540	4	1	0.6	0.06	+0.01	13,500
4:35	520	4	1	+0.4	+1.20	+0.14	--
4:30	410	4	1	0.1	0.88	0.50	2,730
4:27	260	9	5	1.0	1.03	0.68	10,500
4:25	360	9	5	0.1	0.00	+0.86	2,400
4:20	520	9	5	+0.1	+0.30	+0.48	--
4:15	520	9	5	0.0	0.24	0.00	0
4:10	530	9	5	0.1	+0.27	0.16	2,000
4:05	530	9	5	0.2	0.92	0.28	4,000
4:00	440	9	5	0.0	0.00	0.00	0
9:50	430	9	5	0.4	0.62	0.30	10,240
9:45	380	9	5	+0.2	+0.75	+0.18	--
28:15	460	1	2	2.2	3.13	3.18	36,400
28:20	540	1	4	0.3	0.53	1.78	7,200
28:24	400	1	4	1.8	2.22	2.13	29,400
28:27	280	1	4	0.2	0.00	0.35	3,000
28:29	410	1	4	0.6	1.60	0.57	15,120
28:34	490	1	4	+0.4	+0.37	+0.56	--
29:15	480	7	4	2.4	1.36	1.28	69,000

-Continued-

Analysis Reach	Shoreline Length (Ft.)	Annual Recession Rates (Ft/yr)					Annual Volume of Material Loss (Ft^3/yr)[b]
		Schneider et al Short Term[a] (10-15 yrs)	Schneider et al Long Term[a] (110 yrs)	Keillor and DeGroot (1968-1971 to 1975)	SEWRPC (1975 to 1980)	SEWRPC (1963 to 1980)	
29:10	560	7	4	+3.1	+2.82	0.47	--
29:05	700	7	2	1.2	0.62	1.39	33,280
32:50	860	7	2	1.8	1.24	2.33	45,700
32:45	550	7	2	1.2	1.58	1.38	26,600
32:40	570	7	2	4.6	4.45	2.74	93,500
32:35	560	7	2	0.7	1.19	2.56	12,800
32:30	460	7	2	2.7	2.50	2.75	31,500
32:27	280	7	3	0.6	0.41	0.41	5,100
32:25	400	7	3	0.3	0.83	0.53	4,200
32:20	550	7	3	0.1	+0.10	0.37	2,250
32:15	540	7	3	+0.4	+0.53	+0.68	--
32:10	530	7	3	1.6	2.21	2.49	36,000
32:05	520	7	3	0.8	0.72	1.59	15,200
32:00	260	7	3	1.5	1.91	2.25	14,250
Shoreline Length-Weighted Mean[c]		5.02	2.07	2.53	2.09	1.68	--

[a] It should be noted that Schneider et al recession rates shown exclude the portion of the City of Racine and the northernmost 1,300 feet of the Town of Caledonia shoreline, which were not measured in the other studies.

[b] As estimated by Keillor and DeGroot, (1978).

[c] Not including reaches which experience accretion, as shown by a (+) in the table.

Source: SEWRPC

Figure 4

MEASURED BLUFF RECESSION RATES ALONG THE
RACINE COUNTY LAKE MICHIGAN SHORELINE

high exposed bluffs located in that Section would be the most susceptible to the increased wave attack generated during the high Lake level period which occurred during the Keillor-DeGroot study.

A summary of measured recession rates and associated shoreline lengths and the volume of material loss to erosion is shown in Table 11. None of the Schneider recession rates were less than 0.5 foot per year; however, about 44 percent of shoreline as measured by Keillor-DeGroot, about 34 percent of the shoreline as measured by the Commission from 1975 through 1980, and about 51 percent of the shoreline as measured by the Commission from 1963 through 1980 had either accretion or a recession rate equal to or less than 0.5 foot per year. On the other hand, about 48 percent of the shoreline as measured by Schneider on a short-term basis exhibited a recession rate exceedomg five feet per year. None of the Schneider long-term rates, and only about 12 percent of the shoreline measured by Keillor-DeGroot, 9 percent of the shoreline measured by the Commission for 1975 through 1980, and 6 percent of the shoreline measured by the Commission for 1963 through 1980 exceeded five feet per year. It should be noted that according to Keillor and DeGroot, although only 12 percent of the shoreline exhibits a recession rate exceeding five feet per year, that 12 percent of the shoreline accounts for about 66 percent of the total bluff material loss in the County.

These significant levels of bluff recession pose serious problems for both developed and undeveloped portions of the Racine County coastline. Some of the most severe erosion hazards in the coastal area are highlighted below:

1. Lake Park Neighborhood--Town of Mt. Pleasant: Bluff erosion poses a threat to public and private property in the Lake Park neighborhood in the Town of Mt. Pleasant, including several residences; a town park and associated fire station; and street ends, including Larson Street, Kenilworth Avenue, Graceland Avenue, Rosalind Avenue, Bryn Mawr Avenue, and Derby Avenue. The Town has had difficulty funding the improvements required to stabilize this area.

2. City of Racine: Two reaches have been identified as particularly subject to shoreline erosion in the City of Racine. One is the coastal

Table 11

SUMMARY OF BLUFF RECESSION RATES AND VOLUME OF MATERIAL LOSS
ALONG THE RACINE COUNTY LAKE MICHIGAN SHORELINE

Recession Rate (feet per year)	Shoreline Extent: Schneider et al. short term[a] (10-15 years)		Schneider et al. long term[a] (110 years)		Keillor and DeGroot (1968-1971 to 1975)		SEWRPC (1975 to 1980)		SEWRPC (1963 - 1980)		Annual Volume of Material Loss[b]	
	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total	Shoreline Length (feet)	Percent of Total	(square feet per year)	Percent of Total
Accretion	0	0.0	0	0.0	12,530	21.6	11,280	19.4	8,990	15.5	--	--
0.0 - 0.50	0	0.0	0	0.0	12,810	22.0	8,300	14.3	20,560	35.4	96,320	1.5
0.51 - 2.00	2,580	4.5	40,590	69.8	17,040	29.3	21,970	37.7	12,590	21.6	733,000	11.5
2.01 - 5.00	27,870	47.9	17,560	30.2	8,670	14.9	11,260	19.4	12,290	21.1	1,356,310	21.3
5.01 - 15.00	27,700	47.6	0	0.0	7,100	12.2	5,340	9.2	3,720	6.4	4,196,740	65.7
Total	58,150	100.0	58,150	100.0	58,150	100.0	58,150	100.0	58,150	100.0	6,382,370	100.0

[a]It should be noted that the Schneider et. al. recession rates shown exclude the portion of the City of Racine and the northern-most 1,300 feet of the Town of Caledonia shoreline, which were not measured in the other studies.

[b]As estimated by Keillor and DeGroot (1978).

Source: SEWRPC.

reach between William Street and Augusta Street, north of the City of Racine Zoo. The City has applied for U.S. Army Corps of Engineers assistance in installing shoreline protection measures along this reach. The second is a reach extending from 14th Street to a point south of 16th Street--the erosion problems here being associated with a gap in the harbor breakwater to the east. Erosion problems in this area are presently under study by the City. The installation of shoreline protection structures here is contingent upon city acquisition of riparian rights associated with private property immediately south of 16th Street.

3. Town of Caledonia: As previously indicated, the highest recession rates in Racine County in the recent past have been observed in Section 6 of the Town of Caledonia. This area includes the Town of Caledonia Lake Michigan Park, the Crestview Subdivision, Cliffside County Park, the National Guard target range, and private open space land. With respect to property damage, the most imminent problem is the threat posed by bluff recessing to Lakeshore Drive, to associated utility lines, and, ultimately, to residences within the Crestview Subdivision. Bluff recession, if not controlled, would also decrease the area of Cliffside Park and erode the undeveloped open space lands to the north. Other significant areas of bluff recession exist outside of Section 6; for instance, the road end of Five and One-Half Mile Road is severely eroded.

The severity of the problem in the northern part of the Town of Caledonia has been attributed to a variety of interrelated factors. The most important factors, not necessarily in the order of importance, are the following:

1) high lake level;
2) narrow beaches, which are a direct consequence of high lake level;
3) absence of shore protection structures, such as groins, revetments, and seawalls;
4) constant, or at least repeated, attack on the toe of the bluff by waves, due to both narrow beaches and general absence of protective structures;

5) northwest, southeast orientation of the coast and its general concavity to the northeast, which makes it particularly vulnerable to the ravages of winter storm waves from the northeast;
6) steep and high bluffs, which are susceptible to rapid failure by debris fall and debris slide when undercut by wave action at the toe;
7) high content of fine-grain constituents (that is, silt and clay) in the bluff sediments, which when wet are susceptible to failure by slump and flow processes;
8) presence of coarser-grained and more permeable layers in the bluff sediments, through which water can move laterally and emerge at the bluff face in the form of seeps; and
9) location of the reach (especially the northern part) just to the south of the Wisconsin Electric Power Company Oak Creek power plant and its massive groin-like structure that interrupts the north-south longshore current, thereby trapping littoral material to the north and resulting in sediment starvation of the beach area to the south.

SUMMARY

This chapter presents an inventory of certain elements of the natural resource base relevant to coastal erosion, summarizes existing land use and zoning patterns, and sets forth information specific to coastal erosion in Racine County. This information is necessary for the delineation of high-risk erosion areas and for the development of land use regulations based on predicted future coastal erosion rates.

Natural resource data on geology, soils, bluff and beach characteristics, surface water resources, groundwater resources, and climate are presented. The Racine County shoreline is underlain by Precambrian, Cambrian, Ordivician, and Silurian aged bedrock comprised primarily of dolomite, shale, sandstone, and crystalline rock. The bedrock is covered by unconsolidated glacial deposits which range up to 300 feet in thickness. Glacial till deposited by glacial ice is one of the most predominant materials comprising the eroding bluff faces along the County's Lake Michigan shoreline.

Soil properties influence the rate of stormwater runoff and the severity of surface erosion. About 28 percent of the coastal erosion study area is covered by well- or moderately-drained soils which generate relatively small amounts of runoff. About 55 percent of the study area is covered by poorly-drained soils and the remaining 17 percent of the area is covered by man-made features.

