Chapter 2. Environmental Setting

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TAMPA BAY IS FLORIDA'S LARGEST open-water estuary, is home to one of its busiest ports, and receives freshwater runoff from a watershed that covers an area of about 2,200 mi^2 as depicted in Chapter 1, fig. 1–1. This shallow, Y-shaped embayment has a large surface area of almost 400 mi^2 and a mean depth of about 4 m. It is relatively wide (typical widths of 5 to 10 mi), and consists of a number of interconnected bays and lagoons (see Chapter 1, fig. 1–2). Although once assumed to be a drowned river valley, recent geological findings (summarized in Chapter 3) indicate that the bay is underlain by a number of sinkholes and other karst-related features that have played important roles in determining its current structure (Brooks and Doyle, 1998; Donahue and others, 2003; Hine and others, 2009). It is oriented on a roughly northeast-southwest axis that extends about 37 mi from its head in upper Old Tampa Bay and Hillsborough Bay to its mouth in Lower Tampa Bay (see Chapter 1, fig. 1–2). Its bathymetry has been modified by the construction and maintenance of an extensive network of shipping channels, dredged to depths of about 13 m, which extend from the bay mouth to several port, harbor, and industrial facilities located in Hillsborough Bay, Old Tampa Bay, Middle Tampa Bay, and Lower Tampa Bay (fig. 2–1; see also box 2–1). In addition to channel construction and maintenance, a number of other dredge and fill projects have led to the creation of "many square miles of islands and submerged dredged-material disposal sites, four major bridges and causeways that span the bay, and numerous residential and commercial shoreline landfills" (Goodwin, 1987), most of which were constructed in the 1950s and 1960s. By 1985 the cumulative effects of these manmade bathymetric modifications had reduced the water surface area of the bay by 3.6 percent, increased its volume by 1.3 percent and its average depth by 4.4 percent, and reduced its tidal prism by 1.7 percent relative to predevelopment conditions (Goodwin, 1987).

