IMPLICATIONS AND MANAGEMENT OF A SEA LEVEL RISE IN THE SARASOTA BAY REGION

Prepared by: Tampa Bay Regional Planning Council

9455 Koger Boulevard, Suite 216
St. Petersburg, Florida 33702
(813) 577-5151

Prepared for: Sarasota Bay National Estuary Program

1550 Ken Thompson Parkway
Sarasota, Florida 34236
(813) 361-6133

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EXECUTIVE SUMMARY

Sarasota Bay is a small, subtropical embayment on the west coast of peninsular Florida. Like much of coastal Florida, the Sarasota Bay area is experiencing rapid population growth, although most of the development having adverse environmental impact has occurred only in the last 50 years. Recent observations indicate an accelerating rise in sea level that may threaten coastal wetlands and shoreline communities in the future. The Tampa Bay Regional Planning Council received funding from the Sarasota Bay National Estuary Program to evaluate the existing literature on the subject and the potential impacts to regional natural systems, cities and barrier island communities; and to develop a mitigation and management plan to address future needs.

The evaluation indicates that, as a result of the greenhouse effect and local conditions in the Sarasota Bay region, we can anticipate the following to occur:

- The consequences of atmospheric loading of greenhouse gases are likely to increase global temperatures and accelerate rising sea levels above normal climatic cycles. If emissions of CO_2 and other greenhouse gases continue unabated, the earth will warm five to ten times faster than during the retreat of the last ice age, resulting in an average global temperature increase of 1°C by the year 2025 and 3°C before the end of the next century. Global sea level is expected to ascend due to ocean warming creating thermal expansion and as ice sheets and glaciers thaw.

- In Sarasota Bay, the calculated position of mean higher high water (MHHW) in 2115 AD may reach 64 cm (2.1 ft) above present MHHW.

- Tidally influenced wetlands may be greatly affected by rising seas due to the presence of shoreline development which prevents migration of wetland communities into higher lands. Already mangroves have been observed migrating into tidal flats in response to existing sea level changes.

- Shallow ground water systems could experience additional saltwater intrusion which would affect shallow aquifers and septic tank efficiencies.

- The barrier island community of Longboat Key may experience increased incidence of flooding as sea level rises. The beach system is expected to require additional renourishment activities in order to maintain this important recreational and natural resource. Eventually, responsible entities will need to consider maintenance or abandonment of development which is affected by increased flooding events.

- The City of Sarasota will experience increased flooding events along coastal areas. However, due to the topographic elevations in many areas, flooding should not be as widespread as on the barrier islands. The City infrastructure may require additional maintenance to prevent saltwater intrusion or to prevent flooding from affecting services.

Management of sea level rise will require proactive planning in order to lessen future problems and reduce capital expenditures. Comprehensive planning, natural resource permitting and infrastructure design are all tools that are available to mitigate impacts created by rising seas. Demonstration projects and water level monitoring are necessary to determine the extent of rising seas and identify approaches to reduce impacts. The opportunity is available now to ensure maintenance of our resources while buffering urbanized areas from the potential detrimental effects of the rise in sea level.

IMPLICATIONS AND MANAGEMENT OF A SEA LEVEL RISE IN THE SARASOTA BAY REGION

Tampa Bay Regional Planning Council

INTRODUCTION

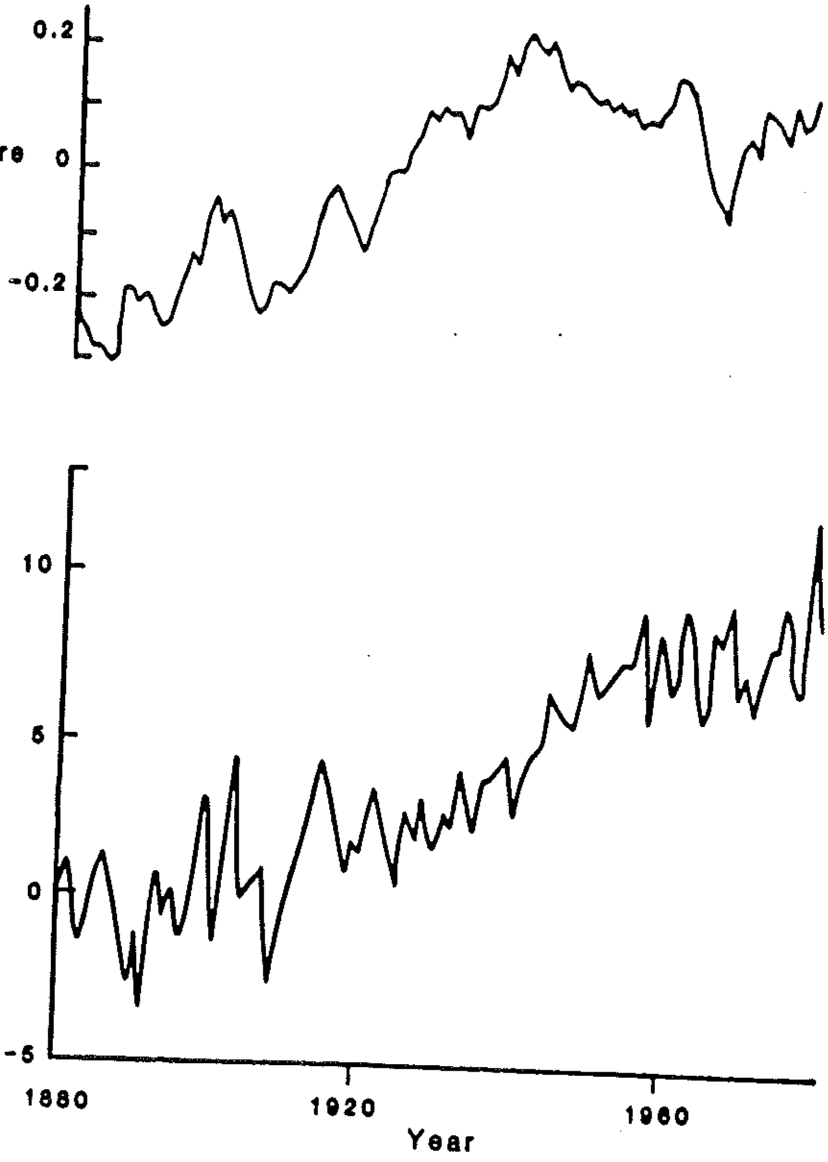
During the past three to four thousand years, the level of the sea has risen slowly, with minimal impact on natural communities. However, recent observations indicate an accelerating rise in sea level that may threaten coastal wetlands and shoreline communities in the future. Although the world-wide sea level has risen only four to six inches in the past century (Figure 1), the National Academy of Science (NAS) and the Environmental Protection Agency (EPA) have estimated that the expected atmospheric warming will create a one- to five-foot rise in the next century. Therefore, the Tampa Bay Regional Planning Council received funding from the Sarasota Bay National Estuary Program to evaluate existing literature on the subject and potential impacts to regional natural systems, cities and barrier island communities, and to derive a mitigation and management plan to address future needs.

Sarasota Bay is a small, subtropical embayment on the west coast of peninsular Florida. Like much of coastal Florida, the Sarasota Bay area is experiencing rapid population growth, although most of its development having adverse environmental impact has occurred only in the last 50 years. Sarasota Bay's economic value is evidenced by intense recreational use, as well as its indirect effect on waterfront property values.

Sarasota Bay constitutes the central geographic feature most responsible, both historically and presently, for the industrial development, aesthetic and recreational values that result in the overall attractiveness of the region and the rapidly-growing population. Compounding the impact of the Sarasota Bay region's phenomenal growth is the population's desire to locate on the region's shoreline. This is evident by the extent of development on the barrier islands and filling for residential and industrial development on the periphery of the bays. Coastal development oftentimes requires hardening of the shoreline to prevent property damage. The magnitude of coastal and low-lying development may pose an intractable problem during a rise in sea level, without adequate long-term planning and management.

The natural ecosystems within the Sarasota Bay region historically have been stressed by development activities. In undeveloped areas a rise in sea level will increase the frequency of tidal flooding throughout a salt marsh, causing the system to migrate landward. The impact of sea level rise on salt marsh acreage also depends on the topographic slope of the marsh and upland areas. If the land has a constant slope throughout the marsh and upland, the area lost to marsh drowning will equal the area gained by the landward encroachment

Figure 1. Global temperature and sea level rise over the last century (Hanson et al., 1981).



Sources: Temperature curve from: J.E. Hansen et al., "Climate Impact of Increasing Atmospheric Carbon Dioxide," Science, 1981, p. 957-966. Sea level curve adapted from: V. Gornitz, S. Lebedeff, and J. Hansen, "Global Sea Level Trend in the Past Century," Science, 1982, p. 1611-1614.

of higher tides. Urbanized upland areas will, however, prevent the landward migration of the marshes and the systems will eventually be lost. Seagrass beds are particularly sensitive to the sun light climate of the overlying water column. An increase in depth can potentially remove existing seagrass beds from the photic zone.

Saltwater intrusion from the expected rise in sea level could also add to wetland losses and contaminate potable groundwater supplies. Rising seas permit saline waters to penetrate upstream and inland. This impact is further exacerbated during periods of drought. Many of the freshwater wetlands in the Tampa Bay region are barely above sea level and could potentially be replaced by salt tolerant marsh and mangroves. In addition, the landward migration of salt water could add to the regional problem of saltwater intrusion into the Floridan Aquifer.

Sarasota and Manatee Counties contain extensive barrier islands fronting the Gulf of Mexico. The islands are a vital economic resource to the region through tourism. A rise in sea level may squeeze the barrier island systems between an advancing sea and human activities aimed at maintaining the economic resource. As an example, the Army Corps of Engineers has begun an analysis of beach renourishment alternatives along Anna Maria and Longboat Keys, without considering the expected rise in sea levels. Beach stabilization alternatives should also evaluate future conditions.

Of equal concern is the general lack of understanding and/or disbelief among local government decision makers that the greenhouse affect with an associated sea level rise will occur in the region. Ongoing local government activities affected by rising seas include purchase of environmentally sensitive lands (buffer/transition lands), siting of power generating facilities (infrastructure development), flood control and development regulations. In the rapidly developing Sarasota and Tampa Bay Regions it is imperative to raise the awareness of local elected officials, regulators and planners of the potential impacts and management mechanisms.

The specific objectives of the project will be to:

1) Document available technical information on the greenhouse effect and the associated rise in sea level on the global and national levels.

2) Determine the extent of potential impacts created by the average predicted rise in sea level for the years 2020, 2065 and 2115 A.D. in the Sarasota Bay area.

3) Graphically depict land cover, habitats, water features, topography, soils and major cultural resource sites in the study area.

4) Evaluate site specific evidence of sea level rise (SLR) within the study area over the past century.

5) Determine the potential impact of the average predicted rise in sea level on natural systems, a coastal city (infrastructure, emergency planning and other social implications), a barrier island community (infrastructure, development, beach and inlet management), and historical resources (archaeological sites and historical structures) in the Sarasota Bay region.

6) Develop management strategies for use by regulatory agencies and local governments in evaluating the potential impacts of a rise in sea level on future development activities and infrastructure.

Management guidelines will be compiled for inclusion into regional and local government comprehensive plans that will assess and plan for impacts of a rise in sea level on natural resources, barrier island systems and city communities. The planning and management guidelines developed will be structured to apply generally to other coastal communities and natural resources in a similar condition. Additionally, the draft and final reports will include recommended demonstration projects, impacts on existing permitting processes and outlines for baseline monitoring.

Sea Level and the Greenhouse Effect

Throughout geological history, sea level has risen and fallen by more than 300 meters. During the last ice age (18,000 years ago) temperatures averaged five degrees Celsius colder than today, and sea level was one hundred meters lower than it is today (Donn, Farrand and Ewing, 1962; in Titus, 1987). The Florida Gulf coast was located 130 to 160 km west of what is now the mouth of Tampa Bay (Fletcher, 1991). The climate in Florida at the time was similar to the present climate in the state of North Carolina (Fletcher, 1991).

Changes in sea level are caused by changes in climate and therefore temperature of the earth. The changes that have occurred historically were predominantly so slow that plant and animal life were able to adapt to the changes in climate and sea level. However, the consequences of atmospheric loading of greenhouse gases is generally believed to have accelerated the rise in global temperatures and therefore will accelerate rising sea levels above normal climatic cycles.

The greenhouse effect is created by gases in the atmosphere which absorb heat (infrared radiation) derived from sunlight. Maintenance of global temperatures is achieved through a balance of sunlight that is received by the earth, reflected from the earth, and absorbed by gases within the atmosphere (Figure 2). Gases in the atmosphere which absorb infrared radiation, thereby effectively preventing its reflection, are termed greenhouse gasses. The climate of the planet may be changing because of the increase of carbon dioxide, methane, nitrous oxide, chlorofluorocarbons and other greenhouse gases resulting primarily by the burning of fossil fuels and deforestation (Figure 3).

Figure 2. A simplified illustration of the greenhouse effect (IPCC, 1990).

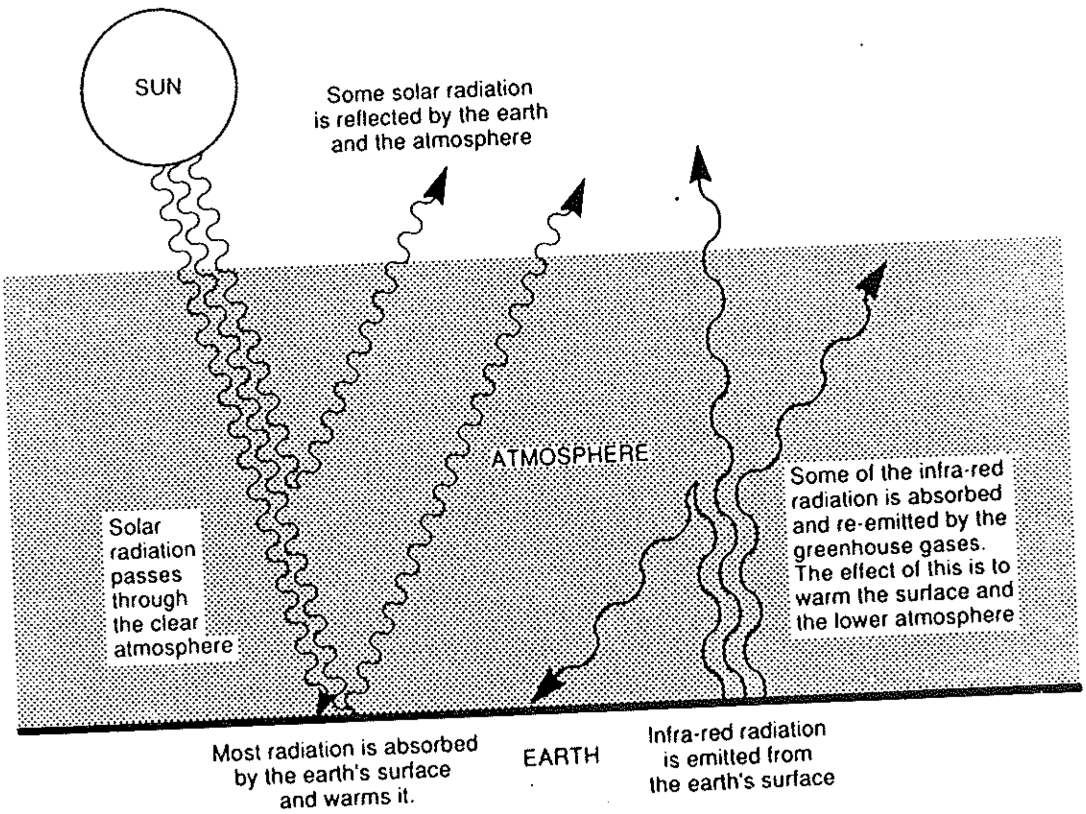


Figure 3. Illustration of climate components and interactions (Houghton, 1984 in IPCC, 1990).

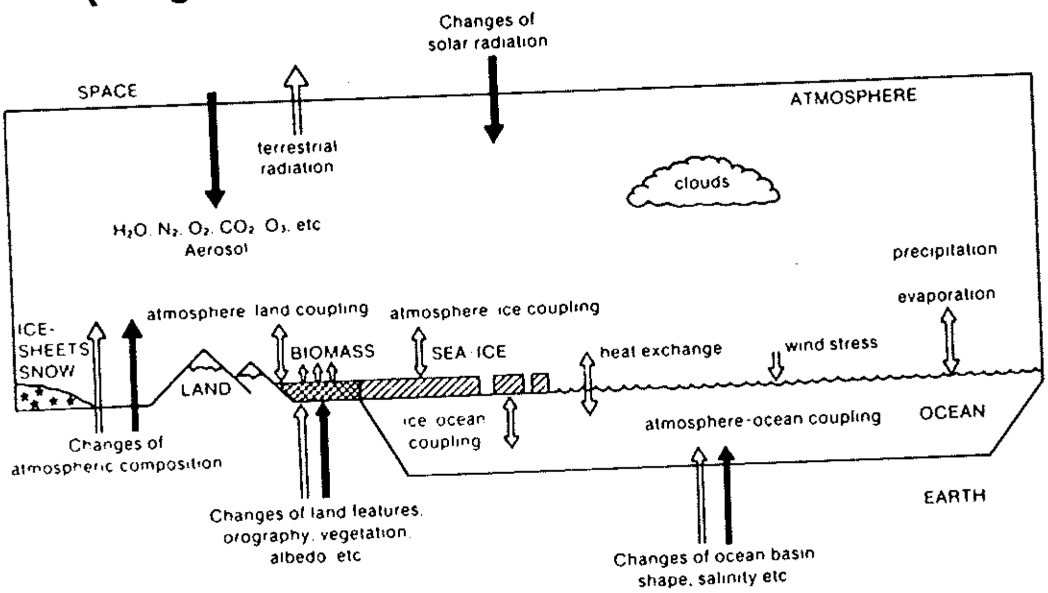
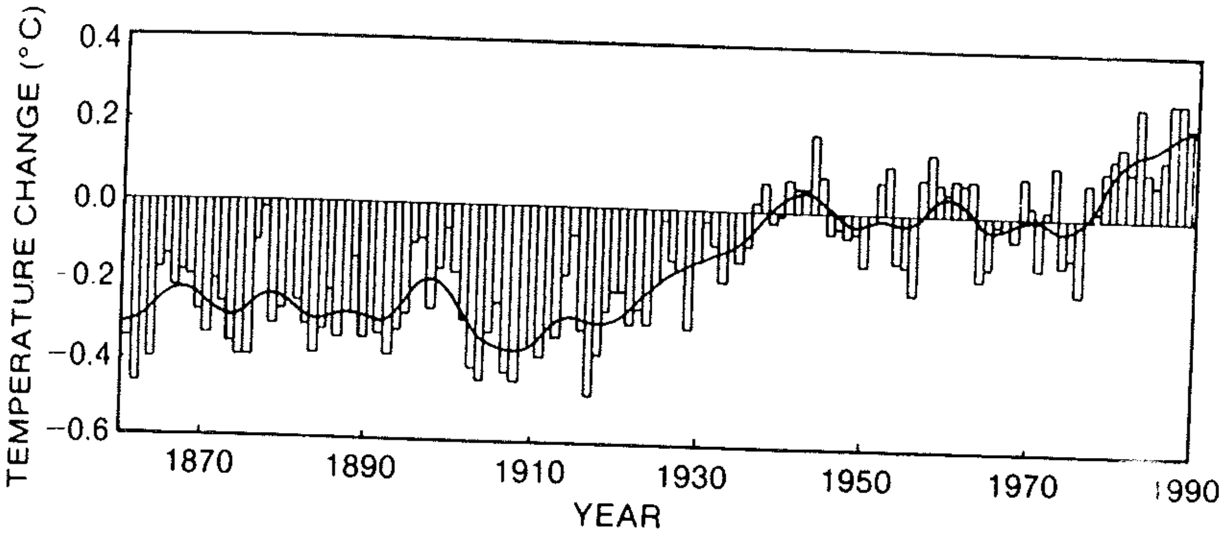


Figure 6. Global mean temperatures, 1861-1989, relative to the average for 1951-80 (Jones and Wigley, 1990).



Sarasota Bay Rate Projection

Sea level has been rising along the west Florida coast, including Sarasota Bay, and is projected to rise at an accelerated rate because of global warming. The Sarasota Bay NEP and Tampa Bay Regional Planning Council have contracted with Mote Marine Laboratories to estimate the vertical level of sea rise in 2020, 2065, and 2115 A.D.

Three aspects of sea level rise are pertinent. The first is the rate. Natural resources, such as wetlands, are sensitive to the rate of sea level change. If, for example, the rate exceeds a wetland's capacity to make and trap sediments it will eventually perish. A second important aspect is level stand. Some coastal features such as historical structures, or infrastructure (seawalls, roads, drainage systems) are inundated when water reaches a certain level. The third aspect of sea level rise that must be considered is the natural variation that will occur at new water levels, as a result of tides or storm surge.

This section establishes the rate, level stand, and tidal variations that are used in risk assessments reported in following sections. The extent of storm surge likely to occur at higher level stands is not calculated, although modeling methods exist for this purpose.

The following methods were employed. First, very recent literature on sea level projection was reviewed and the most authoritative projection was selected. Then, the projection was adapted for Sarasota Bay. This step involved the transfer of necessary data from nearby, comparable sites for which the necessary data are available. Next, tidal variation was added to the level stand projection and conditions in 2020 A.D. and 2065 A.D. were interpolated from conditions calculated for 2115 A.D. Finally, level stands were registered to an accepted vertical scale for mapping purposes.

In general, it must be noted that considerable uncertainty surrounds these projections. The largest measure of sea level rise projected to occur is based on assumptions regarding the ocean, atmosphere, ice, and groundwater that may change as new data from ongoing and new studies become available.

The National Research Council's Committee on Engineering Implications of Changes in Relative Mean Sea Level (1987) defines total relative sea level change (T) as the sum of the local (L) and eustatic (E) components, or

$$T = L + E$$

where L equals subsidence or uplift at a place, and E is the sum of eustatic rise from 1969 to 1990 (E') and eustatic rise projected to occur thereafter (E"). (The year 1969 represents the mid-point of the last 19 year tidal epoch for which the absolute vertical position of tidal datum planes was determined in Sarasota Bay.)

$$T = L + [E' + E'']$$

Subsidence at Sarasota (L) is not known precisely but can be estimated from nearby sites. The National Research Council (1987) adopted a long-term average subsidence rate of 0.8 mm/yr for St. Petersburg. In 146 years, apparent secular sea level could rise by 11.7 cm because of subsidence.

$$L = 11.7 \text{ cm}$$

The value of E' can be estimated as the difference between Sarasota's historic rate of apparent secular sea level rise, and subsidence at St. Petersburg, for the 1969 to 1990 period. Apparent secular sea level rise is not known precisely at Sarasota Bay but can be estimated from sea level trends at nearby sites. Lyles et al. (1988) report a 73 year trend of +2.2 mm/yr (+ 0.2 mm/yr) for Key West and a 61 year trend of +1.9 mm/yr (+ 0.2 mm/yr) for Cedar Key, from which a trend of 2.1 mm/yr may be estimated for Sarasota Bay.

$$E' = 2.1 \text{ mm/yr} - 0.8 \text{ mm/yr} \times 21 \text{ yr}$$

$$E' = 2.7 \text{ cm}$$

The value of E" represents a prediction of future eustatic rise. The Intergovernmental Panel on Climate Change Working Group 1 (Wigley and Raper, 1992) reports the best estimate for the Business As Usual scenario as 48.0 cm in 2100 A.D. This extrapolates to 54.5 cm between 1990 A.D. and 2115 A.D.

$$E'' = 54.5 \text{ cm}$$

$$T = L + [E' + E''] = 11.7 \text{ cm} + [2.7 \text{ cm} + 54.5 \text{ cm}]$$

$$T = 68.9 \text{ cm}$$

Mean annual sea level in 2115 may consequently be 0.69 m higher than mean sea level as last determined in Sarasota Bay. This amount of change is equivalent to 4.7 mm per year.

Mean higher high water was 31.4 cm above mean tide level during the 1960 - 1978 tidal epoch. Mean higher high water in 2115 A.D. may consequently be 0.31 m higher than mean annual sea level that year, or 1.00 m higher than mean sea level as last determined in Sarasota Bay.

All of the preceding calculations are relative to the mean sea level of the 1960 - 1978 tidal epoch. In order to map the projected values it is necessary to register tidal datum planes to an accepted vertical reference standard. The National Ocean Survey determined that mean tide level at Sarasota station # 872-6083 was 12.8 cm above the NGVD for the 1960 - 1978 tidal epoch.

Therefore, mean tide level in 2115 A.D. may reach 81.7 cm (2.7 ft) above NGVD. Similarly, mean higher high water in 2115 A.D. may reach 1.13 m (3.7 ft) above NGVD at Sarasota. By linear interpolation, mean higher high water in 2020 and 2065 may be 63.7 cm (2.1 ft) and 86.8 cm (2.8 ft) above NGVD, respectively.

Results for mean higher high water are summarized below.

Table 1. Vertical position of Sarasota Bay in 2115 A.D., in meters above NGVD.

MLLW	MTL	MHHW
0.51	0.82	1.13

The most significant consequence of these projections is that mean lower low water could reach a vertical level that is higher than the present-day level of mean higher high water near the end of the next century. This means that intertidal features that are only rarely wetted by tides today would be almost continuously underwater in the future. Exactly when this happens depends, of course, on the rate and time-course of sea level rise.

When the North American Vertical Datum (NAVD) of 1988 is adopted, these projections of sea level rise should be adjusted by its difference from NGVD of 1929.

LOCAL OBSERVATIONS OF SEA LEVEL RISE

During the past several decades significant attention has been given to evaluating the greenhouse effect and global warming. Increases in carbon dioxide levels, ozone depletion and atmospheric warming are indications of the greenhouse effect that are currently being described on a global basis. However, the association of sea level rise created by a greenhouse effect is poorly documented to date.

In Sarasota Bay, the calculated position of mean higher high water (mean of higher tidal events) in 2115 AD may reach 64 cm (2.1 ft) above present MHHW. By linear interpolation, mean higher high water in 2020 A.D. and 2065 A.D. may be 14.7 cm (0.5 ft) and 37.8 cm (1.2 ft) above MHHW, respectively. These tide level projections were overlaid on topographic contours for Sarasota Bay as quantified by the Southwest Florida Water Management District. Figure 7 describes the shoreline features reported on U.S.G.S. quadrangles that are based on mean high water (1.5 feet NGVD) for Sarasota Bay. The MHHW line for the years 2065 A.D. and 2115 A.D. are depicted on Figure 8 and 9, respectively, as generated by the Council's ARC/INFO geographical information system. The tabulations of area covered by the MHHW line for each representative year are identified on Table 2.

Table 2. New area covered by the MHHW line in 2065 and 2115 A.D.

MHHW in 2065 (1.3 feet to 3.0 feet NGVD)	6,180 acres
MHHW in 2115 (1.3 feet to 4.2 feet NGVD)	6,810 acres

In the Sarasota Bay area the oldest water level gauging station is located in St. Petersburg, Florida. The tidal station is maintained by the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service Sea and Lake Levels Branch and has been in place since 1947 (U.S. Department of Commerce, 1988). The measurements are reported from a tide gauge which continuously measures sea level heights relative to the land adjacent to the station location (U.S. Department of Commerce, 1988). Analysis of yearly averages are depicted on Figure 10. Ten year averages are illustrated on Table 3.

Table 3. Ten year average water levels at St. Petersburg, Fl. NOS station, No. 8726520 (USDOC, 1988).