Bluff heights along the shoreline range up to over 80 feet. Over one half of the shoreline has bluffs ranging from 20 through 40 feet in height. Slightly under 10 percent of the shoreline has bluffs less than 10 feet in height. The most common bluff composition material is till, which is present in about 90 percent of the bluffs. Other common bluff materials are silt and clay, sand, and gravel. About one third of the bluff faces were either covered or inaccessible.

The most common beach materials are sand and gravel, cobbles, pebbles. The most extensive beaches, ranging from 76 through 125 feet in width, are comprised of sand. About 22 percent of the shoreline has a beach width ranging from one through ten feet; about 25 percent of the shoreline has a beach width ranging from 11 through 30 feet; about 15 percent of the shoreline has a beach width ranging from 31 through 75 feet; and about 6 percent of the shoreline has a beach greater than 75 feet wide. About 32 percent of the shoreline has no defined beach.

The Lake Michigan shoreline extends 14.8 miles in length within Racine County. The coastal erosion study area contains 1.6 miles of perennial streams and 5.1 miles of intermittent streams. Bluff erosion along the Racine County coast contributes nearly eight times as much sediment to the Lake as is transported by the Root River at the City of Racine.

Along the Racine County shoreline, groundwater generally flows towards Lake Michigan. Three major aquifers underlie the coastal area; the deep sandstone aquifer, the Niagara dolomite aquifer, and the shallow sand and gravel aquifer. Numerous groundwater discharges and seepages occur from the bluff slopes, contributing to the instability of these slopes.

Climate impacts on coastal erosion include freeze-thaw actions within bluff material, high surface runoff from frozen soils, Lake ice effects, and high surface runoff and soil erosion during intense storm events. Frozen ground and snow cover is expected throughout approximately four months each winter season. About 13 percent of the annual precipitation occurs as snowfall and sleet. Lake ice formation begins in late November or December and ice breakup normally occurs in late March or early April.

The study area encompasses a total of 2,552 acres, of which about 1,429 acres, or 56 percent, was devoted to urban land uses in 1980. About half of the urban land area was in residential use.

Zoning ordinances are important land use regulations which are presently in effect in the City of Racine, the Villages of North Bay and Wind Point, and the Town of Mt. Pleasant. The Town of Caledonia has adopted the Racine County zoning ordinance. About 91 percent of the coastal erosion study area has been placed in zoning districts which permit intensive urban development. Such districts cover 13.6 linear miles, or 95 percent of the total Lake Michigan shoreline in Racine County.

Bluff erosion may occur as toe erosion, slumping, sliding, flow, surface erosion, and solifluction. Slope failure is often an unpredictable, abrupt process which is constantly being altered by numerous factors. Factors affecting bluff erosion include the physical characteristics of the bluff and beach, wave action at the bluff toe, lake water level fluctuations, ice formation, groundwater seepage, surface runoff, and vegetative cover.

Shoreland development and activities are regulated by federal, state, and local agencies and units of government. The U.S. Department of the Army, Corps of Engineers is the primary federal agency responsible for certain structures, dredging, and wetland protection. The Wisconsin Department of Natural Resources regulates various shoreland activities, including shore protection structures. A County shoreland zoning ordinance requires County review and approval of virtually all man-made alterations within a specified distance from the shore. Comprehensive zoning ordinances of the City of Racine, the Villages of North Bay and Wind Point, and the Town of Mt. Pleasant

regulate land uses within the shoreland area, but are generally devoid of provisions pertaining to Lake Michigan shoreline erosion hazards.

An inventory of shore protection structures indicated that a variety of structures, including bulkheads, revetments, breakwaters, and groins, have been installed along the Racine County coast to provide an artificial protective barrier against direct wave and ice damage, to increase the extent of the beach, to dissipate offshore wave energy, and to stabilize bluff slopes. However, these costly measures, installed by both private shoreline property owners and by public agencies, have had varying degrees of success. An inventory of 216 shore protection structures indicated that while most structures were effective and functional, nearly 75 percent of all structures exhibited some type of failure. About 30 percent of all structures were failing overall, or nonfunctional. Causes of failure include overtopping, where the water level, or waves exceeded the top of the structure; flanking, where the sides of the structure were eroded; collapsing; and faulty design and selection of materials.

The most important Lake Michigan coastal erosion problem in Racine County is recession of the bluffs. Bluff recession threatens human safety, private residences, commercial buildings, streets, parkland, and open natural areas. The rate of bluff recession has been documented in several previous studies. In particular, studies by Schneider et al., and Keillor and DeGroot have presented detailed bluff recession rates. In order to verify and update the previously measured bluff recession rates, the Regional Planning Commission measured bluff recession rates at the specific Keillor-DeGroot measurements sites for the period of 1975 through 1980--which was generally after the Keillor-DeGroot study period--and for the period of 1963 through 1980--which included the Keillor-DeGroot study period. These updated bluff recession measurement results by the Commission were similar to, and verified, the Keillor-DeGroot results.

Over the period of 1963 through 1980, slightly over half of the Racine County shoreline, as measured by the Commission, had either accretion of the bluffs or a recession rate equal to or less than 0.5 foot per year. About 6 percent of the shoreline exceeded five feet per year in bluff recession. The highest recession rate measured by the Commission over the period of 1963 through 1980

was 8.8 feet per year, which occurred in the Town of Caledonia, Township 4 North, Range 23 East, Section 6. The mean recession rate was 1.7 feet per year. Significant bluff recession problems within the Lake Park neighborhood, Town of Mt. Pleasant, the City of Racine, and the Town of Caledonia are described in this chapter.

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RACINE COUNTY COASTAL EROSION MANAGEMENT STUDY

Chapter IV

EVALUATION OF COASTAL EROSION

INTRODUCTION

Shoreline erosion and bluff recession along Lake Michigan is a natural phenomenon which is causing substantial losses of shoreland area in portions of Racine County. The identification of the shoreland areas which are expected to continue to be affected by shoreline erosion and bluff recession is an important basis for any public information and public land use regulatory measures designed to properly relate urban development and redevelopment along the shoreline to anticipated shoreline erosion and bluff recession. Increased public awareness--combined with land use controls and structural erosion control measures--comprise the essential elements of any comprehensive coastal erosion management program. The purpose of this chapter is to describe the extent of shoreland erosion and bluff recession which may be expected to occur over time along the Lake Michigan shoreline of Racine County; to identify erosion risk setback distances; and to identify the potential property losses which may result from continued shoreline erosion and bluff recession. The identification of high erosion risk areas is intended to provide information which will enable public officials and private property owners to better assess potential erosion losses and agree upon the management measures recommended in Chapter V of this report.

The first section of this chapter following this introduction describes the analytic procedures and criteria used for identifying and mapping the erosion risk setback distances. The second section describes the erosion risk setback distances as identified under alternative time periods, assuming that structural shore protection measures are not implemented. The third section describes the erosion risk setback distances, assuming that structural shore protection measures are implemented along certain reaches of the shoreline. A fourth and final section summarizes the chapter.

ANALYTIC PROCEDURES AND CRITERIA

The delineation of high erosion risk areas involves the prediction--based on analyses of existing and historic conditions and of the pertinent physical characteristics of the shoreline set forth in Chapter III--of future bluff recession rates under both nonstructural and structural shoreland protection measures. The basic information used in the preparation of the maps showing the erosion risk setback distances includes the Racine County cadastre file, the bluff recession rates developed by the Regional Planning Commission from historic data for the period of 1963 through 1980, and the shoreland development standards developed by the Racine County Technical Subcommittee on Shoreland Development Standards. The erosion risk setback distances were verified by comparing predicted erosion problem areas to observations reported under the Racine County Coastwatch Program.

Erosion risk setback distances were identified under both assumed nonstructural and structural management alternatives using methods developed under the study to calculate desirable setback requirements. Assumptions concerning the type of management measures to be applied to each reach of shoreland were based on the collective judgement of the Technical Subcommittee on Shoreland Development Standards. The Subcommittee concluded that for the reach of the Racine County shoreline lying north of the southern boundary of Cliffside Park, structural control measures are generally not warranted, and, in most cases, only nonstructural control measures should be implemented. Accordingly, for this reach of shoreline the erosion risk setback distances were delineated assuming only nonstructural measures would be implemented. For that reach of the County shoreline lying south of the southern boundary of Cliffside Park, the Subcommittee concluded that structural control measures--in addition to nonstructural measures--should be considered. Accordingly, the erosion risk setback distances were delineated along this reach under two sets of conditions --one condition assuming the implementation of structural shore protection measures to reduce erosion, and one condition assuming the use of nonstructural measures only. Two reaches of shoreline were treated as exceptions to these general assumptions. These two reaches were: 1) the shoreline within the City of Racine, where major structural protection systems are in place; and 2) the extreme northern shoreline of the Town of Caledonia, which is

covered by fly ash deposits. For these two reaches the erosion risk setback distances should be delineated assuming that structural erosion control measures would be utilized.

Nonstructural Erosion Control Alterantives

A procedure was developed for delineating the erosion risk setback distances from the bluff edge assuming the use of nonstructural erosion control measures only. Except for the two reaches where only structural control measures are considered viable, as noted above, the erosion risk setback distances were delineated for a 25-year, 50-year, and 75-year period of continued bluff recession along the entire shoreline within the County under the assumption that additional structural protection measures will not be implemented. The bluff recession rates used for the delineation were calculated at 101 sites for the period from 1963 through 1980. The 101 sites are the same as those used by Keillor and DeGroot[17]. The bluff recession rates so calculated were compared for consistency to the rates calculated for the period from 1968 through 1975 by Keillor and DeGroot. The comparative data are provided in Chapter III of this report. During the 1963 through 1980 period, the elevation of Lake Michigan ranged from record lows to near record highs, thus providing a full range of lake level conditions. In calculating the desirable setback distance, the face of the bluffs was assumed to be graded to a stable slope of approximately one on two and one half, or about 22°. This assumption concerning the bluff slope is discussed further below. An additional minimum building setback distance as described below was then added to obtain a total nonstructural erosion risk setback distance. Under this procedure the erosion risk setback distance was thus established as the sum of the calculated bluff recession distance, the distance necessary to establish a stable slope, and an additional minimum building setback distance. This procedure is graphically summarized in Figure 5.