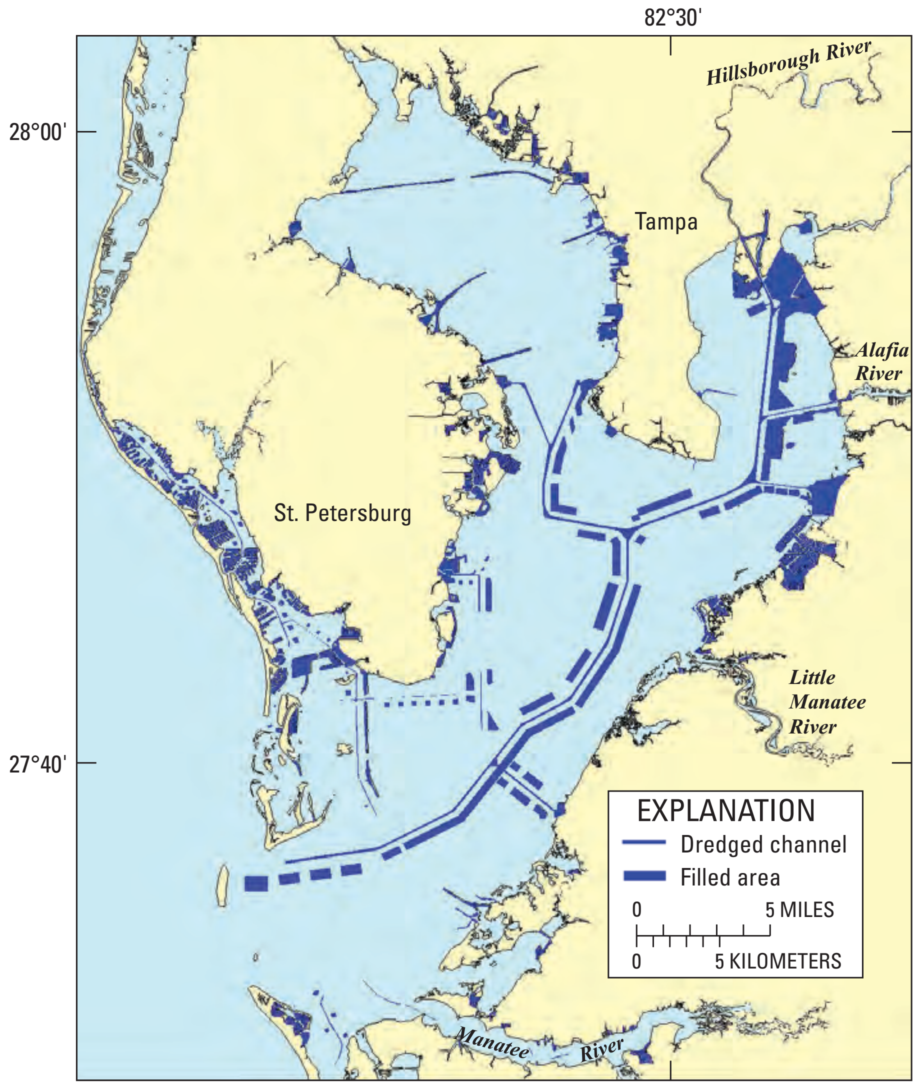

Figure 2–1. Tampa Bay area, showing locations of dredged and filled areas. From Coastal Environmental (1993).

Land Use

The Tampa Bay watershed includes a mix of urban, industrial, agricultural, and natural land uses (table 2–1). Its largest urban centers are located on or near the bay shoreline, in the cities of Tampa, St. Petersburg, Clearwater, and Bradenton (fig. 1–1). On a percentage basis, Boca Ciega Bay (fig. 2–2) and Old Tampa Bay have the most highly urbanized catchments, whereas the Lower Tampa Bay and Middle Tampa Bay subwatersheds contain the highest percentages of row crops, and the Manatee River and Middle Tampa Bay subwatersheds contain the highest percentages of rangeland and pasture (table 2–1).

Upland forest and freshwater wetland habitats currently make up about 20 percent of the watershed (Janicki and others, 2001). An estimated 46 percent of the freshwater wetlands that were present under predevelopment conditions have been lost through dredging, filling, or conversion to other land uses (Stetler and others, 2005). Long-term trends in tidal wetlands and other estuarine habitats are discussed in Chapter 8.

Table 2–1. Summary of 1995 land use in the Tampa Bay watershed, by bay segment.

[OTB, Old Tampa Bay; HB, Hillsborough Bay; MTB, Middle Tampa Bay; LTB, Lower Tampa Bay; BCB, Boca Ciega Bay; TCB, Terra Ceia Bay; MR, Manatee River estuary. From Janicki and others, 2001]

Land use	Surface area (acres)								
	Residential	Commercia/ industrial[1]	Mining	Pasture/ rangeland	General agriculture[2]	Upland forest	Freshwater wetlands	Open freshwater	Total
OTB	55,473	25,962	410	26,414	3,055	11,021	21,130	12,614	156,079
HB	130,334	48,496	97,907	239,611	50,065	76,116	127,820	23,947	794,296
MTB	22,851	11,027	5,459	62,576	37,861	16,644	21,450	7,618	185,486
LTB	2,381	1,838	450	5,023	4,275	761	3,079	709	18,516
BCB	30,489	11,428	7	4,135	141	1,231	544	1,769	49,744
TCB	2,146	630	0	1,705	611	467	410	138	6,107
MR	20,436	7,394	2,921	90,628	39,962	25,701	28,063	5,016	220,121