TIME PERIOD	AVERAGE WATER LEVEL
1950 - 1959	4.25 feet
1960 - 1969	4.30 feet
1970 - 1979	4.41 feet
1980 - 1989	4.52 feet

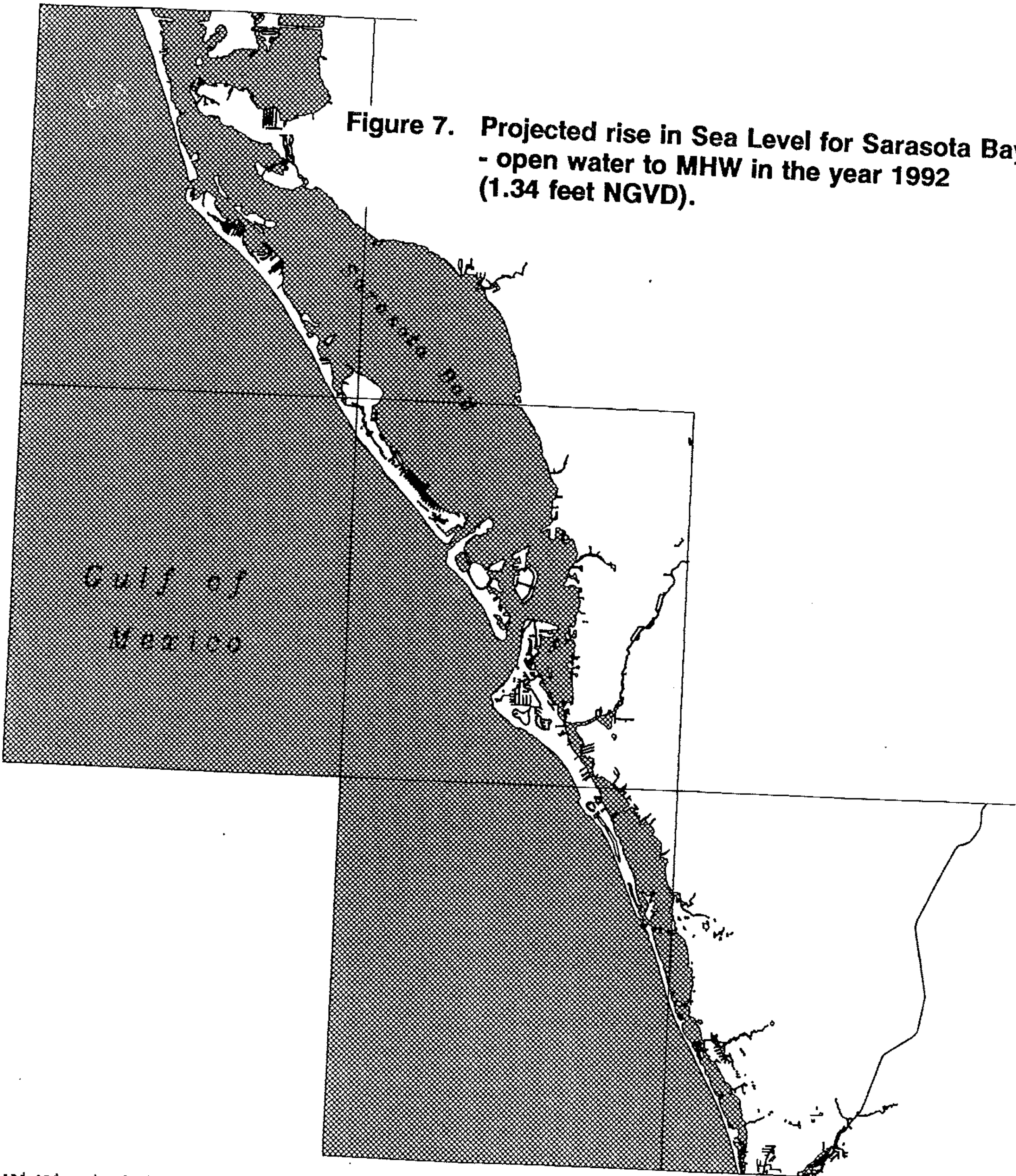


Figure 7. Projected rise in Sea Level for Sarasota Bay - open water to MHW in the year 1992 (1.34 feet NGVD).

Island and peninsula features contain areas of higher elevation that would not become inundated as illustrated.

MHW - MEAN HIGH WATER
MHHW - MEAN HIGHER HIGH WATER
NGVD - NATIONAL GEODETIC VERTICAL DA M

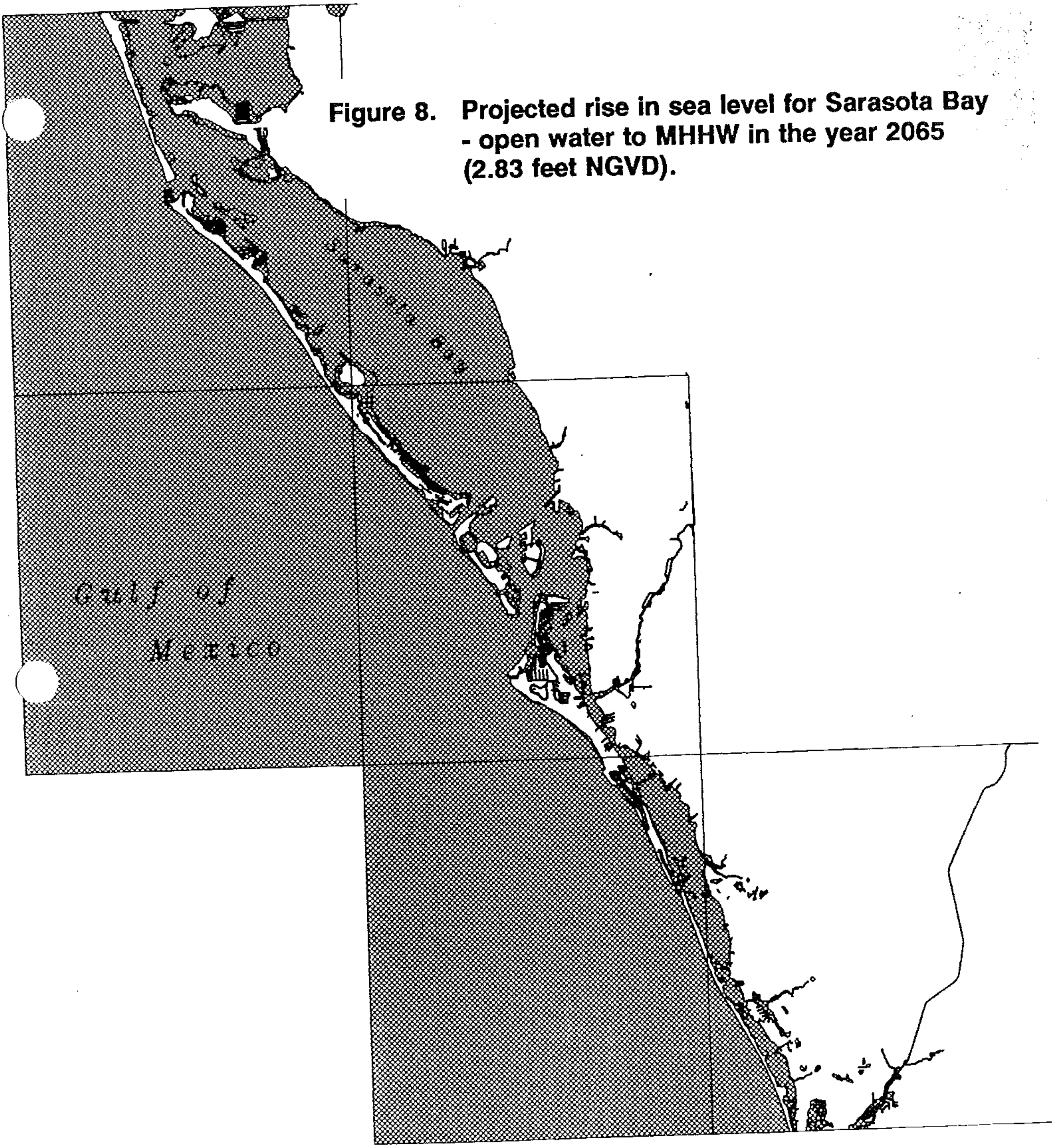


Figure 8. Projected rise in sea level for Sarasota Bay - open water to MHHW in the year 2065 (2.83 feet NGVD).

island and peninsula features contain areas of higher elevation that would not become inundated as illustrated.

MHW - MEAN HIGH WATER
MHHW - MEAN HIGHER HIGH WATER
NGVD - NATIONAL GEODETIC VERTICAL DAT

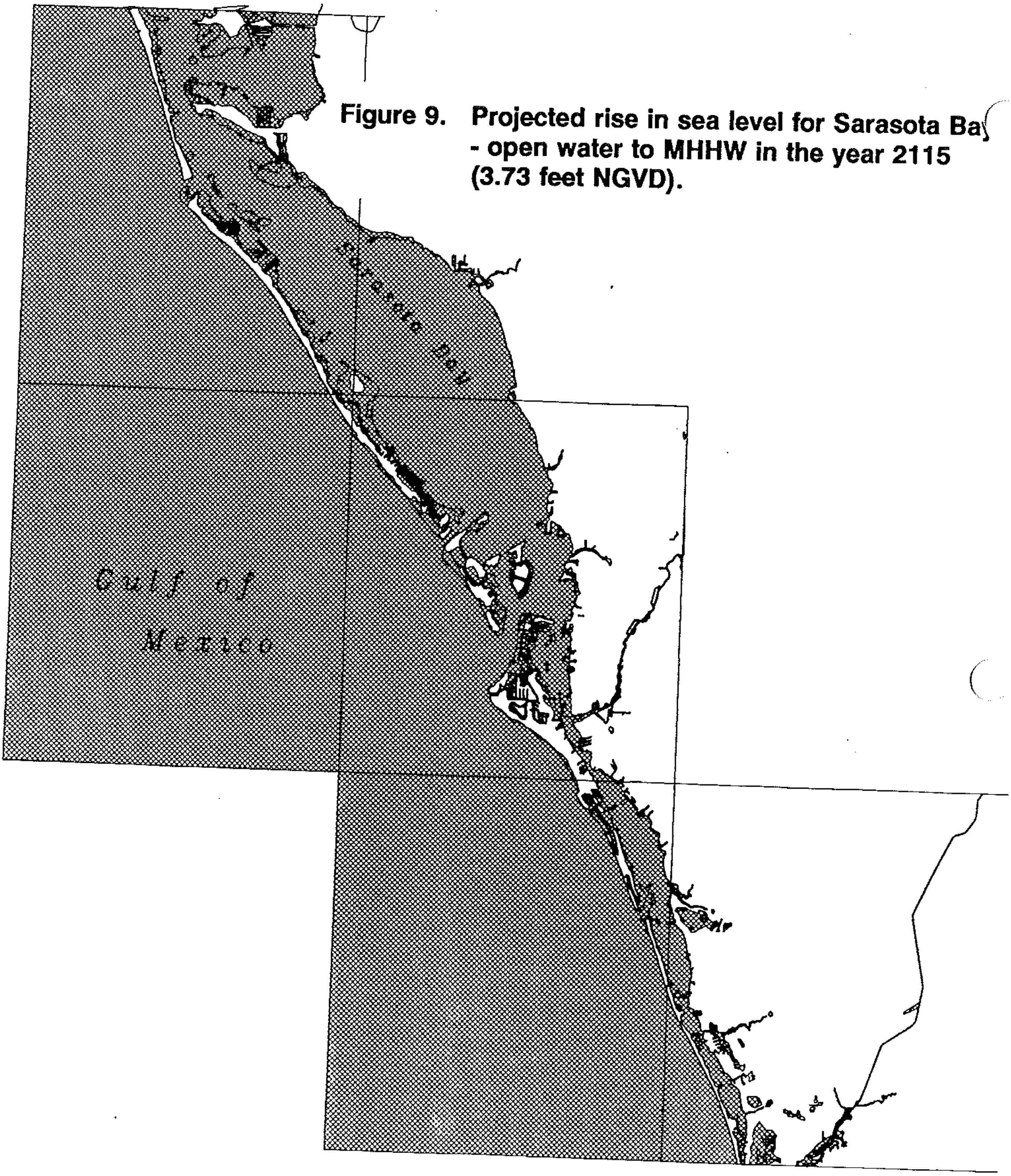
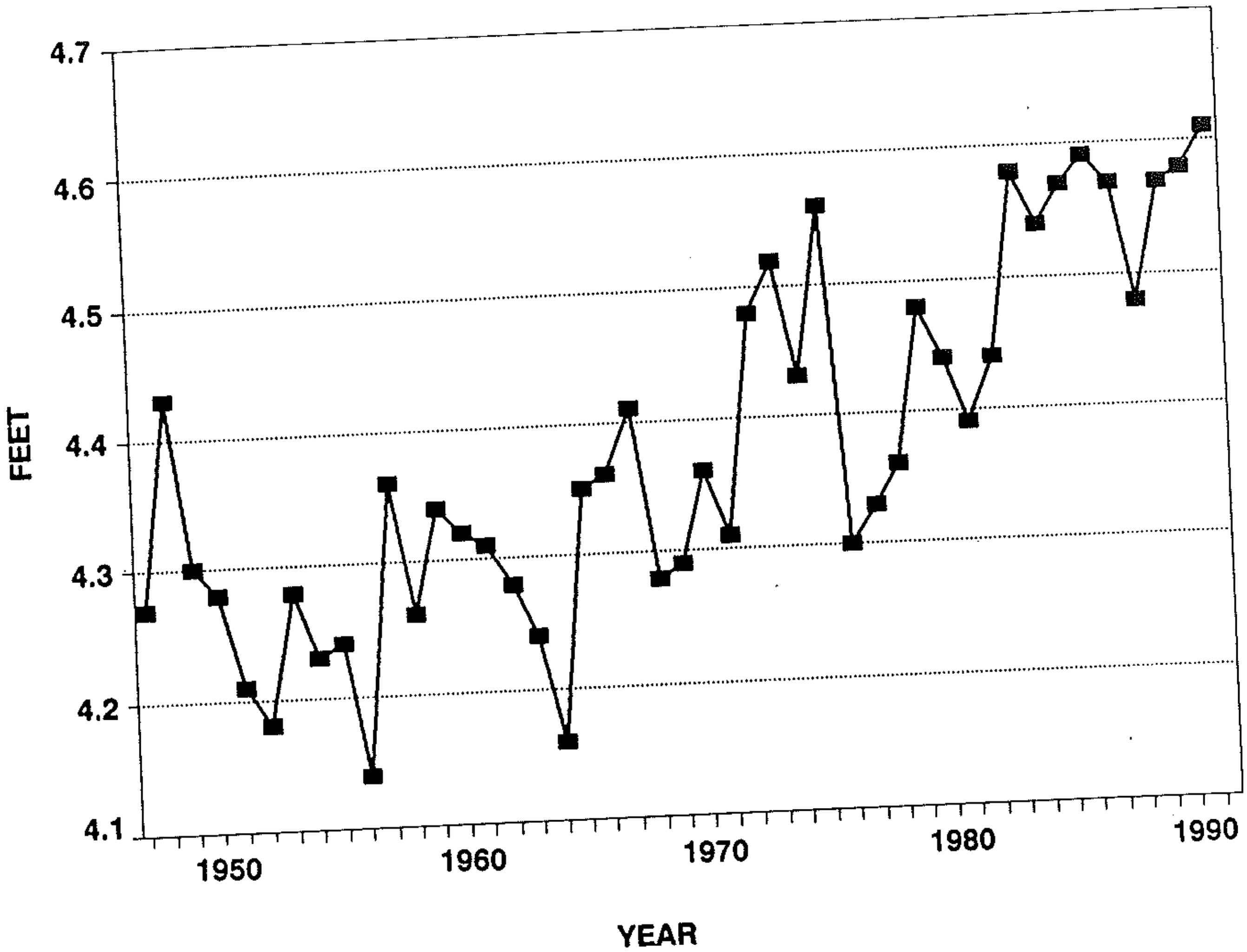


Figure 9. Projected rise in sea level for Sarasota Ba
- open water to MHHW in the year 2115
(3.73 feet NGVD).

Island and peninsula features contain areas of higher elevation that would not become inundated as illustrated.

MHW - MEAN HIGH WATER
MHHW - MEAN HIGHER HIGH WATER
NGVD - NATIONAL GEODETIC VERTICAL DAT

Figure 10. Yearly average water levels at St. Petersburg, Florida (adapted from USDOE, 1988).



The forty year average change converted to metric calculated to 2.06 mm/year, correlating with the apparent secular sea level rise calculation used in the rate assessment for Sarasota Bay (2.1 mm/yr). Clearly, ten year average water levels monitored at St. Petersburg have been increasing over the forty year time frame.

Although not specifically in Sarasota Bay, the affects of SLR can be observed locally. Figure 11 represents the land use inventory (with a focus on wetlands) for the Terra Ceia/ Bishops Harbor area in Manatee County during the 1957 and 1982 time frames. Evaluation of Figure 11 identifies the landward movement of mangrove communities surrounding the mouth of a tidal tributary, and merging with the tidal wetlands of Bishops Harbor by the 1982 inventory. The Geographic Information System (GIS) data base, developed by the U.S. Fish and Wildlife Service and refined by the TBRPC and Florida Department of Natural Resources, requires further verification, but enough valuable information exists to document an expansion into previous upland areas which could be attributed to a sea level rise.

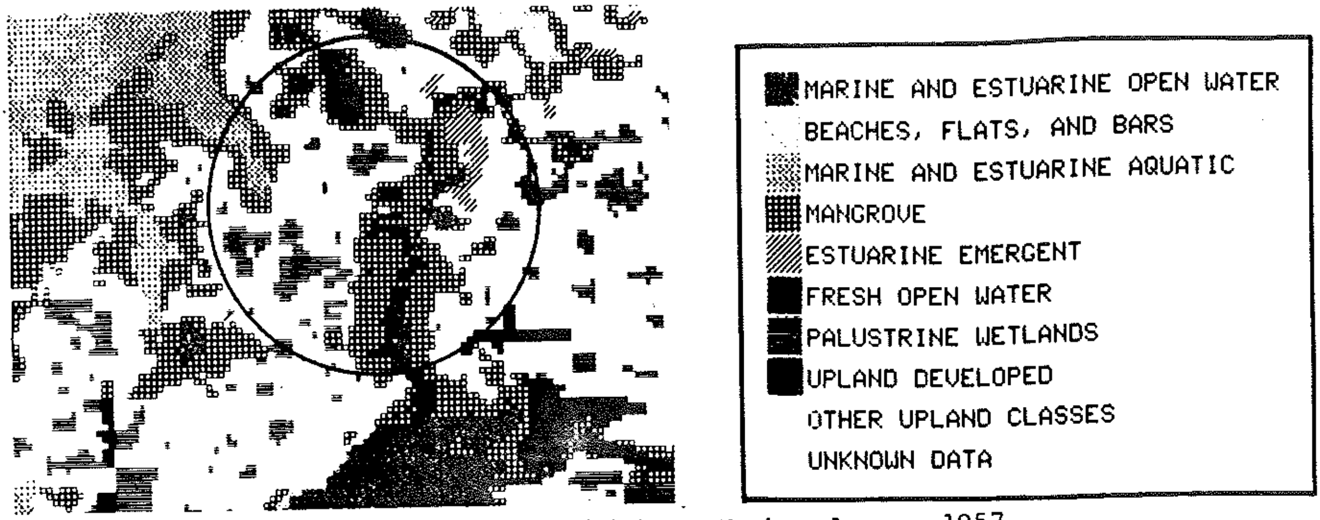
To evaluate if the observed water level changes have affected biological communities, an analysis of wetland trends for mangroves was accomplished for Upper Sarasota Bay by the Florida Department of Natural Resource, Bureau of Marine Research for this project (McGarry, Personal Communication, 1992). The wetland trend analysis evaluated the southern third of the Anna Maria quadrangle and all of the Bradenton Beach quadrangle for the time period between 1948-52 and 1982. This area was chosen due to its relatively flat topography, predominately undeveloped upland fringe and broad extensive mangrove stands which would respond to minor changes in water level over time.

Land use classes for the trend analysis were divided as follows:

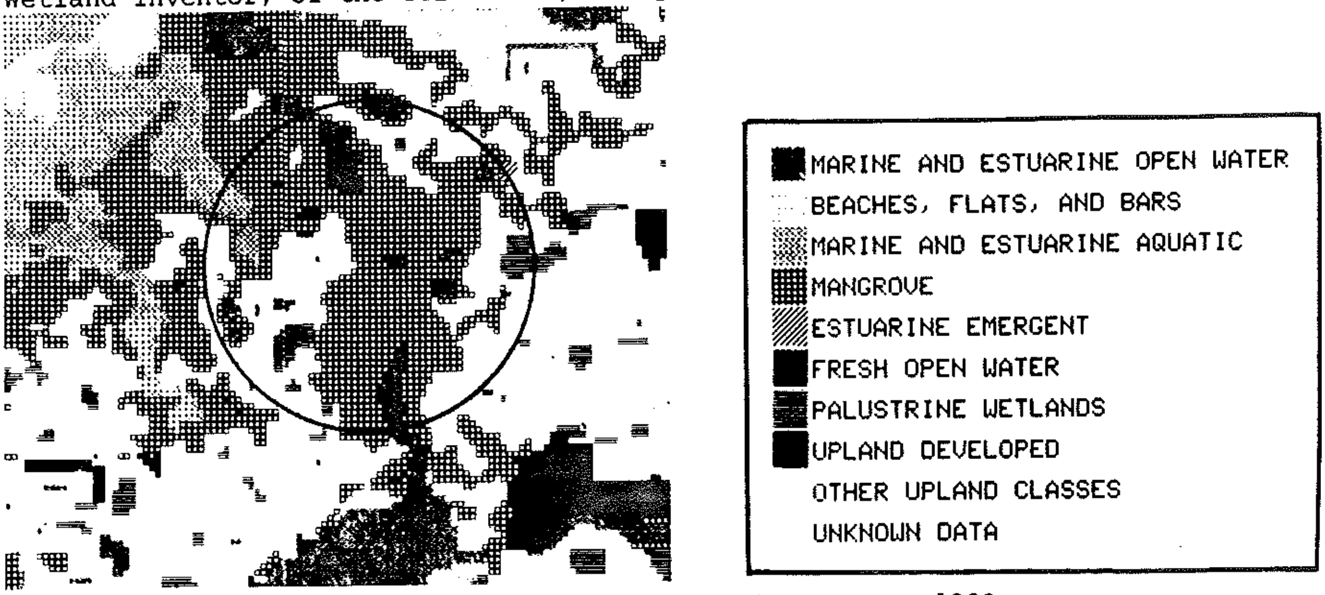
- beaches, flats and bars
- lost mangrove
- unchanged mangrove
- new mangrove
- urban/upland/other

A depiction of this analysis is included on Figure 12. Mangroves would be able to respond to changes in sea level over time by migrating into new lands receiving tidal inundation. Mangroves respond to rising sea level by accumulating peat in situ, thereby retaining their location. At the same time, wetlands can expand inland if low areas are available for recruitment. Figure 12 indicates three areas where new mangrove growth was depicted on northern Perico Island, southern Perico Island and the south shore of Tidy Island.

The new mangrove on northern Perico Island surrounds agricultural fields and may represent growth into fallow lands, mosquito ditching operations or GIS translation error between upland and wetland vegetation. The southern Perico Island new growth may reflect



Wetland Inventory of the Terra Ceia/Bishops Harbor Area - 1957



Wetland Inventory of the Terra Ceia/Bishops Harbor Area - 1982

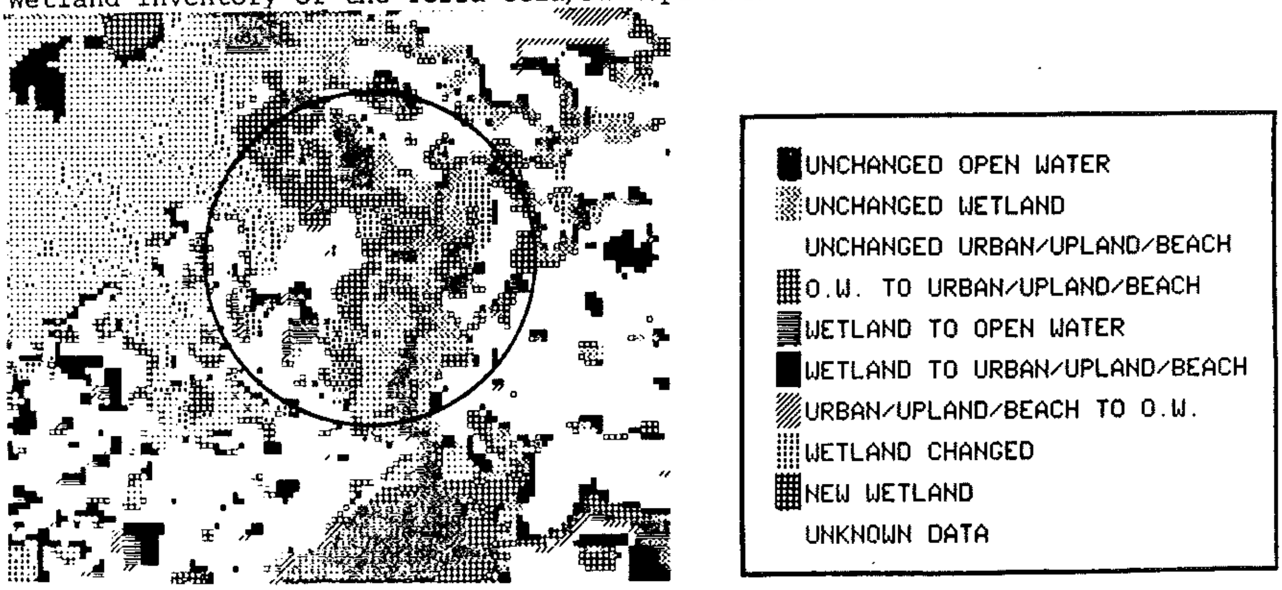
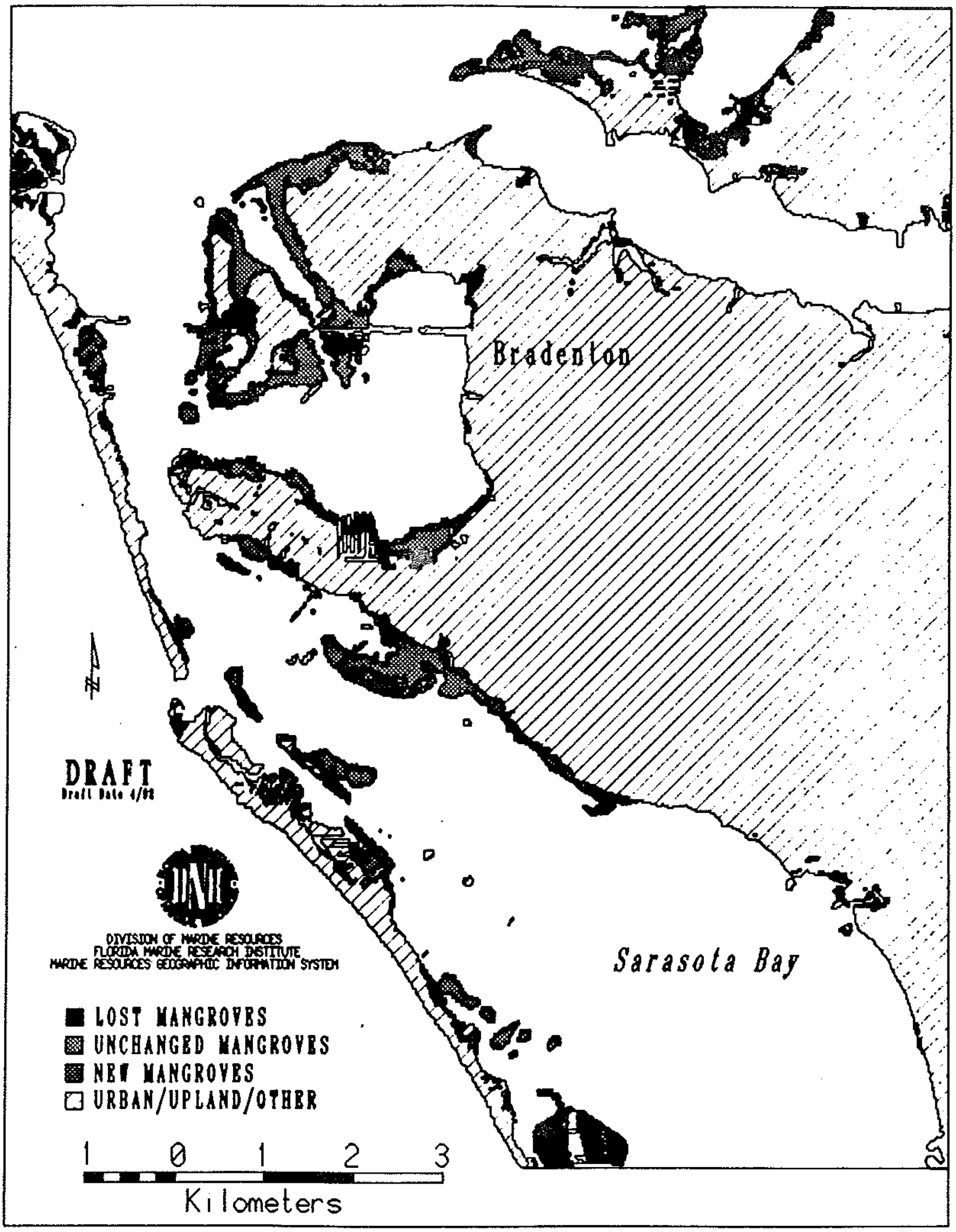


Figure 11. Wetland inventories and trend analysis of the Terra Ceia/Bishops Harbor area - 1957 to 1982. *Sea Level Rise, page 21.*

Figure 12. Mangrove trend analysis for northern Sarasota Bay, 1948-52 and 1982 (McGarry, 1992).



new colonization of a mangrove fringe or a similar translation error, since the new growth contains a lost mangrove fringe indicator along the waterward edge.