Structural Erosion Control Alternative

A procedure was also developed for delineating the erosion risk setback distances from the bluff edge assuming the use of structural shore protection

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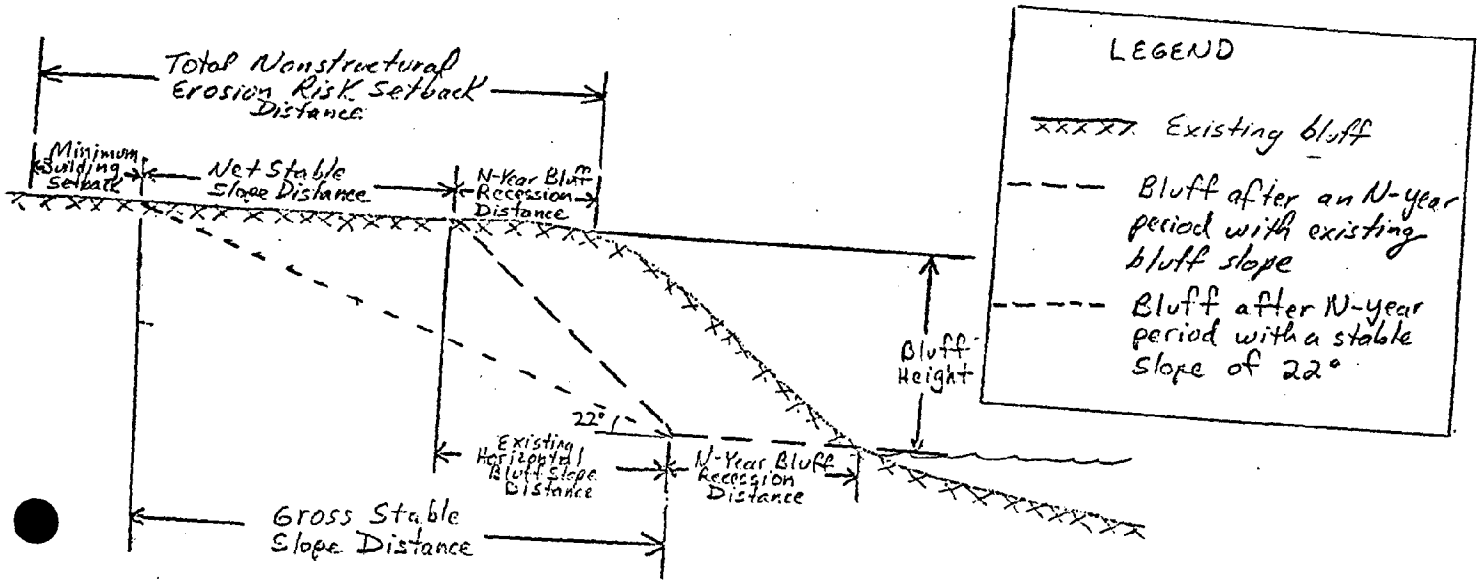
[17] J.P. Keillor and R. DeGroot, Recent Recession of Lake Michigan Shorelines in Racine County, Wisconsin, Volume 1, "Text", and Volume 2, "Appendix". 1978.

Figure 5

GRAPHICAL ILLUSTRATION OF PROCEDURES UTILIZED TO ESTIMATE HIGH EROSION RISK AREAS AND SETBACK DISTANCES WHERE NONSTRUCTURAL ALTERNATIVES ARE CONSIDERED



Total Nonstructural Erosion Risk Setback Distance = N-year Bluff Recession Distance + Net Stable Slope Distance + Minimum Building Setback Distance

where:

Net Stable Slope Distance = Gross Stable Slope Distance − Existing Horizontal Bluff Slope Distance

Gross Stable Slope Distance = $\frac{\text{Bluff Height}}{\tan 22°} = \frac{\text{Bluff Height}}{0.4}$

Minimum Building Setback Distance = 50-100 feet from bluff edge for single-family residences, public utilities, recreational facilities, and existing water-oriented commercial uses, and 200 feet from bluff edge for all other structure types

NOTE: The shoreland area contained within the total nonstructural erosion risk setback distance is referred to as the nonstructural erosion risk area. This area applies to all shoreland reaches not protected by properly designed, constructed, and maintained shore protection structures.

Source: SEWRPC

measures. A setback distance and the anticipated bluff location, assuming structural shore protective measures are properly designed, constructed, and maintained, was developed for use within those reaches of shoreline located south of the southern boundary of Cliffside Park--including the existing protected shoreline of the City of Racine--and the extreme northern shoreline of the Town of Caledonia, which is covered by fly ash deposits.

In the reaches assumed to be potentially provided with structural protection measures, the rate of bluff recession was assumed to be zero once the structural measures were in place. A erosion risk setback distance was delineated based upon the distance required to form a stable bluff slope of one on two and one half, or about 22°. An additional minimum building setback and drainage easement distance as described below was then added to the boundary of the erosion risk area to obtain a total structural erosion risk setback distance. This procedure is graphically summarized in Figure 6.

Stable Slope Angles

The use of an ultimate stable bluff slope of one on two and one half was recommended by the County Technical Subcommittee on Shoreland Development Standards[18]. This slope was similar to stable slopes along the Lake Michigan bluffs reported by Edil and Vallejo[19]. Another report by Vallejo and Edil[20] noted that, given certain physical soil characteristics, the ultimate stable slope may be expected to vary in relation to the height of the groundwater level, measured from the base of the bluff, relative to the height of the bluff. For the Racine County shoreline, the ultimate stable slopes may be expected to range from a minimum of 16°, if the height of the groundwater was

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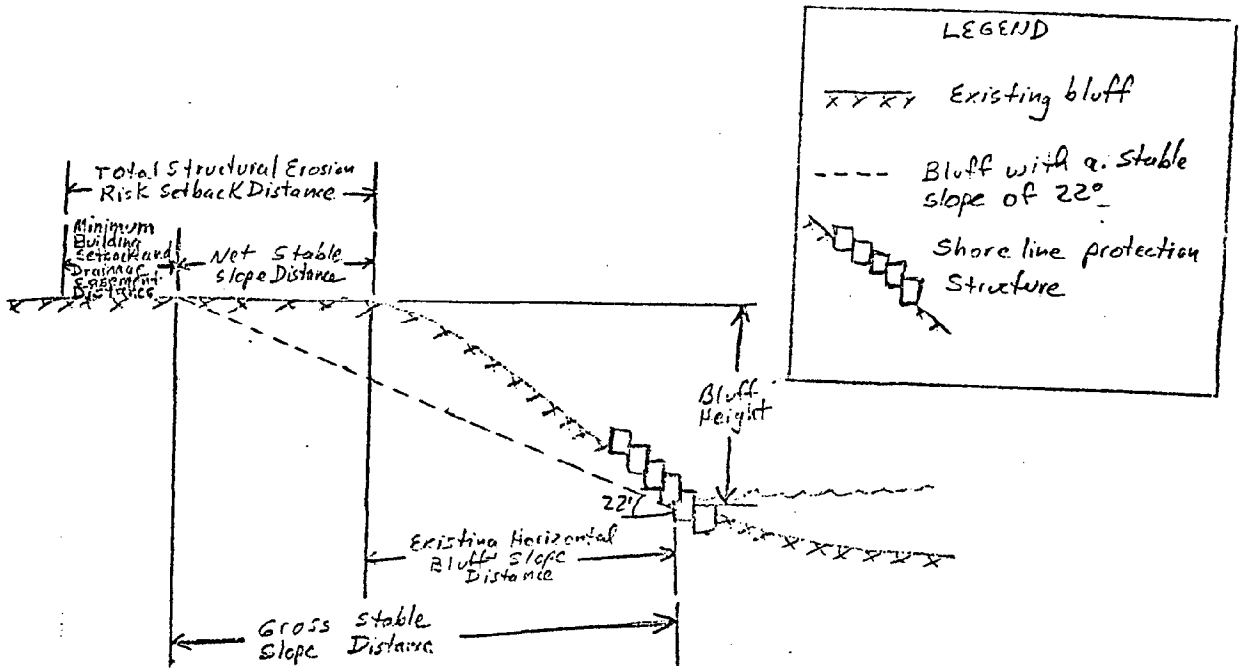
[18] Racine County Technical Subcommittee on Shoreland Development Standards, Recommendations of the Racine County Technical Subcommittee on Shoreland Development Standards to the Racine County Land Use Committee, June 15, 1982. Draft.

[19] T.B. Edil and L.E. Vallejo, "Mechanics of Coastal Landslides and the Influence of Slope Parameters", Engineering Geology, Volume 16, 1980. pp. 83-96.

[20] L.E. Vallejo and T.B. Edil, "Design Charts for Development and Stability of Evolving Slopes", Journal of Civil Engineering Design, Volume 1, No. 3, 1979, pp. 231-252.

Figure 6

GRAPHICAL ILLUSTRATION OF PROCEDURES UTILIZED TO ESTIMATE HIGH EROSION RISK AREAS AND SETBACK DISTANCES WHERE STRUCTURAL ALTERNATIVES ARE CONSIDERED



Total Structural Erosion Risk Setback Distance = Net Stable Slope Distance + Minimum Building Setback Distance

where:

Net Stable Slope Distance = Gross Stable Slope Distance − Existing Horizontal Bluff Slope Distance

Gross Stable Slope Distance = $\frac{\text{Bluff Height}}{\tan 22°} = \frac{\text{Bluff Height}}{0.4}$

Minimum Building Setback and Drainage Easement Distance = 50-100 feet from bluff edge for single-family residences, public utilities, recreational facilities, and existing water oriented commercial uses, and 200 feet from bluff edge for all other structure types.

NOTE: The shoreland area contained within the total structural erosion risk setback distance is referred to as the structural erosion risk area. This area applies to all shoreland reaches protected by properly designed, constructed, and maintained shore protection structures.

Source: SEWRPC

three fourths or more of the height of the bluff, to a minimum of 30°, if no groundwater was contained within the bluff. This information could be used to develop differing stable slopes along the shoreline. However, this refinement in the calculation of stable slopes for specific reaches of the shoreline was not applied in this study because:

1. Groundwater levels, and specifically seepage zones, are highly variable on a seasonal and annual basis.

2. Groundwater seepage zones have been identified at only a relatively select few sites along the county coast.

3. Within the Racne County bluffs, the overall piezometric surface of the groundwater is beneath the bluffs. Within the bluffs, only localized seepage zones, or seasonally high groundwater levels exist. Thus, different stable slopes would exist for different portions of the same bluff.

