ROOKERY BAY LAND USE STUDIES

Environmental Planning Strategies for the Development of a Mangrove Shoreline

Study No. 10

Growth and Land Use

Study No. 11

Economic Implications of Land Development Alternatives

Study No. 12

A Simulation Modeling Approach to the Study of Development Alternatives

THE CONSERVATION FOUNDATION
WASHINGTON, D. C.

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JUNE 1975

THE CONSERVATION FOUNDATION

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* * *

The Conservation Foundation, founded in 1947, undertakes projects and programs serving these purposes: to promote greater knowledge about the earth's resources -- its waters, soils, minerals, plant and animal life; to initiate research and education concerning these resources and their relationship with each other; to ascertain the most effective methods of making them available and useful to people; to assess population trends and their effect upon the environment; finally, to encourage human conduct to sustain and enrich life on earth.

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THE ROOKERY BAY AREA STUDY PROGRAM

The mangrove shores and islands, the bays and lagoons, the marshes and creeks of the southwest Florida coast are a natural resource unit of exceptional value that support a rich and varied population of fish, birds, and wildlife. Yet the accelerated shore development of the 1950's and the 1960's caused widespread environmental damage wherever it collided with these beautiful and productive estuarine areas. With little appreciation of ecological principles of land use and water management, shorelands were stripped of mangroves, bay bottoms were scoured for land fill, and waters polluted with silts, nutrients, and bacteria. The unique and haunting loveliness of the shorelines of Tampa Bay and Ft. Meyers were largely replaced by the geometry of development.

South of Naples, a large part of the mangrove shoreland remained undeveloped -- but threatened. This region is now beginning to experience the pressures of waterfront development: construction of drainage canals, dredging of estuaries, and ripping out and filling of mangrove swamps. Uncontrolled, this movement will destroy much of the area's natural value; if future development does not respect the vital elements of the mangrove-estuary environment, coastal Florida will lose the very qualities that have attracted people to it.

Ecologically sound land-use planning can provide a basis for solving much of the coastal land-use dilemma. The intensity of conflict between development stability, and the unusually high values of south Florida's natural resources, make this an ideal region for exploring ways of reconciling these major land-use conflicts. In recognition of this, the Conservation Foundation, in 1967, launched a demonstration planning project centering on the Rookery Bay region between Naples and the Ten Thousand Islands, an ecosystem characteristic of the mangrove-estuarine environment of south Florida. Rookery Bay itself, and the mangrove shores immediately surrounding it, are held as a wildlife sanctuary by the National Audubon Society. Lands surrounding the sanctuary are still largely undeveloped, but most are in private ownership and development pressure is building strongly. Such development not only threatens the Sanctuary, but could threaten the entire Rookery Bay estuarine ecosystem.

The original goal of the Foundation in undertaking the study was to determine the extent and kind of development which the area could support without destroying the natural estuarine ecosystem. The project was conducted by Foundation staff and consultants through a series of environmental and cultural studies designed to show how development could proceed in ways that respected both environmental fundamentals and economic imperatives.

The study was carried out in two phases. The first, supported primarily by the Ford Foundation, ended in 1969. The major report of this study, Rookery Bay Area Project, was published by the Conservation Foundation in 1968. It presented a trial plan for development which would leave the mangrove forests intact in the interest of protecting the Sanctuary ecosystem.

The second phase, supported primarily by the U.S. Department of the Interior, Office of Water Resources Research, extended from 1970 to mid-1973. It was designed to obtain extensive biological, physical, social, and economic data and to devise methods to incorporate these data into planning strategies designed for compatibility between development and environmental quality. One specific goal was to predict in detail the environmental consequences of the 1968 trial Rookery Bay development plan. Another was to provide the technical basis for a second generation plan and to determine its usefulness to a wider area of the coastal zone and a broader spectrum of effects.

This study is one in a series by Conservation Foundation and University of Miami consultants and staff members reporting individual aspects of the second phase studies. The conclusions reported are those of the authors and do not represent the views or policies of either the Conservation Foundation or the Office of Water Resources Research.

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STUDY NO. 10

GROWTH AND LAND USE

BY

ROBERT A. LEMIRE

LEMIRE AND COMPANY
LINCOLN, MASSACHUSETTS

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Introduction

Since its post-World War II beginnings, the growth of coastal Collier County that poses a threat to Rookery Bay has been largely unstructured and uncontrolled.[1,2] By 1972, the area population had grown to 40,000 from 2,000 in 1952 and some officials were projecting fulfillment of the 600,000 zoning potential by the year 2000. Until very recently, the only deterrents to encroachment upon Rookery Bay seemed to involve the actual purchase of perimeter area in competition with potential developers. In recent years, very real limits to the development rates and potential growth of coastal Collier County have emerged, creating new opportunities for structuring changes around Rookery Bay.

Problems with Growth

A keen realization of these limits to growth now appears to have developed in Collier County government. County officials are aware of shortages of fresh water and limits to area aquifers. They know it takes time and money to develop new sources of water and that the violation of aquifer limits may be irreversible. For example, it has taken Collier County three years and $2 million to increase the coastal area's fresh-water service from 12 mgd (million gallons per day) to 20 mgd in order to accommodate a population growth from 38,000 to 50,000. Whether additional water sources can be found and capacity built to accommodate a growth goal of 140,000 in the next 26 years is an open question. Achieving that capacity sooner seems unrealistic. The availability of new sources of water is of great concern because of the risk of overstressing aquifers with only the growth potential of the next few years. In order to plan for the next increment of growth, an $8.5 million water project is being considered by the County along with an extensive county-wide hydrology study.

Collier County officials are also aware that new houses mean new sewerage facilities, schools, roads, hospitals, libraries, and other public facilities and services that must be provided by county government. The relationship of growth to these expensive commitments has been carefully studied and set down in a recent County-sponsored study: "An Analysis of Density As It Relates to Future Environmental Quality of Naples and Coastal Collier County, Florida."[3] Much of Collier County's growth has been artificially stimulated by developers rather than self-generated; County officials would therefore seem to have considerable opportunity for shaping future growth.

There is a new awareness that the County has the responsibility and the legal power to tailor growth to its natural and economic constraints. This is clearly evidenced in the recent (November 28, 1973) Collier County Commission vote to impose a six-month moratorium on all new rezone petitions to increase the use-intensity or density of property, pending development of a County growth plan. There is also an official position emerging to the effect that: *growth must pay for growth.* This is indicated in the excerpts quoted below from a recent (November 25, 1973) newspaper report:[4]

> *If predictions that Collier's population will double by 1980 are accurate, the cost of the capital improvements which must accompany that growth is staggering.*
>
> *County fiscal agent Ben Driver predicts that if Collier's population does double by 1980, the county's budget will triple and the total number of county employees will quadruple.*
>
> *According to the proposed city-county master plan, 9,000 new dwelling units housing over 30,000 people will be built in coastal Collier County by the end of the decade. These additional residents, the plan says, will require the construction of five new schools, three fire stations, a new city hall, a branch library, more parks, a new incinerator and additional sewage facilities.*
>
> *Says Naples City Planner Jerry Annas, 'Subdivisions and condominiums historically don't pay their way. Large-scale development is very much a drain on the community.'*
>
> *Both Driver and Naples Civic Association president Frank Nelson say that growth could force sharp raises in property taxes.*
>
> *'There's no question that the cost of development will exceed the revenue it generates' says Nelson. 'The tax rate is bound to go up. I'm not against growth, but unless something is done, growth will be a substantial financial burden for most people.'*
>
> *'People must understand that these facilities and services don't come for free' says Nelson, who supports the idea of an entrance fee.*
>
> *'If nothing is done, ad valorem taxes will skyrocket, and that's not fair. The residents here have already paid for their schools and roads.'*
>
> *Collier School Board Chairman R. B. Anderson agrees. 'Something must be done, or we're headed for a financial catastrophe. Having growth pay for growth seems to be the only alternative.'*

That growth has not paid its way is evident in the County's accelerating tax rate. The results of a brief interview survey, conducted as part of our study, illustrate the point. As shown in Table 1, we learned from a sample of 79 dwelling units and 44 mobile home units that the former fell an average of $444 short per unit of paying their way in 1972-73 while the latter fell an average of $517 short.[5]

The accumulative effect of rapid development is illustrated in Table 2 where we have applied a shortfall analysis to the planned housing, school impact, and estimated ad valorem tax revenue figures projected from estimates provided by the developer of a sample housing project, the "Lakewood Country Club Community."[6] Table 2 indicates that Collier County taxpayers can be expected to help make up an annual probable operating cost shortfall increasing

Table 1. Development Shortfall Analysis for the Lakewood Country Club Community. (Excluding Projected Water/Sewer Demand and School Capital Costs)

	Projected New Occupancies Family Housing	Retiree Housing	Accumulative Total Units	(1) Total Students	(2) % of Est.County Enrollment	(3) Projected Ad.Val.Tax Revenue	(4) School Op.Cost @81.3% of $1015/Student	(5) Other Cty Svs @ $162/Unit	(6) To City Costs (4)+(5)	(7) Projected Shortfall (6)-(3)
1973	20	20	40	26	0.2	$ 11,600	$ 21,450	$ 6,480	$ 27,930	$ 16,330
1974	116	134	290	176	1.4	84,200	145,200	46,980	192,180	107,980
1975	116	134	540	328	2.3	156,700	270,600	87,480	358,080	201,380
1976	116	134	790	478	2.9	229,300	394,350	127,980	522,330	293,030
1977	116	134	1,040	629	3.5	301,900	518,925	168,480	687,405	385,505
1978	116	134	1,290	780	4.1	374,400	643,500	208,980	852,480	478,080
1979	116	134	1,540	931	4.7	447,000	768,075	249,480	1,017,555	570,555
1980	62	69	1,671	1,011	5.0	485,000	834,075	270,702	1,104,777	619,777
TOTAL	778	893								

(1) Based on 1.3 students/family unit, as projected by developer.
(2) Based on Collier County School Board.
(3) As projected by the developer. (Does not include commercial area or golf course.)
(4) Based on Collier County School Board.
(5) See Table 1.