The Tidy Island new mangrove category may reflect an actual migration, since the area has contained salt barren and salt prairie communities along the upland fringe, which would allow increased tidal inundation, gradual slopes and a seed source for mangrove colonization. The construction of mosquito ditches may have also led to increased tidal flushing which would support mangrove colonization into previous salt barren areas. The migration of mangrove communities along Tidy Island is similar to the Terra Ceia area in terms of new mangrove growth into salt marsh/salt barren communities. To be noted, much of this area has since been developed into residential uses.

Although not specifically in Sarasota Bay, the affects of SLR can be observed locally. Along the Gulf coast from Cedar Key to Homosassa Springs, rising sea levels have been implicated in sabal palm mortality. Recent observations by the Florida Department of Agriculture and Consumer Affairs indicate that thousands of palms are dying along the coast and researchers have been able to rule out insect infestation or disease (FDACS, 1992; St. Petersburg Times, 1992). Additionally, the report identified palm tree mortality on Egmont Key at the mouth of Tampa Bay.

Early indications show that the dead or stressed tress have a higher salt content than healthy trees that can be linked to soil water conditions. Although, SLR is implicated, aquifer withdrawals, saltwater intrusion and freshwater diversions can also lead to higher salt levels in surface soils (Barnard, Personal Communication, 1992).

The examples cited of <u>in-situ</u> sea level rise identify water level changes, mangrove migration and coastal palm mortality. The identified physical changes and biological responses describe measurable water level increases during recent history. It continues to be necessary to monitor water levels and biological resources to determine if the observed changes are normal sea level fluctuations or the beginning of a global response to atmospheric warming.

IMPLICATIONS FOR NATURAL RESOURCES

Mangroves and Salt Marsh

Mangrove trees are the dominant intertidal natural plant community on the shores of Sarasota Bay. The four types of mangroves include the red (Rhizophora mangle), black (Avicennia germinans), white (Laguncularia racemosa) and the buttonwood (Conocarpus erecta). To a lesser extent, shoreline zones contain isolated pockets of salt marsh vegetation, primarily smooth cordgrass (Spartina alterniflora) and black needlerush (Juncus roemerianus).

The contribution of marsh and mangrove communities to coastal and estuarine systems has been well documented. As primary producers, wetland plants provide direct sources of nutrients and as generators of detritus support initiation of the food chain. Mangroves and salt marsh support critical habitat components for birds (pelican, ibis, spoonbills), fish (trout, redfish, mullet), shellfish (crabs, shrimp) and other wildlife. The roots and leaves of the plant help to settle sediments, reduce turbidity and attenuate wave energy. This action gives mangroves and saltmarsh the ability to stabilize shoreline areas that could otherwise erode.

Sarasota Bay's natural shoreline has been significantly impacted by dredging, filling and shoreline hardening practices. Development over the past 40 years has reduced the amount of natural shoreline by 88 percent. Developed areas consists of 45 percent being bulkheaded, 10 percent rip-rapped and 23 percent artificially filled (SCESI, 1988). Remaining mangrove communities continue to be affected by pruning activities, old mosquito ditches and the encroachment of exotic plants. The significant loss of intertidal habitats affects the ability of Sarasota Bay to support populations of estuarine dependent fish and wildlife and to maintain water quality.

Analysis of geological formations in the State of Florida indicate that marsh and mangrove communities have always been closely tied to sea level conditions. During recent history sea level has risen slowly, allowing sediment from rivers to maintain relatively stable levels of wetland mangrove communities. Sea level rose rapidly during the early Holocene period (>50 cm/100 years) when Florida experienced a rapid submergence (Parkinson and Meeder, 1991). Peat deposits indicated that sea level rose much faster than mangrove swamps could vertically accrete, or coastlines moved landward at a faster rate than mangroves could migrate (Parkinson and Meeder, 1991).

Specifically, Parkinson and Meeder (1991) report that if a rate of 20 to 78cm/100 year SLR occurs "rapid and widespread submergence of south Florida's coastal mangrove swamps (i.e. everglades) will occur if these accelerated rates of sea level rise are realized." In comparison, this study estimates a 58 cm/100 year increase for Sarasota Bay, well within the range projected by Parkinson and Meeder (1991).

The timing and extent of impacts created by SLR on salt marsh acreage also depends on the topographic slope of the marsh and upland areas. If the land has a constant slope throughout the marsh and upland, the area lost to marsh drowning will equal the area gained by the landward encroachment of higher tides. Urbanized upland areas will, however, prevent the landward migration of the marshes and the systems will eventually be lost.

A migrating shoreline driven by a SLR will require upland area to inhabit. Shoreline areas that have been hardened or elevated around the bay periphery will prevent any migration and drown existing mangrove and marsh communities in-place. Undeveloped shorelines will be the best areas available to accomplish restoration activities, either by the construction of planter shelves or filling shoreline to appropriate elevations. All activities to prevent shoreline alterations today will greatly enhance our ability to maintain and restore intertidal vegetation in response to SLR.

Given the projected SLR rates and the extent of shoreline development, it is assumed that eventually mangrove communities will not be able to tolerate the anticipated SLR either by natural sediment accretion or landward migration. In order to maintain the natural benefits provided by mangrove communities to the estuary system, human intervention will be required. Mangrove areas could possibly be supplemented with dredged material to maintain appropriate elevations for survival. Supplementation could be accomplished through hydraulic dredge disposal effluent onto existing stands or tributaries can be enhanced to allow normal sedimentation to be carried and deposited onto mangrove forests. Older mangrove trees may become buried but new recruitment should compensate for expected mortalities from burial.

Careful planning will be required to prevent unintentional impacts due to sediment supplementation. New areas can be created either by construction of upland planter shelves or filling shoreline areas to allow mangrove recruitment. Any restoration activity will need to consider that future SLR alterations can affect restoration activities. However, the construction of the Intracoastal Waterway created disposal islands that have become colonized by mangrove communities. Sister Keys received dredged material and continue to maintain a healthy fringe of mangroves. Inappropriate discharges of dredge material in Tampa Bay have also become colonized with mangroves, including the Hendry Fill/Redfish Creek and the mouth of Alafia River.

Available literature is not as extensive for salt marsh migration. Since mangroves are the predominant shoreline vegetation, salt marsh in many cases may replace mangrove communities as a dominant intertidal plant because of its natural ability for rapid colonization. Currently, salt marsh is primarily used in estuarine wetland restoration projects as a pioneer species. Mangroves are allowed to volunteer in and replace the marsh plants.

Mangroves have the potential to be significantly impacted by the projected rise in sea level. Over time, SLR will overwhelm existing communities and prevent natural landward migration. In order to maintain intertidal forests, substantial restoration/reconstruction activities will be necessary to provide minimal conditions for growth. Reconstruction projects will require the ability to consider future SLR and allow gradual upland transitions to intertidal areas. Preventing shoreline hardening now will promote maintenance of intertidal habitat in the future.

Seagrass Communities

Sarasota Bay supports four types of seagrass, including: turtle grass (Thalassia testudinum); Cuban shoal grass (Halodule wrightii); manatee grass (Syringodium filiforme); and, widgeon grass (Ruppia maritima). These subtidal grasses are a critical component of the Sarasota Bay estuarine system by providing important habitat, refuge and feeding grounds for many important fish and wildlife species. Submerged grasses additionally promote healthy water quality by stabilizing the bay bottom, settling sediments from the water column and absorbing nutrients from the water and benthos.

Seagrasses around Sarasota Bay have suffered extensive losses due to urbanization activities. Losses in seagrass areal coverage has been attributed to dredging for waterfront development, excavation of the Intracoastal Waterway, and input of excessive nutrients from wastewater treatment plants and stormwater runoff.

Currently, seagrass growth is limited in many areas due to light requirements. Seagrass migration may occur into shallower areas as deeper beds become stressed due to lack of sufficient light. If the trend continues into the future, submerged grasses could become confined to shallow water fringes or eliminated along developed shorelines containing seawalls or revetments. However, SLR is expected to move bottom sediments and restructure the Bay's geometry, which will ultimately determine areas suitable for seagrass growth.

Additionally, recent advancements in stormwater treatment and a reduction of wastewater discharges into Sarasota Bay may help to maintain or lead to improvements in estuarine water quality. If this occurs seagrass communities will continue to flourish in existing areas and recolonize where water quality and light climates allow.

As rise in sea level occurs, the health of seagrass communities will be dependant on many variables. Assuming water quality and light levels remain constant, seagrass communities will be maintained or colonize shallow subtidal flats where conditions allow. In the last 40 years approximately 78 percent of the native Sarasota Bay shoreline has been altered for residential and other urban uses. Where development has hardened shorelines the grasses may be eliminated due to increasing depths over time.

Management and restoration of seagrass can be accomplished in several ways to offset the potential adverse effects of SLR. Since seagrasses are intimately tied to water quality conditions and light penetration, efforts to improve water quality can play a major role in seagrass protection/restoration. Eutrophication in the estuary can be reduced through the elimination of nutrient flows from wastewater effluents and stormwater runoff.

To alleviate stormwater pollution all new development since 1982 must retain rainfall on each piece of property and allow the pollutants to be removed by settling processes or biological actions (bacterial decomposition). Older developments built prior to 1982 were not required to store stormwater on-site and therefore it is in these areas where stormwater runoff continues to carry pollution into area streams and rivers (TBRPC, 1989) and eventually, Sarasota Bay (Figure 13). Retrofitting of predeveloped areas can reduce nutrient loadings to the estuary, thereby promoting a healthier light climate.

Recolonization of seagrasses into shoreline fringes can be greatly enhanced through the removal of hardened structures, seawalls, rip rap or other structural adaptations. Replacement of shoreline fringes with gentle slopes will support the natural migration of intertidal wetlands landward, with the eventual replacement by seagrasses when water levels are conducive for persistent growth. Shoreline restoration projects and environmental land purchases support proactive wetland planning for SLR.

Seagrass restoration can include filling of subtidal borrow pits that have been previously excavated for fill material. Filling these dredge holes will increase the bay bottom area available for seagrass colonization. This technique has been successfully used by the Florida Department of Natural Resources in Lassing Park where a subtidal hole (dredged for beach sand) was filled and sediments replanted with seagrass (Fonseca, 1990).

In Sarasota Bay, the techniques of capping historic dredge cuts is being evaluated and considered by the Sarasota Bay NEP and Florida Seagrant (Culter, Personal Communication, 1992). The proposed project recommends capping a dredge hole near the Cortez bridge, adjacent to Leffis Key, using a small conventional dredge with a submerged diffuser head to prevent fine sediment resuspension (Figure 14). The hole would be filled using material excavated for the Leffis Key shoreline restoration project and provide 9,800 square feet available for seagrass recolonization.

In the event that seagrasses are stressed by deeper waters during a SLR, consideration may be given to supplementing the deep water areas with clean sand material to decrease depth sufficient for seagrass growth. This technique will require extensive evaluation, since a trade off will occur between establishing seagrass and impacting potential infauna or other benthic communities.

Figure 13. Trends in stormwater runoff quality and management practices (TBRPC, 1989).

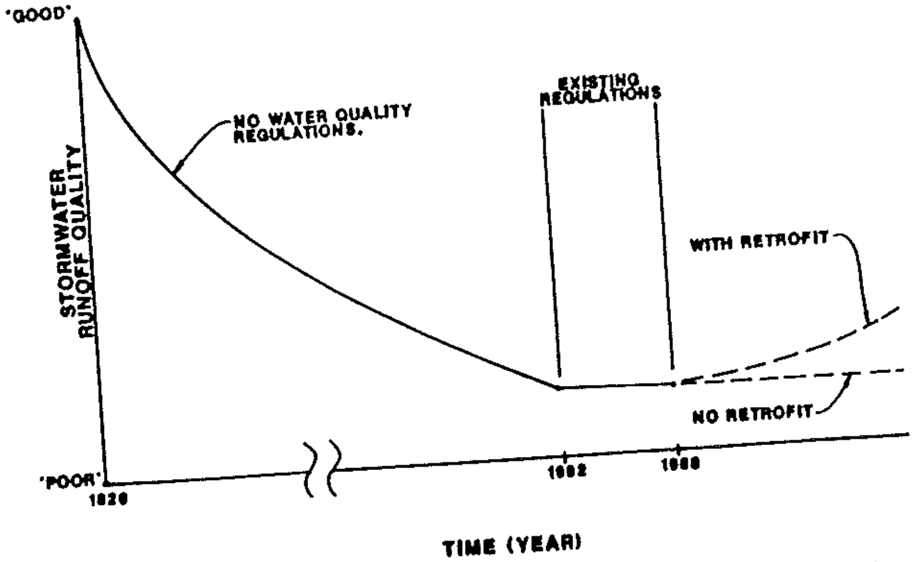
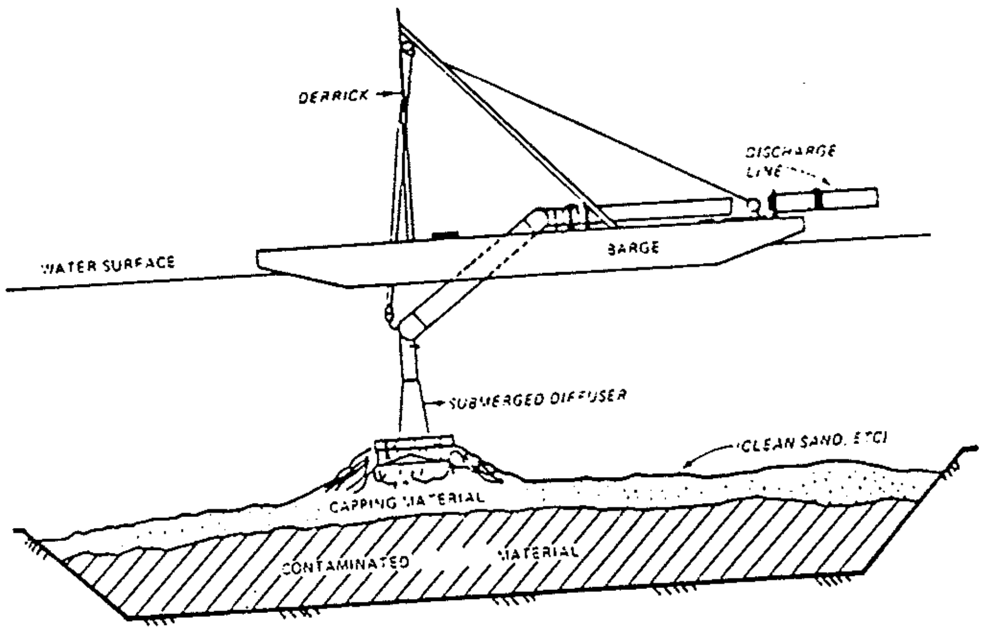


Figure 14. Diagram of sediment capping process (Culter, 1992).



Freshwater Systems

Freshwater wetlands are vegetated communities along rivers, streams, lakes, ponds and in shallow depressions in open fields. These wetland communities support a wide variety of plants, so many different animal species thrive in their moist environment. A combination of soil types, drainage patterns, and vegetation types classify an area as a wetland.

Wetlands, also referred to as marshes and swamps, serve many vital functions. They are natural flood control devices, retaining large amounts of water during heavy rains which are slowly released during drier times. Wetlands help control erosion by trapping sediment washed away during rains; and act as natural filters, cleansing waters of pollutants when the plants capture and retain sediments from runoff.

Rivers and streams meander their way through a range of terrains before terminating in an ocean, sea or bay. These systems are also important because they serve as nursery grounds for many commercially and recreationally important fish species, as well as supporting a wide range of vegetation and other wildlife, including the endangered West Indian manatee. The health of each tributary can greatly influence the condition of Sarasota Bay, therefore it is important to maintain these ecosystems.

Palma Sola Creek flows northwestward for approximately 4.1 miles parallel to Sarasota Bay and outfalls into Palma Sola Bay in Manatee County. The mouth of the creek contains some forested wetlands and maintains its natural alignment to the vicinity of a mobile home park, where it is rerouted between residential developments. The remainder of the drainage basin is dominated by agricultural uses surrounding an elongated marsh system. The headwaters drain a golf course, residential development and other agricultural parcels. TBRPC (1986) classified Palma Sola Creek as being in natural condition due to the extent of marsh retained within the watershed and low development in the tidal reaches.

Bowles Creek flows in a southwestern direction approximately 4.1 miles to Sarasota Bay and enters the bay just north of the Manatee County line. The lower segment of the creek has been extensively channelized for residential development, while the upper two-thirds receives runoff from residential, commercial and industrial development. Considering its urbanized nature, the TBRPC (1986) classified Bowles Creek as being in stressed condition.

Whitaker Bayou runs through the City of Sarasota where it receives urban runoff, and agricultural loadings from the upper watershed area. The City of Sarasota discharged up to 9 MGD of secondarily-treated sewage into the creek which has resulted in its poor water quality classification by FDER (Hand, Tauxe and Friedemann, 1988). The discharge has been eliminated, except for wet weather events, which could lead to improvements in stream and bay water quality conditions.

Phillippi Creek is also highly channelized and receives domestic wastewater discharges and stormwater runoff from adjacent development areas (Flannery, 1989). Phillippi Creek is 19 km in length (Wolf, 1990) and has the largest watershed which drains to Sarasota Bay (Estevez and Merriam, 1989). FDER did not include either Whitaker Bayou, Phillippi Creek, or the area around each mouth in Sarasota Bay as Outstanding Florida Waters in its 1986 determination (FDER, 1986).

Clower Creek is an urbanized tributary to Little Sarasota Bay and also receives domestic wastewater discharges as well as stormwater runoff (Wolf, 1990). Catfish Creek and North Creek enter Little Sarasota Bay near the town of Vamo. Both of these smaller tributaries travel through newer residential developments and golf courses.

Historically, the tidal tributaries to Sarasota Bay were immensely productive systems, providing critical habitat, protective cover, feeding and breeding grounds for early developmental stages of marine and estuarine life forms. In understanding the role of tributaries as fishery habitat, Lewis et. al. (1985) reviewed the life history stages of recreationally and commercially important species of fish and shellfish; including snook, redfish, tarpon, spotted seatrout and pink shrimp, and reported:

> "First, all of the species are near-shore oceanic spawners. Secondly, all use a multitude of habitats throughout their life cycle (i.e., none spend their entire lives in mangroves). Thirdly, all of the species show a preference for a low salinity nursery habitat that often includes marshes or mangroves at the upper limit of tidal influence in tidal freshwater streams."

Due to the many values tributaries provide to area residents and tourists, oftentimes tributaries are the focus of development (Clark, 1991). Tributaries have been altered by man in the following manner:

- hardening - seawalls, erosion control, berm construction
- filling - upland construction, airports, mosquito control
- channelization - agricultural, flood control, navigation
- point source pollution - wastewater effluent, industrial discharges
- non-point pollution - urban, industrial and agricultural runoff
- consumptive water withdrawals - potable, irrigation, cooling water, industrial uses.

Widespread development has severely restricted the function of tributaries to the Sarasota Bay estuary. With the acceleration of SLR, the saltwater/freshwater wedge can be expected to be pushed upstream with the advance of higher tides. Movement of the wedge upstream could move quicker than sediment deposition can occur, therefore the vegetational communities necessary for fishery stages will be displaced.

In tributaries where a salinity barrier has been constructed, the tidal wedge will terminate at the barrier due to increasing depths, therefore an elimination of the oligohaline (low salinity) environment will occur. If the projections are realized, SLR will have major implications for fishery resources due to the anticipated loss of juvenile habitats in the streams and adult habitat areas in mangrove and seagrass communities.

Several management approaches can be utilized to mitigate SLR on tributary systems. Evaluation of freshwater discharges/tidal wedge location and annual cycle will initiate an understanding of existing or predevelopment conditions. When SLR occurs and a documented migration of the wedge is observed, upland excavation and marsh creation should be considered in the new location of the wedge to provide critical habitats.

Areas where salinity structures (dams, weirs, stream impediments) exist, consideration should be given to removing the structures to allow normal tidal inundation into upstream areas. Since many of the structures were constructed to prevent saltwater intrusion into drinking waters and irrigation waters, an analysis should be accomplished now to see if the structures are still appropriate (e.g. conversion of agricultural lands to urban uses).

Freshwater flow can be provided below salinity structures to achieve a balance in the saltwater/freshwater wedge at the appropriate location within the stream. One analysis of supplementing freshwater flows to a man-made canal and urbanized tributary using advanced wastewater effluent has been accomplished in Boyer and Clark (1989) for Upper Tampa Bay.

Careful consideration needs to be given to tributary alterations and restoration activities that may stimulate saltwater intrusion by directing saltwater inland along the tributary paths.

Groundwater Supplies

Saltwater intrusion from the expected rise in sea level could also contaminate potable groundwater supplies. Rising seas permit saline waters to penetrate upstream and inland. This impact is further exacerbated during periods of drought. In addition, the landward migration of salt water could continue to add to the regional problem of saltwater intrusion into the Floridan Aquifer, the principal source of drinking water in west central Florida. Since more water will be stored in the aquifer systems at higher elevations, Nuttle and Portnoy (1992) hypothesize that rising seas will increase surface runoff and decrease groundwater discharge to the coast.

The Southwest Florida Water Management District and the United States Geological Survey monitor groundwater conditions along the Gulf Coast. Saltwater intrusion is a concern and will require continued monitoring by these agencies to balance withdrawals with saltwater levels. Methods to mitigate saltwater intrusion, now and during exacerbated conditions brought on by SLR, include the reduction of groundwater withdrawals, reduction of impervious surfaces and irrigation with stormwater or wastewater effluent. Additionally, deep well injection of treated stormwater or wastewater effluent can force brackish waters to retreat.

Septic tanks will be negatively affected by SLR since the design of household effluent disposal in septic tanks requires soil filtration before migration of waste to adjacent ground or surface water resources. Sea level rise will continue to bring groundwater levels closer to the septic tank drain field providing a conduit for poorly treated waste to enter and contaminate groundwater systems. Older areas containing septic tanks may not have been permitted or designed using today's standards. The problem of inadequately treated wastewater generated by older septic tanks will be intensified.

Sea Level Rise, page 34.

ANALYSIS OF A BARRIER ISLAND - LONGBOAT KEY

The Town of Longboat Key is on a 4.21 square mile barrier island located between Sarasota Bay and the Gulf of Mexico. It is located within the boundaries of both Sarasota and Manatee counties, and presently has limited lands still available for development (Reynolds, Smith and Hills, 1989).

The community is characteristic of barrier islands along Florida's west coast. Many of the problems and processes witnessed there are similar to coastal areas throughout the country. This community can provide a guideline for measuring the rate of sea level rise, its effects on natural and developed systems, and the steps that can be taken to study and respond to the changes caused by a rise in sea level.

Development

The town can be characterized as primarily residential, with no industry and little commercial development. The island has one main road, Gulf of Mexico Drive, which is connected to bridges at both ends of the key. These bridges, which span Longboat Pass at the northern end of the key and New Pass at the southern, then connect to secondary routes leading to the mainland. By the year 2115, a sea level rise of 2.1 feet will mean that abandonment of some existing development could be required since portions of the barrier island will be submerged during higher high tides.

Residential land uses on Longboat Key are divided into several categories: high, medium and low density (single family) residential. Single family residential land uses comprise 785 acres, or 29 percent of the total land area of the Town of Longboat Key. Residential multifamily land uses include duplexes, multifamily structures, condominium units and time-share units. Multifamily uses comprise 585 acres, or 22 percent of the total land area of Longboat Key (Reynolds, Smith and Hills, 1989).

Commercial land uses in the town amount to 97 acres, or four percent of the total land area. Most of this is tourist/resort uses. There are 289 acres, or 11 percent of the area, classified as vacant land. However, most of this is subdivisions which are platted but not fully developed. A limited quantity of land, one percent (three acres) is classified as public land and utilities, respectively (Reynolds, Smith and Hills, 1989).

The population of the town has been increasing over the last 20 years and is projected to steadily increase until buildout. Growth is primarily from the immigration of new residents, who are mainly affluent retirees from the northeast and midwest United States. There has also been an increase in the number of young people with families.

The Town of Longboat Key is located entirely on a barrier island, with a flat topography consistent with other barrier islands in the vicinity. Slopes are generally less than five percent, with contour lines at 5 and 10 feet (Figure 15) (Reynolds, Smith and Hills, 1989). These contours are sandy ridges or dunes. The whole island is located within the hurricane flood zone and is subject to surge tides. In addition, the town is fully located in the 100-year floodplain and part of Longboat Key is located in the 100-year velocity zone (Figure 16). The velocity (V) zone is considered the high-hazard area, and is concentrated along the Gulf side of the island (Reynolds, Smith and Hills, 1989).

A rise in sea level will increase the risk of damage and destruction to development and infrastructure on the barrier island. The low topography and proximity within the 100-year floodplain will result in even greater losses due to storm surge, increased flooding, and erosion. By the year 2020, with a sea level rise of 0.5 feet above present MHHW, many components of the barrier island's development and infrastructure will experience some degree of adverse impact.

Property damage and destabilization of waterfront property will be increasingly widespread by the year 2020. By that time, the mean higher high water for this area could equal a 0.5 foot rise above present-day MHHW. Land uses along the Gulf of Mexico in both the Sarasota and Manatee County portions of Longboat Key include high density residential and single family residential. The Sarasota Bay side of the Key also has a large number of single family residential units, with scattered areas of high density residential, especially within the Manatee County portion of the Key (Reynolds, Smith and Hills, 1989). The waterfront property will naturally be the most susceptible to damage associated with a rise in sea level. Figure 17 identifies the locations of water dependent uses.

As illustrated on Figures 7, 8 and 9, the Gulf shoreline of Longboat Key may experience higher levels of inundation during mean higher high water events. More significantly, however, will be the flooding along Sarasota Bay. Areas that could be affected include:

- northern end of Longboat Key
- Sleepy Lagoon and Emerald Harbor
- Greer Park
- Harborbay Isle, and
- The Gulf side along Longboat Club Drive and the Islander Golf Club.

Some areas may not experience significant difference in flooding events from 2065 to 2115. Other areas, such as Harborbay Isle, may experience increasingly higher levels of flooding as time goes by.

Storm events coupled with high tides will result in an accelerated rate of destruction of waterfront property. Loss of beach will accelerate erosion and increase the risk of property damage. Subsidence (from compaction of the earth, groundwater withdrawal or tectonic

Figure 15. Five foot contour intervals on Longboat Key, Florida (RS&H, 1989).