4. Groundwater conditions can change significantly as the bluff recedes and strata of permeable bluff materials are eroded, covered, or disturbed.

Therefore, a stable slope angle of one on two and one-half, or approximately 22°, is used in this study for the coastal reaches evaluated. This stable slope angle represents the approximate average of stable slopes expected under a full range of groundwater conditions.

EROSION RISK SETBACK DISTANCES CONSIDERING NONSTRUCTURAL CONTROL MEASURES

The delineation of the nonstructural erosion risk setback distances identifies the shoreland areas of Racine County that may be expected to be affected by shoreline erosion and bluff recession over time. With the use of the County cadastre file and attendant cadastral maps, erosion risk setback distances can be determined for individual parcels of land.

Table 12 indicates, for each coastal erosion analysis reach, the distance the top of the bluff may be expected to recede over a 25-, 50-, and 75-year period. These distances were determined by multiplying the average annual recession rates established for the period of 1963 through 1980 by the period of recession being evaluated. The table also indicates the gross stable slope distances, assuming a slope of one on two and one half. Since most bluff slopes are not vertical, the existing horizontal distance of the bluff slope was subtracted from the gross horizontal stable slope distance to estimate the net stable slope distance, or the additional horizontal distance the top of the bluff would need to recede, or be regraded, to form a stable slope. In Table 12, the bluff recession distance--determined from historic measured rates of recession--and the net stable slope distance are added to a minimum building setback distance to establish the total nonstructural erosion risk setback distance for a 25-, 50-, and 75-year period of time.

Areas within the nonstructural erosion risk setback distances are shown on 1 inch = 400 feet large scale topographic maps in Maps 9 through 22 contained in the back of this report. The maps show the 25-, 50-, and 75-year erosion risk setback distances. Real property boundaries, as described in the County cadastre file, are also shown on the maps. Finally, the coastal erosion analysis reaches are shown on the maps so that the user may determine the bluff recession rate used at any site, as well as the bluff height.

The land area and number of existing structures contained within the 25-, 50-, and 75-year erosion risk areas as delineated on Maps 9 through 22 are set forth in Table 13. The 25-year bluff recession distance and stable slope distance--excluding the minimum setback distance--contains approximately 137 acres of land, or about 5 percent of the coastal erosion study area. One hundred and one structures lie in whole or in part within the 25-year risk distance. About 185 acres of land, or about 7 percent of the study area, and 122 structures lie in whole or in part within the 50-year erosion risk setback distance. About 227 acres of land, or about 9 percent of the study area, and 139 structures lie in whole or in part within the 75-year risk setback distance.

H0116-G

Table 12

PREDICTED BLUFF RECESSION DISTANCES FOR THE
RACINE COUNTY SHORELINE OF LAKE MICHIGAN

Coastal Erosion Analysis Reach	Recession Distance[a] (feet) 25 yr.	50 yr.	75 yr.	Bluff Height	Gross Horizontal Stable Slope Distance[b] (feet)	Existing Horizontal Slope Distance (feet)	Net Horizontal Stable Slope Distance[c] (feet)	Total Recession Distance[d] (feet) 25 yr.	50 yr.	75 yr.
6:41	108	195	283	60	150	95	55	163	250	338
6:39	59	107	155	72	180	88	92	151	199	247
6:37	177	320	462	80	200	35	165	342	485	628
6:35	164	296	428	80	200	60	140	304	436	568
6:33	93	168	243	70	175	60	115	208	283	358
6:31	205	370	535	80	200	90	110	315	480	645
6:29	235	424	614	100	250	110	140	375	564	754
6:23	273	493	714	82	205	106	99	372	592	813
6:20	247	447	646	80	200	80	120	367	567	766
6:15	228	412	596	72	180	110	70	298	482	666
6:10	233	422	610	68	170	75	95	328	517	705
6:05	88	159	230	66	165	90	75	163	234	305
6:00	81	147	212	62	155	58	97	178	244	309
8:40	126	227	329	60	150	70	80	206	307	409
8:35	69	124	180	60	150	90	60	129	184	240
8:30	83	150	217	62	155	68	87	170	237	304
8:27	76	138	200	66	140	50	90	166	228	290
8:20	69	124	180	66	165	70	95	164	219	275
8:15	47	86	124	54	135	57	78	125	164	202
8:10	18	32	46	46	115	87	28	46	60	74
8:05	7	12	17	40	100	60	40	46	52	57
8:00	17	31	45	40	100	50	50	67	81	95
17:50	6	12	17	40	100	55	45	52	57	62
17:45	0	0	0	38	95	80	15	15	15	15
17:40	11	20	28	30	75	60	15	26	35	43
17:35	9	16	23	40	100	60	40	31	38	45
16:27	71	129	186	38	95	40	55	126	184	241
16:25	67	121	175	38	95	45	50	117	171	225
16:20	44	80	115	38	95	45	50	94	130	165
16:15	39	70	102	34	85	33	52	91	122	154
16:10	102	184	266	32	80	38	42	144	226	308
16:05	57	103	149	20	50	40	10	67	113	159
16:00	18	33	48	20	50	32	18	36	51	66
21:50	14	26	37	34	85	35	50	64	76	87
21:45	14	25	36	12	30	30	0	14	25	36
21:40	0	0	0	20	50	60	0	0	0	0
22:30	11	20	29	30	75	30	45	56	65	74
22.25	5	8	12	32	80	60	20	25	28	32

Table 13 (continued)

Coastal Erosion Analysis Reach	Recession Distance[a] (feet) 25 yr.	50 yr.	75 yr.	Bluff Height	Gross Horizontal Stable Slope Distance[b] (feet)	Existing Horizontal Slope Distance (feet)	Net Horizontal Stable Slope Distance[c] (feet)	Total Recession Distance[d] (feet) 25 yr.	50 yr.	75 yr.
22:20	12	21	31	32	80	72	8	20	29	36
22:15	16	28	40	28	70	33	37	52	65	78
22:10	5	10	14	24	60	40	20	25	30	34
22:05	10	18	27	20	50	28	22	32	40	49
22:00	31	55	80	14	35	26	9	40	64	89
27:50	11	20	29	8	20	0	20	31	40	49
27:45	16	29	42	8	20	0	20	36	49	62
27:40	53	96	138	10	25	0	25	78	121	164
27:35	61	111	160	10	25	0	25	86	136	185
27:30	2	3	5	10	25	0	25	27	28	30
27:27	5	8	12	16	40	20	20	25	28	32
27:25	15	27	39	18	45	25	20	35	47	59
27:20	0	0	0	24	60	30	30	30	30	30
27:15	0	0	0	26	65	28	37	37	37	37
27:10	14	25	36	30	75	28	47	61	72	83
27:05	0	0	0	24	60	38	22	22	22	22
27:00	18	33	48	22	55	35	20	38	53	68
33:50	0	0	0	20	50	40	10	10	10	10
33:45	22	40	58	28	70	30	40	62	80	98
33:40	0	0	0	20	50	30	20	20	20	20
33:30	8	14	20	20	50	40	10	18	24	30
33:27	1	1	1	28	70	45	25	25	26	26
33:25	45	81	117	30	75	38	37	82	118	154
33:20	4	8	11	28	70	58	12	16	20	23
33:15	13	24	34	30	75	28	47	60	70	81
33:10	0	0	0	30	75	40	35	35	35	35
33:05	13	23	33	32	80	37	43	56	66	76
33:00	10	18	27	34	85	28	57	67	75	84
4:50	0	0	0	34	85	30	55	55	55	55
4:45	6	11	15	38	95	30	65	71	76	80
4:40	0	0	0	30	75	60	15	15	15	15
4:35	0	0	0	38	95	60	35	35	35	35
4:30	16	28	40	42	105	61	44	59	72	84
4:27	21	38	55	42	105	50	55	76	93	110
4:25[e]	0	0	0	40	--	--	--	0	0	0
4:20[e]	0	0	0	38	--	--	--	0	0	0
4:15[e]	0	0	0	38	--	--	--	0	0	0
4:10[e]	0	0	0	40	--	--	--	0	0	0
4:05[e]	0	0	0	40	--	--	--	0	0	0
4:00[e]	0	0	0	40	--	--	--	0	0	0

Table 1-3 (continued)

Coastal Erosion Analysis Reach	Recession Distance[a] (feet) 25 yr.	50 yr.	75 yr.	Bluff Height	Gross Horizontal Stable Slope Distance[b] (feet)	Existing Horizontal Slope Distance (feet)	Net Horizontal Stable Slope Distance[c] (feet)	Total Recession Distance[d] (feet) 25 yr.	50 yr.	75 yr.
9:50[e]	0	0	0	40	--	--	--	0	0	0
9:45[e]	0	0	0	40	--	--	--	0	0	0
28:15	98	178	258	40	100	35	65	164	243	322
28:20	55	100	144	40	100	55	45	100	145	189
28:24	66	119	172	40	100	30	70	136	189	242
28:27	11	20	28	40	100	38	62	73	82	90
28:29	18	32	46	40	100	38	62	80	94	108
28:34	0	0	0	40	100	60	40	40	40	40
29:15	40	72	104	40	100	25	75	115	147	179
29:10	14	26	38	40	100	27	73	88	99	111
29:05	43	78	112	40	100	55	45	88	123	158
32:50	73	130	189	34	85	40	45	117	175	234
32:45	43	77	112	38	95	45	50	93	127	162
32:40	85	153	222	34	85	43	42	127	195	264
32:35	79	143	207	32	80	45	35	114	178	242
32:30	85	154	223	30	75	40	35	120	189	258
32:27	13	23	33	34	85	40	45	58	68	78
32:25	16	30	43	30	75	35	40	56	70	83
32:20	11	21	30	30	75	35	40	51	61	70
32:15	0	0	0	30	75	25	50	50	50	50
32:10	77	137	202	30	75	35	40	117	179	242
32:05	49	89	129	38	95	40	55	104	144	184
32:00	70	126	182	38	95	45	50	120	176	232

[a]Calculated by applying the annual recession rates measured by the Regional Planning Commission for the period of 1963 through 1980 to the recession period evaluated.