Table 2. Sample Dwelling Unit Tax Revenue Shortfall Analysis for the Year 1972-73.

Sample Area	Units	(1) Avg.Unit 1973 Ad.Val.Tx.	(2) School Children Per Avg. Unit	(3) Avg.Unit Cty School Cost 81.3%of$1015/ Student	(4) Avg.Unit Non-School City Cost	(5) Avg.Unit TotalCost (3)+(4)	(6) Avg.UnitTax Shortfall (5)-(1)
DWELLING UNITS, MARCO ISLAND							
Goodland Rd.	52	$ 99	.75	$ 619	$ 162	$ 781	$ 682
Barfield Dr.	27	$ 448	.33	$ 272	$ 162	$ 434	$ (14)
Sub-Composite	79	$ 218	.61		Sub-composite shortfall		$ 444
TRAILER UNITS							
Henderson Creek Derhenson Dr.	14	$ 67	.64	$ 528	$ 162	$ 690	$ 623
Moorehead	17	$ 70	.53	$ 437	$ 162	$ 599	$ 529
Hitchingpost Oregon Trl.) Osage Trl.)	13	$ 72	.38	$ 313	$ 162	$ 475	$ 403
Sub-Composites	44	$ 69	.52		Sub-composite shortfall		$ 517
COMPOSITE	123	$ 165	.58		COMPOSITE SHORTFALL		$ 470

(1)(2) School Board calculates over-all average of .89 students per dwelling unit indicating larger actual average new county dwelling unit shortfall.

(3) Source for cost/student: Dr. James McGee, Asst. School Superintendent, figure does not include amortization of estimated $621 school capital cost per new dwelling unit (81.3% of annual operating expenses are derived from county property taxes).

(4) Based on 1972-73 non-school county expenses of $2,852,000 ÷ 16,092 dwelling units = $162. 1973-74 budgeted non-school cost of $4,939,000 indicates substantially larger 1973-74 figure.[5]

from $16,330 in 1973 to over $600,000 by 1980 -- without inflation or increase in services. Adding the capital costs for the equivalent of more than one new school plus whatever street, water, sewerage, and other capital facility costs might fall to the County would add to costs. This provides a feel for the potential burden of growth that would have to be borne by the existing population, many of whom would be marginally able to pay for it at best.[7]

Limits on Growth

Fortunately, Collier County officials recognized the growth problem some two years ago when they commissioned a comprehensive coastal area planning program: the Greater Naples Urban Area Master Plan. Starting with three optional plans calling for populations of 400,000, 275,000, or 200,000 by the year 2000, this program appears to have distilled down to a "Preferred Development Plan," the low option, which projects a six per cent annual population growth rate and a total population of 200,000 by the year 2000.[8] This plan has been refined to the 23 sectors indicated in Table 3, six of which impinge on the Rookery Bay Sanctuary (Figure 1). In these six areas, covering some 50,000 acres, less than one dwelling unit per acre is contemplated -- far less than expected from previous zoning allowances. Therefore, development that might impact Rookery Bay would be severely limited by County plans. In all probability, such tentative limits will be established at the termination of the six-month moratorium (scheduled for May 30, 1974). *In the meantime, it is imperative that these probable future limits be reviewed in terms of their potential impact on Rookery Bay.*

Conservation Opportunity

The opportunity to influence the location and design of development in order to protect the ecosystem now exists. Therefore, the subject should be carefully studied in terms of: 1) presently planned development, 2) other potential developments, 3) land ownership, 4) acceptable development formats, and 5) opportunities for planning land use to minimize adverse impacts on Rookery Bay. It is quite possible that through careful negotiations, developments planned for critical "Preservation" and "Conservation" lands in the six sectors bordering Rookery Bay -- essentially Water Management District 6[9] -- could be directed toward readily developable land consistent with the Resource Buffer plan recommended by a Conservation Foundation consultant team.[10] It would be important for the County planners to incorporate these recommendations into the final form of the "Preferred Development Plan." The strategy should also include conservation of the drainage patterns throughout the Whole Rookery Bay watershed to protect the quality and quantity of inflowing fresh water, as recommended.[9,10]

Some of the tools, other than restrictive zoning, that could be brought into play in restructuring development that would be detrimental to the long-run preservation of the Rookery Bay ecosystem include: 1) outright acquisition of bordering land, 2) gifts, 3) use of transfer development rights, and even 4) the voluntary undertaking of acceptable development by concerned citizens who would

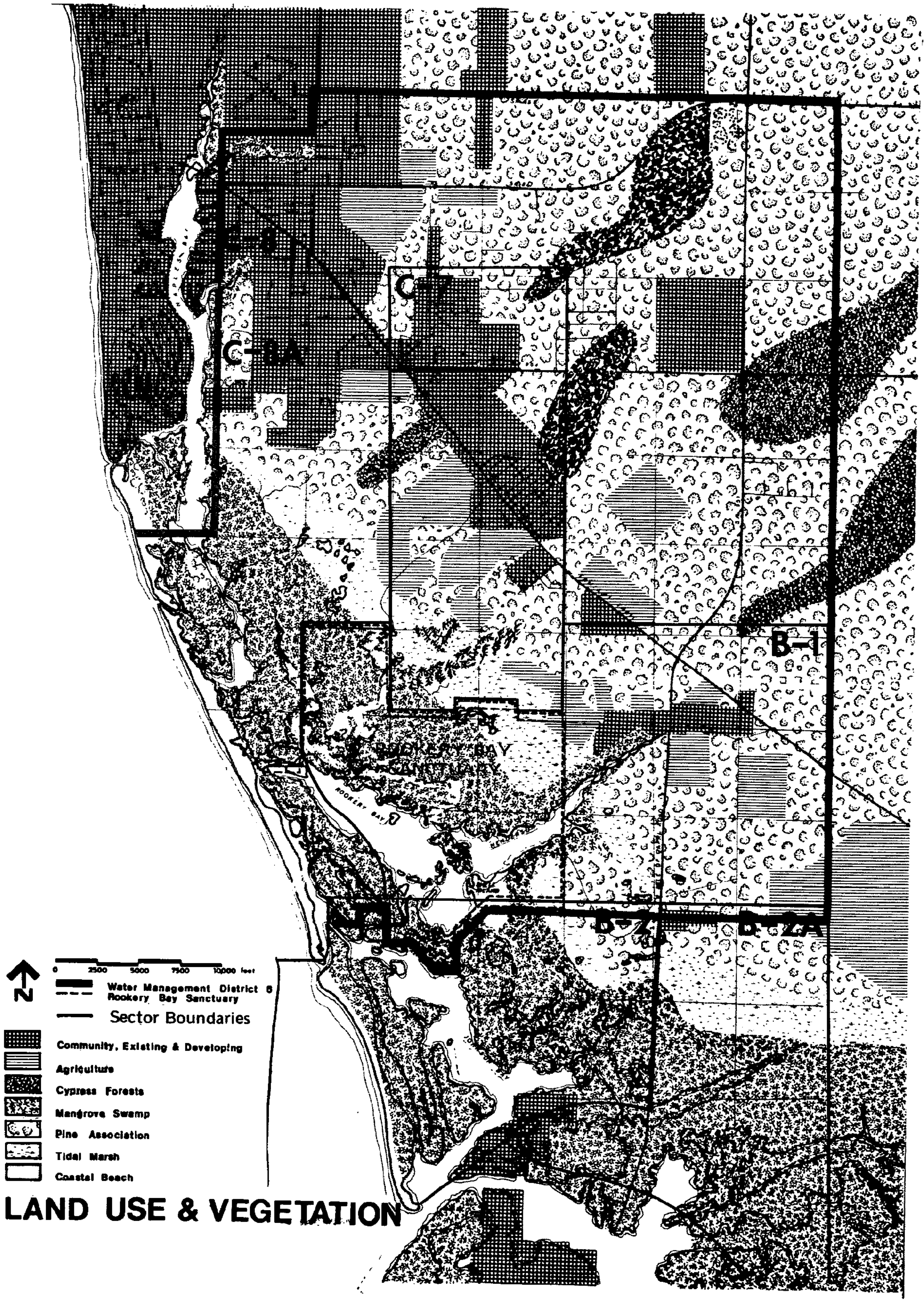


Figure 1. The Rookery Bay vicinity with development sectors that impinge on Rookery Bay and the Sanctuary. (See Table 3.)

Table 3. A DEVELOPMENT PLAN

Dwelling Unit (DU), Planned Unit Dwelling (PUD),
and Agriculture Distribution by Section to the Year 2000 --
population 200,000 (June 21, 1973)[6]

Proposed Land Use

Urban PUD		Suburban PUD		Agriculture		Sub-Total	Total	New DU's
Acres	DU	Acres	DU	Acres	DU	New DU	DU	Next 5 Yrs.
0	0	0	0	0	0	1,300	2,000	
0	0	0	0	0	0	700	2,790	
0	0	0	0	0	0	2,100	5,700	
0	0	0	0	0	0	200	650	
0	0	0	0	0	0	30	230	
0	0	0	0	0	0	670	1,130	
0	0	0	0	0	0	5,000	12,500	1,500
0	0	2,190	1,314	0	0	1,714	1,974	
1,760	3,520	2,600	1,560	0	0	7,480	8,890	
1,550	3,100	1,150	690	0	0	3,940	4,260	
0	0	420	252	0	0	3,052	4,252	
0	0	0	0	0	0	2,300	3,220	
0	0	3,100	1,860	0	0	1,915	1,930	
1,370	2,740	906	540	0	0	5,780	6,520	
1,610	3,220	0	0	0	0	4,720	5,860	
0	0	0	0	0	0	0	0	
0	0	5,650	3,390	0	0	3,690	3,700	
0	0	6,095	3,659	0	0	3,659	3,664	
6,290	12,580	22,111	13,265	0	0	38,250	44,270	3,500
0	0	7,000	4,200	4,100	40	4,240	4,290	
0	0	4,000	2,400	8,250	80	3,880	4,360	
0	0	0	0	16,000	160	160	160	
0	0	11,000	6,600	28,350	280	8,280	8,810	1,000
0	0	3,620	2,175	500	5	2,480	2,670	
0	0	2,400	1,440	0	0	1,800	1,970	
0	0	0	0	0	0	19,000	20,640	
0	0	6,020	3,615	500	5	23,280	25,280	3,000
							90,860	9,000

Table 3 (con't.)