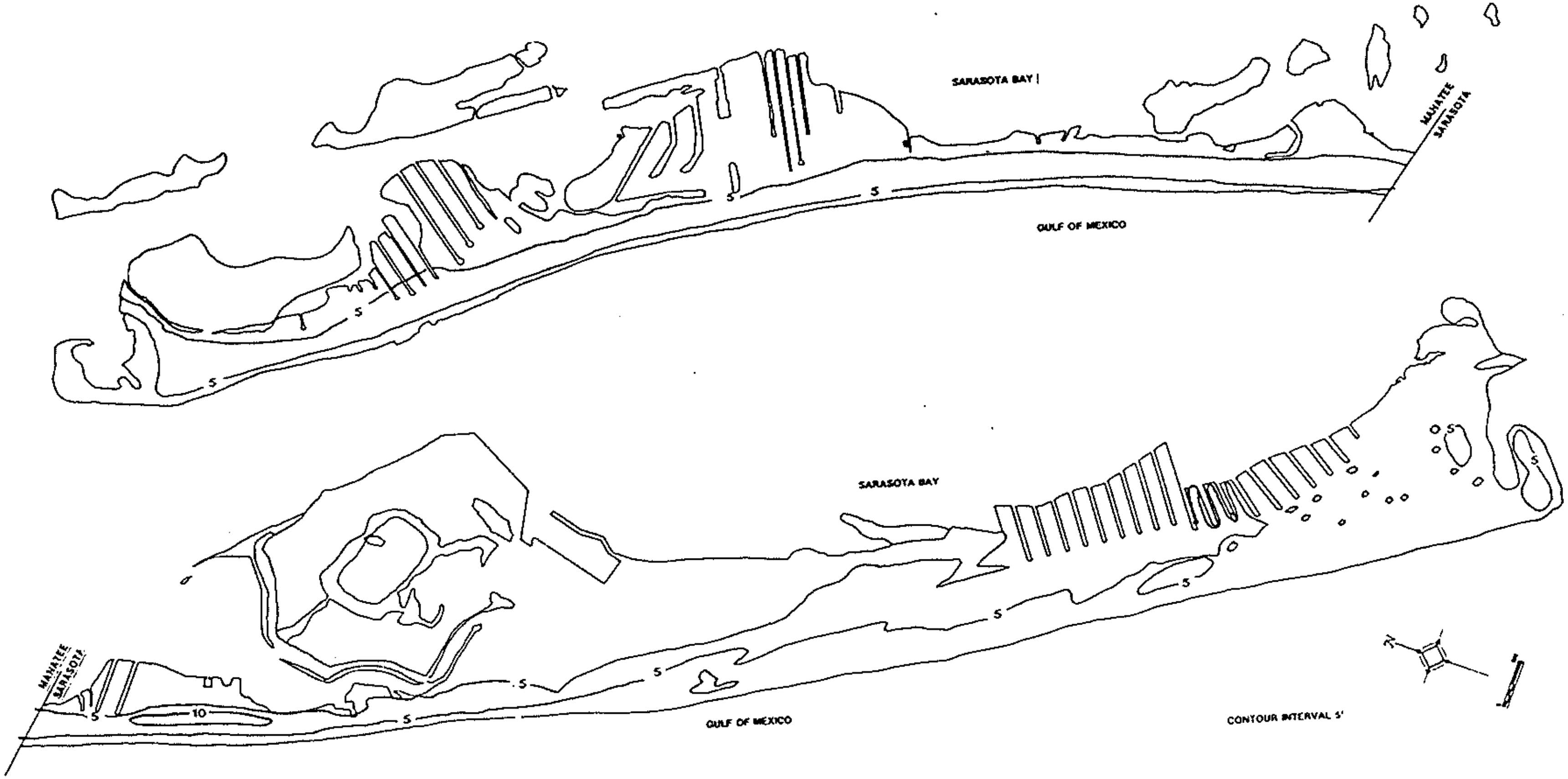


Figure 16. Flood zones on Longboat Key, Florida (RS&H, 1989).

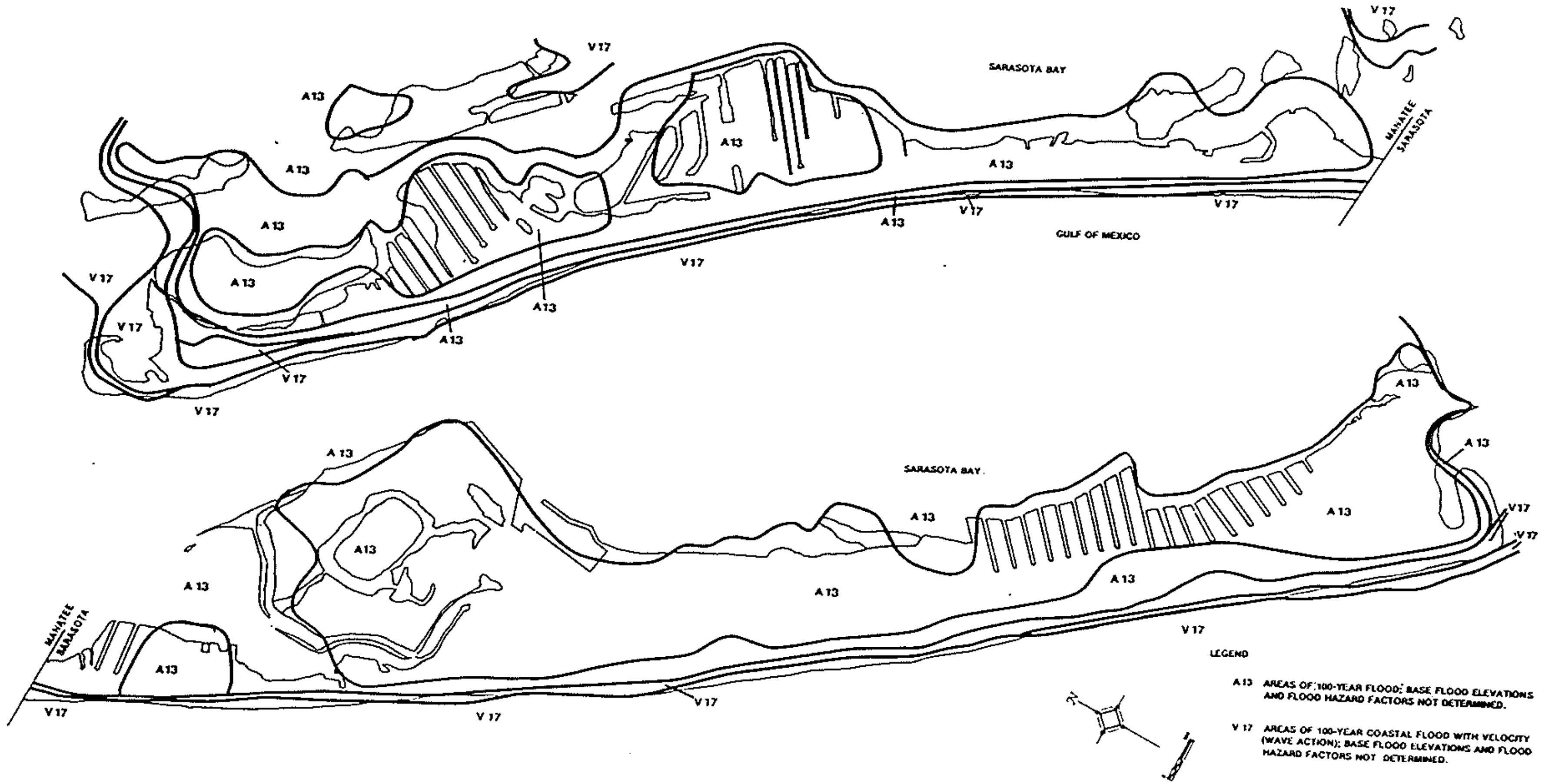
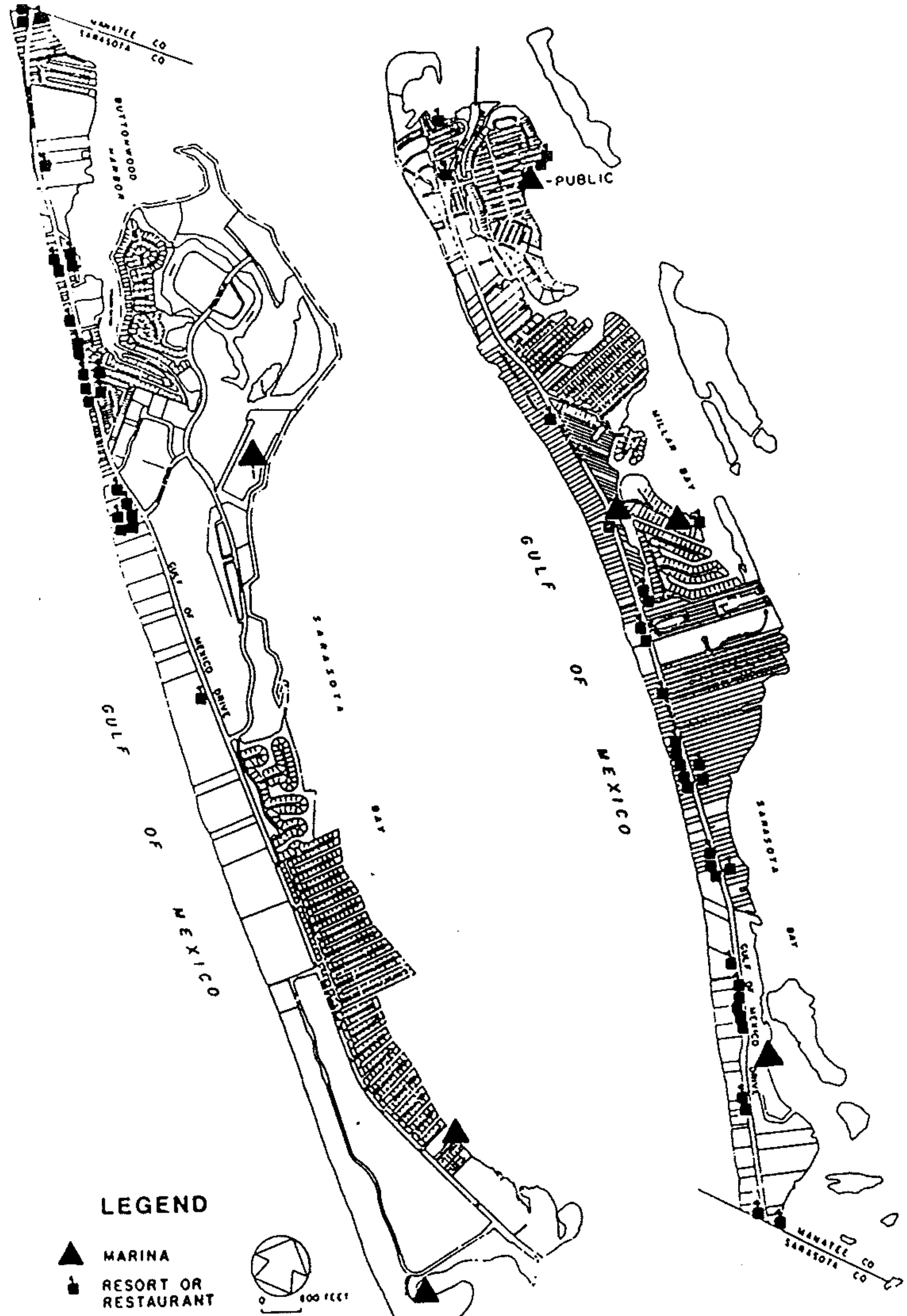


Figure 17. Water dependent uses in the Town of Longboat Key (RS&H, 1989).



movement), can also exacerbate flooding and associated property damage. The area around Baytown, Texas on Galveston Bay has experienced frequent high-tide flooding due to subsidence (National Academy Press, 1987).

Although there is little land left for new development on the key, all new development and redevelopment will need to consider the future impacts caused by the rise in sea level. Town building codes have already been revised to conform with accepted shoreline building standards. Construction practices will need to be altered so that the dangers from flooding, erosion and storm surges are lessened. This could include elevating development through the use of pilings (so that bottom floors are above flood water levels), the placement of all crucial equipment on higher stories, increased ability to withstand high velocity winds, and increased setbacks from the shoreline. New development could be restricted in high hazard areas.

Many existing structures will need improvements to withstand the increased risks. As sea level rises and coastal areas are permanently inundated, structures will need to be placed farther back from the shore, or removed completely. Relocation, reconstruction and eventual acquisition or abandonment are all possibilities. However, given the large tax base of the town, it is unlikely that abandonment or acquisition will be embraced by residents or local government. Additionally, residents might not be willing to leave without exploring all other options.

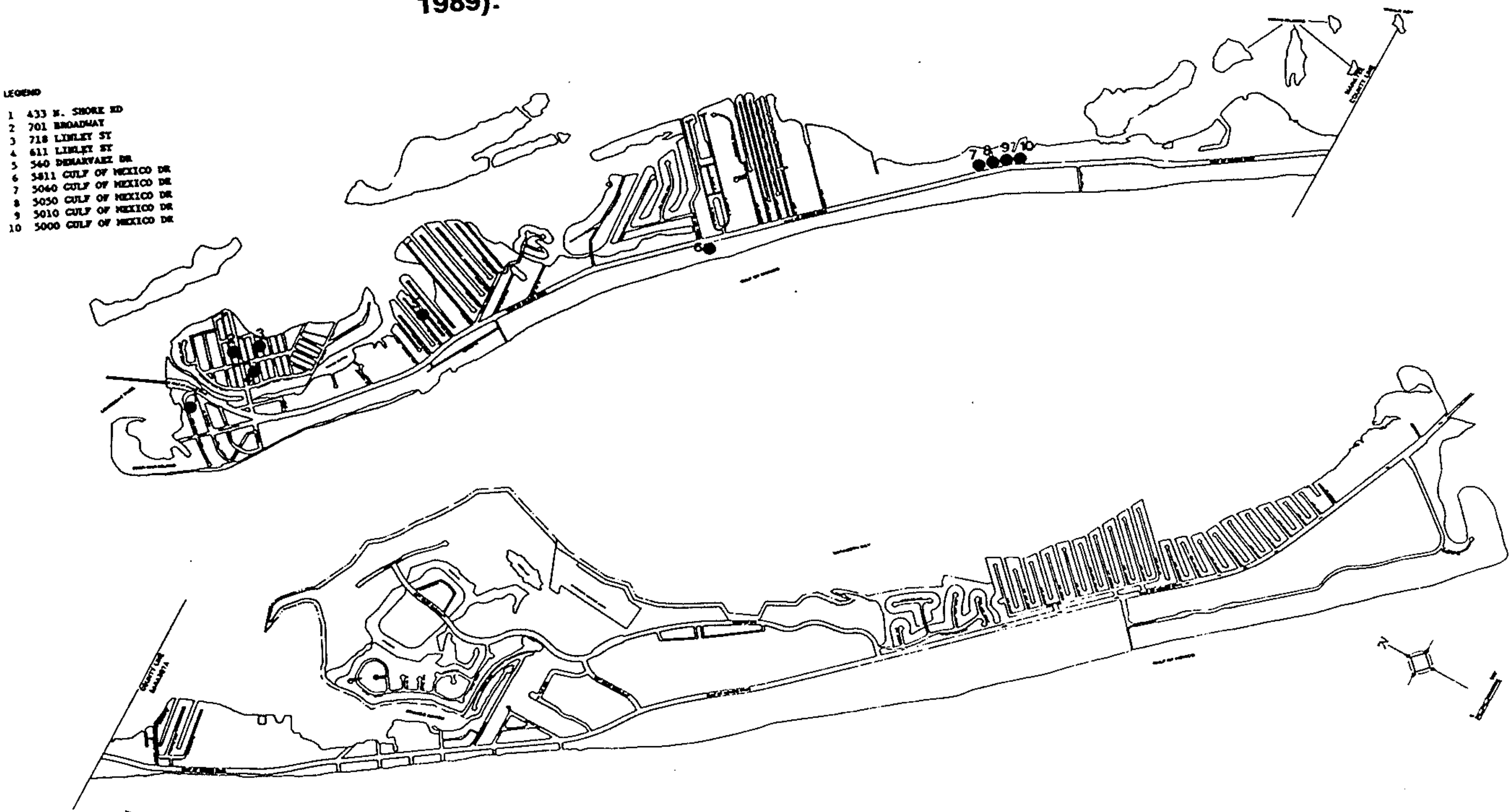
The affects of sea level rise on the developed Longboat Key will be wide ranging and will require continual monitoring and eventual action. Preparations for future changes, including both physical and policy actions, should be contemplated and implemented prior to the onset of severe damage.

Infrastructure

By 2020, a 0.5 foot rise in sea level could negatively impact the infrastructure on Longboat Key. Potable water is provided by Manatee County, and the system is in good condition, however it is possible that the source of water might be impacted by saltwater intrusion, as rising sea level will also alter mainland watersheds and well fields. There are ten residences using wells for potable water on the Manatee County portion of the island (Figure 18). It is likely that these wells will be affected by increasing salt water intrusion, as some of them will lie within land projected to be at the mean higher high water line in 2065 (Figure 8). See the section on the City of Sarasota for management guidelines on potable water.

The Town of Longboat Key has mandatory wastewater service and there are no septic tanks on the island. The sanitary sewer system is owned by the town and serves only as a collection system. All wastewater is pumped to Manatee County and treated by the Manatee County Utilities System (Reynolds, Smith and Hills, 1989). The system is in good condition; however, rising sea level will have an adverse effect on this system of collection,

Figure 18. Existing water wells in the Town of Longboat Key (RS&H, 1989).



transport and treatment. Damage to structures and infrastructure (mains and treatment facility) from storms and flooding would hinder the operations of the system. Additionally, increasing population both on the key and in Manatee County would place increased pressures on the sanitary sewer system by increasing demand. Thus, both damage and population could adversely effect the ability of the system to effectively treat sewage. Possible solutions for the future include moving or raising the waste water treatment facility, but the cost would probably be prohibitive. Strengthening and/or reinforcing mains might provide added security.

All drainage systems are maintained by the Town of Longboat Key, with drainage directed into either Sarasota Bay or interior retention areas, with one exception, which drains into the Gulf of Mexico. All new development must have stormwater retention plans. Increased episodes of flooding from sea level rise will stress this system, which might require extensive renovations to make it able to handle increased drainage capabilities. The anticipated changes in weather patterns, coupled with increases in coastal flooding, will require a reworking of drainage capacity to prevent damage from unchecked stormwater runoff.

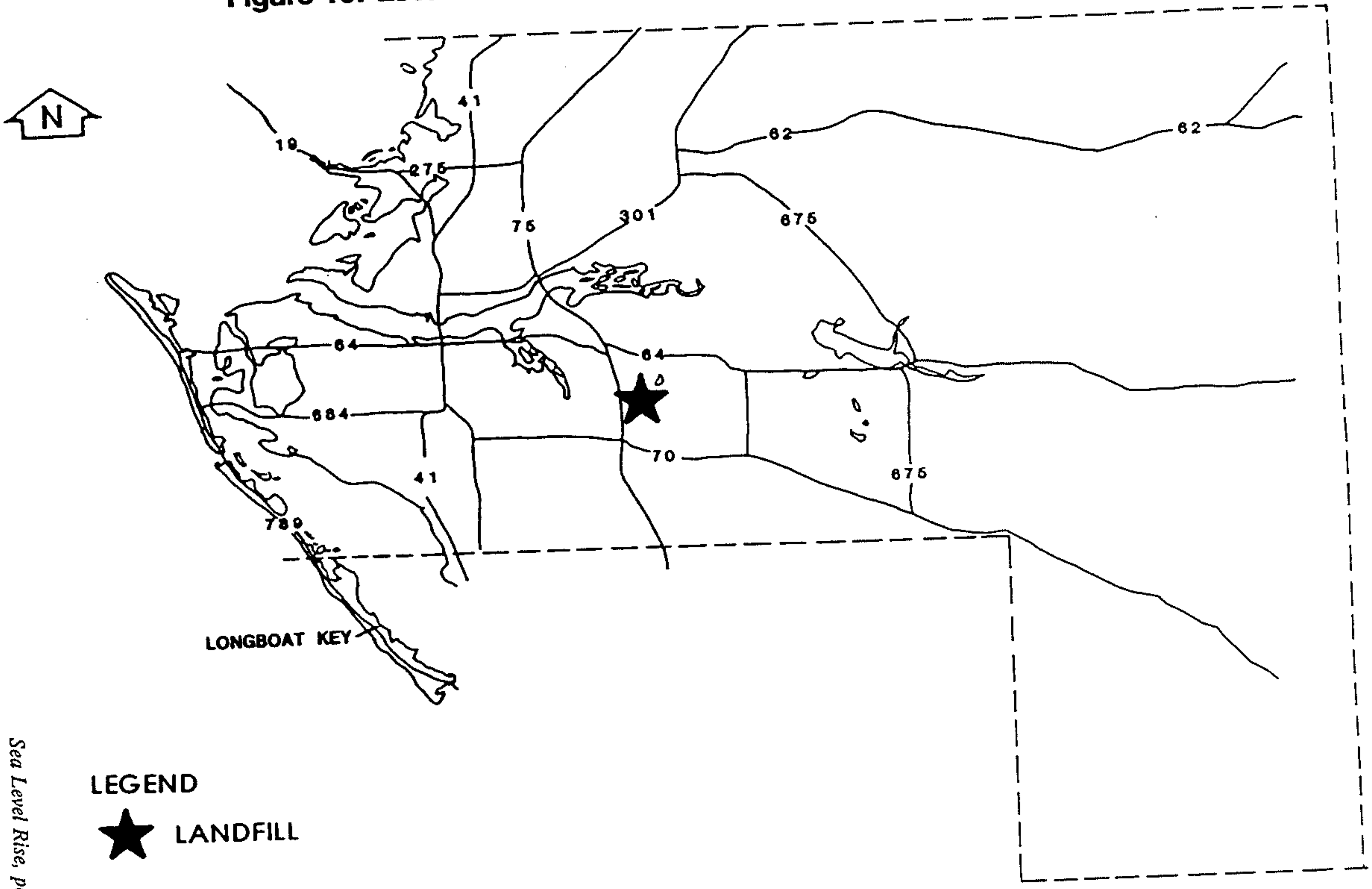
One study which projected costs for the overhaul of the urban gravity drainage system in Charleston, South Carolina revealed that \$2.4 million dollars would be needed for a complete retrofit needed to deal with an 11 inch rise in sea level (National Academy Press, 1987). While Longboat Key is much smaller than Charleston, the changes needed to accommodate a 15 inch rise in sea level by 2065 would be significant.

Solid waste on the Key is disposed of at the Manatee County Landfill on Lena Road (Figure 19). Problems with the transport of waste from the Key to the landfill are possible when the rising sea level causes more instances of inundation of transportation routes, and damage to roads from erosion and storm surge. Difficulties may also arise from changes in the aquifer level, groundwater flow patterns and their effect on leaching. The use of dikes or other containment structures/devices might help reduce these problems (National Academy Press, 1987).

Problems resulting from flooding and/or destruction of electric power lines and transformer stations are obvious. Solutions might include elevating or relocating some of these services. These would certainly involve tremendous cost. Other services which might be disrupted by rising water levels include telephone lines and television cables.

Storm flooding and periodic tidal inundation of Longboat Key transportation arterials, including causeways, would be a devastating impact caused by rising sea levels. Traffic problems would be commonplace as a result of street decay and flooding. Problems with emergency services (police, fire and paramedics) could cause life threatening situations. One of the greatest dangers would be from the loss of key evacuation routes in the event of a severe storm situation.

Figure 19. Location of the Manatee County landfill.



There is an extensive history of storms causing significant flooding and property damage within the study area. A total of 30 known hurricanes and tropical disturbances have come within a 50 mile radius of the Manatee County shoreline since 1900. In October 1921, a hurricane caused tidal flooding 7 feet above normal, and much of the northern end of Anna Maria Island was covered with five feet of water. Another hurricane caused most of the barrier islands to flood and damage totalling $1 million in 1926. The "No Name Storm" of June 1982 resulted in serious erosion and damaged a recently nourished beach (Doyle, Sharma, Hine, Pilkey Jr., Neal, Pilkey Sr., Martin, and Belknap, 1984).

A hurricane or tropical storm could have devastating results for the residents of Longboat Key (see Figure 20 for the high hazard zone map). The flooding of roadways and causeways would trap residents in extremely vulnerable and unstable areas. Figure 21 illustrates existing evacuation routes.

Higher populations would hinder emergency management operations, and elevated sea levels would decrease the time available for complete evacuation. Because land and beach areas will have already been eroded and property impacted because of higher water levels, severe storms and high tides would result in even greater degrees of destruction and losses than would occur at present. Frequent analysis and redevelopment of the SLOSH maps, and an updating of the evacuation plans and routes will help keep the Key prepared for severe storms.

The Town of Longboat Key has a total of 417 acres (15 percent of total land area) classified as existing open space (Reynolds, Smith and Hills, 1989). This land use category combines recreational and open space uses, including golf courses, public recreation facilities, public beach accesses, open space areas, and offshore island groups (Whale Key and White Keys in Sarasota Bay). While destruction of developed areas might result in greater financial losses, the damage or destruction of open space areas will have quality of life impacts.

As illustrated above, the infrastructure impacts from sea level rise will put economic, procedural and quality of life strains on the population of Longboat Key. Wise planning and a commitment to research and change before negative impacts occur will provide the best defense for the islands' residents and infrastructure.

Beach and Shoreline Systems

Many residents choose to occupy areas such as Longboat Key because of its beaches and natural resources. The shoreline has always been an attractive amenity for people, offering great natural beauty, a close recreational resource and high property values. However, with rising sea levels, the beaches could be among the first features to be permanently lost.

Much of the shoreline on Longboat Key has been stabilized by seawalls and groins, which has resulted in an artificial narrowing of the beach in several areas. Figure 22 identifies the location of shoreline structures around the bay. These structures trap sand in the immediate

Figure 20. High hazard zones in the Town of Longboat Key (RS&H, 1989).