[b]Calculated by multiplying the bluff height by a factor of two and one-half.

[c]The Net Horizontal Stable Slope Distance represents the additional horizontal distance required for the bluff to attain a stable slope angle. It is calculated by subtracting the Existing Horizontal Slope Distance from the Gross Horizontal Stable Slope Distance.

[d]The Total Recession Distance is calculated by the following formula:
Recession Distance + Net Horizontal Stable Slope Distance = Total Recession Distance

[e]Slopes have been stabilized by engineering measures.

Source: SEWRPC

Table 13

LAND AREA AND NUMBER OF STRUCTURES CONTAINED
WITHIN THE 25-, 50-, AND 75-YEAR NONSTRUCTURAL EROSION
RISK SETBACK DISTANCES FOR THE RACINE COUNTY LAKE MICHIGAN SHORELINE: 1982

The potential economic losses resulting from further bluff recession may be estimated by determining the value of the land and structures located in the high erosion risk area. The potential value of land lost to bluff recession was estimated based on the assumptions[21] that land in the shoreland area suitable and proposed for intensive urban development has a value of about $20,000 per acre, and that land in the shoreland area proposed to remain in agricultural, and other open uses has a value of about $4,000 per acre.

These potential land values were then applied to the acreage that may be expected to be lost to shoreline erosion and bluff recession. The classificaton of a land parcel as developed or undeveloped is based on planned year 2000 land use patterns in the study area. The value of the structures and related improvements affected by bluff recession was determined by using the assessed valuation of the affected improvements, as set forth in the County cadastre file. These assessed valuations were factored to approximate market values, based on the published State equalized value assessment ratios for each community concerned.

The approximate value of the land and structures contained within the 25-, 50-, and 75-year erosion risk setback distances are set forth in Table ~~IV-9~~ 14. Within the 25-year erosion risk setback distance--excluding the minimum setback distance--the total economic value of land and structures is approximately $3.7 million, of which about $1.7 million, or 46 percent represents the value of the land, and about $2.0 million, or 54 percent, represents the value of the structures or improvements. The 50-year erosion risk setback distance has an approximate land and structure economic value of about $4.4 million, of which $2.1 million, or 48 percent, represents the land value and $2.3 million, or 52 percent, the structure value. Within the 75-year erosion risk setback distance, the total economic value of the land and structures is $5.0 million, of which $2.6, or about 52 percent, represents the land value and $2.4 million, or about 48 percent represents the structural improvement value. The economic values presented above do not include the value of public utilities and improvements such as streets and sewers.

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[21] These land value assumptions are based upon market value information used in SEWRPC Community Assistance Planning Report No. 80, A Lake Michigan Public Access Study for Racine County. (1982).

Table 14

ESTIMATED ECONOMIC VALUE OF LAND AND STRUCTURES CONTAINED WITHIN THE EROSION RISK SETBACK DISTANCES FOR THE RACINE COUNTY LAKE MICHIGAN SHORELINE

EROSION RISK SETBACK DISTANCES CONSIDERING STRUCTURAL CONTROL MEASURES

The erosion risk setback distance for those shoreline reaches currently protected by adequate shore protection structures, and for those reaches within which the provison of new shore protecton structures are recommended to be considered, was delineated as the distance from the existing bluff edge needed to establish a stable slope, plus a minimum building setback distance. This procedure was set forth in Figure 5.

The maintenance of existing development within the nonstructural erosion risk setback distances may require the provision of structural shoreline protection measures, or structure relocation to prevent or delay the potential loss of such development to bluff recession. Studies have indicated that the majority of structural measures installed to prevent Lake Michigan erosion have been at least partially unsuccessful[22]. Structural measures that are known to be effective require a substantial capital investment and entail a substantial maintenance cost. Proper consideration of structural alternatives and of relocation requires detailed, site specific, evaluations of the physical characteristics of the bluff and beach, the causes of erosion, the intended use of the shoreline, the degree of hazard posed by erosion, the existing investment or value of the property, and the resources which can be committed to the undertaking. In addition, the selection of structural protection measures must consider the initial cost of the structure, the availability of needed materials and expertise, and the frequency, cost, and convenience of maintenance. A description of different types of structural shoreline protection measures was provided in Chapter III. Appendix B presents an inventory of existing shoreline protection structures located along the Lake Michigan shoreline of Racine County.

The Racine County Technical Subcommittee on Shoreland Development Standards concluded that effective shoreline protection requires a combination of bluff stabilization, surface water and subsurface water control, and bluff toe

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[22] Coastal Zone Laboratory, University of Michigan, "Engineering-Economic Analysis of Shore Protection Systems: A Benefit/Cost Model." May, 1976.

protection. The Subcommittee reported that a building within a high risk area should be considered for relocation if the building can be moved by conventional methods at a cost equal to, or less than, 30 percent of the value of an equivalent building located on secure ground[23].

The Subcommittee recommended that structural shoreline protection measures should be provided if it can be shown that the measures will effectively reduce shoreline erosion and not adversely affect adjacent sections of the shoreline nor impair public rights in navigable waters; that there will be no significant reduction in public access, use, and enjoyment of the shoreline environment; and that any adverse impacts on fish and wildlife resources caused by the structure will be compensated for by providing fish and wildlife preservation measures. It was recommended that such shoreline structures should be required to protect new buildings within the 50-year erosion risk setback distance which are not readily relocatable. The Subcommittee recommended that all shoreline protection structures should meet a set of minimum criteria and be based on sound engineering design. The criteria recommended by the Subcommittee are presented in Table 15.

Map 23 identifies those portions of the Racine County shoreline developed for intensive urban uses which are most likely to benefit from certain structural shore protection measures. As shown on the map, and quantified in Table 16, about 2.1 miles of the shoreline, or about 14 percent of the total County shoreline, are most likely to require surface water drainage improvements, based on the distribution of poorly and very poorly drained soils in the study area. About 5.7 miles of shoreline, or about 38 percent of the County total, are most likely to require subsurface drainage improvements. Soils in these areas are better drained, resulting in greater water infiltration. Those shoreline areas, totaling about 2.6 miles, or about 18 percent of the County total, which are developed for intensive urban uses and are currently exhibiting a bluff recession rate in excess of one foot per

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[23]Racine County Technical Subcommittee on Shoreland Development Standards, Recommendations of the Racine County Technical Subcommittee Shoreland Develment Standards to the Racine County Land Use Committee, Draft. June 5, 1982.

Table 15

MINIMUM CRITERIA FOR SHORELINE PROTECTION STRUCTURES ADAPTED FROM CRITERIA RECOMMENDED BY THE RACINE COUNTY TECHNICAL SUBCOMMITTEE ON SHORELAND DEVELOPMENT STANDARDS[1]

Category	Criteria Required to be Met
Support Information	1. Determine lake bottom profiles offshore of proposed structure and within 300 feet on both sides of the structure from the structure out to a water depth of at least 12 feet.
	2. Locate existing and planned septic tank systems on the property to be protected and on adjacent properties, and consider the impact of the systems on bluff stability.
	3. Consider wave design height, wave directions, and the erosive impacts of wave action on the proposed structure.
Structural Design	1. Size the structure for design waves under the 100-year recurrence interval high lake level, or 581.2 feet above the National Geodetic Vertical Datum.
	2. Provide measures to protect the base of the structure against wave scouring.
	3. Design loose rubble revetment structures with a slope no greater than one on two.
	4. Avoid structural damage or erosion on the landward side of the structure by preventing the overtopping of the structure by storm waves, or by providing for the positive drainage of any water which overtops the structure.
	5. Provide measures to prevent excessive erosion along the flanks of the structure.
	6. Provide adequate bedding materials to prevent undercutting of the structure.
Bluff Stabilization	1. Regrade the bluff to a one on two and one half slope; unless detailed site-specific engineering analyses indicate that a different slope would be stable.
	2. If the groundwater level is higher than the lake level and threatens bluff stability, provide subsurface drainage facilities to intercept the groundwater, if necessary.
	3. If necessary, provide facilities for drainage of surface water runoff to prevent surface erosion and saturation of the soils in the bluff.
	4. Provide adequate vegetative cover of the bluff slope after regrading.

[1]See Racine County Technical Subcommittee on Shoreland Development Standards (1982).

Source: SEWRPC

Map 23

RACINE COUNTY SHORELINE AREAS MOST LIKELY TO BENEFIT
FROM SELECTED STRUCTURAL SHORELINE PROTECTION MEASURES

Table 16

RACINE COUNTY SHORELINE EXTENT MOST LIKELY TO BENEFIT FROM SELECTED STRUCTURAL SHORELINE PROTECTION MEASURES

year, would most likely benefit from the provision of properly designed and constructed shoreline protection structures such as groins and revetments.

Map 23 also shows which shoreline areas developed for intensive urban uses would require regrading for a distance of 50 feet or more from the top of the bluff, in order to achieve a stable slope. These shoreline areas total about ____ miles, or __ percent of the County total. It should be recognized that the specific structural protection measures required at any specific site can be determined only on the basis of detailed engineering analyses. Such structural measures should only be employed following a careful evaluation of the economic costs and benefits of nonstructural measures and of building relocation, as well as of structural alternatives. The decision to invest in a shore protection structure is influenced by a number of variables including property values, intended development, and degree of erosion.

Protective structures could be installed to substantially reduce land and structure losses in most reaches of the Lake Michigan shoreline of Racine County. Shoreline protection structures may be expected to have a capital cost ranging from $100 per foot of shoreline for temporary protection structures, to more than $300 per foot of shoreline for protection structures with a life expentancy of 25 years or more, and an annual maintenance cost ranging from $_____ to $_____ per foot of shoreline.

The capital cost of new structures of a permanent nature that could be installed at locations likely to benefit from such structures, as shown on Map 23, is estimated to be $___ million, with an annual maintenance cost of $_____. These costs can be compared to the potential property losses within the 50-year nonstructural erosion risk setback distance of $4.4 million.

SUMMARY

The identification of the shoreland areas which are expected to continue to be affected by shoreline erosion and bluff recession enables public officials and private property owners to better assess potential erosion losses and evaluate potential erosion management measures. Erosion risk setback distances were

determined under two sets of conditions--one condition assuming the implementation of structural shore protection measures, and one condition assuming the use of nonstructural measures only. Setback distances under each of these two sets of alternative conditions were determined for each of 101 coastal erosion analysis reaches along the Racine County shoreline.