Existing Land Use

Sectors	Total Acres	Vacant* Acres	Residential			
			Acres	DU	Acres	DU
Urban Area-Naples						
N-1	1,280	505	155	700	400	1,300
N-2	845	75	320	2,090	50	700
N-3	1,550	270	590	3,600	165	2,100
N-4	515	140	105	450	35	200
N-5	1,015	20	35	200	6	30
N-6	600	105	100	460	35	460
Sub-Total	5,805	1,115	1,305	7,500	691	4,790
Urban Area-County						
C-1	3,520	2,775	35	260	160	400
C-2	9,080	6,580	280	1,410	950	2,400
C-3	4,610	3,890	340	320	250	150
C-4	2,620	1,285	165	1,200	900	2,800
C-5	3,900	3,120	145	920	650	2,300
C-6	3,840	3,685	60	15	270	55
C-7**	6,310	5,715	165	740	900	2,500
C-8**	2,805	2,290	265	1,140	680	1,500
C-8a**	3,200	2,560	0	0	0	0
C-9	6,400	6,300	10	10	350	300
C-10	6,420	6,270	5	5	0	0
Sub-Total	52,705	44,170	1,470	6,020	5,110	12,405
Area-A						
A-1	15,360	15,190	10	50	0	0
A-2	18,560	17,845	85	480	1,600	1,400
A-3	16,000	15,920	0	0	0	0
Sub-Total	49,920	48,955	95	530	1,600	1,400
Area-B						
B-1**	12,160	11,240	25	190	150	300
B-2**	11,280	7,575	25	170	150	360
B-3	11,520	4,655	135	1,640	3,200	19,000
Sub-Total	34,960	23,470	185	2,000	3,500	19,660
TOTAL	143,390	117,710	4,055	16,050		

* Also includes agriculture.
** Sectors bordering and impinging on Rookery Bay, as obtained on November 26, 1973.

be encouraged to acquire land for special purposes.

Outright acquisition of land for conservation, recreation and preservation bordering the Rookery Bay Sanctuary has been the product of private generosity to this date. However, the County may find it desirable to consider the purchase of certain bordering lands by drawing on State and Federal assistance programs, and by bonding a substantial portion of the residue. Lincoln, Massachusetts, provides an example of how well this can work. The town has purchased some 850 acres, or close to ten per cent of the land in the town, with State and Federal funding assistance (close to 75 per cent) and with long-term bonding to handle most of the balance. In this way, the townspeople have been able to play a key role in determining Lincoln's land-use destiny without imposing a serious new tax burden on local property owners. Coupled with Town purchase, there has been active land conservation action by groups of private citizens.

Concerned citizens working through the Rural Land Foundation of Lincoln, Massachusetts, have successfully pioneered a technique of development to achieve a number of local public purposes while creating opportunities for landowners to dispose of land at fair market values.[11] In brief, the Rural Land Foundation was created as a tax-exempt organization in response to a particular need -- to save an historically important segment of a 100-acre land tract that was threatened with overall development. Some 30 individuals endorsed notes of $10,000 each, backed first by the land to be purchased and secondly by their private wealth. The resultant bank loan of $300,000 was used to acquire the land and to plan and develop it. As completed, the area accommodates ten homes that pay their way in taxes to the town. In addition, some 58 acres, containing an old Colonial road corridor that is rich in the historic events of 1775, have been deeded to the Lincoln Land Trust for posterity. The goodwill generated by this project, plus a $40,000 residual profit, have since been used to *catalyze* several town projects including a subsidized moderate income housing project, the town's commercial center, and a key relocation project for families displaced by the Minuteman National Park. This was, of course, accomplished under fortuitous conditions, but it suggests one type of creative development control that has worked.

In some cases, the tax-shelter value of gifts of land to charitable or tax-exempt institutions -- such as the National Audubon Society, the United States Government, the State of Florida, or Collier County -- can be used as an inducement to owners or developers to forgo some development or at least to cooperate with efforts to relocate and restructure potentially damaging development. The Federal Government encourages donations to publicly-supported, non-profit organizations and municipalities through provisions of the Internal Revenue Code.[12] Individuals and corporations may deduct the full value of their charitable gifts subject to certain limitations of the tax code. In brief, cash contributions in any one year are fully deductible up to 50 per cent of the donor's adjusted gross income, while gifts of appreciated land and other property held over six months are deductible, at fair market value, up to 30 per cent of adjusted gross income. In addition, when a donor contributes long-term capital gain property, the basic tax saving is increased by the amount of capital gains tax which would have been payable if the property had been sold, rather than given away.

An example, cited by the Nature Conservancy, shows that an individual with adjusted gross income of $40,000 who is in a 50 per cent tax bracket can realize accumulated tax savings of $43,000 by donating a piece of land that cost him $44,000 and is now valued at $72,000.[13] In this case, the donor is allowed a deduction of 30 per cent of his adjusted gross income, or $12,000 a year. Over the six years' allowed deduction, the donation would generate income tax savings totaling $36,000. In addition, the donor would avoid a potential capital gains tax, estimated at 25 per cent of the unrealized gain of $28,000, or $7,000. The importance of this conservation tool is well reflected in the Nature Conservancy's vital statistics, which show that some 300,000 acres throughout the United States have been preserved through the Conservancy's action.

Although quite new and untested, the fast evolving concept of *transferable development rights* (T.D.R.'s) should be considered to be a useful means of shifting development from environmentally sensitive areas which unfortunately were zoned for such development, to more appropriate areas, as deemed agreeable to parties concerned. As proposed in pending legislation in both Maryland and New Jersey, this procedure makes it possible to overcome the tragedies of earlier zoning in an economical way without the arbitrary treatment of owners who have acquired land with the expectation of realizing a profit potential from rezoning action.[13] This is achieved by separating development "rights" vested in the land (by past zonings) from the land itself, and allowing them to be transferred to tracts designated as potentially suitable for development. In brief, this process involves: determination of the zoning potential of an entire planning area; determination of acceptable development/population levels; adjustment of existing development rights to make them compatible with an acceptable development pattern; rezoning in terms of desirable development levels; and permission of development rights to migrate to suitable locations through a free market, or a negotiated process. As conceived, this approach has the advantage of structuring development to suit community needs in a fair and equitable way at minimum community cost. Wisely administered, the use of transferable development rights should permit the preservation of environmentally critical land that has been zoned for development, without unfairly penalizing the present owners. Acceptable development could be concentrated without creating undue windfall benefits.

As this very brief review shows, there are a great many creative tools and techniques that can be brought to bear to shape future development in a way that will be acceptable to, and may even enhance, the Rookery Bay Sanctuary.

Protection of Investments

As drafted, the County's "Preferred Development Plan" projects a total of 9,000 new dwelling units over the next five years in the coastal area (of which some 1,500 units are in Water Management District 6) and 72,315 units over the next 26 years for an estimated total of 91,715 dwelling units by the year 2000. It is important to note that these projections imply substantial private and public investment. An average value of $40,000 per unit, for example, implies a $3.6 billion private commitment to housing alone. This *does not include* all the roads, schools and recreation areas that will be required to service this growth. It should be apparent that the long range viability of these investments must be protected by adequate planning. Clearly, the future amenities of coastal Collier County must be sufficiently assured to justify the enormous public and private investment that is projected. Billions of dollars in mortgages, municipal bonds, and private savings must be amortized and made good. The risk to municipal bond investors and bank depositors of a sharp loss of value due to environmental damage must be considered, along with the burden of growth on County taxpayers and the adverse environmental impact of uncontrolled growth.

Collier County governmental leadership seems to be aware of this need to protect investments. It would seem reasonable, therefore, to work on the assumption that effective planning assistance and governmental support will be available for the assurance of sound land use in and around Rookery Bay.

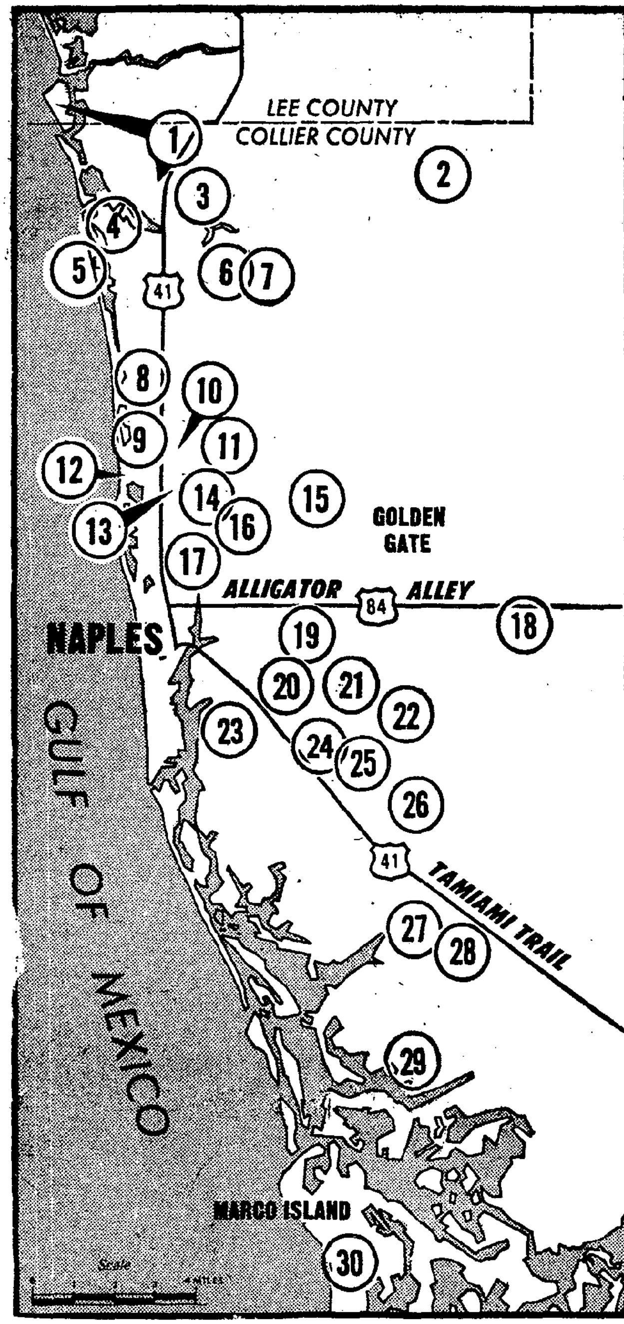
The main difficulty of structuring growth, of course, is dealing with approved and on-going projects and with built-in developer expectations. For example, the County must resolve the problem of owners of lots that can never be built upon because environmental constraints require that they will remain under water or because needed services will never reach them. Even with adept land-conservation strategies such as we have suggested, there will still remain some tough problems for local government and the courts.[14] To protect Rookery Bay, ongoing or approved development throughout the watershed should be carefully reviewed to determine how best to minimize adverse impact, following recommendations of the various Conservation Foundation studies.[9,10] A list of planned or approved coastal Collier County projects for such review is attached as Figure 2.[8]