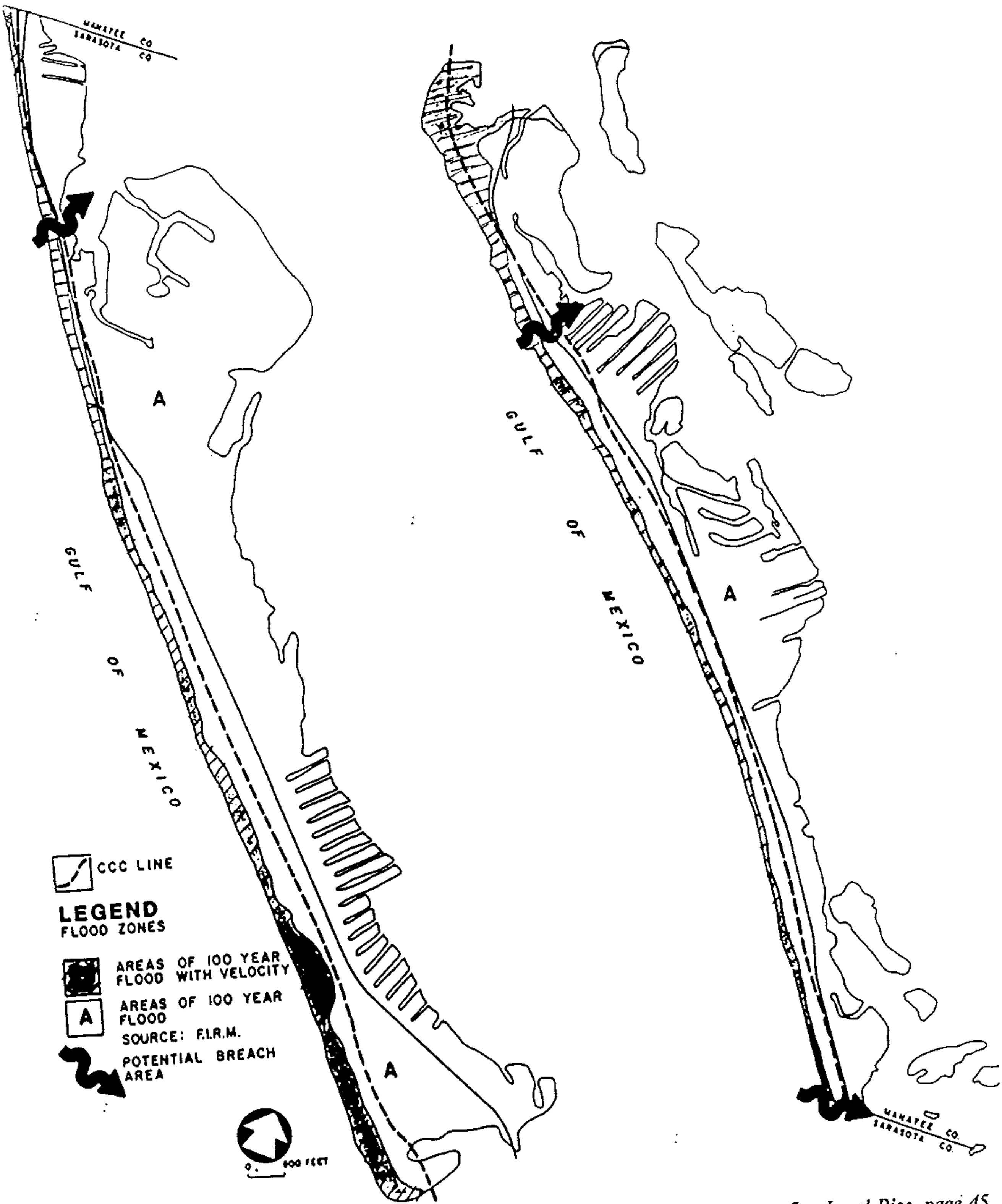
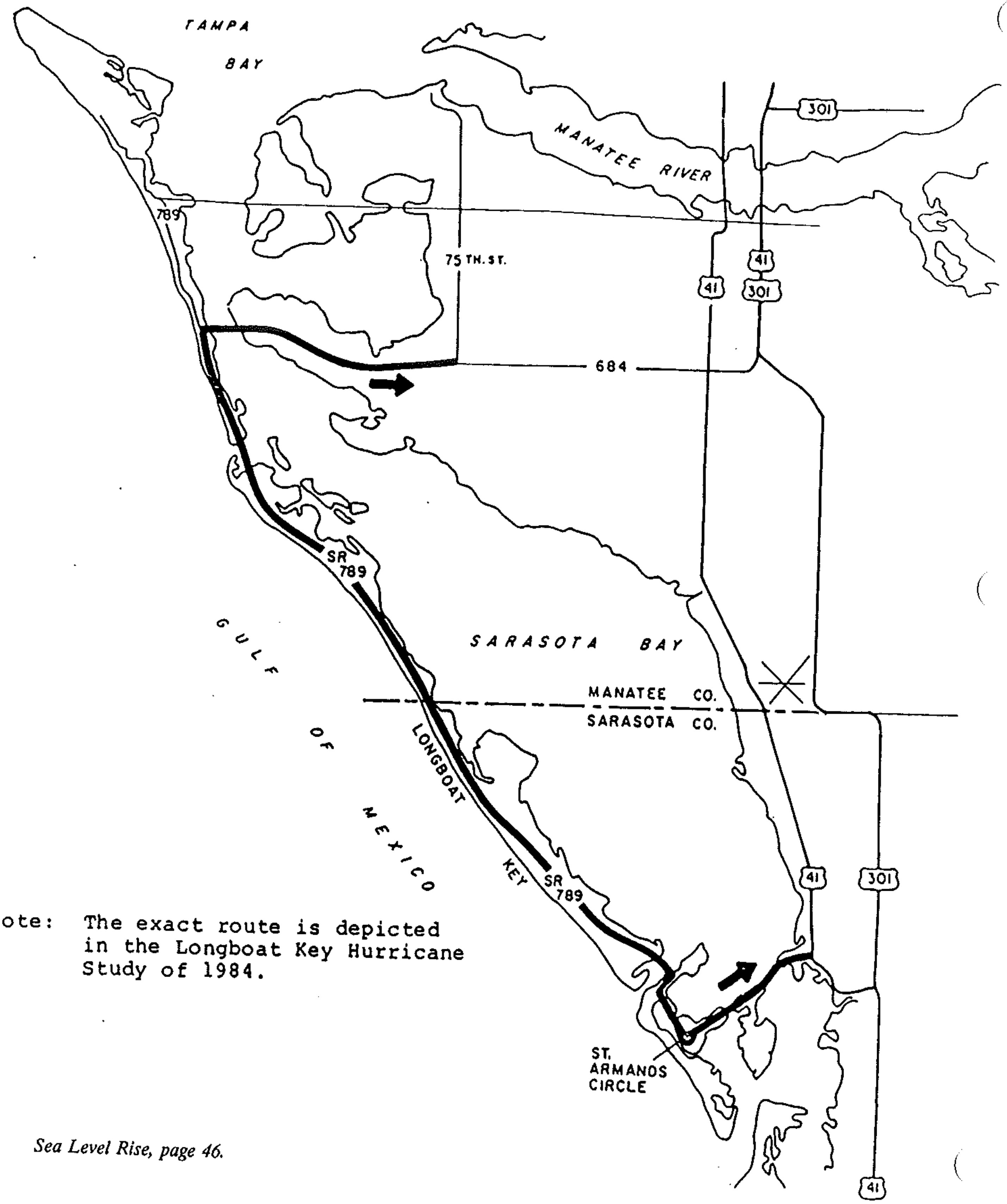
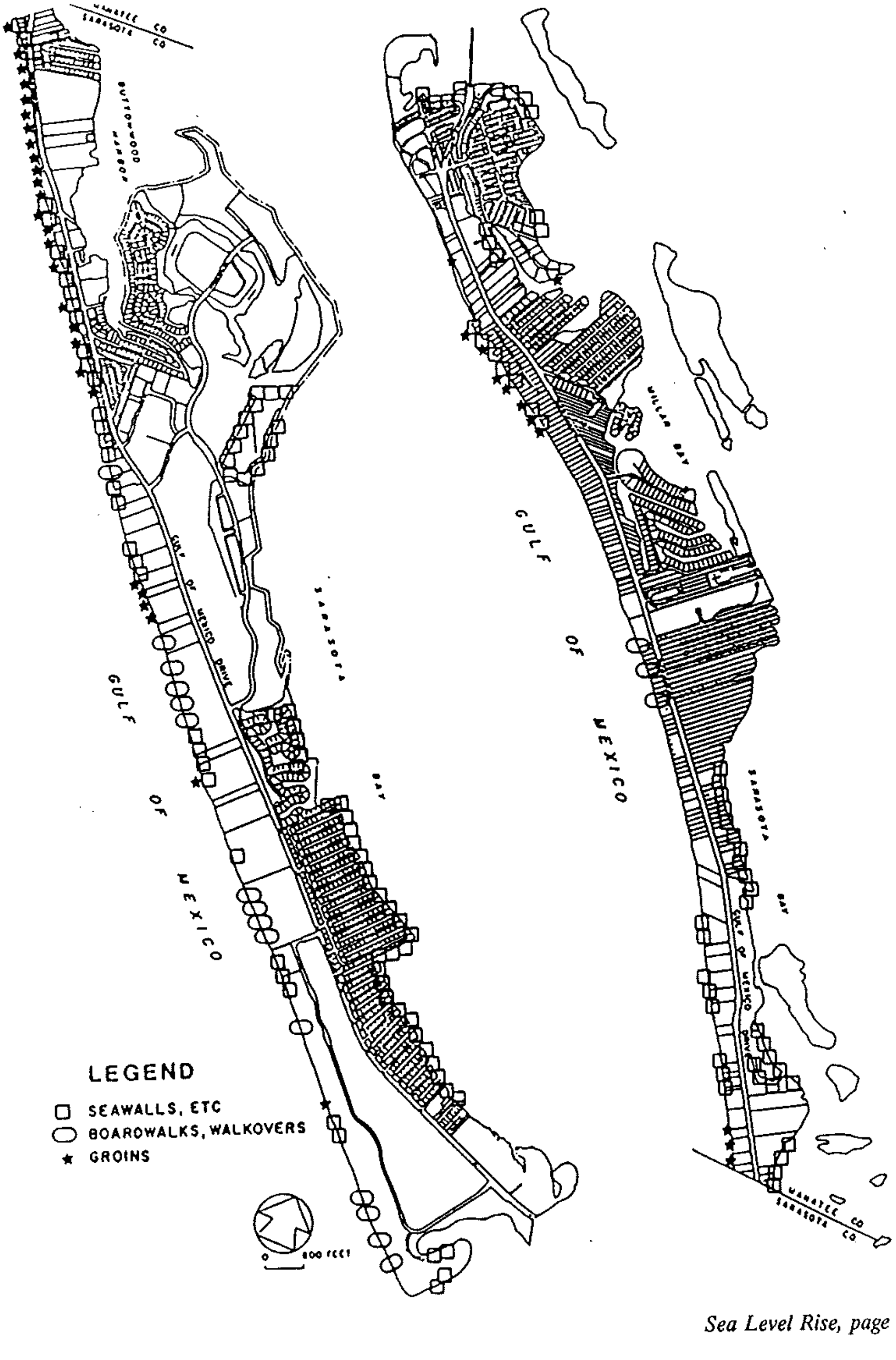


Figure 21. Evacuation routes for the Town of Longboat Key (RS&H, 1989).



Note: The exact route is depicted in the Longboat Key Hurricane Study of 1984.

Figure 22. Shoreline structures in the Town of Longboat Key (RS&H, 1989).



vicinity, but locations down current are deprived of sand, causing erosion. Some areas of Longboat Key have experienced severe sand loss, partially due to the placement of erosion control structures.

Plans are currently underway for a renourishment project along the Gulf coast of Longboat Key. The design calls for the renourishment of 49,980 linear feet of shoreline with approximately 2.86 million cubic yards of beach grade material from offshore ebb tidal shoals. It is anticipated that the project will begin by January 1993 (Nowicki, Personal Communication, 1992). Projected costs for the project total approximately 17 million dollars, with a breakdown as follows:

Table 4. Longboat Key Renourishment Project Costs (Erickson, Personal Communication, 1992).

beach fill	$12,000,000
mobilization and demobilization	1,000,000
dune revegetation/crossovers	775,000
pull structures/hardbottom reef	400,000
miscellaneous contingencies	2,126,250
finance charges	300,000
construction supervision	150,000
Total	$16,751,250

As sea level rises during the next century, it is likely that renourishment projects will again be required. Costs for these projects continue to increase. In the recent past, costs used to run approximately $1 million dollars for each mile of beach nourished. Presently, they are about $1.5 million for each mile (Nowicki, Personal Communication, 1992). Thus, the costs for renourishment activities might be a prohibitive factor in the future with sea levels rising between 0.5 and 1.2 feet between 2020 and 2115.

There are few dune systems left to prevent property damage and beach loss in the event of storms and high tides associated with rising sea levels. The locations of repeatedly damaged structures are depicted on Figure 23. Additionally, as sea levels continue to rise through the next century, renourishment projects will need to be increasingly more frequent and extensive. These costly projects will need constant maintenance, so eventually rising sea levels could make these projects economically unfeasible.

Beaches and coastal habitats will be seriously impacted by rising sea levels. Figure 24 identifies the present locations of beach areas on Longboat Key. The beaches on Longboat Key have already experienced losses, severe in some areas, due to erosion. The rates of

Figure 23. Repeatedly damaged structures in the Town of Longboat Key (RS&H, 1989).

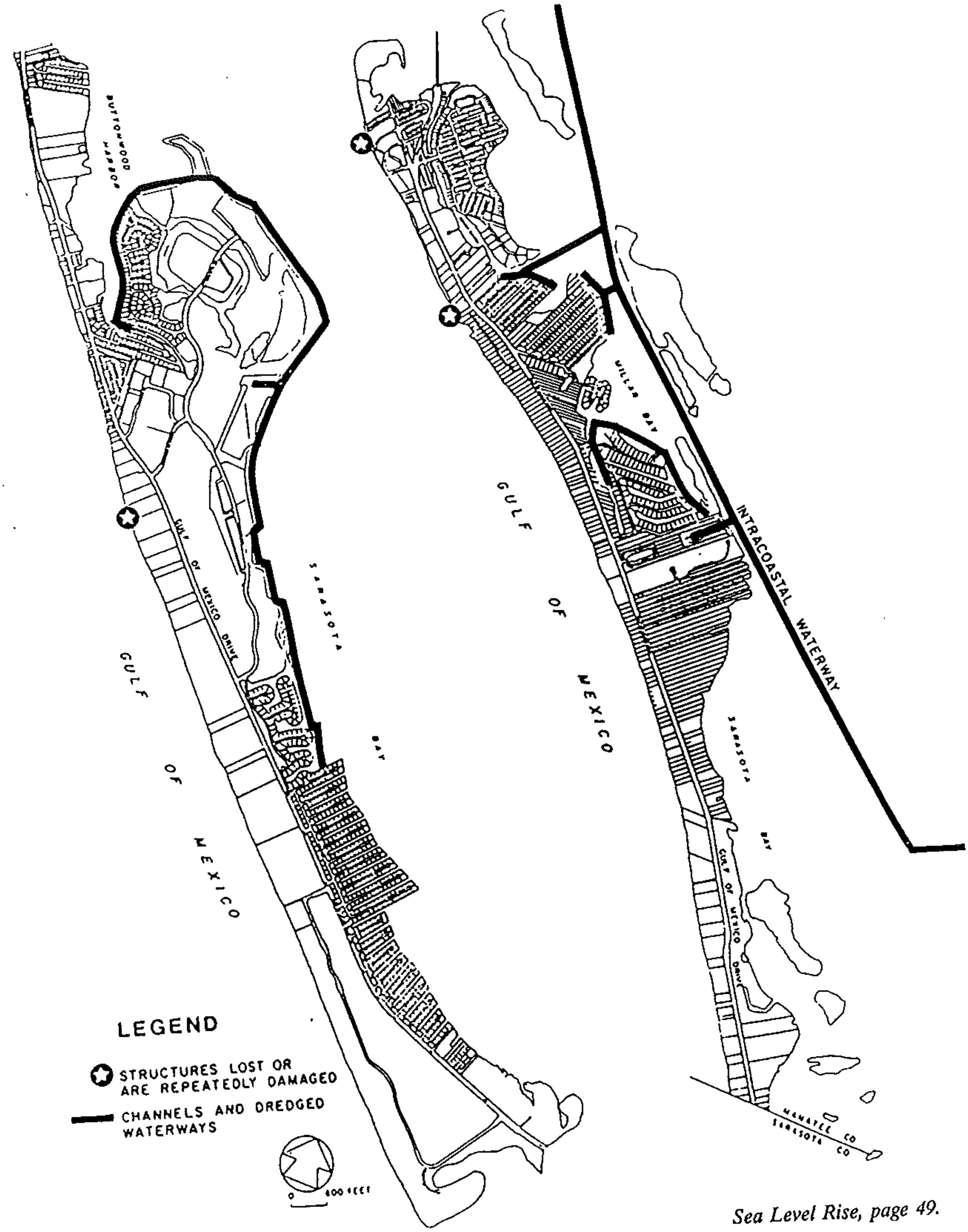
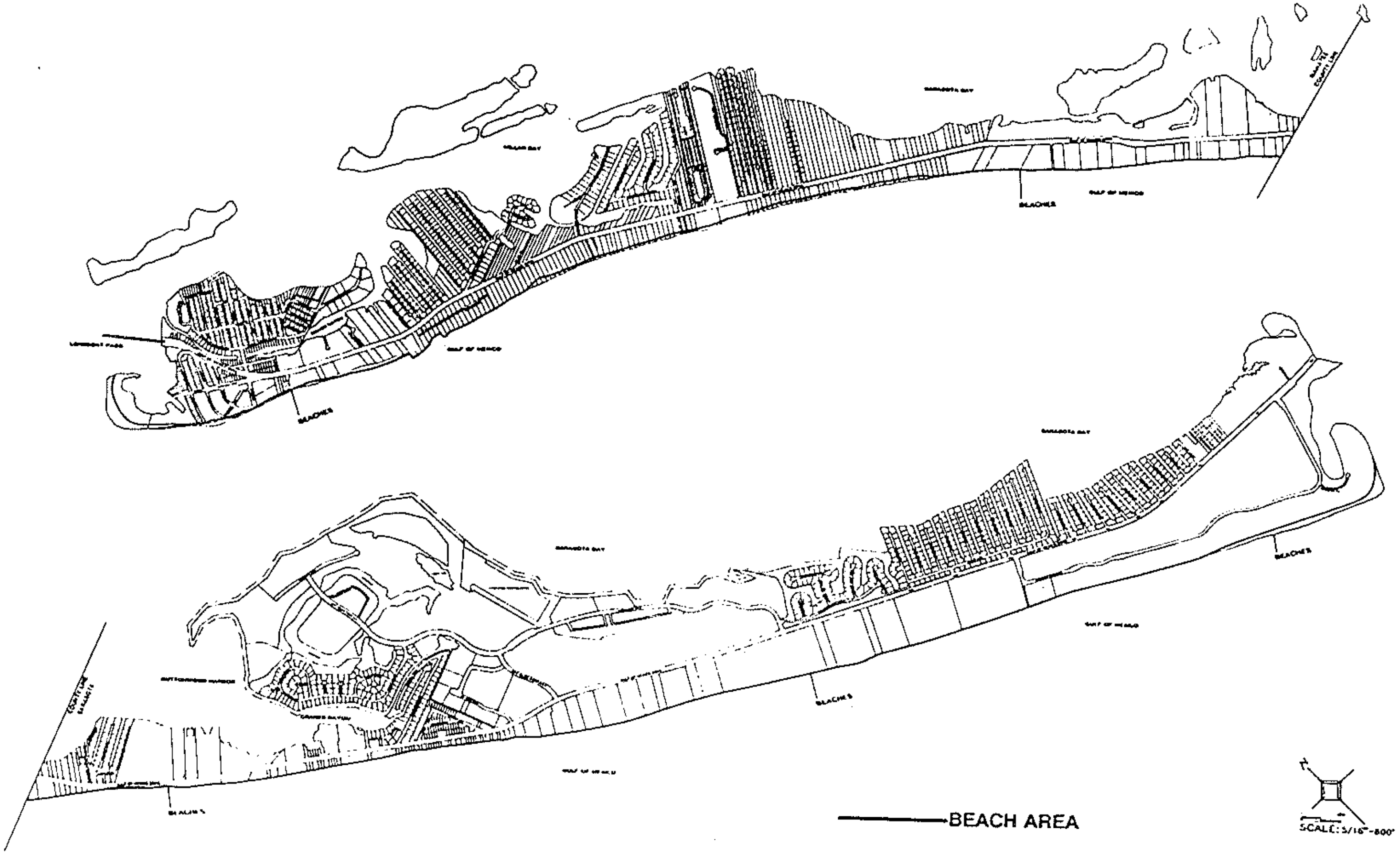


Figure 24. Beach areas on Longboat Key (RS&H, 1989).



erosion will be accelerated because of the simple inundation of land, and the accelerated erosion of beaches and dunes will result in higher wave action and thus higher water levels. Natural, undeveloped barrier islands will migrate and eventually "roll over"; however, the developed island of Longboat Key would lose many structures if this were to occur.

Management techniques for the beaches and coastal areas could take several forms. Shoreline structures such as seawalls, groins, rip rap and jetties are known to cause problems such as increased erosion and altered deposition of sediment. Additionally, these methods only offer short-term solutions. For these reasons, non-structural measures are usually preferred. The following "truths of the shoreline" offer a quick explanation of the effects of engineering on the shoreline, and the role development plays in coastal "problems" (Doyle, et al., 1984).

Truths of shoreline:

- There is no erosion problem until a structure is built on a shoreline.
- Construction by man on the shoreline causes shoreline changes.
- Shoreline engineering protects property on the beach, not the beach itself.
- Shoreline engineering destroys the beach it was intended to save.
- The cost of saving beach property through shoreline engineering can often be greater than the value of the property to be saved.
- Once you begin shoreline engineering, you can't stop it!

Regulations dealing with structural and non-structural methods are in effect in several states. In North Carolina, the use of any type of stabilizing or hardened shoreline structure is prohibited (Edgerton, 1991). They favor the use of beach nourishment and structural relocation. However, these methods carry their own difficulties. Beach nourishment is expensive, can be damaging to marine life, and often requires continuous applications over time, especially in the event of a severe storm. Relocation also is very costly and depends on the availability of land. In the case of Longboat Key, with only 11 percent of its land area left vacant, relocating within the Key would not be possible for many.

Setback regulations are another method of preserving shoreline areas. These laws restrict development in locations that can be expected to suffer from erosion. Florida's Beach and Shore Preservation Act allows the Florida Department of Natural Resources (FDNR) "to establish construction control lines that define the portion of the beach-dune system that is subject to severe fluctuations based on a 100-year storm surge, storm waves, or other predictable weather conditions" (Edgerton, 1991).

However, unlike Maine's Sand Dune Law, which requires that sea level rise be considered when examining building sites, the Florida Act does not specifically address sea level rise. It requires that FDNR make 30 year erosion projections on a site-by-site basis, but these projections are based on historical knowledge of shoreline changes. Structures intended to last longer than 30 years could face serious damage given the proposed acceleration in sea level rise. South Carolina has dealt with the possibility of changes in erosion rates caused by sea level rise by establishing a setback baseline which would be recalculated every five to ten years. Based on the average erosion rate for the preceding 40 years, the South Carolina policy will gradually factor in sea level rise (Edgerton, 1991). A similar approach within the Florida Act would be quite useful in planning for the anticipated changes caused by the rising sea level.

The ephemeral nature of the shoreline does not readily lend itself to regulations and management of permanent structures. The examination of varied alternatives will be crucial to the future security and stability of shoreline Longboat Key.

Barrier Island Dynamics

Extreme development on Longboat Key has resulted in very few natural ecosystems remaining today. The key had typical estuarine communities in its predevelopment time, and thus experienced normal barrier island dynamics, but at the present very few pristine areas remain. Natural shoreline processes have been altered by the presence of development, but continue to operate and influence the coast.

The shoreline along the key still shows the influence of natural beach dynamics. Shorelines are continually changing, advancing and retreating as they are influenced by the wind and water. Beaches change with the seasons, with sand moving in the direction of the prevailing currents. In winter, fine sand grains are pulled offshore where they form sand bars. In summer, gentler waves deposit sand back on the beach. However, if sand grains move too far offshore or an extremely active storm season occurs, there can be a net loss of sand.

Sand is also transported along the coast. Prevailing currents will move sand in one direction. Problems arise when erosion control structures, such as groins and jetty's, are constructed. These structures trap sand in the immediate vicinity, but locations down current are deprived of sand and increased erosion occurs. Longboat Key has experienced some severe sand losses, partially due to the placement of erosion control structures. Figure 22 illustrates the location of seawalls, boardwalks and groins on the key.

On the East Coast, the documented rate of sea level rise has been 1 to 2 millimeters per year, and significant coastal erosion has been observed (Edgerton, 1991). As the shoreline tries to establish new equilibrium positions according to the Brunn rule, the shoreline continues to recede and there is an accompanying decrease in shore slope. Figure 25 provides an illustration of the Brunn rule (Edgerton, 1991). Also, deeper coastal waters increase wave generation and thus will increase the probability for overtopping of barrier islands. These processes can also be experienced on Florida's west coast.

The northern 4.5 miles of Longboat Key, which is situated in Manatee County, advanced approximately 355 feet from 1883 to 1968, according to the U.S. Army Corps of Engineers.

Figure 25. Illustration of the Bruun rule (Barth and Titus, 1986 in Edgerton, 1991).

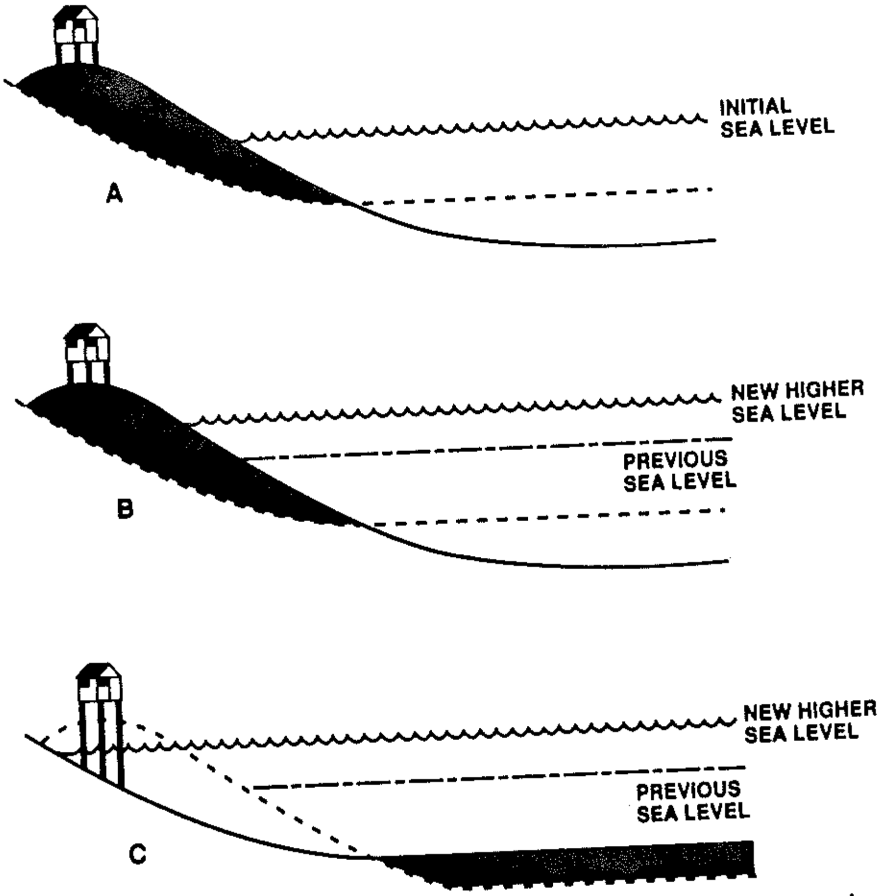


Figure 3.1 *The Bruun rule:* **(A)** *initial condition;* **(B)** *immediate inundation when sea level rises;* **(C)** *subsequent erosion due to sea level rise. A rise in sea level immediately results in shoreline retreat due to inundation, shown in the first two examples. However, a 1-meter rise in sea level implies that the offshore bottom must also rise 1 meter. Waves will erode the necessary sand from upper part of the beach as shown in part* **(C)**.

However, the southern portion of the key (located in Sarasota), retreated an average of 173 feet during this same time frame. The entire shoreline continued to retreat from 1946 to 1968 at most locations along the Manatee County beaches. Net erosion for the system has been observed because the offshore 6-, 12-, and 18 foot depth contours have generally moved landward between 1926 and the present (Doyle, et al., 1984).

Erosion and accretion trends are also indicative of the shoreline changes along the Sarasota County shoreline. The southern section of Longboat Key lies within the borders of Sarasota County. Longboat Key retreated an average of 242 feet from 1883 to 1967 (Doyle, et al., 1984). The placement of fill from the dredging of New Pass at the southern end of the key greatly influenced the shoreline dynamics of the key.