Under the nonstructural erosion control alternative, the distance of continued bluff recession was determined for a 25-year, 50-year, and 75-year period, based on the annual recession rates measured for the period of 1963 through 1980 by the Regional Planning Commission. In calculating the desirable building setback distances, the face of the bluffs was assumed to be graded to a stable slope of one on two and one half, or about 22°. An additional minimum building setback distance was then added to the bluff recession distance and the stable slope distance to obtain a total nonstructural erosion risk building setback distance.

Maps 9 through 22 at the back of this report, show the erosion risk setback distances for the 25-year, 50-year, and 75-year periods. Real property boundaries, as described in the County cadastre file, are also shown on the maps. The shoreline area contained within the 25-year bluff recession distance and stable slope distance--excluding the minimum setback distance--is about 137 acres in size, or 5 percent of the study area, and contains, in whole or in part, 101 existing structures. About 185 acres, or 7 percent of the study area, and 122 structures lie within the 50-year bluff recession and stable slope distance. The 75-year bluff recession and stable slope distance contains about 227 acres, or 9 percent of the study area, and 139 structures.

Within the 25-year area affected by bluff recession or the stable slope distance--excluding the minimum setback distance, the land has a total economic value of about $1.7 million, and the structures have a value of about $2.0 million, for a total value of about $3.7 million. Fifty years of bluff recession, along with a stable slope distance would affect an area with a land value of about $2.1 million and a structure value of about $2.3 million, for a total value of about $4.4 million. Over a 75-year period, bluff recession and stable slope formation would affect an area with a land value of about $2.6 million, and a structure value of about $2.4 million, for a total value of

about $5.0 million. These values do not include the value of public utilities and improvements such as streets and sewers.

The structural erosion control alternative assumes the use of properly designed, constructed, and maintained shore protection structures. A total structural erosion risk setback distance was determined as the sum of the stable bluff slope distance--assuming a stable slope of 22°, and a minimum building setback distance.

Effective shoreline protection may require a combination of bluff stabilization, surface water and subsurface water control, and bluff toe protection. Building relocation may also be considered. Proper consideration of structural shore protection measures and of relocation requires detailed, site-specific analysis of the physical characteristics of the beach and bluff, the causes of erosion, the intended use of the shoreline, the degree of hazard posed by erosion, the existing value of the property, and the resources which can be used for the project. The Racine County Technical Subcommittee on Shoreland Development Standards recommended a set of minimum criteria to be met when designing, constructing, and maintaining shore protection structures.

Shore protection structures are most likely to be constructed to protect the existing developed urban shoreline areas. It was determined that about 5.7 miles of shoreline, or about 38 percent of the County total, are most likely to require subsurface drainage improvements and 2.1 miles of shoreline, or 14 percent of the County total, are most likely to require surface water drainage improvements. Those shoreline areas, totaling about 2.6 miles, or about 18 percent of the County total, which are developed for intensive urban land uses and are currently exhibiting a bluff recession rate in excess of one foot per year, would be most likely to benefit from the provision of shore protection structures such as groins and revetments. About ____ miles of developed shoreline, or about __ percent of the County total, would require grading for a distance of 50 feet or more from the toe of the bluff, in order to achieve a stable slope. If shore protection structures with a long-term life expectancy of 25 years or more were installed for the entire ____ miles of developed shoreline which are now protected by shore structures, or are only partially protected, it would require a capital cost of approximately $___ million, and an annual maintenance cost of about $_____.

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RACINE COUNTY COASTAL EROSION MANAGEMENT STUDY

Chapter V

RECOMMENDATIONS AND CONCLUSIONS

INTRODUCTION

The primary purpose of the Racine County coastal erosion management study is to identify high erosion risk areas along the Lake Michigan shoreline of Racine County, and to develop public informational and regulatory measures designed to guide urban development and redevelopment in proper relation to these high risk areas. The location and extent of the high erosion risk areas as delineated in Chapter IV of this report provide the primary basis for the formulation of these public informational and regulatory measures. The delineation of the high erosion risk areas prepared under this study, coupled with the findings and recommendations of companion coastal zone studies and the County Coastwatch Program, make it possible to implement new nonstructural erosion control measures, as well as to refine the need for further structural shoreline protection measures, in order to reduce shoreline erosion damages.

The first section of this chapter suggests important public informational and educational uses of the findings and recommendations of this study. The second section sets forth required changes in the County shoreland zoning ordinance to implement certain recommendations of this study, changes which could also be incorporated into local municipal ordinances as may be required. The third section describes a proposed procedure for modifying the extent of the high erosion risk areas. The fourth section describes a proposed procedure for periodically updating the delineation of the high erosion risk areas. The fifth and final section summarizes the chapter.

PUBLIC INVOLVEMENT IN COASTAL EROSION MANAGEMENT

Public involvement in the management of the Lake Michigan shoreland area of Racine County is essential to obtaining the political support required for the success of that management effort. Such involvement requires that pertinent information concerning the problems and opportunities existing in the shoreland

area be made available to interested and concerned citizens. The findings and recommendations of this study provide a valuable reference which can help to inform the general public and key interest groups about the location and extent of high erosion risk areas along the Lake Michigan shoreland, and of actions that can help to reduce that risk.

Placing findings and recommendations such as those set forth in this report before the public allows affected parties to act more judiciously and responsibly of their own accord with respect to development and redevelopment of the shoreland area--thereby relieving the burden on regulation and enforcement to some extent. The findings and recommendations set forth in this report can serve as a "fair warning" guide for, and as such a valuable service to, groups such as realtor-brokers, shoreline property owners, developers, and prospective buyers. It is crucial that groups such as these be fully cognizant of the potential problems and hazards associated with coastal shoreline development.

With the information made available through particularly the mapping element of this study, all of the directly impacted groups will have ready access to information helpful in addressing issues such as: the appropriate uses for high erosion risk areas; the need for special setbacks for buildings, special development techniques, or structural shoreline protective measures in certain areas; and in attaining better understanding by groups involved in real estate transactions of the threat of shoreline erosion to the real property being transferred. Public information and understanding also affords individuals a better opportunity to choose from an educated standpoint actions or measures which are more protective, more safe, or more compatible with the existing land uses and resource features than the minimum requirements which may be dictated by public regulations.

The projections made herein of erosion and bluff recession may be regarded by some as a potential threat to real property values, such values being related to existing and potential uses of the high erosion risk areas. It is not the study findings, however, which create a threat in this respect, but rather the forces in the natural environment which conflict with certain existing and intended uses of the land. To fail to openly and extensively communicate the risk entailed to the general public would be an irresponsible course of action by the public agencies concerned.

RECOMMENDED ORDINANCE AMENDMENTS

Racine County currently has a shoreland zoning ordinance which regulates the location of structures, and certain land uses and land management practices, within a specified distance to the Lake Michigan shoreline. These regulations can be made more effective by including provisions directly related to the erosion hazards which threaten specific reaches of the shoreline. Such a nonstructural approach to reduce the physical and economic impacts of bluff erosion constitutes one viable tool for protecting new development and redevelopment along the affected shoreline area.

Regulations can be developed which protect proposed development from excessive shoreline erosion and bluff recession risk by identifying the high erosion risk area and establishing minimum setback distances from this area, and by restricting or prohibiting the location of buildings and other land uses which are vulnerable to damages or destruction from erosion within that area. These regulations can be readily incorporated into the existing County zoning ordinance, which regulates the uses of land, the areas and dimensions of lots, and the location of structures on such lots. Zoning can also control grading, filling, vegetation removal, and certain other land management practices. To be constitutionally valid, however, regulation of the uses in high erosion risk areas must serve valid public objectives; have a reasonable basis for the classification of uses subject to the regulations; leave the property owner with some reasonable use of his property; and provide sufficient standards to prevent arbitrary decision-making.

Recommended amendments to the Racine County shoreland zoning ordinance which would regulate in the public interest land uses, activities, and structure locations within the high erosion risk area are set forth in Appendix D. The amendments include provisions defining pertinent terms; designating the lands to be regulated; specifying the necessary regulation of land use and structure location; specifying the regulation of certain land disturbance activities; and describing procedures for modifying the location and extent of the designated high erosion risk area. Such provisions with appropriate adaptation may also be incorporated into local municipal zoning ordinances. The Regional Planning Commission will, upon request, assist municipal units of government

in the incorporation of provisions related to high erosion risk areas along the Lake Michigan shoreline of Racine County into such local ordinances.

Identification of High Erosion Risk and Total Setback Distances

The total setback distance for buildings and other land uses from the top of the bluff along shoreline areas currently protected by properly designed, constructed, and maintained structural shore protection measures should be estimated for each property by the following formula, which formula is graphically illustrated in Figure 6 of Chapter IV of this report. This erosion risk setback distance should apply over the entire length of shoreline of a property.

Total Structural Erosion Risk Setback Distance = Net Stable Slope Distance + Minimum Building Setback and Drainage Easement Distance

Where: Net Stable Slope Distance = Distance Required to Achieve a 1 on 2½ Bluff Slope

This formula may also be used to determine the appropriate setback distance along shoreline areas proposed to be protected by new shoreline protection structures. The distance required to achieve a one one two and one half bluff slope is set forth for each coastal erosion analysis reach in Table 12 of Chapter IV of this report. The property boundaries, as shown on the cadastral maps, contained within each analysis reach are shown on Maps 9 through 22 enclosed at the back of this report. The minimum setback distances to be used in the formula are as follows:

- 200 feet for all structures except public utilities, public recreation facilities, and single-family residential units.

- 100 feet for public utilities, public recreation facilities, and single-family residential units, except that the minimum setback distance may be reduced to the average distance from the bluff edge of adjacent structures located within 100 feet of the proposed structure, although the minimum setback distance cannot be less than 50 feet.

A shoreline protection structure may be considered effective and properly designed if it meets the criteria established by the Racine County Technical

Subcommittee on Shoreland Development Standards, as set forth in Table 15 of Chapter IV of this report.