Land use	Percent of surface area								
	Residential	Commercia/ industrial[1]	Mining	Pasture/ rangeland	General agriculture[2]	Upland forest	Freshwater wetlands	Open freshwater	Total
OTB	35.5	16.6	0.3	16.9	2.0	7.1	13.5	8.1	100
HB	16.4	6.1	12.3	30.2	6.3	9.6	16.1	3.0	100
MTB	12.3	5.9	2.9	33.7	20.4	9.0	11.6	4.1	100
LTB	12.9	9.9	2.4	27.1	23.1	4.1	16.6	3.8	100
BCB	61.3	23.0	0.0	8.3	0.3	2.5	1.1	3.6	100
TCB	35.1	10.3	0.0	27.9	10.0	7.6	6.7	2.3	100
MR	9.3	3.4	1.3	41.2	18.2	11.7	12.7	2.3	100

[1] Includes commercial, industrial, institutional, transportation and utilities.
[2] Includes row crops, nurseries, orchards, groves, and feedlots.

Climate and Weather

The region has a humid subtropical climate with an average annual temperature of about 72 °F and average annual rainfall that ranges from 50 to 55 in. in different parts of the watershed (Lewis and Estevez, 1988; Wolfe and Drew, 1990). About 60 percent of the annual rainfall usually occurs during the summer (mid-June through September) rainy season, in the form of localized convective thunderstorms and occasional tropical storms and hurricanes. During the dry season, which generally extends from October through early June, the rainfall that occurs is usually associated with the passage of large-scale frontal systems. Rain events associated with frontal passages are most common during the January-through-March period, producing a period of somewhat elevated rainfall during an otherwise dry season (Flannery, 1989). The months of lowest rainfall are usually November, April, and May. Mean daily rainfall values for the period of record (1900s–2007) at four locations in the Tampa Bay watershed are shown in fig. 2–3.

Figure 2–2. Boca Ciega Bay shoreline development and land use, 2002. Photo by Southwest Florida Water Management District.

Seasonal and annual rainfall amounts are highly variable from year to year, and the region experiences frequent periods of substantially above- and below-average rainfall (Fernald and Purdum, 1998). Rainfall patterns throughout Florida are influenced by sea-surface temperature in the Atlantic and Pacific Oceans (Fernald and Purdum, 1998). Variations in this temperature occur on a number of different time scales, and statistical studies have reported correlations between multidecadal fluctuations in sea-surface temperature, rainfall, and streamflow patterns in the eastern U.S. and Florida (for example, Ehnfield and others, 2001; McCabe and Wolock, 2002; Kelly, 2004; McCabe and others, 2004; Metz and Lewelling, 2009). In addition to these multidecadal fluctuations, shorter-term variations in sea-surface temperature in the tropical Pacific Ocean, associated with the El Niño/Southern Oscillation teleconnection, have global weather effects and