Proposal for a Commission

Based on past experience, it is believed that the preservation of Rookery Bay within the context of a growing Collier County can best be achieved by a dedicated, on-site, National Audubon Society volunteer commission, created for this special purpose. Working with the important base-line data developed by the Conservation Foundation, and drawing on all the techniques available to shape local land use decision-making, such a commission should be able to catalyze solutions to whatever threats to Rookery Bay persist or may emerge. The commission should include: dedicated experts knowledgeable in the environmental tolerance of Rookery Bay; politically aware individuals who are involved in the day-to-day running of Collier County, especially coastal area land-use matters; and one or more persons well versed in county zoning matters and general land-use legal instruments.

Funds should be obtained or provided by the National Audubon Society for the commission's operation. A limited budget of $15,000 should cover travel, appraisal, legal, and other miscellaneous expenses. In addition to identifying and correcting perimeter and watershed threats to the Rookery Bay Sanctuary,

Figure 2. Proposed residential development in Collier County (adapted from the Miami Herald, November 18, 1973).



Collier's Future Growth (Excludes new developments in Naples)

Location	Name	Acres	Units	Type	Plans Submitted	Permits Issued
1	Treasure Island	55	—	S,MF	no	no
	Barefoot Beach	301	499	S	yes	no
2	Miscellaneous	—	447	S,MF	yes	yes
3	Imperial Golf and Country Club	700	450	S	yes	no
4	Wiggins Pass	266	4000	S,MF	yes	no
5	Solara	2.6	52	MF	yes	yes
6	Victoria Park	159	790	S,MF	yes	some
7	Four Seasons	175	140	S	yes	no
8	Westinghouse — Coral Ridge	1,924	—	S,MF	no	no
9	Park Shore Unit 4	194	658	MF	some	some
10	West Lake	16	79	S	complete	
	Sorrento Villas	6.5	80	MF	complete	
11	Forest Lakes	36	430	MF	yes	some
	Naples Bath and Tennis Club	154	640	S,MF	yes	no
	Turtle Lakes	231	1800	MF	yes	some
12	Park Shore 2	126	1763	S,MF	yes	some
13	High Point Country Club	39	764	MF	yes	some
14	Wilderness Club	220	375	S	yes	no
15	Krehling	500	4400	S,MF	some	no
16	Poinciana Village	4.2	94	MF	yes	yes
17	Spanish Trace Apts.	9.5	134	MF	yes	yes
18	Millstream	900	3600	S,MF	yes	no
19	Bridle path	318	1300	S,MF	yes	no
20	The Glades	200	1000t	MF	yes	some
	Kings Lake	311	1200	S,MF	yes	no
	Lakewood	302	1629	S,MF	yes	yes
	Riveria Golf Estates	358	1816	S,MH	yes	yes
21	Lely Estates	200	1600	S,MF	no	no
22	Wing South	9	59	S	yes	some
23	Naples Townhouses	37	375	MF	yes	yes
24	Vista Palms	6	96	MF	yes	yes
25	Country Club Manor	7.5	144	MF	yes	yes
26	Lely Estates	3600	9700	S,MF	no	no
27	Trailer Park	16.3	233	MH	yes	no
28	Gulf Winds East	12	168	MF	yes	some
	SWJ Corp.	1332	10,886	S,MF	yes	no
29	Twin Towers	7.6	268	MF	yes	yes
	Pointe Capri	17	516	MF	yes	yes
	Gulfview	7.6	265	MF	yes	yes
30	Unit 24 Marco	2161	3749	S	yes	no

Total Units Shown — 56,217
Units for which permits have been issued — 10,130

Key: S — single family
MF — multi family
MH — mobile home

the suggested commission should be charged with the development of rules and regulations for acceptable public use of the Rookery Bay Sanctuary.

There is every reason to believe that such a commission, working in an advocacy role within the context of Collier County's comprehensive planning effort, can provide for the long range preservation of the Rookery Bay Sanctuary while assuring its role as a valued Collier County natural resource and responsibility.

Acknowledgements

I wish to thank John M. Allen, Supervisor of the Rookery Bay Sanctuary for the National Audubon Society, and all the others who so willingly shared their abundant knowledge of Collier County with me: David Bruner, attorney; Sewell Corkran, planning commissioner; Edward T. LaRoe, Collier County Conservancy (now Coastal Ecologist, Office of Coastal Environment, NOAA); Arnold E. Lamm, Naples City Council; James McGee, Assistant School Superintendant; Ruth Van Doren, County Commissioner. I am particularly grateful to Charles G. (Jim) Garrett who so efficiently gathered the sample data underlying the shortfall analysis contained in Table 1.

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Study No. 11

ECONOMIC IMPLICATIONS OF LAND DEVELOPMENT ALTERNATIVES

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INTRODUCTION

"Florida in 1973 faces the disturbing possibility that its population may double by the year 2000. Our environment and our quality of life are threatened. Our goals are a healthy environment and a viable economy. We believe these are compatible and, in fact, are interdependent because our economy, perhaps as no other state's, is vitally linked to maintaining the integrity of its natural systems."

Florida 2000: Governor's
Conference on Growth and
the Environment

The Rookery Bay Sanctuary is an area of nearly undisturbed marsh, mangrove swamp, and estuary lying south of Naples, Florida, along the Gulf of Mexico. Most of the 25,000 acres of land which surround the Sanctuary and comprise its watershed (Water Management District 6) are potential single-family and multiple-family homesites, with access to water or with a water view.

In the current market for Florida real estate, proximity to water commands a premium price. However, waterfront homesites are provided at the cost of disruption of the sensitive landscapes and aquatic ecosystems. In the low-lying shorelands of southwest Florida, the natural landscape typically has been remade by excavation -- creating building sites on filled land areas between artificial canals or lakes. The natural waters receive polluted runoff from the built-up areas -- nutrients, toxic substances and sediments -- and runoff is often changed in quantity and timing. The result is to degrade the biological integrity of the estuaries to the extent that they receive land drainage.

This study explores a range of possible real estate developments in Water Management District 6, which comprises the immediate Rookery Bay watershed, in order to reveal the dimensions of the tradeoff between public benefits and private profits. We present estimated effects on development profit potentials but leave the comparison with natural ecosystem values to others.

Development Pressures

If Florida's population increases over the next 20 years at substantially the same rate as it did in the 1960-70 decade, then several million persons will be added to the state's population in the next 10 to 20 years. It appears to us that the south Florida coastal areas may bear the brunt of much of Florida's new growth.

Unmanaged growth means allowing the private market to develop land wherever it is profitable without regard to the social costs of development. The market forces will develop as much land, in whatever fashion is possible and at as high a population density as private profits dictate. But the unmanaged market is often insensitive to limitations of resources, such as water supply, aesthetic values such as open space, natural or uncongested public use areas, or costs to local government for schools and other public services.

Attempts to manage growth must deal with the strong pressures generated by the profit opportunity in land development. Among other things, growth policy specifies carrying capacity limits for an area and a pattern for the use of land. In the Rookery Bay watershed the primary consideration in growth limitation is the maintenance of the unique natural quality of the Rookery Bay Sanctuary and surrounding estuaries.

THE LAND DEVELOPMENT MODEL

We have looked at the implication of alternative development possibilities for damage to Rookery Bay and measured the market values that might be foregone in order to protect the natural system. The economic evaluation used here is residual returns to land development -- market values of land prepared for building sites. We could devise no accounting of ecological values in dollar units, so diverse and widespread are the natural values of the Rookery Bay ecosystem.

Our purpose in the model is to depict the type and density of development likely to ensue from various combinations of market, political, and legal forces at work in Water Management District 6 -- 24,000 acres bisected by the Tamiami Trail, with 12,000 acres lying west of the highway and 12,000 acres lying east of the highway. Much of the area west of the highway lies near the water level; 8,000 acres lie below 5-5½ feet elevation (and above mean sea level). Of this, 5,000 acres lie below 2 feet elevation. The tract east of the Tamiami Trail includes 2,000 acres of low-lying cypress forests.

The first step in modeling land development is to select prototypes. In choosing prototypes we studied existing and proposed residential developments in southwest Florida which are representative of potential development of one or another of the tracts in our study area. The tract west of the Tamiami Trail is attractive to development as a water-oriented second home and recreation home development. The tract east of the highway is suitable for typical urban/recreational development.

To simplify the analysis we assume that the entire land area is under single ownership and that the objective of development is to maximize residual returns to the land. We made estimates for the various sets of population and land development constraints following the strategies outlined below for various development prototypes.

Recreation/Second Home Development

A. Venetian-Style Waterfront Development

In Venetian-style developments about one-third of the land area is dredged to form canals and to provide fill to elevate the remainder above the 5½ foot (M.S.L.) minimum building elevation (code calls for 7 foot minimum floor elevation).* Houses are placed on lots of ¼ acre with each lot abutting a canal. Very little acreage would remain as undisturbed natural area.