The high erosion risk distance for all portions of the coastline not protected by proper shore protection structures shall be the 50-year total bluff recession rate distance from the existing bluff edge, as presented in Table 12 of Chapter IV of this report, plus a net stable slope distance--as defined above, plus a minimum building setback distance--as defined above. This area defined by this distance is shown on Maps 9 through 22 for the entire County shoreline except for the protected portion of the City of Racine shoreline and the extreme northern shoreline in the Town of Caledonia, for which bluff recession rates were not determined. These maps should be used for general information purposes. The required setback distance for each property should be calculated, over the entire length of shoreline, by the following formula which is graphically illustrated in Figure 5 of Chapter IV of this report:

Total Nonstructural Erosion Risk Setback Distance	=	50-Year Bluff Recession Distance	+	Net Stable Slope Distance	+	Minimum Building Setback Distance

Property boundaries within each coastal erosion analysis reach, as set forth in the cadastre maps, are shown in Maps 9 through 22.

Prohibited, Conditional, and Permitted Uses

Within the calculated total structural and nonstructural erosion risk setback distances, all permanent structures are prohibited within the specified bluff recession distance, net stable slope distance, and appropriate minimum building setback distance. New onsite sewage disposal systems are also prohibited within the erosion risk setback distances because they contribute moisture and weight to the bluff soils which may create unstable slope conditions and because such systems are unlikely to be removed if, or when, the bluff erodes at the site, thereby contributing to pollution of the shoreline environment. Replacement of existing systems is, however, not prohibited.

The recommended amendments specify as conditional uses within the calculated erosion risk setback distances, land disturbance activities, tree cutting or other vegetation removal, the construction of structural shoreline protection

measures, and buildings and structures which can be relocated. Such conditional uses require for approval that certain specified criteria or provisions be met.

Permitted uses within the total structural and nonstructural erosion risk setback distances, unless restricted by other zoning ordinance provisions, include open space uses, storage of portable equipment and supplies, accessory buildings such as storage sheds, and minor structures such as driveways, sidewalks, patios, and fences. Permitted uses thus include the placement of structures or materials which can be readily moved prior to erosion damage, and minor structures with a relatively low economic value.

MODIFICATION OF THE TOTAL STRUCTURAL AND NONSTRUCTURAL EROSION RISK SETBACK DISTANCE

The delineation of the total structural and nonstructural erosion risk setback distances may be modified upon submittal by an applicant or property owner of acceptable engineering studies which indicate that the actual recession rate is different than that set forth in this report for the appropriate coastal erosion analysis reach, that the stable slope conditions are different than indicated herein, or that the height of the bluff is different. In addition, the erosion risk setback distance may be modified if structural shoreline protection measures and bluff stabilization measures which satisfy the criteria established by the Racine County Technical Subcommittee on Shoreland Development Standards, are constructed. Such construction is allowable as a conditonal use.

Although the provision of the required technical information is the responsibility of the landowner, various governmental agencies can supply useful maps and data. Historic recession rates for any specific shoreland parcel can be measured from aerial photographs available from the Southeastern Wisconsin Regional Planning Commission for the years 1963, 1967, 1970, 1975, and 1980, or from similar suitable information available over a relatively long time period. The bluff height at any specific parcel may be measured by a field survey, or on the large-scale topographic maps available from the Racine County Planning and Zoning Department. The evaluation of the stability of the

slope and the identification of the specific stable slope angle will, in most cases, require a field survey and technical assistance from a qualified professional geologist, soil scientist, or engineer.

PERIODIC UPDATING OF HIGH EROSION RISK AREAS

It is recommended that the total structural and nonstructural erosion risk setback distances be refined periodically to reflect changes in the bluff characteristics and to incorporate new bluff recession rates into the long-term average rate. The formulae for establishing setback distances can and should continue to be used with the new recession rates. Bluff heights should be redefined at approximately 10-year intervals, as updated large-scale topographic maps become available for the shoreline. Similarly, bluff recession rates should be re-measured, at approximately 10-year intervals, as appropriate aerial photography becomes available. The 1963 aerial photographs of the Regional Planning Commission should continue to be used as the base period for measuring recession. Updated topographic maps may also be used to refine and update bluff recession rates. A stable slope of 22° should continue to be used unless new technical studies indicate that an alternative angle is more appropriate, or where site-specific studies have indicated a stable slope different than 22°. Maps 9 through 22, provided at the back of this report, should be updated at approximately 10-year intervals, to reflect the revisions in the bluff characteristics and recession rates.

SUMMARY

This coastal erosion management study for Racine County provides a basis for developing public informational and regulatory measures designed to guide urban development and redevelopment in proper relation to the associated risk of shoreline erosion. The findings and recommendations of the study provide a valuable reference which can help to inform the general public and key interest groups about the location and extent of high erosion risk areas along the Lake Michigan shoreland, and of actions that can help to reduce that risk. Regulations can be developed which protect proposed development from excessive shoreline erosion and bluff recession risk by identifying the high erosion risk area and establishing minimum setback distances from this area, and by

restricting or prohibiting the location of buildings and other land uses which are vulnerable to damages or destruction from erosion within that area.

Recommended amendments to the Racine County shoreland zoning ordinance which would regulate land uses, activities, and structure locations within the high erosion risk setback distances are set forth in Appendix D. Such provisions may also be incorporated into local municipal zoning ordinances. The ordinance amendments designate setback distances from the existing bluff edge, within which certain uses and the placement of structures, is restricted or prohibited.

For those shoreland areas currently protected by proper shore protection structures and for those shoreland reaches not currently protected by proper shore protection structures, formulae are recommended to determine erosion risk setback distances. Within the calculated total structural and nonstructural erosion risk setback distances, all permanent structures are prohibited. New onsite sewage disposal systems are also prohibited. Conditional uses include land disturbance activities, tree cutting, the construction of structural shore protection measures, and buildings and structures which can be relocated. Permitted uses within these erosion risk setback distances include open space uses, storage of portable equipment and supplies, accessory buildings such as storage sheds, and minor structures such as driveways, sidewalks, patios, and fences.

The delineation of the erosion risk setback distances may be modified upon submittal by an applicant or property owner of acceptable engineering studies which indicate that the actual recession rate is different than that set forth in this report for the appropriate coastal erosion analysis reach, that the stable slope conditions are different than indicated herein, or that the height of the bluff is different. In addition, the erosion setback distance may be modified if proper shore protection structures are implemented. It is recommended that the erosion risk setback distance be refined at approximately 10-year intervals to reflect changes in the bluff characteristics and to incorporate new bluff recession rates into the long-term average rate.

The adoption and implementation of the recommended ordinance amendments for the Racine County shoreline of Lake Michigan would help reduce the serious and

costly shoreline erosion and bluff recession problems affecting the County shoreline. The implementation of these recommended ordinance amendments may thus be expected to provide a safer, more helthful and more pleasant, as well as more orderly and efficient, environment within the shoreland area.

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RACINE COUNTY COASTAL EROSION MANAGEMENT STUDY

Chapter VI

SUMMARY

INTRODUCTION

The erosion and recession of the coastal bluffs along the Lake Michigan shoreline of Racine County constitutes a serious loss of valuable natural resources as of real property and improvements thereto. Bluff recession rates in Racine County range up to 14 feet per year, averaging almost two feet per year along the unprotected reaches of the shoreline. This bluff recession results in the loss of approximately three acres of land each year, and 6.3 million cubic feet of shore material.

This erosion and bluff recession along the Lake Michigan shoreline of Racine County may be managed by a coordinated set of structural and nonstructural meaures which reduce shoreline erosion and the damages which result from such erosion. Structural shore protection measures include groins, breakwaters, revetments, bulkheads, piers, and surface water and groundwater drainage and control techniques. Nonstructural measures include land use regulations, building setback requirements and restriction on certain land management practices, and public acquisition of shoreland areas. Currently, shoreland development in the unincorporated portions of Racine County is regulated by the County Shoreland Zoning Ordinance. Because of the high value of shoreland resources and the varying degrees of shore erosion occurring along the coast, there is a need to establish more refined building setback requirements and related regulations which are more specifically linked to expected future bluff recession rates and slope conditions.

Several previous studies on coastal erosion in Racine County have established an extensive data base which permitted the prediction of future shoreline conditions and the formulation of regulations which can assist in more rationally adjusting both rural and urban development and redevelopment to these expected future conditions. These studies have been conducted by the Racine County

Coastwatch Program, the University of Wisconsin Sea Grant Program and Extension Service, and Racine County with financial and technical assistance from the federally supported Wisconsin Coastal Management Program.

PURPOSE

The primary purpose of this coastal erosion management study was to delineate and map high erosion and bluff recession risk areas along the Lake Michigan shoreline of Racine County and to develop a set of land use regulations properly related to the existing and probable future shoreline erosion and bluff recession rates. The study identifies the extent of shoreline erosion and bluff recession which may be expected to occur over time along the Lake Michigan shoreline of Racine County; recommends erosion risk setback distances for buildings along shoreline reaches protected by proper shore protection structures, as well as along reaches not so protected; quantifies the potential property losses which may be expected to result from continued shore erosion and bluff recession in the absence of a sound management program; and recommends a set of provisions which may be incorporated into existing shoreland regulations to restrict certain land uses and practices, as well as to guide the placement of new buildings, within those shoreland areas susceptible to erosion and bluff recession. Recommendations for both structural and nonstructural coastal erosion control measures previously made by the Racine County Technical Subcommittee on Shoreland Development Standards were adapted and incorporated into the findings and recommendations this study.

ORGANIZATIONAL STRUCTURE

The purpose, scope, and content of the study was developed under the guidance of the Coastal Erosion Advisory Committee, comprised of persons who have knowledge and experience related to the technical aspects related to coastal zone management, as well as persons who are intimately familiar with the Racine County coastal environment. The composition of this Committee, given on the inside front cover of this report, includes representatives from the University of Wisconsin Sea Grant Program, the City of Racine, the Town of Caledonia, the Racine County Coastwatch Program, the Racine Board of Realtors, the Wisconsin Department of Natural Resources, the Sierra Club, and private

engineering consulting firms. The study itself was subsequently carried out cooperatively by the staffs of the Regional Planning Commission and the Racine County Planning and Zoning Committee.