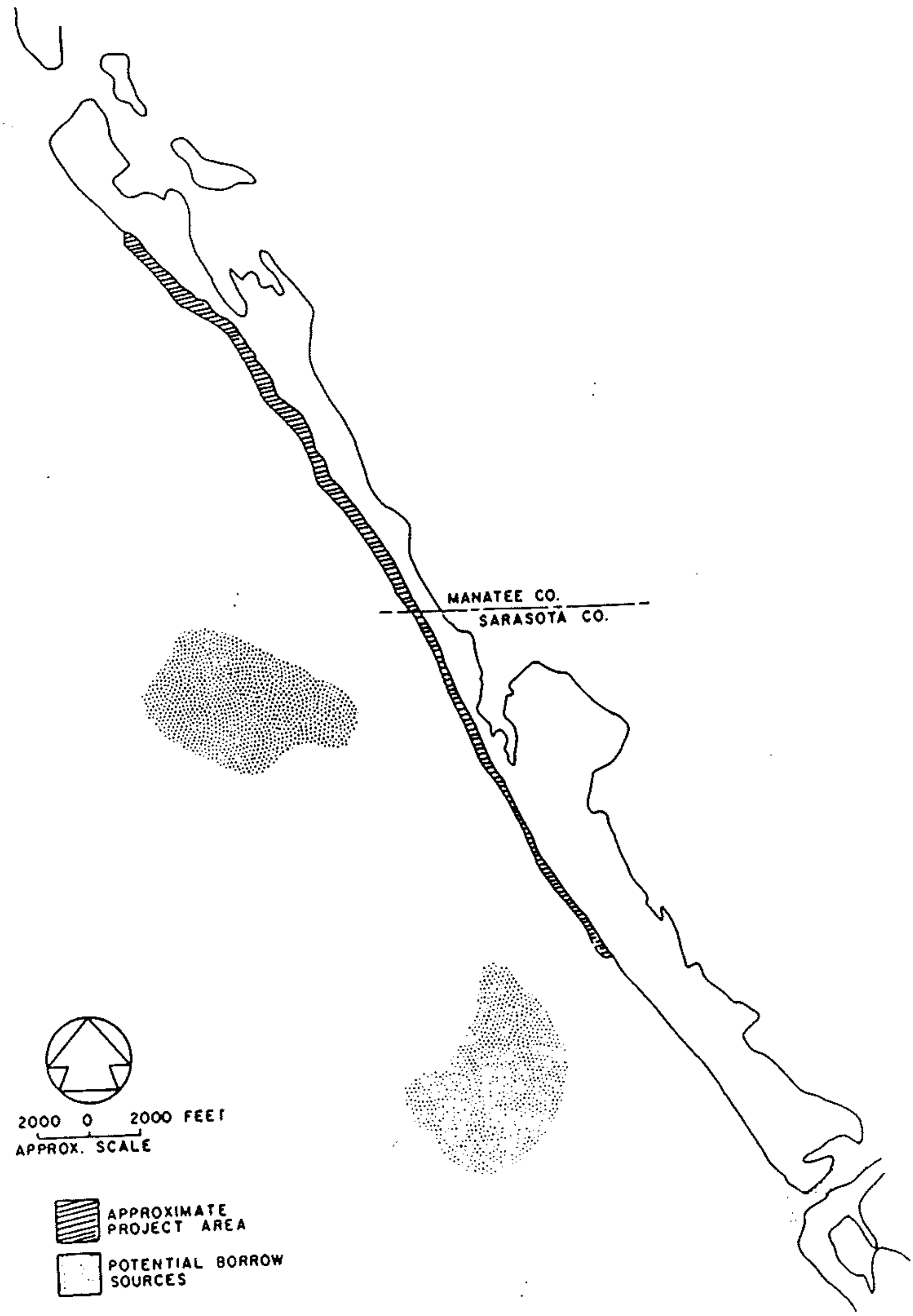
The sea level along Atlantic coast has risen approximately one foot in the past century (Edgerton, 1991). This one foot rise can cause enough erosion and flooding to result in a shift of beach location between 5 and 100 feet or more landward, depending on the shoreline slope (Edgerton, 1991). A similar rise along Florida's west coast will result in barrier island migration and erosion, as well as alteration of the dunes. However, in undeveloped areas the islands will retreat through overwash and accretion on the mainland side, maintaining their total mass while moving toward the mainland. However, the high concentration of development on Longboat Key will result in flooding and property destruction as the island naturally tries to retreat.

In an attempt to protect property and facilities, and to restore their beaches, governments and individuals in Manatee and Sarasota County have installed assorted structural devices along Longboat Key. The methods include seawalls, revetments, groins, jetties, and beach nourishment (Figure 26). While temporarily slowing shoreline retreat, these structures have not been effective in eliminating or diminishing long-term beach erosion. Additionally, where seawalls and rock revetments have been installed, there is no natural beach. Evidence also indicates that renourishment is a costly and unstable process. After the "No Name Storm" in June 1982, severe beach erosion occurred on a recently renourished beach (Doyle, et al., 1984). Thus, renourished beaches often require frequent maintenance.

Inlet Dynamics

Several Conservation Areas have been designated on the key, and along with the remaining wetland fringes, constitute the last remaining undeveloped lands on Longboat Key. Inlet dynamics on the fringe will be altered by a rise in sea level, with these fringe coastal areas becoming inundated first. Normally, tidal inlets are dynamic and have substantial influence on the natural processes of barrier islands (Doyle, et al., 1984). Large tidal inlets such as Tampa Bay generally do not laterally move large distances. This can result in the build-up of shoals called ebb-tidal deltas. The shoals can extend quite a distance from shore, and will transform in response to incoming wave action. This, in turn, will influence the level of wave energy that a nearby beach receives, resulting in accretion or erosion.

Figure 26. Location of beach nourishment areas in the Town of Longboat Key (RS&H, 1989).



Shoreline retreat continues today. The stretches of shoreline at the mouth of inlets have fluctuated back and forth much more than shorelines further from the inlets. Small tidal inlets such as Longboat Pass and New Pass respond and change much more rapidly than other coastal areas. These inlets move laterally in the direction of net longshore transport. The areas near Passage Key and Longboat Pass have experienced rapid erosion and accretion (Doyle, et al., 1984). Obviously, this can cause extreme problems for any development in the immediate vicinity. Structures located on the downdrift side of these inlets can quickly become endangered by the rapid migration of the inlet.

Additionally, mainland shorelines can be impacted, resulting in losses to valuable coastal development, due to changes or the appearance of a new inlet. When a new inlet was created on Nauset Beach (a barrier spit on Cape Cod in Massachusetts) during a winter storm in 1987, the mainland shoreline receded by 75 feet during 1987. One house was destroyed, others relocated, and still others had to install large revetments for protection, which caused accelerated erosion in nearby areas (Platt, et al., 1991). Because Longboat Key has been altered so extensively by development, the natural processes of inlets have been artificially changed.

As the sea level rises during the next century, inlets will continue to be influenced by wave action, but change could occur much more rapidly. Increased wave action and higher storm surges will increase the pace of erosion, but accretion could be reduced because of higher overall water levels and an actual reduction in land area on the key. Inlets could substantially increase in size and number due to a higher mean sea level, decreased accretion and increased areas experiencing washover. Movement patterns of inlets might also change due to rising sea levels. Instead of moving laterally in the direction of longshore transport, the presence of development on the island will interrupt the natural shift of the inlet resulting in flooding of land (possibly developed), and a larger inlet.

ANALYSIS OF A COMMUNITY - CITY OF SARASOTA

The City of Sarasota is a well-developed, established city which contains many characteristic components of a Florida community. A rise in sea level could adversely impact several components of the city community. By the year 2020, a predicted rise in sea level of 0.5 feet will begin impacting the infrastructure, drainage, transportation and development within in the city, especially those areas closest to Sarasota Bay.

Development and Infrastructure

The City of Sarasota is a highly urbanized area. The city operates four utility systems: potable water, sanitary sewer, drainage and solid waste. These systems will each experience some degree of impacts from rising sea levels, with resulting problems and changes in the economical, societal, and environmental aspects of the city.

By 2115, a sea level rise of 2.1 feet would result in widespread inundation of the coastline and potentially damage a large number of residential units located in the coastal vicinity. Vacant land accounts for only 8.9 percent of the land uses within the city. Residential uses comprise 52.7 percent of the land uses, commercial/office space equals 9.2 percent, community facilities 14.2 percent, industrial uses 2.8 percent, open space and recreational 10.0 percent, conservation uses 2.2 percent and agricultural uses 0.1 percent (City of Sarasota, 1991).

There are a large number of residential land uses bordering Sarasota Bay within the City of Sarasota. Scattered parcels of recreational and vacant land are also present, but most of the shoreline is composed of residences. Directly adjacent to these residential areas are a large number of commercial and office buildings. As indicated by Figures 8 and 9, several areas could experience significant impacts due to sea level rise by the year 2065 and 2115, including:

- portions of St. Armands and Lido Keys
- the northern part of Siesta Key,
- along Big Pass
- segments of Bay Island, and
- the shoreline of Phillippi Creek

However, only the shoreline stretches within the City limits will be effected by increased SLR by 2115. The shoreline of Philippi Creek and adjacent development could experience the greatest inland impacts of higher sea levels.

The City provides potable water to the entire population of Sarasota through a public water supply system. Two sources provide the City's water supply: the Verna wellfield, located 17 miles east of the city, and a reverse osmosis system at the St. Armands/City well-field location (City of Sarasota, 1991). It can be expected that the Verna wellfield will not experience adverse impacts due to a rise in sea level because of it's removed location. However, the St. Armands/City well-field is located directly adjacent to Sarasota Bay, in the northwest portion of the city (Figure 27).

As sea levels rise through the next century, salt water intrusion into the groundwater in this area is strongly anticipated. In fact, by 2115, some of the wells might actually become contaminated by salt water, given their proximity to the bay at less than 2000 feet, and could be rendered useless. Previously documented saltwater intrusion on Long Island, NY has shown that the interface between fresh and saltwater advances 3-60 meters per year, depending on local pumping conditions (Edgerton, 1991).

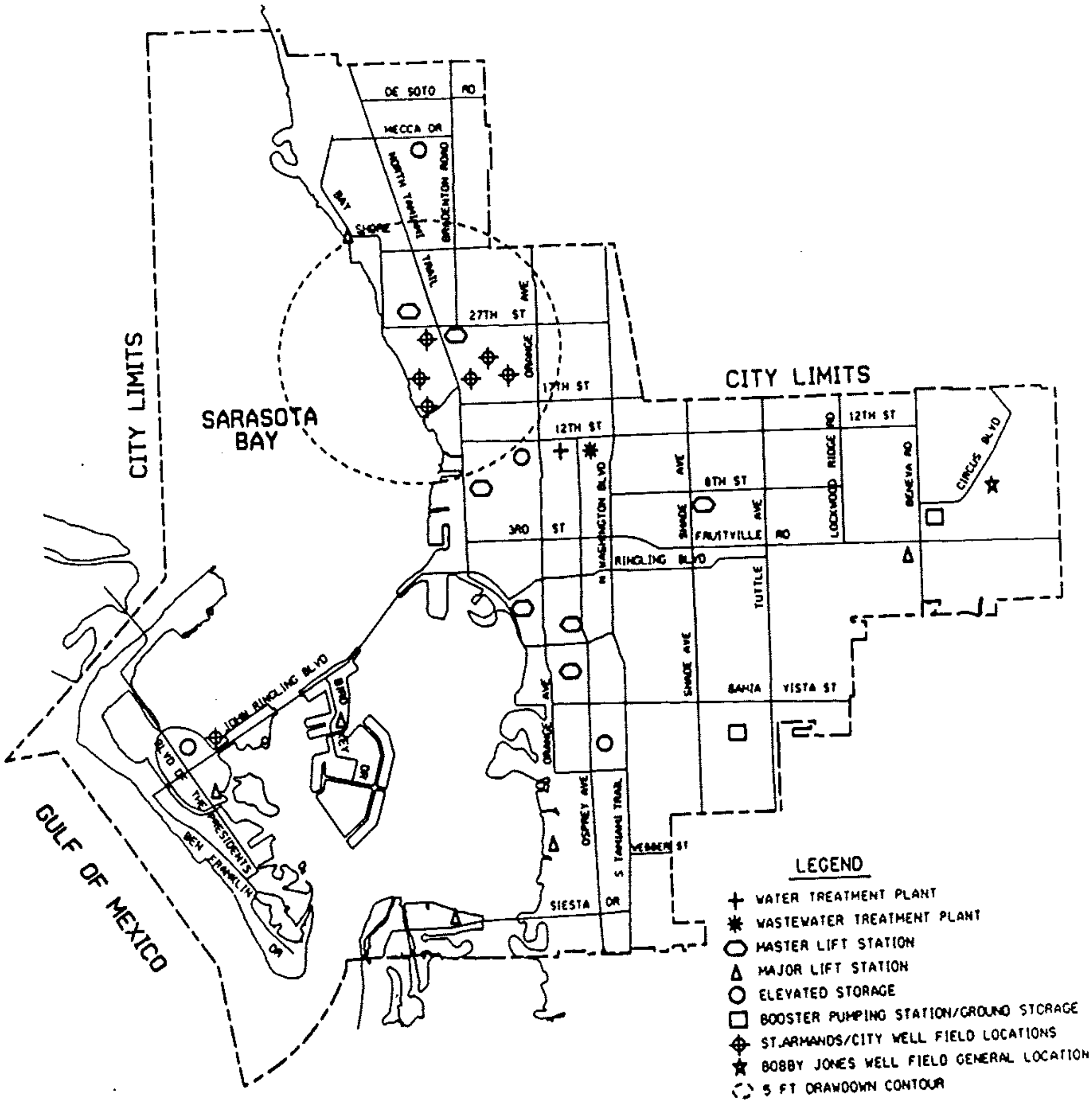
Solutions for dealing with salt water intrusion, including building desalinization plants or relocating water intakes, are expensive and would require the commitment of more human and environmental resources. Additional steps include locating new pumping stations, placement of new sewage and hazardous waste treatment facilities, and the acquisition of lands for future reservoirs. Governments and Water Management Districts would need to implement policies to ensure sufficient water supplies and allow for the development of new and alternative sources of water. Other steps include the legalization of water markets, diminishing federal subsidies to prevent the artificially low prices, and altering the formulas which are used for water allocation (Titus, 1990).

The City of Sarasota provides public sanitary sewer service to more than 97 percent of the developed areas of the city. Figure 27 identifies the locations of sanitary sewer facilities. There are no private facilities located within the city limits. In the past, wastewater received at the city treatment plant was treated, chlorinated and discharged into Whitaker Bayou. Beginning in 1989, a reuse program came on-line on a small scale. With the reuse system, treated effluent is held in a storage pond and used for irrigation. The treated wastewater is currently used for irrigating a ranch and golf course, and more golf courses and residences are planned for inclusion in the near future (Hazy, Personal Communication, 1992).

Historically, water quality in Sarasota Bay and Whitaker Bayou was adversely impacted by the disposal of treated effluent (City of Sarasota, 1991). The establishment of the reuse system has led to improvements in water quality in Whitaker Bayou, especially in the area south of the discharge point (Hazy, Personal Communication 1992). However, it does not appear that the City will ever be able to reclaim 100 percent of the treated wastewater and have no discharge into Whitaker Bayou at all times throughout the year. The intense rains during June 1992 filled the storage pond to capacity, and the City was again compelled to discharge into Whitaker Bayou (Hazy, Personal Communication, 1992).

Increased water levels from the predicted rise in sea level could adversely impact the infrastructure of the sewer system, by the flooding of lift stations and damage to pipelines.

Figure 27. Potable water and sanitary sewer facilities in the City of Sarasota (City of Sarasota, 1991).



As the population continues to increase, increased levels of effluent could cause the pollution problem to worsen. However, the reclamation system should offset these problems somewhat.

Solid waste from the City of Sarasota is collected and transported to the Sarasota County Bee Ridge Class I landfill. This landfill is nearing capacity and the County is currently investigating a new location for a solid waste disposal facility. A rise in sea level will adversely impact some transportation routes within the city, and this will result in problems for the collection and transportation of solid waste. In addition, changes in the water table could impact water quality surrounding the landfill.

Drainage in the City of Sarasota is handled by a system of natural and manmade conveyance and retention/treatment facilities, including storm sewers, culverts, and ditches. The system is divided into 12 drainage basins within the city limits. Stormwater runoff has been identified as a major contributing factor in the degradation of water quality in Sarasota Bay and surrounding waters (City of Sarasota, 1991). The City is investigating an improved system which would require more on-site detention and treatment for all new construction and possible consolidation with Sarasota County.

However, rising sea levels will increase the frequency of flooding in low-lying and coastal areas and could require widespread changes in the drainage system, including the relocation and addition of retention basins, movement of drainage outfalls, and more capacity to deal with pollution of the surrounding waters.

Flood Control and Emergency Management

The entire coastline of the city bordering on Sarasota Bay, as well as the barrier islands, are part of the A and Z zones of the flood insurance rate maps of the Federal Emergency Management Agency (FEMA). The "A" zones are areas subject to 100-year flood hazard and "V" zones are subject to 100-year flood hazard and associated wave action (City of Sarasota, 1991). These areas are heavily developed and include residential, commercial, recreational, and community uses. Floodplain locations are depicted on Figure 28.

These areas will be influenced by a 0.5 (2020) and 2.1 (2115) foot rise in sea level. More developed areas will be regularly flooded, and by the year 2115, the coastal areas directly adjacent to the bays could be permanently inundated. In the case of a major storm event, the increased storm surges will result in a widespread damage further inland. Also located within the A and Z zones are many water-dependent and water-related uses such as boat ramps, marinas, waterfront parks, public beach accesses and parking, piers, concessionaires and resorts (Figure 29). Because the city's economy is closely related to its varied and abundant coastal resources, damage to these resources will adversely impact the economic base of the city. In addition, federal programs [the National Flood Insurance Program (NFIP), administered by FEMA], that provide financial support in times of natural disasters could become more costly (Titus and Barth, 1984).

Figure 28. Floodplains in the City of Sarasota (City of Sarasota, 1991).

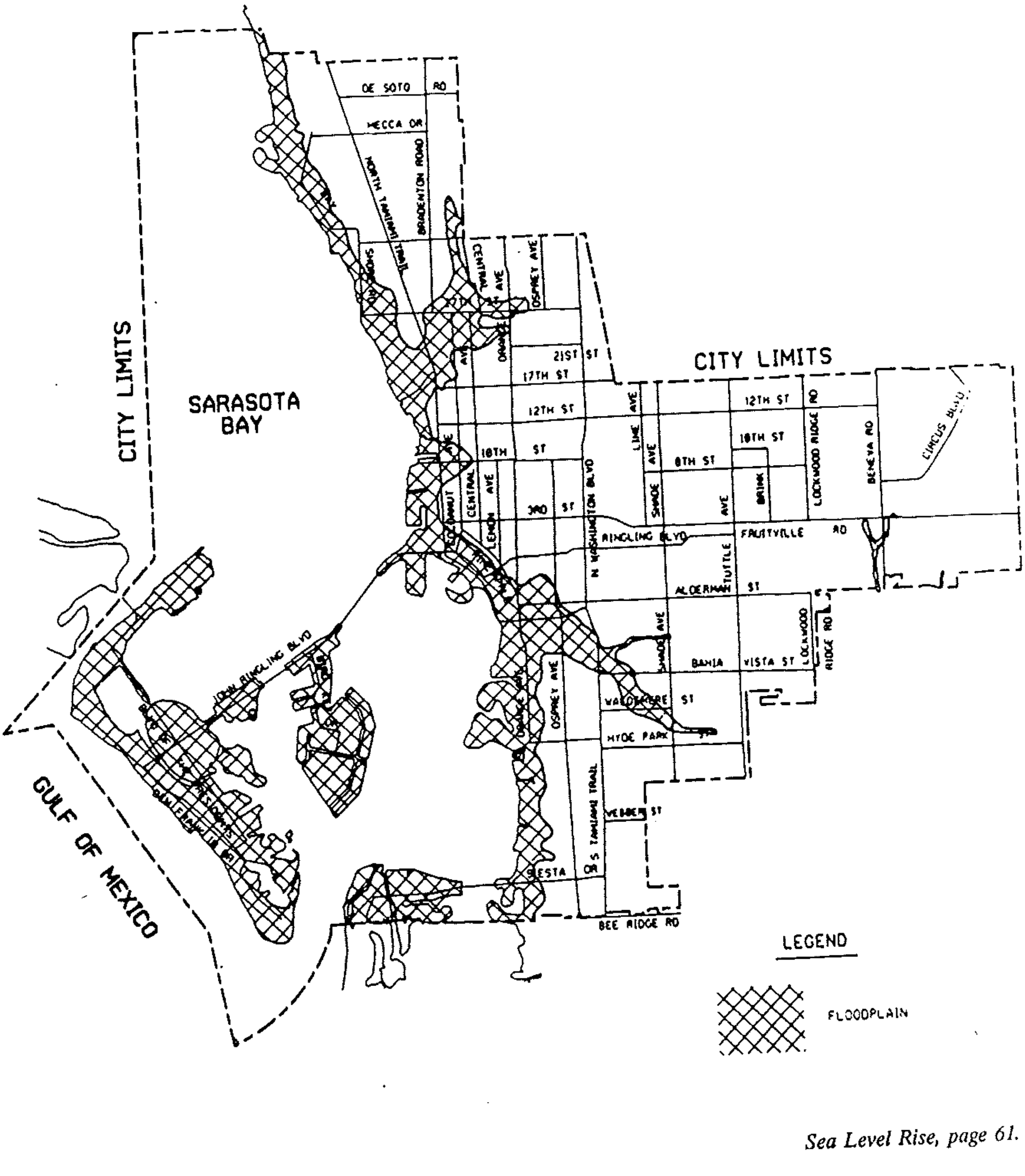
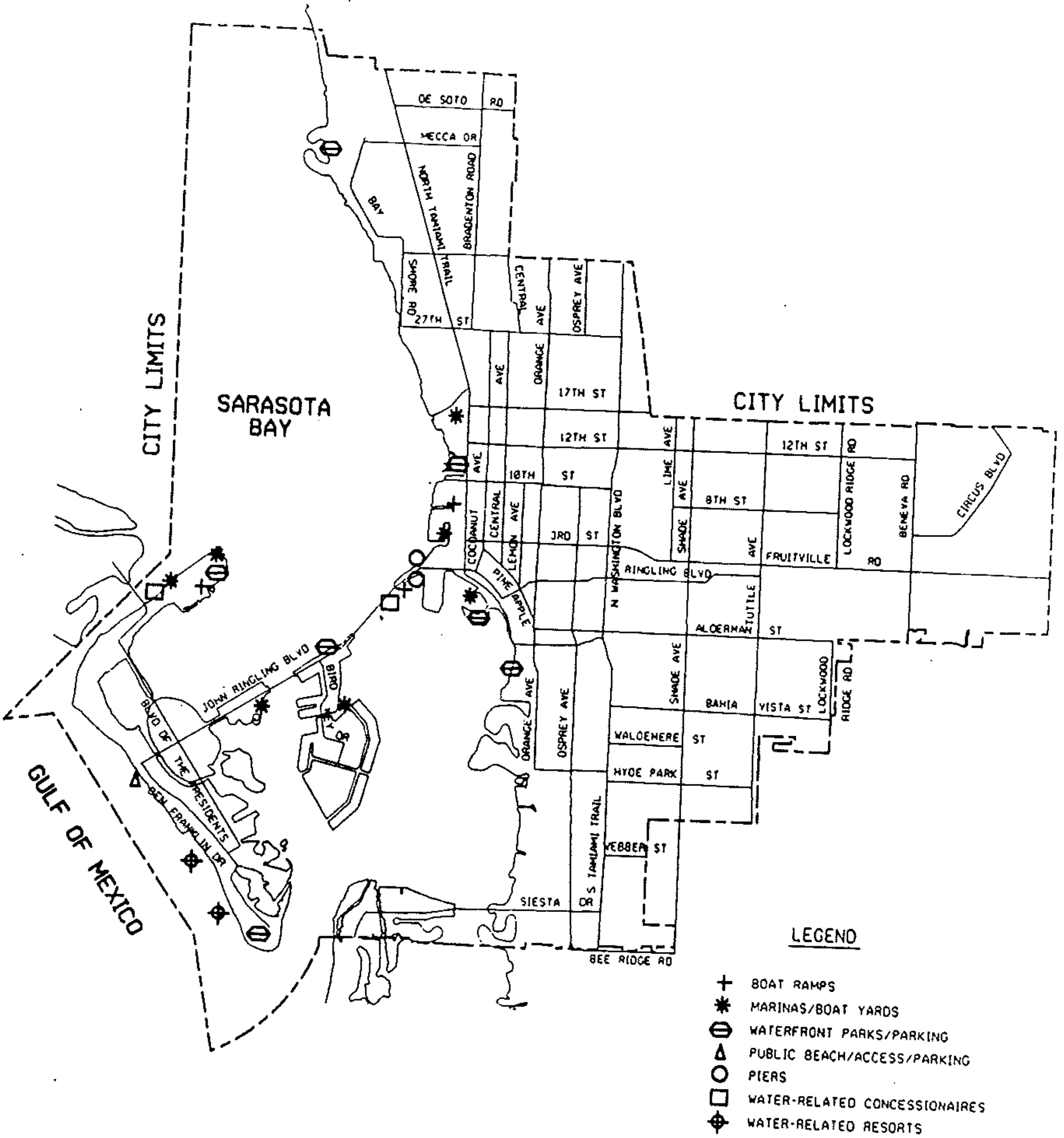


Figure 29. Water dependent public facilities in the City of Sarasota (City of Sarasota, 1991).



The City of Sarasota has approximately 40 miles of coastal shoreline within its corporate boundaries. Of these 40 miles, 8 miles are in a natural state and 32 miles have been altered by some type of structure, such as seawalls and revetments (City of Sarasota, 1991). Figure 30 identifies the location of seawalls around the bay. While these hardened structures will offer some protection against the impacts caused by a rise in sea level, eventually they will not be effective in holding back the tide. Additionally, they will not offer complete protection in the case of a major storm event. These structures are also known to cause adverse impacts to nearby beach areas, causing artificial erosion and accretion. The removal and/or redevelopment of these structures further inland would be very costly and again would not offer complete insurance against damage caused by rising water levels and flooding. The options, including retreat and redevelopment, or increasing protective structures, both carry increased costs and problems.

In the event of a hurricane, Sarasota has many resources which will be at risk. In the future, the increased sea levels will result in an even greater threat to lives and property within the city. Storms that at present require minimal evacuation will in the future with the predicted rise in sea level result in greater numbers requiring evacuation. A depiction of the hurricane vulnerability and storm category zones is located on Figure 31.

Added to already stressed transportation resources and damage to roadways from sea level rise, these storms could create a much greater degree of hardship than they would at present. Some of the primary hurricane evacuation routes in the city are located in close proximity to Sarasota Bay, and therefore would most likely be flooded in the event of a major storm. At the present time, there is a shortage of shelter space in Sarasota County (City of Sarasota, 1991). The hurricane evacuation routes and shelter locations are illustrated on Figure 32. It can be expected that in the future, increased population and the need for greater numbers to evacuate because of the rising sea level will result in an even larger demand for shelter space.

Transportation

The City of Sarasota currently maintains a transportation system in coordination with Sarasota County, the Sarasota-Manatee Airport Authority, and the Florida Department of Transportation. Most data for traffic volumes is only available for State and some county roads. There are several identified problem areas, and there may be many more on roads without data.

Several principal and minor arterials within the city limits are located very near Sarasota Bay and connect the mainland and barrier islands (Figure 33). These roads could be severely impacted by the impending rise in sea level. Most of these are at Level of Service (LOS) C, D, or E, which indicate medium to poor levels of service, meaning traffic back-ups, delays and problems are common. Figure 34 identifies the levels of service on main arterials in the region. While the city is working on level of service improvement strategies,

Figure 30. Shoreline features in the City of Sarasota (City of Sarasota, 1991).