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*Since we completed our analysis, a strong Federal flood protection law was passed which would require minimum first-floor levels to be raised above the 100-year flood height for community participation in the Federal floodplain insurance program. This would require first-floor levels up to 12 feet or higher along the Collier coast forcing land preparation costs up and profits down.

B. High Density Setback Waterfront Development

This plan would involve developing land above the 2 foot contour by excavation for fill to elevate the land and to create lakes. Land below the 2 foot (M.S.L.) contour would remain in the natural state seaward of a wide perimeter interceptor waterway dredged in the wetlands whose function has been described in this series by Tabb and Heald (Rookery Bay Study No. 6). The developed area would contain a mix of high-rise and garden apartments, and single-family homes to achieve a high density. There would be community marinas and golf courses to receive runoff water and provide open space.

C. Low Density, Higher Elevation Development

This prototype is based on the concept of a density of 1.5 dwelling units per acre of developed area and corresponds to the preferred gross density of Collier County's proposed coastal area master plan (as of late 1973). Development is permitted above the 5½ foot (M.S.L.) contour of land elevation only. Under this plan only 3,000 acres would be developed on approximately ½ acre lots, some of them in cluster-style development. Cypress drainage areas are preserved.

D. High Density, Higher Elevation Development

The land lying above the 5½ foot (M.S.L.) elevation is developed to an urban density of 10 units per acre, implying almost entirely apartment living. Most land below 5 feet is preserved but some is developed at 0.2 units per acre following the proposal of Veri et al (1973, Rookery Bay Study No. 2, this series).

Urban/Recreational Development

E. Medium Density with No Preservation

This type of development is common to areas at some distance from the coast where residential developments on one-half to one-quarter acre lots in drained cypress and pine lands cater to non-water oriented, moderate income tastes.

F. Low Density with Cypress Preservation

This prototype is the counterpart of type C as far as carrying capacity is concerned and in the preservation of cypress lands and other natural drainage ways.

G. Low Density/High Preservation

This prototype is based on the proposed Collier County preferred plan as was type C and has a gross density of 1.3 units per acre of developed land, generally in lots of 1/2 - 3/4 acre or larger. A total of 5,500 acres would be preserved.

ANALYSIS

In Table 1 we have summarized land development, environmental and economic characteristics of each prototype. In Table 2 we give estimates of costs for various land development operations.* By studying the data on the various combinations of prototypes for the two sections of Water Management District 6, we are able to describe the possible range of land development options, environmental impacts, and economic returns.

Our basic data (Tables 1 and 2) are taken from analyses of existing or proposed real estate developments in Collier and Lee Counties, Florida. They represent engineering and design studies and appraisals of the market done by or for real estate developers and are of a proprietory nature. Therefore, we are not free to name the particular developers or developments from which they were obtained. The data are generalized for coastal areas in Collier and Lee Counties rather than specialized for Water Management District 6.

Under each possible type of growth policy, one combination of prototypes will be chosen by a developer who aims to maximize the gross value of his land. These profit maximizing cases are shown in Table 3.

Growth policy possibilities would be limited by recent preliminary decisions to control population growth in Collier County and by the desire to avoid damages to coastal aquatic ecosystems. It does not appear that the state or local governments will approve developments in low-lying shorelands which disturb much of the land surface and threaten water quality in the estuaries.

Thus, unconstrained development, although interesting as a basis for comparison with historic practice, is not now a viable option in Collier County's Water Management District 6. Hence, limited population with development confined to lands above the 5½ foot contour appears to be where the realistic options lie. The options are compared below in terms of residual land values in millions of dollars:

Density	Dredge-and-Fill	No Dredge-and-Fill
Unlimited	$300	$251
24,000 units	$170	$139
13,000 units	xx	$ 85

*The interest rate used here is an arbitrary 7.2% and it is assumed that in prototypes C through H the principal is paid off in an average of 2 years, making the total interest about 15% of the principal. Prototypes A and B take more time to develop so the average holding time of the principal is greater; we have assumed it to be 3.7 years making the total interest payments about 30% of the principal amount. All of this assumes of course that the developer has judged the market properly so that his absorption rate (lot sales rate) is sufficient to retire his debt in the above mentioned period of time.

An assumed unlimited population with dredge-and-fill permitted (case I) would produce a plan with 69,000 high-value dwelling units and a residual land value of $300 million. This appears unrealistic in view of limits of the developing county growth plan and environmental protection. If dredge-and-fill is prohibited, it is still possible to get 70,000 dwelling units by very high density development, but with a lower market value so that residual land values drop to $251 million, a decrease of $50 million. The environmental improvement of this change is of major proportions (Rookery Bay Study No. 2), and derives from keeping the low-lying areas intact instead of disturbing them with dredge-and-fill operations. Impervious area is also much reduced but sewage production remains much the same.

At a low population density calling for dwelling unit limits of 24,000, the model shows residual land values of $170 million under dredge-and-fill. Imposition of the population limit decreases land values to less than $100 million with dredge-and-fill controls. If we can assume that the population limits are dictated by publicly desired county growth policy, then it is the land use strategy and not the population limits which are imposed by the consideration of preserving Rookery Bay. Under a population ceiling conforming to 23,000 - 24,000 residential units, limitation of development to areas above the 5½ foot contour would result in a reduced potential in developers' land sale values of about $31 million.

In our opinion, actions required just to protect Rookery Bay, with no other considerations, require principally a limitation of major development to the 5½ foot contour and the prohibition of waterside dredge-and-fill -- option II of Table 3. Thus, it is defensible to say that $31 million maximum potential in foregone land values would be the cost of saving the Bay. This number, however, may be an overstatement for two reasons. The first reason is that the residual values we have been estimating would actually be realized over a period of years, perhaps 20 or 30. Thus, their present worth, when discounted by the current interest rate, would be substantially less and the difference between them, the cost of saving the Bay, would be correspondingly less.

For example, $31 million realized in equal increments over a 20-year period is equivalent to a present sum of $15.75 million at an interest rate of 10 percent. Thus, before we can debate the economics of saving the Bay, we must know the time pattern of profits foregone and the private discount rate.

The second reason the cost of saving the Bay is overstated has to do with the fact that under the "no-dredge-and-fill plan" considerable acreage of lands might be donated to conservation purposes with potential income tax savings for private owners: at the very best, landowners whose lands are downgraded by development restrictions may write off the loss in value against their taxable income and in that way reduce the private loss. Also, there may be many social advantages to be gained, other than environmental, from control of rate and type of development.

Appendix A -- Tables

List of Tables

Table 1. Attributes of the prototype development plans (see text for explanation). A = acre; U/A = residential units/acre; M.G.D. = millions of gallons per day.

	West of Tamiami Trail				East of Tamiami Trail		
	A	B	C	D	E	F	G
Land Use							
total land area (A)	12,000	12,000	12,000	12,000	12,000	12,000	12,000
preservation area (A)	4,000	5,000	9,000	7,000	0	2,000	5,500
conservation area (A)	0	0	0	2,000	0	0	0
development area (A)	8,000	7,000	3,000	3,000	12,000	10,000	6,500
gross density over total area (U/A)	1.2	2.4	0.4	2.5	3.3	1.6	0.7
gross density development area (U/A)	1.8	4.2	1.5	10.0	3.3	1.9	1.3
gross density on land after dredge-fill (U/A)	2.7	5.8	-	-	-	-	-
Environmental Factors							
excavation	Venetian	interceptor	no canals	no canals	no canals	no canals	no canals
density	moderate	high	low	very high	moderate	low	low
preserved areas	none	below 2 ft (M.S.L.)	below 2 ft (M.S.L.)	below 2 ft (M.S.L.)	none	cypress forests	extensive
total units	14,400	29,400	4,500	30,400	39,600	19,500	8,600
population[1]	43,200	73,500	13,500	64,000	119,000	58,500	25,800
managed turf (A)[2]	3,800	4,200	2,400	1,000	8,000	7,700	5,200

Table 1 (cont.)

	A	B	C	D	E	F	G
water surface created (A)[3]	2,600	1,900	-	-	-	-	-
impervious surfaces (A)[4]	1,600	1,900	600	2,000	4,000	2,300	1,300
volume of sewage (M.G.D.)[5]	5.4	9.2	1.7	8.0	14.9	7.3	3.3
Private Economics							
land development costs ($/unit)[6]	5,850	3,030	3,690	1,330	2,970	3,540	4,340
market value ($/unit)[7]	14,000	8,500	11,000	5,000	6,500	9,000	10,500
residual to the land ($/unit)[8]	8,150	5,470	7,310	3,670	3,530	5,460	6,160
residual to the land ($ x 10^6)[9]	117.5	161.0	32.9	111.6	139.8	106.5	53.0

Table 1 (cont.) Footnotes

[1] Different prototypes have different average populations per unit. Based on census data from South Florida we used the following: The very high density prototype D has 2.1 persons/unit, medium density prototype A has 2.5 persons/unit, and the rest (all single family home developments) have 3 persons/unit.

[2] Managed turf is equal to total area, minus preservation area, conservation area, water surface, and impervious area. Its significance is that it is an indication of the amount of chemical fertilizer that will be added to the area.

[3] Only two prototypes involve dredge and fill (A & B). The reasons that the amount of water surface is greater for A than for B are these: A covers a larger area overall, and it covers more very low land, requiring a higher ratio of canal to land in order to bring the land up to 5 foot (M.S.L.) minimum grade.

[4] As density increases, impervious surface per housing unit decreases. This is because of shorter road and driveway length per unit that come with smaller lots and smaller roof area per unit for apartments as opposed to single family homes. See Leopold, Luna B., 1968, Hydrology For Urban Land Planning - A Guidebook on the Hydrologic Effects of Urban Land Use, U.S. Geological Survey Circular 554.

[5] Sewage is estimated at 125 gallons/person/day.

[6] These are the land preparation costs on a per unit basis (construction is not included here or anywhere in the model). These are broken down in Table 2 and explained in the footnotes to Table 2.