INVENTORY FINDINGS

A coastal erosion study area was defined and delineated under the study being that area of Racine County lying within approximately 1,000 feet of the ordinary high water mark of Lake Michigan. The study area thus includes all lands subject to existing county shoreland zoning regulations. The study area is comprised of those lands which most directly affect or are most directly affected by, Lake Michigan erosion processes. The study area encompasses 2,552 acres of land and 14.8 miles of Lake Michigan shoreline.

Elements of the natural resource base of the study area pertinent to understanding and coastal erosion include the geology, soils, bluff and beach composition and topography, surface water resources, groundwater resources, and climate of the coastal area. The study area is underlain by, in successively descending order, dolomite, shale, sandstone, and crystalline layers of bedrock. Up to 300 feet of unconsolidated glacial deposits cover the bedrock. About 28 percent of the study area is covered by well- and moderately-drained soils, and about 55 percent of the shoreland area is covered by poorly- and very poorly-drained soils.

Although some bluff heights in Racine County exceed 80 feet, most of the shoreline has bluffs ranging from 20 to 40 feet in height. The bluffs are comprised of till, silt, clay, sand, and gravel. Nearly one third of the shoreline has no beach. Most of the shoreline with a beach has a beach width ranging from one to thirty feet, although the maximum beach width exceeds 300 feet.

Along the Racine County shoreline, groundwater generally flows toward Lake Michigan. Three major aquifers underlie the coastal area; the deep sandstone aquifer, the Niagara dolomite aquifer, and the shallow sand and gravel aquifer. Numerous groundwater discharges and seepages occur on the bluff slopes, contributing to the instability of these slopes.

The type, degree, and extent of shore erosion damage is determined by the interrelationship of the natural and man-made features of the study area. About 56 percent of the study area was devoted to urban land uses in 1980. About half of the area devoted to urban land uses was devoted to residential uses. Land use in the study area is currently regulated by County and municipal zoning ordinances. Municipal zoning ordinances are in effect in the the City of Racine, the Villages of North Bay and Wind Point. The Town of Caledonia has adopted the Racine County zoning ordinance. The Town of Mt. Pleasant has adopted its own zoning ordinance, but that ordinance is in effect a joint County-Town ordinance. About 91 percent of the study area has been placed in zoning districts which permit intensive urban development. The zoning ordinances are, moreover, generally devoid of provisions pertaining to the regulations of development and redevelopment in relation to Lake Michigan shoreline erosion hazards.

Numerous types of shore protection structures are currently present along the Racine County shoreline. These structures, which include groins, bulkheads, revet ments, and breakwaters, have had varying degrees of success. An inventory of 216 shore protection structures indicated that nearly 75 percent of all structures exhibited some type of failure. About 30 percent of all structures were failing overall, or were nonfunctional.

The most important Lake Michigan coastal erosion problem in Racine County is recession of the bluffs. Bluff recession is caused by the sliding and slumping, as well as the surface erosion of the bluff slopes. Factors affecting bluff erosion include wave action at the bluff toe, lake water levels the physical characteristics of the beach and bluff including the configuration as well as the soils, ice activity, groundwater seepage, and surface runoff. The rate of bluff recession has been documented in several previous studies. Over the period from 1963 through 1980, bluff recession along the unprotected reaches of shoreline, as measured by the Regional Planning Commission, averaged 1.7 feet per year. Slightly over half of the unprotected reaches of shoreline had a bluff recession rate equal to, or less than, 0.5 foot per year. The highest recession rate measured was 8.8 feet per year.

EVALUATION OF COASTAL EROSION

The identification of the shoreland areas which may be expected to continue to be affected by shoreline erosion and bluff recession enables public officials and private property owners to better assess potential erosion losses and evaluate alternative erosion management measures. Erosion risk setback distances were accordingly determined under two sets of conditions--one condition assuming the implementation of structural shore protection measures, and the other assuming the implementation of nonstructural measures only. Recommended setback distances under each of these two sets of alternative conditions were determined for each of 101 coastal erosion analysis reaches along the Racine County shoreline.

The bluff recession distance was determined under an assumption that nonstructural erosion management measures only would be implemented for a 25-year, 50-year, and 75-year period, based on the annual recession rates measured for the period of 1963 through 1980 by the Regional Planning Commission. In calculating the desirable building setback distances, the face of the bluffs was assumed to be graded to a stable slope of one on two and one half, or about 22°. An additional minimum building setback distance was then added to the bluff recession distance and the stable slope distance to obtain a total nonstructural erosion risk building setback distance. (See Figure 5 of Chapter IV of this report).

Maps 9 through 22 contained at the back of this report, show the erosion risk setback distances for the 25-year, 50-year, and 75-year periods. Real property boundaries, as described in the County cadastre file, are also shown on the maps.

The land lying within the 25-year bluff recession distance and stable slope distance--excluding the minimum setback distance--has an estimated value of about $1.7 million, while the structures have an estimated value of about $2.0 million, for a total value of about $3.7 million. The land lying within the 50-year bluff recession and stable slope distance has an estimated value of about $2.1 million. While the structures have an estimated value of about $2.3 million, for a total value of about $4.4 million. The land lying within

the 75-year bluff recession and stable slope distance has an estimated value of about $2.6 million, while the structures have an estimated value of about $2.4 million, for a total value of about $5.0 million. These values do not include the value of public facilities and utilities such as streets, sewers and water mains.

The desirable building setback distance was also determined under an assumption that properly designed, constructed, and maintained shore protection structures would be provided. A total structural erosion risk setback distance was determined as the sum of the stable bluff slope distance--assuming a stable slope of 22°, and a minimum building setback distance. (See Figure 6 of Chapter IV of this report).

Effective shoreline protection may require a combination of bluff stabilization, surface water and subsurface water control, and bluff toe protection. Existing building and onsite sewage disposal system relocation may also be considered. Proper consideration of structural shore protection measures and of relocation requires detailed, site-specific analyses of the physical characteristics of the beach and bluff, the causes of erosion, the intended use of the shoreline, the degree of hazard posed by erosion, the existing value of the property, and the resources which can be used for the project. The Racine County Technical Subcommittee on Shoreland Development Standards recommended a set of minimum criteria to be used in the design, construction, and maintenance of shore protection structures. These criteria as adapted for this study are set forth in Table 15 of Chapter IV of this report.

Shore protection structures are most likely to be constructed to protect the existing developed urban shoreline areas. It was determined that about _____ miles of shoreline, or about __ percent of the County total, are most likely to require subsurface drainage improvements and _____ miles of shoreline, or __ percent of the County total, are most likely to require surface water drainage improvements. Those shoreline areas, totaling about ____ miles, or about __ percent of the County total, which are developed for intensive urban land uses and are currently exhibiting a bluff recession rate in excess of one foot per year, would be most likely to benefit from the provision of shore protection structures such as groins and revetments. About ____ miles of

developed shoreline, or about __ percent of the County total, would require grading for a distance of 50 feet or more from the toe of the bluff, in order to achieve a stable slope.

RECOMMENDATIONS

The findings of this coastal erosion management study provides a basis for developing public informational and regulatory measures designed to guide urban development and redevelopment in proper relation to the associated risk of shoreline erosion and bluff recession. The findings of the study provide a valuable reference which can help to inform the general public and concerned special interest groups about the location and extent of high erosion risk areas along the Lake Michigan shoreland, and of actions that can help to reduce that risk. Public land use regulations can be developed which protect proposed development and redevelopment from excessive shoreline erosion and bluff recession risk by identifying the high erosion risk areas and establishing minimum building setback distances from these areas. Recommended amendments to the Racine County shoreland zoning ordinance which would regulate land uses, activities, and structure locations within the high erosion risk setback distances are set forth in Appendix D to this report. With proper adaptation, these provisions may also be incorporated into local municipal zoning ordinances. The ordinance amendments designate setback distances from the existing bluff edge, within which certain land uses and management practices, and the placement of structures, is restricted or prohibited.

For those shoreland areas currently protected by proper shore protection structures, the following formula is recommended to be used to determine the erosion risk setback distance:

Total Structural Erosion Risk Setback Distance	=	Net Stable Slope Distance	+	Minimum Building Setback Distance

The net stable slope distance is the distance the bluff would need to recede, or be regraded, to achieve a stable slope of one on two and one half. The recommended minimum building setback distance is 100 feet for public utilities, public recreation facilities, and single-family residential units; and 200 feet for all other permanent structures. However, the minimum setback distance

for public utilities, recreation facilities, and single-family residential units may be reduced to the average distance from the bluff edge of adjacent structures, although the minimum setback distance cannot be less than 50 feet.

For those shoreland reaches not currently protected by proper shore protection structures, the required setback distance is determined by the following formula:

Total Nonstructural Erosion Risk Setback Distance	=	50-Year Bluff Recession Distance	+	Net Stable Slope Distance	+	Minimum Building Setback Distance

The net stable slope distance and the minimum building setback distance are the same as defined above. The 50-year bluff recession distance is based on the annual bluff recession rates, as determined by the Regional Planning Commission for the period of 1963 through 1980, multiplied by 50 years.

Within the calculated total structural and nonstructural erosion risk setback distances, the location of new, permanent major buildings should be prohibited. New onsite sewage disposal systems should also be prohibited. Conditional uses and management practices should include land disturbance activities, tree cutting, the construction of structural shore protection measures, and buildings and structures which can be relocated. Permitted uses within these erosion risk setback distances may include open space uses, storage of portable equipment and supplies, accessory buildings such as storage sheds, and minor structures such as driveways, sidewalks, patios, and fences.

The delineation of the erosion risk setback distances may be modified upon submittal by an applicant or property owner of the findings of engineering studies showing that the actual shoreline erosion and bluff recession rate is different than that set forth in this report for the appropriate coastal erosion analysis reach; that the stable slope conditions are different than indicated herein; or that the height of the bluff is different. In addition, the erosion setback distance may be modified if proper shore protection structures are implemented. It is recommended that the erosion risk setback distance be refined at approximately 10-year intervals to reflect changes in the bluff characteristics and to incorporate new bluff recession rates into the long-term average rates.

The adoption and implementation of the management measures herein recommended for the Lake Michigan shoreland area of Racine County will help reduce the serious and costly erosion and bluff recession problems affecting the County shoreline. The implementation of these recommended measures may thus be expected to provide a safer, more healthful and more pleasant, as well as more orderly and efficient, environment within the shoreland area, promoting the public health, safety and general welfare.

APPENDICES

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