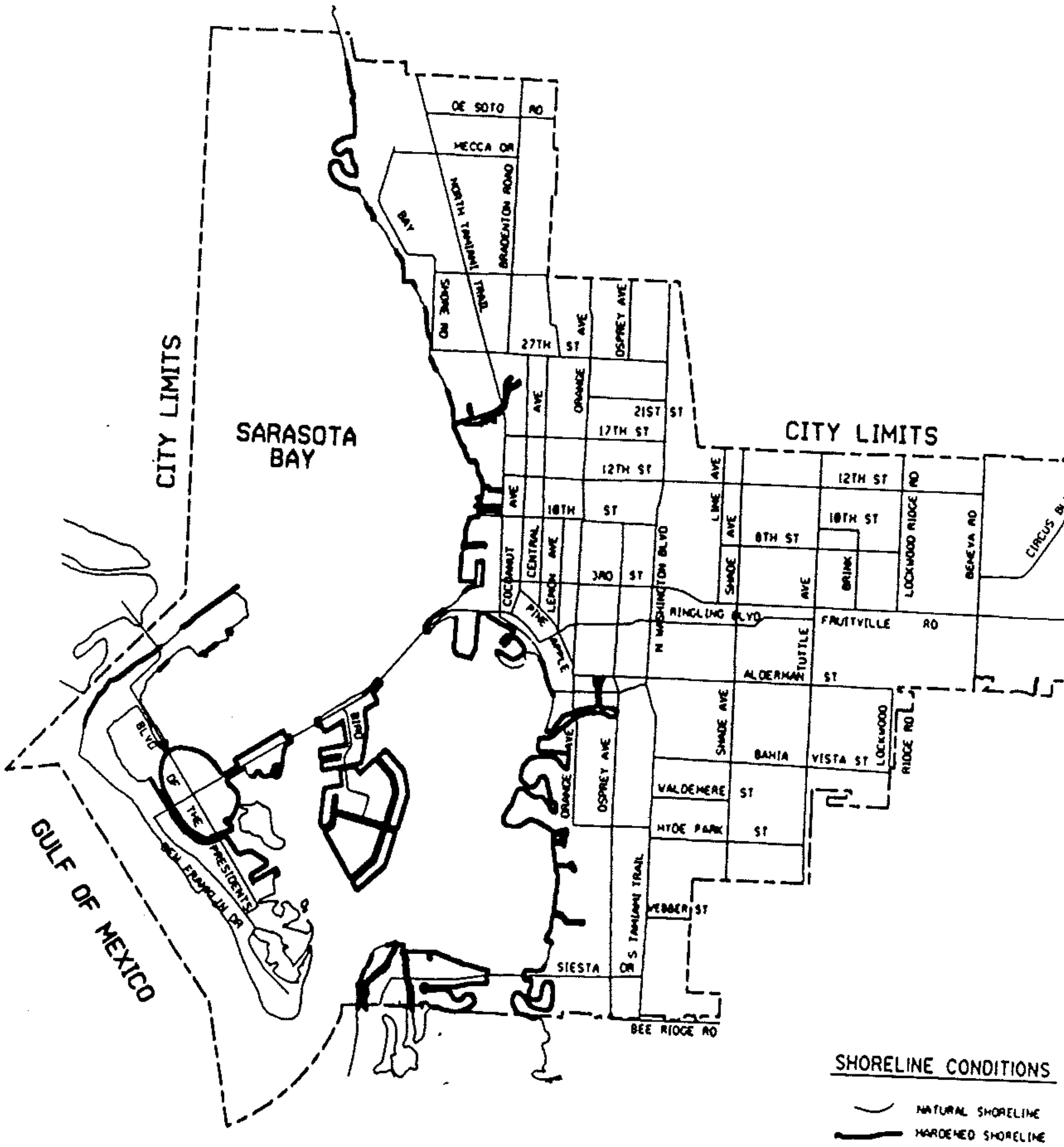


Figure 31. Hurricane vulnerability and storm category zones for the City of Sarasota (City of Sarasota, 1991).

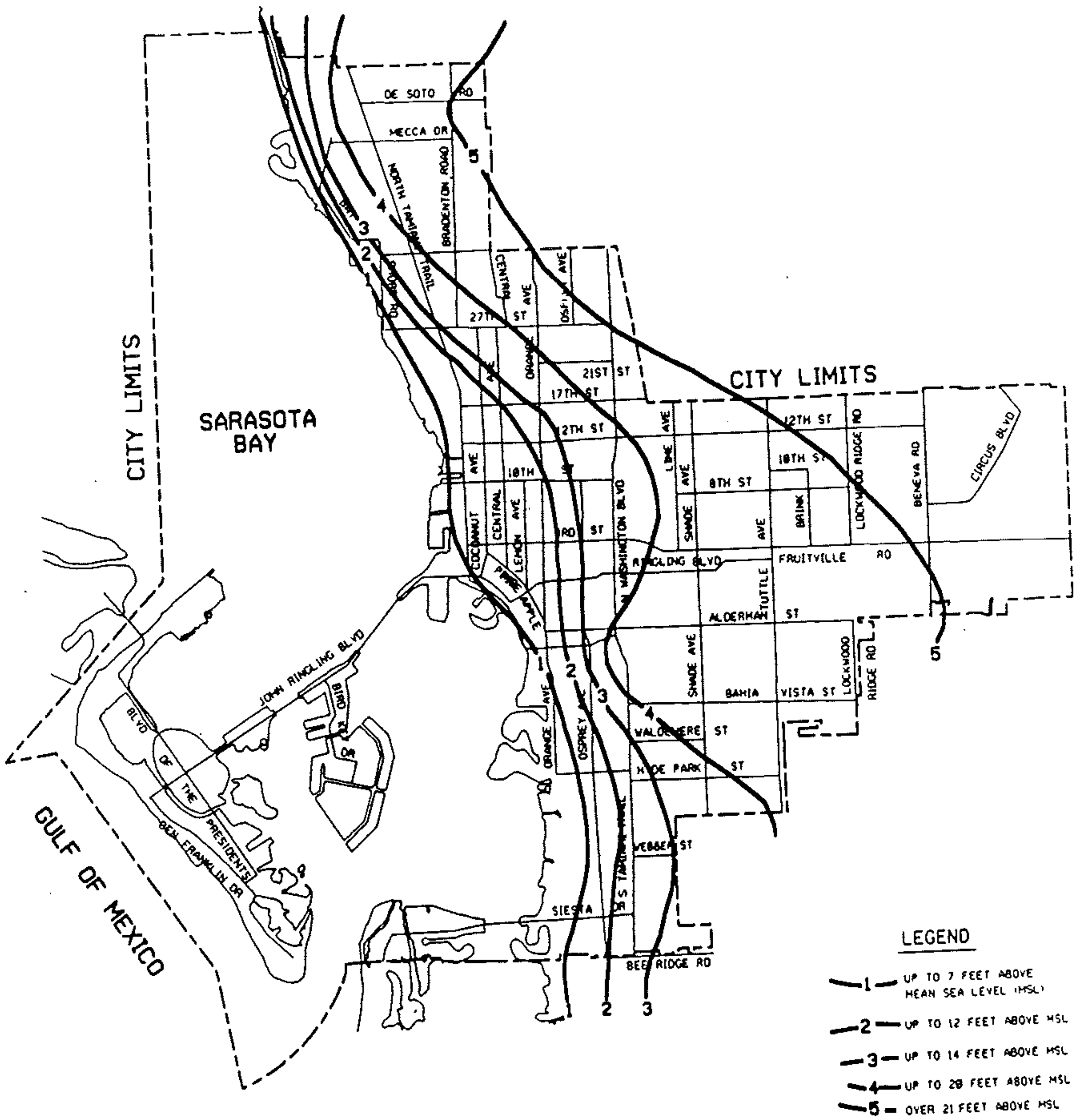


Figure 32. Hurricane evacuation routes and shelters in the City of Sarasota (City of Sarasota, 1991).

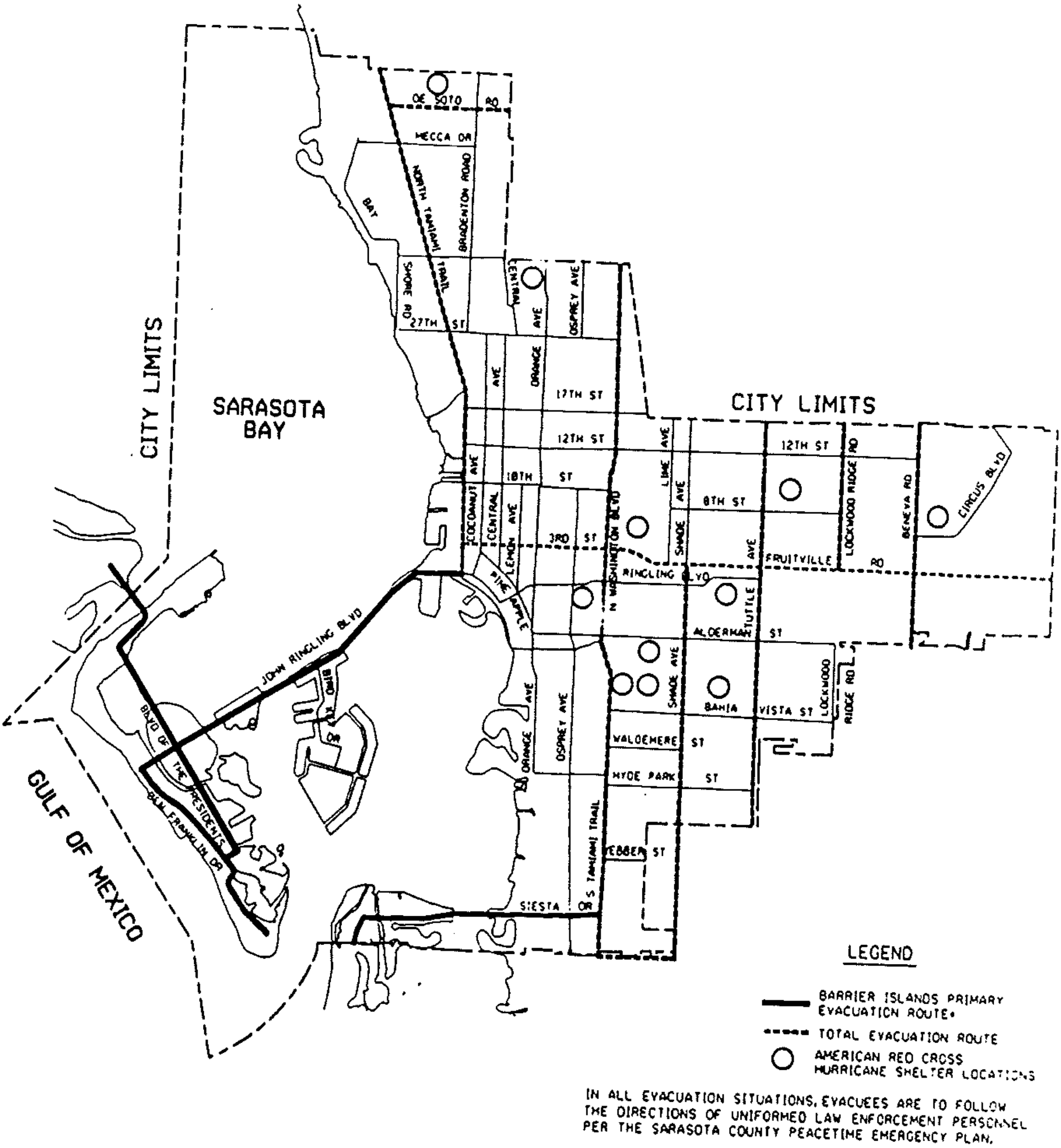


Figure 33. FDOT roadway functional classifications in the City of Sarasota (City of Sarasota, 1991).

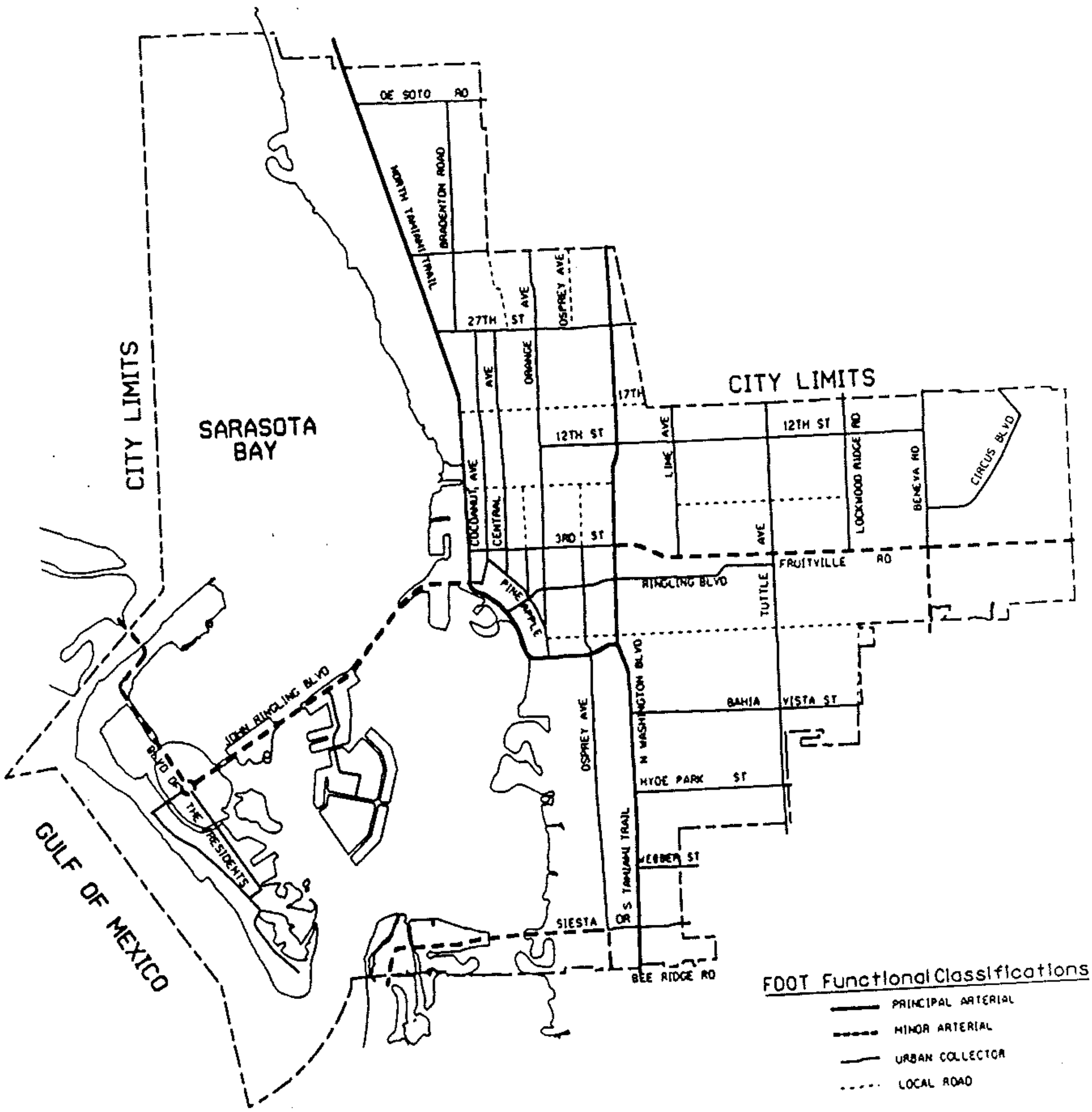
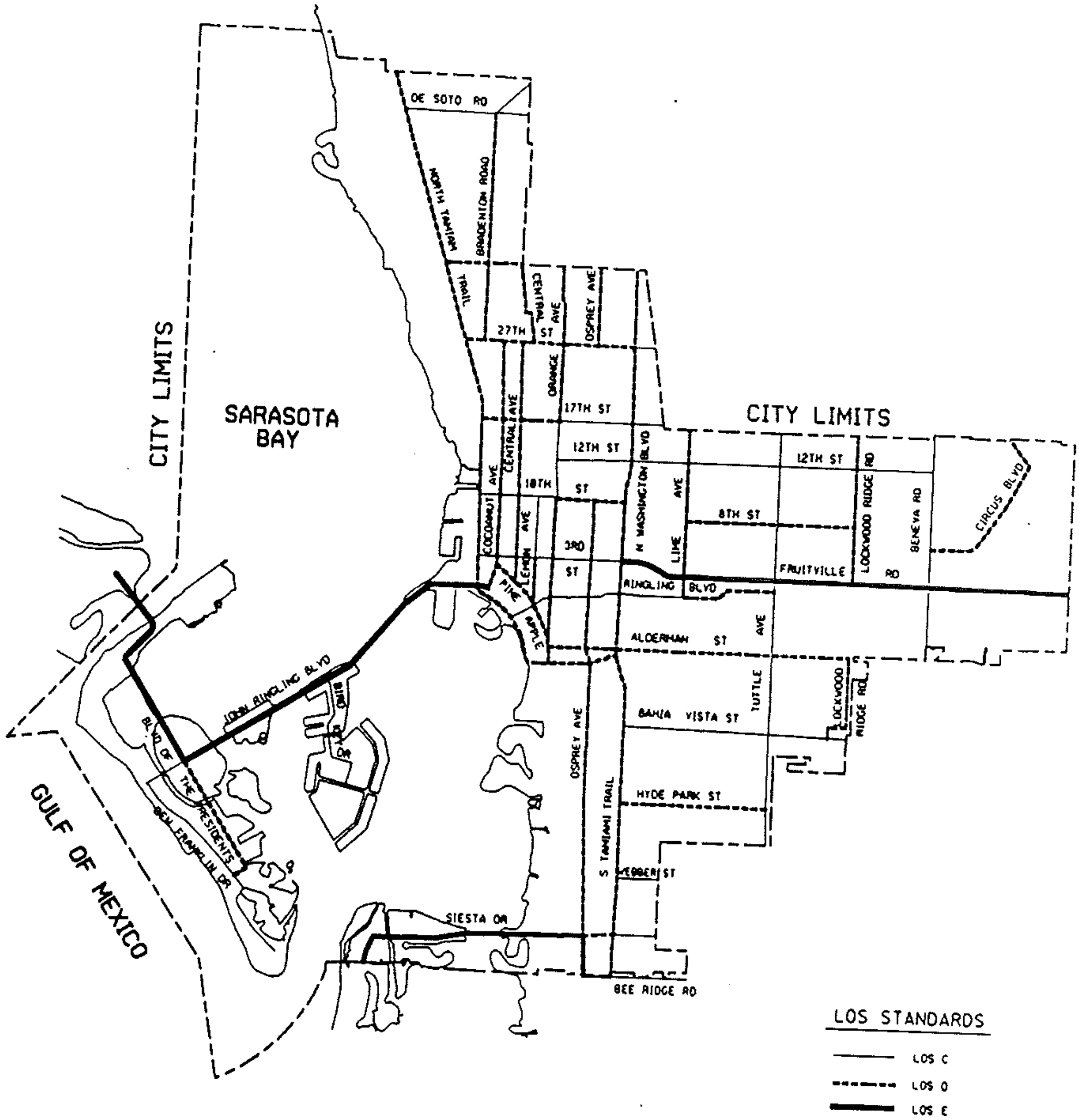


Figure 34. Level of service standards for roadways in the City of Sarasota (City of Sarasota, 1991).



future conditions will require great strides and renovations within the transportation system to avoid severe problems in transportation within the city. Increased population and damage and inundation of roadways from sea level rise will take its toll in the future if great improvements are not made to the transportation system.

Because our society heavily depends on car transportation for mobility, damage to our roadways will negatively affect all aspects of life - food, medical service and many others depend on safe and efficient roads. These will need close attention and deserve advanced changes before SLR makes human mobility in this area exceedingly problematic.

CULTURAL RESOURCE ASSESSMENT

The potential impact on cultural resources of the proposed scenario of an effective sea level rise in Sarasota Bay of approximately five feet by A.D. 2115 has been investigated in the creation of a data base of 264 sites and structures. These resources are located below the five-foot topographic contour line. A literature search has indicated structural and non-structural approaches exist whereby negative impacts of the effective sea level rise may be mitigated. The decision of which approaches to take must be made on site-specific bases. The cultural resources of the study area are valuable from intrinsic, economic, and scientific perspectives, and their protection should be a component of local and regional efforts in planning for the effects of sea level rise.

The estuary of Sarasota Bay is one of seventeen comprising the National Estuary Program (NEP). The present inter-disciplinary study of the impacts of a projected effective sea level rise of approximately five feet by 2115 A.D. (Estevez 1991) is a present status and future trends assessment, one of fourteen studies currently underway for the Sarasota Bay NEP. To date, this sea level rise project, being conducted jointly by the Tampa Bay Regional Planning Council and Mote Marine Laboratory, is the only one of its kind within NEP.

As well as assessing potential impacts on present day infrastructures, the present sea level study addresses the possible effects upon cultural resources, the subject of this section. Intrinsic, economic, and scientific values of cultural resources have become factors taken into consideration by public management and planning officials. The cascading effects of federal legislation on state, regional, and local laws have served to educate the public and their elected officials in the important ways in which the past may serve the present. The economic benefits of properly interpreted and managed cultural resource sites have increasingly been recognized by local tourism development agencies. A 1988 State-financed survey by the S.R.I. Research Center found that seven of ten tourists expect to visit an historic site while visiting Florida. Concurrently, the adaptive reuse of standing historic structures has illustrated the wisdom inherent in using what is available rather than in destroying to create anew at considerably greater expense.

The intrinsic values of archaeological sites and historic structures relate to that ineffable parameter known as "quality of life," a concept thought by some as originating in the Bill of Rights and therefore owed to every American citizen. The degree to which that "quality" is sought, offered, and maintained ultimately resides in each community within its own particular social context. A sense of where a people has been provides a framework from which a desired future may be charted. The scientific values of cultural resources serve to further define and elaborate the varied elements of humanity's past.

Much of the prehistory and history of the present study area occurred along the coast. The creation of the estuaries by eustatic sea level rise at the termination of the Wisconsin glacial epoch at 10 - 15,000 BC presented the first Floridians with a bountiful and readily accessible source of food and raw materials. Rivers and creeks not only provided the fresh water necessary for estuarine food webs but also a means of access to interior resources. Subsequent immigrants often found that the most ideal locations for settlements had been selected and repeatedly occupied by earlier prehistoric peoples. Accessibility was often the deciding factor, with navigable waterways providing the key. Prior to the construction of interior roads, and later railways, reliable interconnections between communities required coastal locations. Today, building upon that historical precedent and the continuing attraction of the waterfront view, settlement patterns maintain their coastal orientation.

A projected effective sea level rise of five feet (defined study area for the cultural survey) could destroy many of the cultural resources of the study area if anticipatory management plans and funding mechanisms are not in place prior to even incipient effects. It must be appreciated that the scenario of the present study does not project a sudden and complete inundation to the present five-foot contour line, but rather a relatively imperceptible and gradual rise -- with all the concurrent erosion that such a rate would entail. Particularly in the case of archaeological sites, such creeping erosion would, in the end, be far more destructive than a catastrophically sudden and complete flooding. While historic structures would indeed be swept away by such an event, some cultural resource sites would be afforded a level of protection from vandalism that many are lacking in their present sub-aerial rather than submarine circumstances.

The objectives of this section were to inventory the known cultural resources of the impact zone of the study area, compute their respective Universal Transverse Mercator coordinates for Geographic Information System mapping, and to investigate available techniques to mitigate the negative impacts of the proposed sea level rise scenario. In addition, specific mitigative techniques for selected test case areas, nominally a barrier island and a mainland community, were to be suggested.

Survey Description

The inventory of known cultural resources within the study area largely depended upon a review of the Florida Master Site File (FMSF) maintained by the Florida Department of Historical Resources, Tallahassee. The keeper of the FMSF provided the latest printouts for Manatee and Sarasota Counties, with the author's own files providing additional data. Sarasota County's Department of Historical Resources was of particular value as an even more current data source for its sites and structures, as a complete transfer to Tallahassee has not been completed of the information obtained from a recent coastal zone survey (Deming, et al. 1990).

Tabulation of data for the respective portions of Manatee and Sarasota Counties was not entirely comparable due to the fact that Manatee County's coastal zone has not yet been subjected to a systematic cultural resources survey. In order to include at least a preliminary sample of known, potentially FMSF-listable historic structures, a cursory "windshield survey" was made of Anna Maria Island and Longboat Key with the assistance of a professional historian/historic preservationist. It should therefore be stressed that the tabulation herein represents a sample of the endangered cultural resource sites of the study area rather than a totally comprehensive listing. A currently proposed historic survey of Anna Maria Island will, if funded, certainly add many more structures to the present tabulation.

Once the data base of known cultural resources was established, sites listed as destroyed were eliminated from further consideration. Reference to United States Geological Survey quadrangle maps (7.5 minute series, topographic) eliminated any sites located above the five-foot contour line. The remaining site files were then reviewed for missing locational data and Universal Transverse Mercator coordinates were computed as was found to be necessary.

The Universal Transverse Mercator (UTM) grid system provides a simple and accurate method of recording geographic locations. Its chief advantages over the Geographic Coordinate system (latitude/longitude) are its greater reliability, due to its measurements being cited in linear, decimal units, rather than in angular, non-decimal units; simplicity of notation; and greater precision - locations pinpointed to within thirty feet as compared to about 100 feet in the latitude/longitude system.

In the UTM system, the Earth is divided into sixty zones, running north and south, each six degrees wide. Each zone is numbered, beginning with Zone 1 at the 180th meridian near the International Date Line, with zone numbers increasing to the east (Florida is within Zone 17). Any point in a zone may be referred to by citing its zone number, its distance in meters from the equator ("northing"), and its distance in meters from a north-south reference line ("easting"); these three figures describe a unique point on the Earth's surface (Cole, 1977).

In order to assess available techniques for mitigating cultural resources from inundation effects, a literature search was initiated. The resources of the Department of Anthropology, University of South Florida, Tampa, were of particular value in this endeavor. References for salt water environments were minimal: Most studies have centered on fresh water inundation effects (Carrell, et al., 1976), though some of the suggested mitigative techniques would be applicable to the present study.

Cultural Survey Results

The final inventory indicates that 264 cultural resource sites and structures are located within the projected impact zone of the study area: 160 in Manatee County and 104 in Sarasota County. These may be summarized as follows:

Table 5. Summary of Cultural Resource Sites within the Study Area.

Location	No. Prehistoric	No. Historic
Unincorporated Manatee County	8	
City of Anna Maria		17
City of Bradenton Beach		8
Longbeach/Longboat Key		8
Village of Cortez		119
Unincorporated Sarasota County	38	47
City of Sarasota	16	3

The accompanying tabulation lists and GIS location map (located in Appendix A) identify the individual cultural resource sites and structures that will be subject to destruction or damage under the given scenario of sea level rise. These are identified by FMSF number (if assigned), site name (if any), and UTM coordinates.

Methods available for addressing the negative impacts of sea level rise upon coastal cultural resource sites and structures include structural and non-structural approaches to shoreline protection, physical relocation, and mitigation by data recovery. Economic considerations on a site/structure-specific basis will typically decide which approach or mixture of approaches is taken.

Structural shoreline protection measures include bulkheads, seawalls, revetments, offshore breakwaters, and jetties. The choice of which, if any of these methods might be considered would depend upon the nature of the site (its composition and topography) and its particular location (e.g. exposure to prevailing winds, near-shore water depth, fetch length, shoreline configuration). Additional factors to be considered would be the potential secondary effects of a chosen approach to adjacent shorelines: It is recognized, for example, that breakwaters and jetties protect one area while robbing or starving other areas of normal sediment accumulation. Financial costs of structural approaches may prohibit their use in many cases. A review of the use of structural approaches may be found in Garrett (1984:67-75).

Certainly the least expensive method of erosion control is non-structural: the use of vegetation (U.S. Army Corps of Engineers 1981, U.S. National Park Service 1991). The natural buffering effects of coastal wetland plants have long been recognized. As with structural approaches, however, site-specific factors must be taken into consideration. Low energy shorelines support particular vegetational associations that would not withstand the energy regimes of more exposed locations. Destructive bioturbative effects - direct root disturbances and upheaval, as well as potential physio-chemical effects of growth, dissolution, and the use of chemical fertilizers are potential drawbacks to vegetational stabilization of sites.

At least in the case of some historic structures, physical removal and relocation to higher ground is an available preservation option. It may be feasible to elevate structures in place upon pilings or fill in order to maintain structure/site context without the additional expense of acquiring property at a higher elevation elsewhere.