[7] These are rough estimates of lot values. In some of the higher density prototypes, a lot as such does not exist but it is possible to separate out construction costs and profits to construction and consider the remainder of the sales price to be the "lot value." Two basic principles of land value are demonstrated in these estimates. One is that people will pay a considerable amount for immediate access to water. The other is that while lot prices increase with an increase in lot size, price per unit area decreases with an increase in lot size. For example, if a 1/4 acre lot were to cost $6,000, a 1/2 acre lot would cost more than $6,000 but less than $12,000.

[8] This is simply the difference between development cost and market value of the lot. It is not a profit figure, since the original cost of the raw land has not entered the calculation.

[9] This is the above figure multiplied by the number of units being developed. Following is an example of the significance of this term. Suppose residual to the land were $100,000,000 and the raw land costs were $60,000,000, then the profit to the land developers would be $40,000,000. The residual is an economic variable that the potential developer would look to in evaluating an investment option. If he were offered the raw land for $95,000,000, he would certainly reject the offer as he stands to gain only $5,000,000 (less than 5% and that would be over a period of many years).

Table 2. Detailed Land Development Costs by Prototype, in dollars per residential unit.

	A	B	C	D	E	F	G
Dredge and Fill[1]	770	310	-	-	-	-	-
Seawall[2]	1,100	110	-	-	-	-	-
Street and Utility Lines[3]	1,100	450	1,300	250	1,000	1,300	1,700
Sewage Plant[4]	370	280	490	250	300	360	440
Clearing, Drainage, Grading[5]	60	30	320	60	180	320	540
Recreation, Landscaping[6]	100	350	100	100	100	100	100
Sales, Promotion, Adm.[7]	1,000	800	1,000	500	1,000	1,000	1,000
Subtotal, land dev't costs	4,500	2,330	3,210	1,160	2,580	3,080	3,780
Interest on development[8]	1,350	700	480	170	390	460	560
TOTAL land development costs	5,850	3,030	3,690	1,330	2,970	3,540	4,340

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1 In B there is less low-lying land being raised to 5 feet (M.S.L.) than in A; specifically, in B all land between mean high water and 2.0 feet is left untouched while in A it must be raised some 3 feet. Also in B the dredge and fill costs are divided among many more units than in A. The cost of locally derived fill is $0.35/cu. yd.

2 In the case of B, there is less length of canal than in A. An average housing unit in B has only about 8 linear feet of canal front (e.g., a 20-unit apartment building would have 160 feet; some units would have no canal frontage whereas some may have 50 or 75 feet). In A the units average 78 feet of canal frontage. The cost of one linear foot of seawall is $14.

3 In prototypes B and D, much of the building is vertical, it is built up and is clustered so that much of the transportation and utility services are internal to the structure. The differences in per-unit costs between A, C, E, F, and G are purely functions of gross density (on land under development) while the cost on B and D is both a function of density and the economics of transportation and utility services in building vertically.

4 Sewage plant capital costs are a function of level of treatment and scale. We have assumed tertiary treatment in all cases. The larger the plant capacity the lower the capital cost per million gallons per day. Capital costs of treatment plants were estimated on the basis of data in Robert V. Thomann, Systems Analysis and Water Quality Management, Environmental Research and Applications, Inc. New York, New York, 1972.

5 Clearing, drainage and grading are calculated on a per acre basis, $600 per gross suitable acre for prototypes C through G, so lower gross densities mean higher per unit costs. For A and B these costs are much lower, only $150 per gross suitable acre, since drainage has already been taken care of by the dredge operation.

6 B is far higher than the others simply because there is a great deal of commonly held land any any improvements of it are a part of land development costs. This prototype would also probably involve construction of marinas since there is navigable water available to everyone but most units would not have individual boat moorings adjacent to their homes. In all cases the recreation and landscaping would probably include golf courses and swimming clubs.

7 This is only a very gross approximation of the costs of promotion, sales and administration. It is difficult to estimate since promotion and sales campaigns differ widely. But the higher density prototypes would probably have lower costs.

8 It is assumed that the capital funds for developing the land are borrowed at 7.2% per annum. If the developer has sufficient capital to pay for all or part of the development he is sacrificing the interest his money otherwise could be earning. Therefore, what is listed here as interest is actual interest payments and/or interest earnings foregone.

Table 3. Specifications of Growth and Development. A = acre (Source: Tables 1 and 2).

Cases	I	II	III	IV	V
Constraints:					
County plan targeted no. units	no limit	24,000	no limit	24,000	12,000
Dredge and fill	allowed	allowed	not allowed	not allowed	not allowed
<u>Land Use Characteristics</u>					
Prototypes chosen: West	B	A	D	C	C
East	E	G	E	F	G
Development model no. units	69,000	23,000	70,000	24,000	13,100
Population estimate	192,600	69,000	183,000	72,000	39,300
Gross density total (U/A)	2.9	0.95	2.9	1.0	0.55
Gross density on developed land (U/A)	3.6	1.6	4.7	1.8	1.4
Preservation area, including Rookery Bay Sanctuary/A	5,000	9,500	7,000	11,000	14,500
Conservation area/A	0	0	2,000	0	0
Developed area/A	19,000	14,500	15,000	13,000	9,500
<u>Private Economic Value</u>					
Total residual to the land (millions)	300.8	170.5	251.4	139.4	85.9
<u>Environmental Indicators</u>					
Water surfaces created/A	1,900	2,600	0	0	0
Impervious surfaces/A	5,900	2,900	6,000	2,900	1,900
Sewage M.G.D.	24.1	8.7	22.9	9.0	5.0
Managed turf/A	12,200	9,000	9,000	10,000	7,600

Study No. 12

A Simulation Modeling Approach to the Study of Development Alternatives

BY

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Introduction

The objective of this project was to design a simulation model of the Rookery Bay - Collier County area which would be capable of comparing the effects of alternative land development schemes on the Rookery Bay estuarine ecosystem. The project was conducted by an interdisciplinary team from the Department of Environmental Sciences of the University of Virginia.

The ideal sequence in the development of such a project is normally to: 1) define the problem; 2) state its objectives; 3) structure a conceptual model to meet the stated objectives; 4) design the research to yield the information needed for the model; 5) implement and exercise the model on the computer, and 6) upgrade the model based on further research and results. Inasmuch as the field research on the project was not designed for the purpose, and less than three months was available for the effort, only the first three steps of the developmental sequence above were completed to any degree. Step 5 is attempted using some of the diverse data generated by project research plus data from other sources. Step 4 is outlined and step 6 suggested.

The simulation model of the estuarine ecosystem must be capable of responding to simulated natural and cultural (developmental) stresses so as to furnish the probable consequences of management decisions affecting not only the immediate environs of Rookery Bay, but also the adjacent coastal zone and the drainage basin which nourishes it. Thus any natural or man-induced alterations to any of the parameters which affect the estuarine ecosystem such as energy flux, nutrient levels and cycling, circulation, water quality or quantity, or interrupted trophic level linkages should ideally be capable of simulation and response. The major natural stresses to the coastal ecosystem are those which affect the hydrologic cycle; man-induced stresses can generally be linked to land use environmental impacts.

THE MODEL

Model Description

Our initial efforts were devoted to developing a conceptual model, and determining which of its components could be produced within the allotted time. The model was structured into four sub-models: 1) land use; 2) watershed and hydrology; 3) estuarine hydrodynamics, and 4) estuarine ecology. The relationship of these sub-models to one another is shown in Figure 1.

Conceptually, the sub-models are linked as follows:

1) The Land Use Sub-Model is defined by the size of the watershed and its surface characteristics as controlled by the various land uses within it. These land uses provide environmental impacts which affect air and water quality. Both land uses and population densities vary with each of the proposed development schemes for the watershed. The major input to this sub-model is rainfall, which either runs off directly into the estuary or infiltrates the soil picking up nutrients, pollutants, etc., as it moves toward the estuary. The output from this sub-model provides input to the watershed hydrology sub-model.

2) The Watershed Hydrology Sub-Model simulates stream flow within the Rookery Bay watershed. In addition, the flowing water serves to transport the water quality parameters generated by the land use sub-model. Outputs include the stream flow hydrograph sub-model and overland runoff, which serves as an indirect input to the hydrodynamic sub-model flowing through the mangrove shoreline segment of the ecological sub-model.

3) The Estuarine Hydrodynamic Sub-Model driven by these inputs, and oceanic tidal amplitudes and salinities, predicts the temporal and spatial distributions of a variety of physical and chemical water parameters within the estuary which also serve as input and limiting functions for the estuarine ecology sub-model.

4) The Estuarine Ecology Sub-Model serves to simulate the dynamic interactions between the physical system and the ecological components of the Rookery Bay estuary. It is divided into four segments: mangrove shoreline, benthic, planktonic, and pelagic. These segments contain the ecological objectives to which much of this study is directed.

Constraints and Limitations

Due to the limited time available for what is normally a lengthy and complex process, an attempt was made to utilize "off-the-shelf" models. That is, models were used which have been developed and proven to accurately simulate environmental processes provided they are accurately parameterized, utilize correct internal coefficients, and have inputs from adequate data bases.

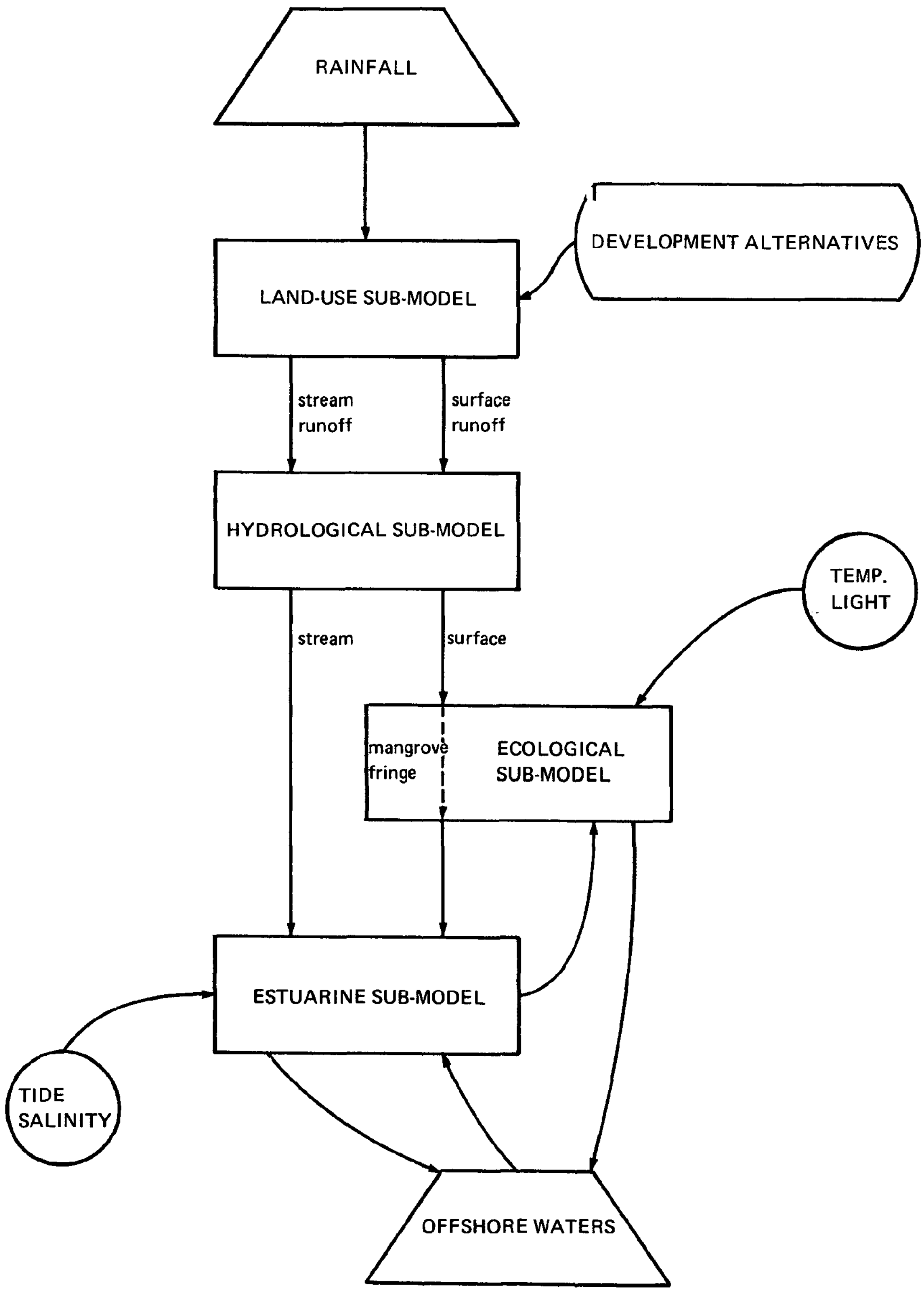

Figure 1. Combination development impact model for the Rookery Bay watershed.

The models described here are not specifically models of Rookery Bay. They are models of processes present in estuarine areas and uplands similar to the South Florida area. Rookery Bay itself was 'modeled' by providing the appropriate parameters to these general process models. For example, the watershed sub-model requires local infiltration rates and hourly precipitation rates, and the estuarine hydrodynamic sub-model requires the surface area, volume, and tidal amplitude of Rookery Bay. The values of these parameters supplied to the sub-models were those measured in western Collier County and the Rookery Bay estuary.

The overall systems model which was previously described represented the conceptual base from which the physical and ecological sub-models developed. With the limited resources, including time available, we decided, inasmuch as water quality was a primary concern, that the initial emphasis would be on the development of the watershed and estuarine hydrodynamic sub-models. The importance of water level and temporal distribution of discharge for the South Florida ecosystem has been well established (Tabb, 1963). If these two models can be made operational for Rookery Bay then important effects of land use alternatives on the water volumes, quality, and periodicity can be studied. Later, when sufficient information is available on the communities of Rookery Bay, effort can be devoted to detailed ecosystem modeling.

Rookery Bay Model

Land Use

The soils of the coastal lowlands of South Florida have been developed on marine sands of the Pamlico Formation and have extremely good infiltration when the water table is several feet below the surface. For the most part these soils are low in organic matter and require extensive fertilization.

The Rookery Bay estuary is dominated by Henderson Creek and canal (surface area, 217.64 sq. mi.) to the south and Stopper Creek (9.8 sq.mi.) to the north, with overland flow through mangrove swamps in between (6.29 sq. mi.). The drainage basin is sparsely populated, with a total population of 1583 persons (1970). Other land use consists of a few hundred acres of row crops which are intensively cultivated, using up to 3000 lbs. of fertilizer per year.

For the purposes of this study all of the sewerage was considered to be treated to a level of .0525 lbs. BOD per capita per day and discharged to Henderson Creek. Background BOD levels in Henderson Creek were assumed to be 4 mg/l and no land surface runoff BOD was added because the high infiltration and poor runoff characteristics of the soils suggests this source to be minimal. On the other hand, storm sewer drainage was considered to add up to 0.062 lbs. of BOD per capita per day for a 2" rain, decreasing linearly below that to 0.0 BOD at .5" rain. Eutrophication effects from nitrates and phosphates originating with agriculture and lawn fertilization were considered, but temporarily ignored, because the estuarine module could not handle them without biological uptake coefficients -- and these were not available.

With this model land use plans, including larger population levels can be analyzed for their effect on estuarine water quality as measured by BOD and by nutrients when those data are available.

Watershed Analysis

To assess the impact of development on water quality in Rookery Bay, it is necessary to be able to estimate changes in the quantity and quality of the fresh water delivered to the bay. Thus, one of the components of a mathematical model of the entire system must be a model of the hydrologic cycle of the watershed.

One of the best-known models of watershed functioning was developed by Crawford and Linsley (1964) and is known as the Stanford Watershed Model (SWM). Because this model has been successfully applied to numerous watersheds and because it is relatively easy and economical to use, we adopted a version of the SWM for use at Rookery Bay.

The Stanford Watershed Model* is a digital computer simulation of the hydrologic cycle of a watershed. It is a deterministic model in that a single output, streamflow, is predicted from two inputs, rainfall and evaporation, using several parameters which are descriptive of various fluxes and storages, (e.g., parameters provided to the model include an infiltration index, percent impervious area, slope, length of overland flow, etc.). A complete description of the model is given by Crawford and Linsley (1964).

In adapting the SWM for any particular watershed the model must be "tuned" using historical data. That is, the various parameters in the model are adjusted until the predicted stream flows give a reasonably good estimate of gauged flows in the watershed for some period of record. Normally, about five years of hourly precipitation data, daily pan evaporation data and daily stream flow data are used in this calibration phase of the work. However, when this study was undertaken, flow data were available only for 1970-71. The closest weather bureau station reporting hourly rainfall proved to be at Fort Meyers, Florida, and the closest pan evaporation data station was Flamingo Ranger Station near Everglades, Florida. The necessary parameters for the model were estimated using published guides (Crawford and Linsley, 1964; NOAA Technical Memorandum MWS HYDRO-14, 1972). The drainage area upstream of the gauge was estimated at 6 sq. mi. from the map prepared by Veri et al (1973).

During model validation experiments the low flow predictions compared favorably with the observed data but the predicted high flows were only a fraction of the observed. The only explanation for these results is that during peak flow periods, significant quantities of water enter Henderson Creek from outside the basin as defined by Veri et al. (1973).

An adjustment for the extra basin flows into the area was made by simply adding an influent hydrograph for the upstream end of Henderson Creek. The simulated data (by necessity) then almost perfectly match the observed hydrograph. This influent hydrograph was assumed to be linearly related to the amount of precipitation occurring so that it could be adapted to simulate wet and dry years.

In a low precipitation year (29" annual precipitation) significantly less fresh water is delivered to the bay than for a moderate year, 1970-71 (42" annual precipitation). But the minimum stream flow rates, which are a critical factor in water quality analysis, are comparable in magnitude for both low and moderate years. During a wet year (69" annual precipitation), the very high peak flows indicate that salinities in the bay might be significantly depressed over those for a "normal" year.

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* The version of the SWM used in this study was a FORTRAN translation of the original subalgol program which was provided by Mr. Eric Anderson of NOAA.

Several conclusions can be drawn from the observed data for 1970-1971 and the simulation models:

1) The extended low flows are so low (on the order of .1 cfs) that they cannot be significantly lowered by development. In fact, since water would probably have to be imported to support development, the low flows would be expected to increase (e.g., a population of 50,000 using an average of 100 gpd per person would result in a discharge of almost 1 cfs).

2) The high flows in Henderson Creek are dominated by water entering from outside the basin, thus reducing the effect on flow schedule or volume of development within the basin.

From 1) and 2) above it appears that the most important direct effect of development within the watershed will be on the quality of fresh water delivered to Rookery Bay. Less important will be the effect on flow schedule and volume. The next step in the watershed modeling effort would be to add the capability to handle nutrient runoff and BOD input to provide proper inputs for the estuarine hydrodynamic sub-model.

Estuarine Hydrodynamics

The analysis of the water quality, hydraulics and salinity distributions were made with a one-dimensional numerical computer model. The model, a modified version of the MIT Unsteady Salinity Intrusion Model (Thatcher and Harleman, 1972) assumes all flows and distributions are in the longitudinal direction only, i.e., they are averaged over a cross-section. All inflows of fresh water and pollutants (BOD) are assumed to occur at the head of Henderson Creek. A tidal range of .9 feet and a salinity of 33% were specified at the mouth of the model estuary. Using these boundary conditions, and the equations of conservation of mass and momentum, the model computes elevations, discharges and salinities within a tidal cycle for each section of the model. The model is capable of handling BOD and dissolved oxygen, but their introduction was beyond the scope of this study. By using different values of fresh water inflow at the head of Henderson Creek, the model can be used to simulate the water quality in Rookery Bay. Inasmuch as this model is one-dimensional and neglects lateral inflows, evaporation and wind stresses, its ability to provide an accurate prediction of the highly complex hydrodynamic and water quality parameters of this estuary may be questioned. However, this model does serve to illustrate general trends and the kinds of analyses which could be made with a more sophisticated computer model. However, the present model can yield solutions which bracket the possible limits of water quality degradation resulting from increased development of the adjacent lands.