Mitigation of impact via data recovery may often be the most cost effective approach. While the cultural resource site or structure itself is ultimately lost, at least some of the knowledge it contains can be saved by various techniques of excavation and documentation. The difficulty lies in deciding just what is to be salvaged. Archaeological investigations are directed by explicit research designs created to test particular implications of hypotheses: It is not possible to recover "everything," since it is not known today what questions might be raised tomorrow for which potential data exist in a site or structure undergoing salvage. "Data" exist only insofar as they relate to particular inquiries, and inquiries change as knowledge evolves. This dynamic nature of knowledge mandates that at least a sample of our limited supply of intact cultural resources be preserved for future investigations.

Discussion

The present study has identified 264 cultural resource sites and structures within the proposed sea level rise effective impact zone. As much of the study area has not been subjected to systematic survey (e.g. unincorporated Manatee County and the barrier island municipalities), it is certain that additional, presently unknown and/or unrecorded resources will also be subjected to damage or destruction under the present scenario. Insofar as the perceived danger to cultural resources is generally low (Estevez 1990), recognition of the actual threat should be encouraged. Rather like eagles or wood storks, existing cultural resource sites and structures are a type of "endangered species" in that once the last one is gone, no more can be created. While some of our current creations may become cultural resources for far future generations, humankind's more distant past will become unavailable for direct investigation unless some sample of it is conserved and protected.

As noted above, site-specific approaches will be needed whether structural, non-structural, or a mix of mitigative techniques as necessary. The choice of which if any of the listed 264 cultural resources will be preserved from the destructive effects of sea level rise will ultimately reside with the communities in which they are located. If selections are made and funding mechanisms established in advance of immediate and pressing needs, some sample, at least, of our past may be saved for the future.

Site Specific Recommendations

Specific remedies for test cases will be suggested at such time as selections are made. As previously discussed, the choice of which mitigative techniques to apply must be determined on site specific bases. Indeed, whether any actions will be taken at all will depend upon local governmental policy and individual site owner choice: It seems probable that unless some public incentives are offered, individuals will largely ignore the potential destructive effects of sea level rise upon the cultural resources portions of their private properties. Therefore, only general recommendations can be made at this point.

Longbeach/Longboat Key

The community of Longbeach, located at the north end of Longboat Key in Manatee County, was the subject of a windshield survey and a strictly judgmental selection was made of the following historic structures:

Table 6. Historical Structures in Longbeach, Manatee County.

Location	Description
631 Broadway	pressed block
630 Broadway	pressed block
760 Broadway	wood frame
789 Broadway	pressed block
701 Linley	cross gable
721 Linley	cross gable
671 Linley	gable end
661 Linley	gable end

The three pressed block structures, by the nature of their construction and sizes, would not be likely candidates for relocation. Data recovery via photographic documentation and research would be the recommended approach. The remaining five wooden frame structures could be relocated elsewhere or elevated in place.

Cortez

The fishing village of Cortez in Manatee County contains forty-eight FMSF-listed and seventy-one potentially FMSF listable historic structures, as well as portions of an archaeological shell midden site (8Ma22/140). A local application for historic district status on the National Register of Historic Places has been made for the village. Regrettably, in the context of the present study, only the roadbed of SR 684 (Cortez Road) and a small area in the southwestern portion of the community are higher than five feet above present mean sea level. While most of the structures of concern within Cortez are of wooden frame construction and so are moveable, their sheer numbers would seem to obviate such an approach. If Cortez is to survive, as is the very strong desire of many of its native inhabitants, the only apparently feasible approach would appear to be in place vertical "relocation." Placement of its structures on pilings would in fact mirror historical construction techniques previously used in this important Florida fishing village.

The Cortez shell midden (8Ma22/140), while largely destroyed by dredging and condominium construction, nonetheless still contains potentially significant scientific data. It is recommended that systematic archaeological testing of the site be conducted.

City of Sarasota

Within the boundaries of the City of Sarasota, only three identified historic structures are located within the projected sea level rise impact zone: the dock of the John Ringling residence (CadZan) and two homes located on St. Armand's Key. Structural reinforcement of the Ringling dock may be an effective approach for its protection. The St. Armand's Key structures should be subjected to a program of architectural data recovery.

Sixteen archaeological sites are located within the impact zone of the City of Sarasota. The following Table 7 indicates recommended management approaches:

Table 7. Management approaches for the City of Sarasota archaeological sites.

FMSF#	Condition	Recommendation
8So34	good-excellent	revetment/data salvage
8So94	altered	data salvage
8So35	altered	data salvage
8So39	partially destroyed	data salvage
8So92	altered	data salvage
8So38	mostly destroyed	data salvage
8So97	altered	data salvage
8So40	partially destroyed	data salvage
8So42	largely destroyed	data salvage
8So46	largely destroyed	data salvage
8So45	largely destroyed	data salvage
8So47	largely destroyed	data salvage
8So95	altered	data salvage
8So50	largely destroyed	data salvage
8So51	good-excellent	revetment/data salvage
8So52	largely destroyed	data salvage

Given the previously reported presence of human skeletal remains at 8So35 and 52, these two locations would have a greater priority for archaeological data salvage efforts were the sixteen sites to be ranked for future mitigative efforts.

MANAGEMENT OF SEA LEVEL RISE

Comprehensive Planning

In 1985, the population growth and related development experienced by the Tampa Bay region, and the state of Florida as a whole, prompted the Florida legislature to take an historic step by passing the State and Regional Planning Act (Chapter 186, Florida Statutes). The Florida legislature established an integrated planning process designed to manage future growth - comprised of the State Comprehensive Plan, state agency functional plans, comprehensive regional policy plans and local government comprehensive plans.

In accordance with Chapter 163, Part II, Florida Statutes, and Chapter 9J-5, Florida Administrative Code, local governments in the Tampa Bay region, and throughout the state, are required to prepare and adopt local comprehensive plans that are consistent with and further the State Plan and the applicable regional plan. Although not required to address specific state and regional plan goal areas, local plans must address a minimum number of "elements," e.g., future land use, coastal management and conservation elements, that are directly related to the State Plan, agency functional plans and the regional plan. As an example, the purpose of the coastal management element is to have local government plan for, and where appropriate restrict, development activities where such activities would damage or destroy coastal resources.

Local government plans provide the conduit to construct and implement basin-wide resource protection goals and policies which then can be implemented though local zoning and land use ordinances. Land use designations should also consider locations within the watersheds. Staggered densities along tributary systems will buffer runoff impacts, wetland losses and maintenance of habitats from often unintentional impacts.

Long-term planning recommendations to address SLR should be included in state, regional and local comprehensive plans. Regional and local comprehensive plans are routinely evaluated and updated, allowing the opportunity for inclusion of appropriate policies which address management of SLR. The State Comprehensive Plan serves as the framework for each level of comprehensive plans, and therefore recommendations should fall under the following state goals:

Goal 8: Water Resources

<u>State Goal</u>: Florida shall assure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of natural systems and the overall present level of surface and groundwater quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards.

Recommended Policies:

- Development shall not rely on groundwater withdrawals that would increase salt water intrusion, interfere with other existing uses of water, or cause damage to important ecosystems, agriculture or area geology.

- The region shall encourage the use of water conservation measures such as, but not limited to:

    - xeriscape principles;
    - measurable water conservation objectives and programs for implementation;
    - water and wastewater reuse systems;
    - encouraging all levels of government, to design sewage treatment facilities which allow future reuse of water, located in areas that minimize adverse effects of effluent discharge on aquifers and surface water quality;
    - water saving devices, irrigation systems and low volume plumbing fixtures;
    - establishing water conservation utility rates; and
    - establish consistent per capita water use methodology.

- Develop and promote water conservation techniques and water recycling methods. Encourage the preservation of wetlands, vegetation and natural open space to reduce runoff, increase impoundment and to ensure the recharge of aquifers.

- By 1995, as financially feasible, a study for the identification and location of permitted septic tanks associated with all residential, commercial and industrial activities shall be conducted by local governments and the Florida Department of Health and Rehabilitative Services. Such a study shall, at minimum, assess the potential adverse effects on groundwater resources, water supply wells and groundwater recharge potential.

- Concurrent with wastewater treatment plant and local collection/ transmission system expansion, restrictions shall be initiated to require the hookup of existing septic tanks to the maximum extent feasible. New septic tank permits within the area served by the expansion shall not be granted after such service is available.

- Local governments should upgrade or retrofit drainage systems in urbanized areas to include improved stormwater treatment for the improvement of water quality, in accordance with Chapter 17-302, FAC, as amended, and State Water Quality Standards.

- Redevelopment projects should provide or support stormwater quality and quantity improvements within the affected drainage basin. Local governments should upgrade or retrofit drainage systems in urbanized areas to include improved stormwater treatment for the improvement of water quality, in accordance with Chapter 17-302, FAC, as amended, and State Water Quality Standards.

- Local government comprehensive plans should incorporate the following:

  - Adoption of criteria for work in lake, riverine and wetland systems which will protect water quality, wildlife habitat and natural hydrologic functioning of these areas;
  - Conservation of valuable upland habitat and wetland systems;
  - Preservation of habitat for endangered and threatened species;
  - Coordination of ecological minimum flow criteria and hydroperiod for surface waters;
  - Utilization of biological treatment methods and natural areas for stormwater treatment in areas of development/ redevelopment to the maximum feasible extent; and
  - Delineation of the 100-year riverine flood plain(s) using best available topographic or drainage information.

- In Development of Regional Impact proposals, developers shall assess the cumulative impacts of activities, such as dredge and fill, waste disposal and construction, on the health of the natural systems.

- All surface water withdrawals shall be limited, by ordinances or permitting, to amounts that will preserve the minimum natural seasonal flows and levels for surface watercourses in order to protect natural resources and ecosystem values.

- The region shall ensure that surface- and groundwater necessary for the protection and procreation of fish and wildlife, the functioning of natural ecosystems, and recreation and navigation is reserved and committed to serve these needs in balance with potable water supply needs.

Goal 9: Coastal and Marine Resources

State Goal: Florida shall ensure that development and marine resource use and beach access improvements in coastal areas do not endanger public safety or important natural resources. Florida shall, through acquisition and access improvements, make available to the state's population additional beaches and marine environment, consistent with sound environmental planning.

Recommended Policies:

- Strategies shall be identified in the coastal management elements to protect beaches, dune systems, existing mangroves, salt marshes and seagrass beds, and improve water quality and other natural marine habitats. Protective mechanisms identified in the coastal management elements shall be implemented through local land development regulations and monitored as part of conditions of development approval.

- Where appropriate, land development regulations and conditions of development approval shall encourage shorelines lacking wetland vegetation to be planted with native wetland vegetation in order to minimize potential flood damage, stabilize the shoreline and trap sediments, reduce non-point source pollutants and provide additional habitat for fish and wildlife.

- Development and other activities which damage coastal beaches and dune systems shall be prohibited. The restoration of coastal dune systems shall be of highest priority. In all land use decisions, including DRIs, natural beach processes shall be maintained by prohibiting structures that adversely affect sand transport.

- Local governments should establish fixed or dynamic setbacks that will provide a buffer for existing natural shorelines and may preserve an area into which shallow water habitats might be able to migrate.

- Formulate methods for incorporating potential sea level rise into longshore sediment transport, littoral circulation and erosion/accretion dynamics models. Establish a baseline for measuring accretion and erosion along shorelines and institute a monitoring program for areas of significant concern.

- Establish fixed or dynamic shoreline setbacks that site development away from erosion prone areas and reduce the need for coastal protection devices that exacerbate erosion problems.

- Condition permits for shoreline development to require the use of non-intrusive environmentally benign shoreline protection and the removal of structures that are damaged or destroyed by erosion and flooding, which could accelerate erosion or create a safety hazard.

- Initiate geologic mapping program to determine accretion and erosion patterns and a monitoring program to establish their rates. Conduct programs using non-structural engineering alternatives to mitigate shoreline and dune erosion such as vegetation enhancement for dunes and sediment renourishment for beaches.

- Require consideration of sea level rise as one of the criteria for site specific geotechnical studies. Incorporate the potential for sea level rise over the useful life expectancy of the development and assess the need to require the developer or land owner to assume the risks.

- Establish criteria for incorporating sea level rise into the environmental impact review process for all public or publicly funded projects. The potential impact of sea level rise on the project site and the probable useful life expectancy of the project are two of the essential variables that should be addressed by the review process.

- The planting of native marine vegetation in front of seawalls to act as a natural buffer is encouraged. Where existing waterways are not seawalled, native marine vegetation shall be used for shoreline stabilization, where technically feasible.

- The preferred replacement material for failed or damaged existing concrete seawalls shall be rip-rap of appropriate material, principally natural materials such as limestone boulders, or native marine vegetation.

- The region shall encourage the development of a strict flood plain management program for the 25-year and 100-year flood plains by state and local governments to preserve hydrologically significant wetlands and other natural flood plain features.

- Dredging or spoiling of undisturbed submerged bottom lands shall be prohibited.

- Permitting and reviewing agencies shall encourage the development and use of innovative and efficient spoil disposal methods which reduce adverse environmental impacts and financial costs of spoil disposal. The use of dredge material disposal areas for multiple uses, such as recreation and wildlife habitat shall be encouraged.

- The use of government funds for public infrastructure improvements which would subsidize or encourage development or redevelopment in the coastal high hazard areas shall be avoided, unless consistent with the approved local government comprehensive plan.

Goal 10: Natural Systems and Recreational Lands

<u>State Goal</u>: Florida shall protect and acquire unique natural habitats and ecological systems such as wetlands, tropical hardwood hammocks, palm hammocks, and virgin longleaf pine forests, and restore degraded natural systems to a functional condition.

<u>Recommended Policies</u>:

- The undeveloped 100-year riverine and 25-year coastal flood plain areas shall be protected by combining protective measures such as buffer zones for wetlands, transitional areas, flood storage and wildlife resources into one management composite.

- New dredging, reroutings, channelizations or other alterations within that adversely affect environmentally sensitive surface water bodies, wetland systems or groundwater hydrology shall be prohibited.

- The use of buffer zones of natural vegetation between agricultural lands and water bodies shall be required.

- The undeveloped barrier islands shall be protected from development that impedes geological function and environmental character and function of the islands and immediate vicinity.

- Provide direct financial incentives for removing and relocating structures along flood prone or eroding shorelines to provide property owners with an alternative to structural protection.

- Create tax adjustments or exemptions as incentives for maintaining undeveloped shoreline and estuarine areas in their natural state.

- Develop public acquisition programs designed to acquire critical or sensitive shallow water habitats and adjacent property. Provide mechanisms for public support of private acquisition, trust and conservancy organizations. Local governments should seek grants or low income loans that place environmentally sensitive areas into conservatories or open space uses.

- Institute programs to educate the general public, shoreline property owners, and potential developers about the values and functions of shallow water habitats and the impacts upon them from human activities. Develop programs to enhance public participation by combining public educational efforts and research projects. Use a variety of education and information sources and encourage grass roots and voluntary efforts.

- Regulate individual developments and new subdivisions to require sewer hook-ups in the floodplain. Ensure that regulations prohibiting placement of both public and private waste facilities in the coastal flood plain take into account the potential for accelerated sea level rise.

- The Tampa Bay region shall support a high priority for public land acquisition by the State of Florida and local governments for recreation and/or open space use of property within areas of the region projected to receive major hurricane damage from coastline storm surges.

- The region's park and open space system shall encompass and encourage restoration of natural features, scenic areas and sites of historic and archaeological significance.

The recommended policies are not prioritized and are intended to be considered by local and regional governments for adoption into comprehensive plans. Policies have been tabulated from the Tampa Bay Regional Planning Councils adopted Comprehensive Plan (Future of the Region, 1987, 1992), policies under consideration, and Klarin, Branch, Hershman and Grant (1990) report entitled "Sea Level Rise Policy Alternatives Study: Volume 2, An Analytical Review of State and Federal Coastal Management Systems and Policy Responses to Sea Level Rise."

PERMITTING PROCESS RECOMMENDATIONS

Resource protection efforts were greatly expanded in the 1980's with adoption of wetland protection and stormwater management regulations by the Florida Legislature. Water Use Permits (WUPs) are administered by the SWFWMD and are used to govern freshwater withdrawals from ground and surface water sources. The WUP process offers the opportunity to evaluate major activities that affect freshwater distribution to the Sarasota Bay estuary and groundwater withdrawals. WUP renewals and new applications need to be tied to the Sarasota Bay Framework for Action to maintain inflows and prevent additional saltwater intrusion.

The stormwater permitting process, through Chapter 17-25, F.A.C. administered by the Florida Department of Environmental Regulation, and Chapter 40D-4 administered by the Southwest Florida Water Management District (SWFWMD), provides the conduit to balance freshwater flows in tributaries and buffer water quality impacts while increasing wetland habitats. An environmentally sound stormwater treatment system can provide water quality treatment through construction of vegetated littoral shelves while gradually releasing freshwater to the receiving water body. The treatment height of the pond can be designed to enhance adjacent wetland communities by restoring historic hydroperiods. The potential increase in flooding caused by a sea level rise would require a new examination of the role of retention ponds and drainage structures. All new development must require some form of stormwater drainage and retention, and with higher sea levels and increased flooding, increased capacity in retention ponds and drainage courses will need to be added.

Domestic wastewater permits, administered by FDER, can be a source of AWT wastewater effluent to supplement underground aquifer systems either for potable supplies or irrigation. However, public perception may limit the use of AWT effluent in potable water supplies. Highly treated effluent can also enhance freshwater flow to the estuary in areas where flow has been reduced. Highly treated effluent can be used to achieve ideal salinity gradients in impacted tributaries or man-made tributaries, or to improve circulation and flushing. Additionally, wastewater treatment plants, associated pipelines and discharge points also must consider how higher water levels will impact their intake, treatment, and discharge of effluent. Higher sea levels could flood discharge pipes, and the changing water table and increased inundation could cause land subsidence which could damage or displace pipelines.

Septic tank permitting is also required by the Department of Health and Administrative Services and local governments. Future permit actions should limit septic tank citing to areas above the 100 year floodplain and areas containing soil conditions and groundwater levels sufficient to treat generated effluent for the next fifty years, the anticipated structure life. Expansion of WWTP service lines should give priority consideration to transmission of effluent from older septic tank areas to reduce the potential contamination of surface and groundwaters.

Wetland modification permits (or dredge and fill permits) administered by the US Army Corps of Engineers, FDER and local governments should be coordinated with stormwater permits to restore channelized tributaries by reducing shoreline slope, increasing cross-sectional area and planting with native aquatic plants. Developments can combine wetland mitigation and stormwater treatment in some cases by constructing a meandering tributary alignment with a high and a low flow passage from a previously channelized system. Agricultural ditches and flood control channels recontoured along one side will allow habitat and water quality improvements, while maintaining the other side for future maintenance activities.

Wetland permits must provide a front line defense to prevent additional loss of shoreline vegetation to buffer a SLR. Hardened shorelines will not migrate and therefore will drown any existing vegetational communities. The wetland permitting process needs to consider upland uses adjacent to the wetlands as a buffer zone or described transitional area. This would require legislative authorization to enhance the Warren Henderson Wetlands Protection Act of 1984. Local governments often have the best tools to manage upland transitional areas through regulation of land use and wetlands together.

Dredge and fill permits for beach nourishment can be useful tools for reclaiming shoreline area lost due to sea level rise, thereby retaining some of the economic base for the barrier island community. However, several points need to be considered during dredge and fill permitting for beach nourishment during a sea level rise. The quantity of sand and the size of the proposed beach must be carefully evaluated to see how long it will last based on SLR projections. The level of the water in 20 years needs to be considered to determine whether or not a project is worth the time, effort and expense. Even now, nourishment projects must often be repeated frequently because of severe erosion and the persistent threat of property damage. Other considerations include:

- quantities of important benthic and hardbottom habitats that could be destroyed or damaged, especially over longer time frames (20-100 years).

- cost of renourishing frequently over time because of losses to SLR.

- the influence that taking fill from offshore borrow areas might have on wave and beach dynamics as sea level continues to rise. After a beach nourishment project in Connecticut, the new beach quickly eroded due to changed wave patterns caused by a dredged hole on the continental shelf (Doyle, et al., 1984).

Infrastructure planning for buildings and transportation routes will also be influenced by an impending rise in sea level. Building codes and zoning will need to consider projected sea level increased especially during review of coastal structures. The consideration of future impacts, insurance and the need for structural capabilities for dealing with flooding (ie. building on stilts) should all be considered during the permitting process, before damage can occur.

All transportation routes, especially those along the Gulf and Sarasota Bay, will be greatly effected by a sea level rise. Frequent flooding and resulting damage will call for changes in roadwork permitting. Any new roads will need to consider future flooding and perhaps evacuation status as the frequency and severity of flooding increases as sea level rises. The realignment of existing routes may also need to be considered. Thus, permitting for future infrastructure changes or additions will need to carefully estimate the impacts caused by a sea level rise, and what steps need to be taken to offset problems and maintain services.

LONG-TERM BASELINE MONITORING

The advance of sea level into higher elevations is anticipated to accelerate in the near future. The 1980's and 1990's have been a period of speculation as to extent and timing of SLR along our coastal shores. It has been adequately documented that SLR is a natural feature of global climatic conditions, but the acceleration of SLR brought on by industrialization will require sufficient time to chronicle, independent of background rates. Several examples have suggested that SLR has already occurred within the study area, possibly brought about by anthropomorphic changes.

To document SLR, baseline monitoring has already begun. The National Oceanic and Atmospheric Administration (NOAA) National Ocean Service maintains a long-term tidal station at St. Petersburg, Florida, since 1947. Reporting of sea level from this tide station will maintain a highly accurate record of sea level conditions into the future. The degree of accuracy and long-term period of record constitute the best choice for documenting SLR locally.

DEMONSTRATION PROJECTS

Many projects to buffer or monitor a potential SLR have been identified within the text. The following section is intended to serve as a listing of recommended projects that can be accomplished by the Sarasota Bay National Estuary Program and included within the Comprehensive Conservation and Management Plan for future implementation by bay managers.

Monitoring Ongoing SLR

To observe the timing and extent of a SLR, the continuous recording of sea levels is required. The closest station is the St. Petersburg NOS Station (No. 872-6520). The two oceanic stations used in the rate projections for accuracy are the Cedar Key Station (No. 872-7520) and the Key West Station (No. 872-4580) (NOAA, 1990). Periodic analysis of the water level gauges will document current conditions and detail required response.

Estuary Restoration

The Sarasota Bay NEP, FDER-PRTF, SWFWMD-SWIM and local governments have accelerated shoreline habitat restoration initiatives along the periphery of the bay. Recent projects include the City Island Project, Leffis Key Bayside Park, Caples Shoreline Restoration and Centennial Park. All of these projects not only support habitat enhancement today but will additionally proved shoreline fringes where marsh and mangrove communities can migrate in the advent of a SLR. All future projects should include an upland buffer element to secure future transitional areas.

Projects which remove hardened shoreline areas will benefit intertidal habitats as well as future seagrass communities. The armored shoreline potentially will drown advancing inter- or subtidal wetlands as water levels increase. Additionally, the structures create a higher energy environment, through wave deflection, which restricts mangrove or seagrass colonization. The Caples Shoreline Project and Centennial Park initiative are good examples of projects which will mitigate the affects of SLR.

Currently, the SWFWMD-SWIM program provides a series of aerial photographs of Sarasota Bay and Tampa Bay every two years. The inventory provides excellent seagrass information, which over time will detail trends in coverage. A demonstration project in future years will be an evaluation of seagrass migration along the landward fringe of seagrass beds. Care should be taken in separation of species since <u>Ruppia maritima</u> tends to grow in shallower water (intertidal at times) than most other species. As previously described, an analysis of mangrove migration was accomplished using historic information. However, future trend analysis may be limited due to the extent of development of shoreline areas.

Bay bottom dredging activities has created borrow holes in many areas of the bay that can be restored through capping. Filled holes have been successfully replanted with subtidal seagrass beds (Fonseca et.al., 1990). Restoration of the Leffis Key holes are currently under consideration by SBNEP and Seagrant (J. Culter, Personal Communication, 1992). Capping and revegetation of dredged holes will create new benthic areas and assist in the mitigation of a SLR.

Tributary Protection

Tributaries to Sarasota Bay have received significant development pressures from agricultural uses and urbanization over the last 100 years. One important demonstration project entails undertaking a historic analysis of tributaries including the following parameters (from Clark, 1991):

1. evaluate historic and existing freshwater flows and salinity patterns in the larger tributaries to Sarasota Bay

2. analyze remaining natural communities and potential restoration areas to reestablish those communities that have been displaced, and consider management of the saltwater wedge/productivity zones to coincide with remaining structural habitat, and

3. combine established optimum salinity gradients and habitat elements onto existing land use maps and develop a list of tactics for each responsible agency to enhance the tributary systems.

This project will help identify those areas in need of restoration of habitat or enhancement of freshwater flows. The variety of benefits provided by tributaries (water quality enhancements, circulation/flushing improvements, fishery restoration and others) make tidal creek restoration one of the most critical and beneficial forms of habitat renovation projects.

Septic Tank Removal

In areas containing septic systems, which have created water quality problems in Sarasota Bay or have the potential during a rise in sea level, efforts should be taken to remove the systems and replace with public transmission and treatment systems. Currently, the City of Sarasota sewers 97 percent of the community (City of Sarasota, 1991). Longboat Key does not contain any septic systems on the barrier island (Reynolds, Smith and Hills, 1989). Future Analysis should focus on Little Sarasota Bay where older development and reduced flushing make septic tank removal an important consideration.

Historical and Archaeological Sites

As previously discussed, the choice of which mitigative techniques to apply must be determined on site specific bases. Whether any actions will be taken at all will depend upon local governmental policy and individual site owner choice. It seems probable that unless some public incentives are offered, individuals will largely ignore the potential destructive effects of sea level rise upon the cultural resources portions of their private properties.

In Longbeach/Longboat Key the three pressed block structures, by the nature of their construction and sizes, would not be likely candidates for relocation. Data recovery via photographic documentation and research would be the recommended approach. The remaining five wooden frame structures could be relocated elsewhere or elevated in place.

The fishing village of Cortez in Manatee County contains forty-eight FMSF-listed and seventy-one potentially FMSF listable historic structures, as well as portions of an archaeological shell midden site (8Ma22/140). A local application for historic district status on the National Register of Historic Places has been made for the village. Regrettably, in the context of the present study, only the roadbed of SR 684 (Cortez Road) and a small area in the southwestern portion of the community are higher than five feet above present mean sea level.

While most of the structures of concern within Cortez are of wooden frame construction and so are moveable, their sheer numbers would seem to obviate such an approach. If Cortez is to survive, as is the very strong desire of many of its native inhabitants, the only apparently feasible approach would appear to be in place vertical "relocation." Placement of its structures on pilings would in fact mirror historical construction techniques previously used in this important Florida fishing village.

The Cortez shell midden (8Ma22/140), while largely destroyed by dredging and condominium construction, nonetheless still contains potentially significant scientific data. It is recommended that systematic archaeological testing of the site be conducted.

Within the boundaries of the City of Sarasota, only three identified historic structures are located within the projected sea level rise impact zone: the dock of the John Ringling residence (CadZan) and two homes located on St. Armand's Key. Structural reinforcement of the Ringling dock may be an effective approach for its protection. The St. Armand's Key structures should be subjected to a program of architectural data recovery.

SUMMARY

Review of recent water level information identifies that sea level is rising locally. The greenhouse effect is anticipated to accelerate rising seas, creating problems for both the natural and cultural environments of Sarasota Bay. The Tampa Bay Regional Planning Council evaluated conditions in Sarasota Bay that will be affected by a rise in sea level and provided recommendations to monitor its effects and lessen impacts. The analysis identified numerous tools to manage sea level rise including comprehensive planning, natural resource permitting and infrastructure design. Demonstration projects and water level monitoring are necessary to determine the extent of rising seas and identify approaches to reduce impacts. It is anticipated that programs such as the Sarasota Bay National Estuary Program will promote public awareness to better prepare the bay area for the effects of anticipated rising seas.

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TBRPC Staff

Julia E. Greene, Executive Director
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Tampa Bay National Estuary Program
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Holly Greening
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