Figure 2 illustrates the computed values of the salinity, tidal height, and discharge over a tidal cycle at the middle station for typical conditions in the bay, (fresh water inflow = 3.5 cfs; tidal amplitude = .9 ft.; entrance salinity = 33 o/oo).

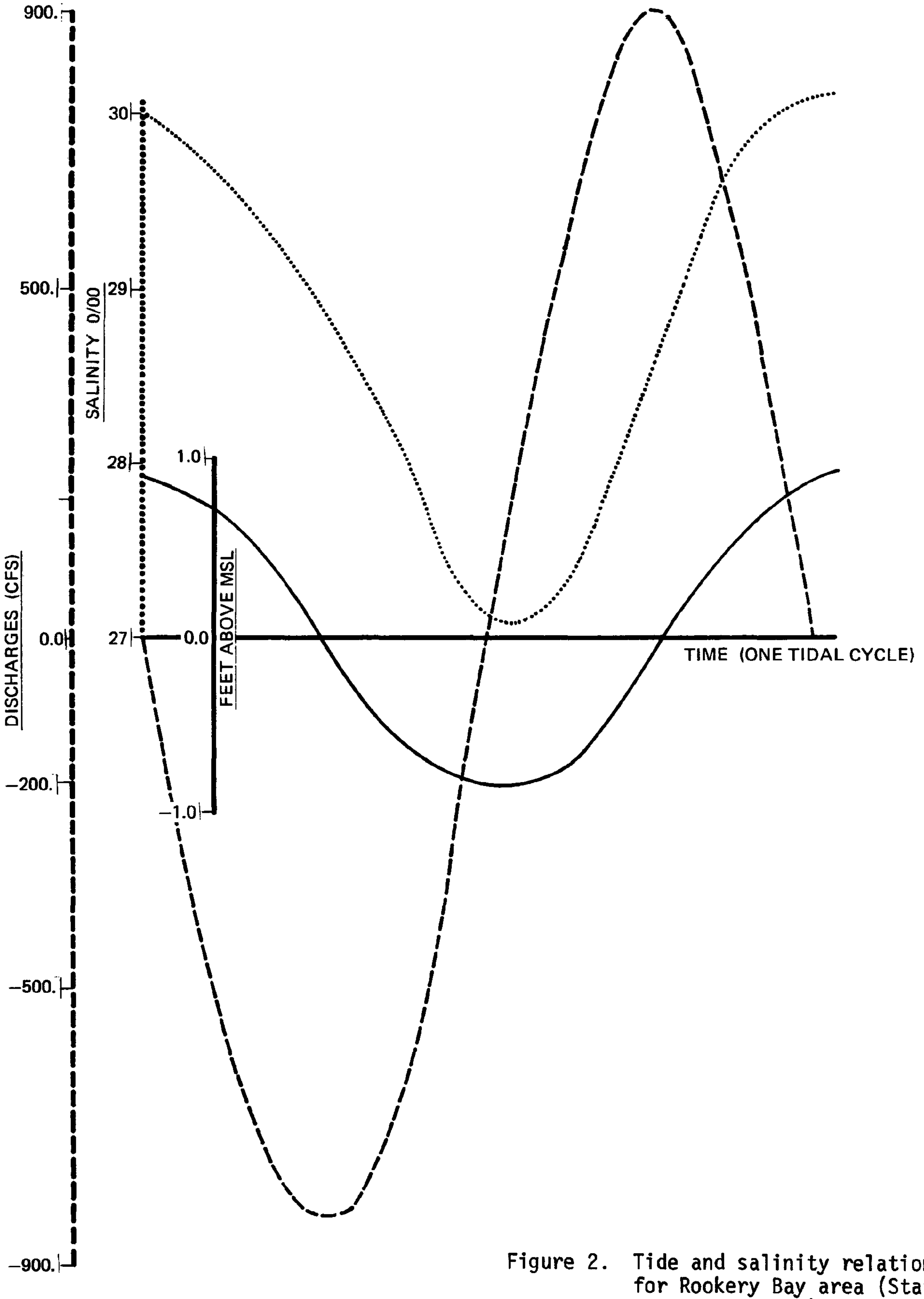

Figure 2. Tide and salinity relations for Rookery Bay area (Station 13, mid-estuary): tidal elevation (solid line), tidal discharge (dashed line), and salinity (dotted line).

The model can be used to illustrate the hydrodynamic coupling between water quality parameters (Figure 3). By increasing inflow of fresh water from 3.5 cfs to 100 cfs one can observe the effects of high rainfall on the distribution of salinity in the bay at low and high water slack tide. In this example the toe of the high water slack salinity has been moved from far up Henderson Creek down to the middle reaches of the bay. Other changes, e.g., tidal range, mean depth or channel geometry, can also be examined.

Ecosystem Analysis

The ecosystem analysis sub-model was designed to simulate the dynamic changes in the functional ecological components of the Rookery Bay estuary and its mangrove fringe. Although the fate of the biota of the estuarine area is one of the prime reasons for this study, the dynamic aspects of the ecology were not modeled past the conceptualization stage, since there were not sufficient quantitative data available to allow further development at the time.

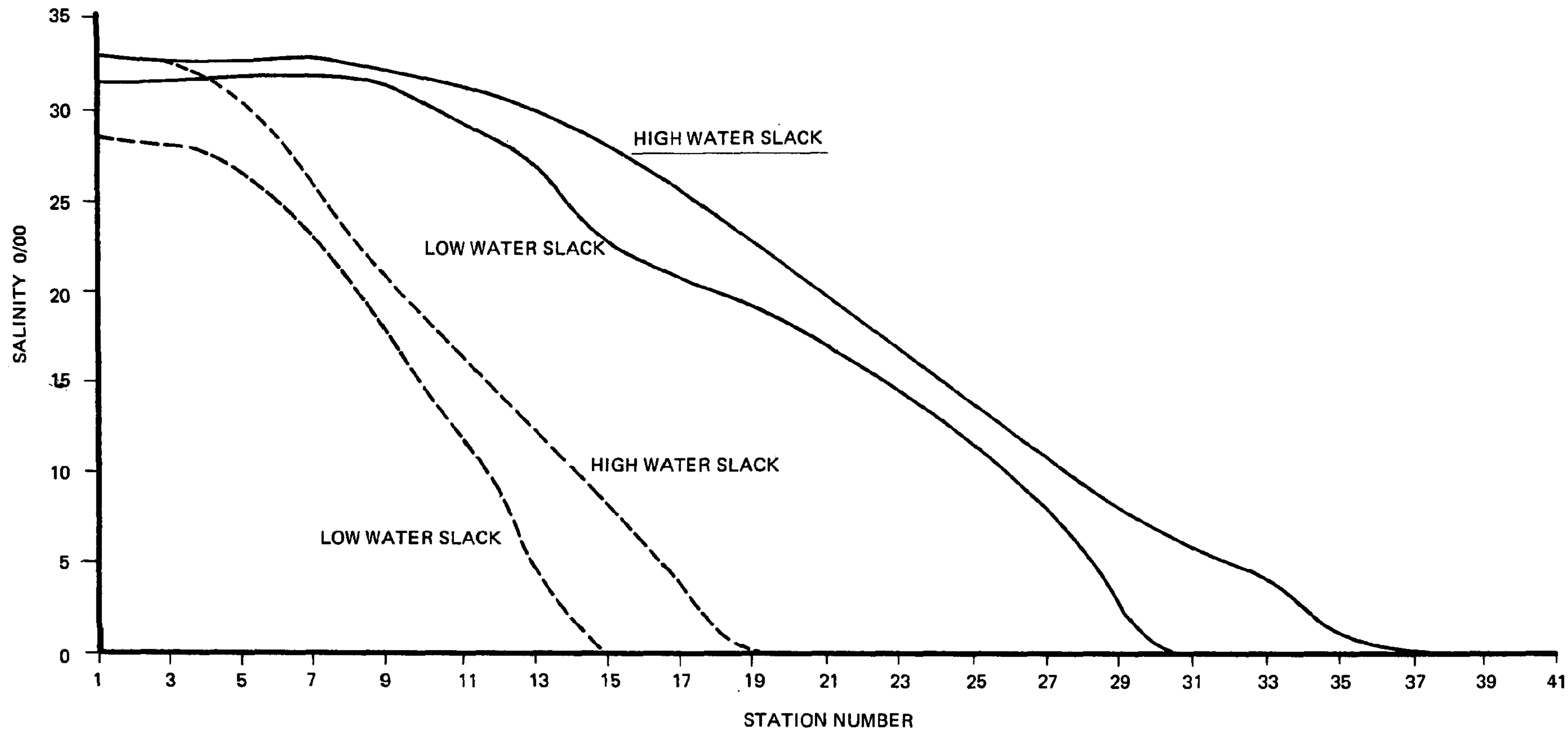

Figure 3. Longitudinal salinity distribution for Henderson Creek discharge rates of 3.5 c.f.s. (solid line) and 100 c.f.s. (broken line).

Model Improvement

Our study must be considered exploratory and the models need considerable further development. The most obvious requirement is the development of an adequate ecological model which would be based on: theoretical information currently available, specific information emanating from the final reports currently being prepared for the Rookery Bay project, and some future studies which would be needed. In the land-use segment, better information on land use, both present and projected, is needed. Some of this is presently in preparation.

Currently, the watershed and estuarine hydrodynamics sub-models run at different time scales and thus are not interactively coupled. The estuarine model could be expanded to include lateral inflows, evaporation and water quality parameters such as nitrates and phosphates.

The above-noted model improvements and developments are all possible within the current state-of-the-art. The primary major innovation is in linking the models developed in different disciplines. Our experience with the Rookery Bay project has convinced us that this integration of various sub-models into a dynamic, interacting overall system model is feasible. Such an endeavor would be not only of academic interest, but the resulting product would be capable of helping to answer the basic question first addressed: "What will be the impact of regional development on the environment of South Florida estuaries?"

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