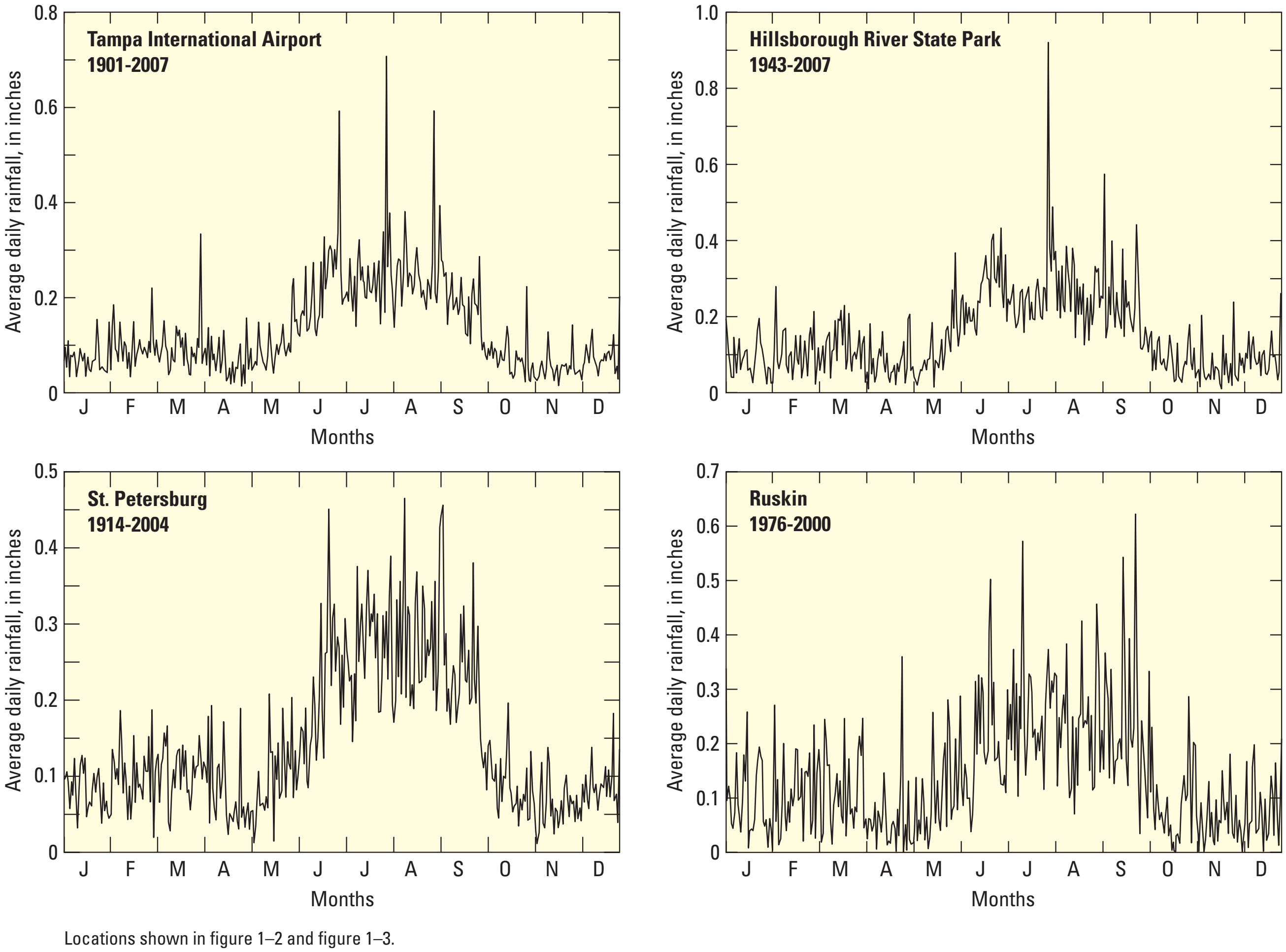

Figure 2–3. Mean daily rainfall for available periods of record at four sites in the Tampa Bay watershed. Data from National Weather Service.

produce episodes of flooding and drought in Florida. During strong El Niño events (which are associated with above-average sea-surface temperature in the eastern equatorial Pacific Ocean) the mid-latitude jet stream over North America moves farther south during the winter months, and the subtropical jet brings additional moisture from the equatorial Pacific across the Gulf of Mexico, producing higher than average winter rainfall (Lipp and others, 2001; Schmidt and others, 2001). Because these rain events occur during the normally dry winter months, at a time when air temperature and evaporation rates are low, they tend to generate higher values of net precipitation and groundwater recharge than does rainfall occurring at other times of year (Swancar, 2005). During summer and fall strong El Niño episodes are also associated with the suppression of tropical cyclones (Fernald and Purdum, 1998). At the other extreme, strong La Niña (very cool eastern equatorial Pacific sea-surface temperatures) phases of the El Niño/Southern Oscillation are associated with drier than normal winter weather conditions (Fernald and Purdum, 1998; Schmidt and others, 2001). Due to its pronounced effects on rainfall, the phase of the El Niño/Southern Oscillation cycle can be used to predict dry-season flow levels in rivers in the west-central Florida region (Coley and Waylen, 2006).

Box 2–1. Digital Elevation Model of Tampa Bay

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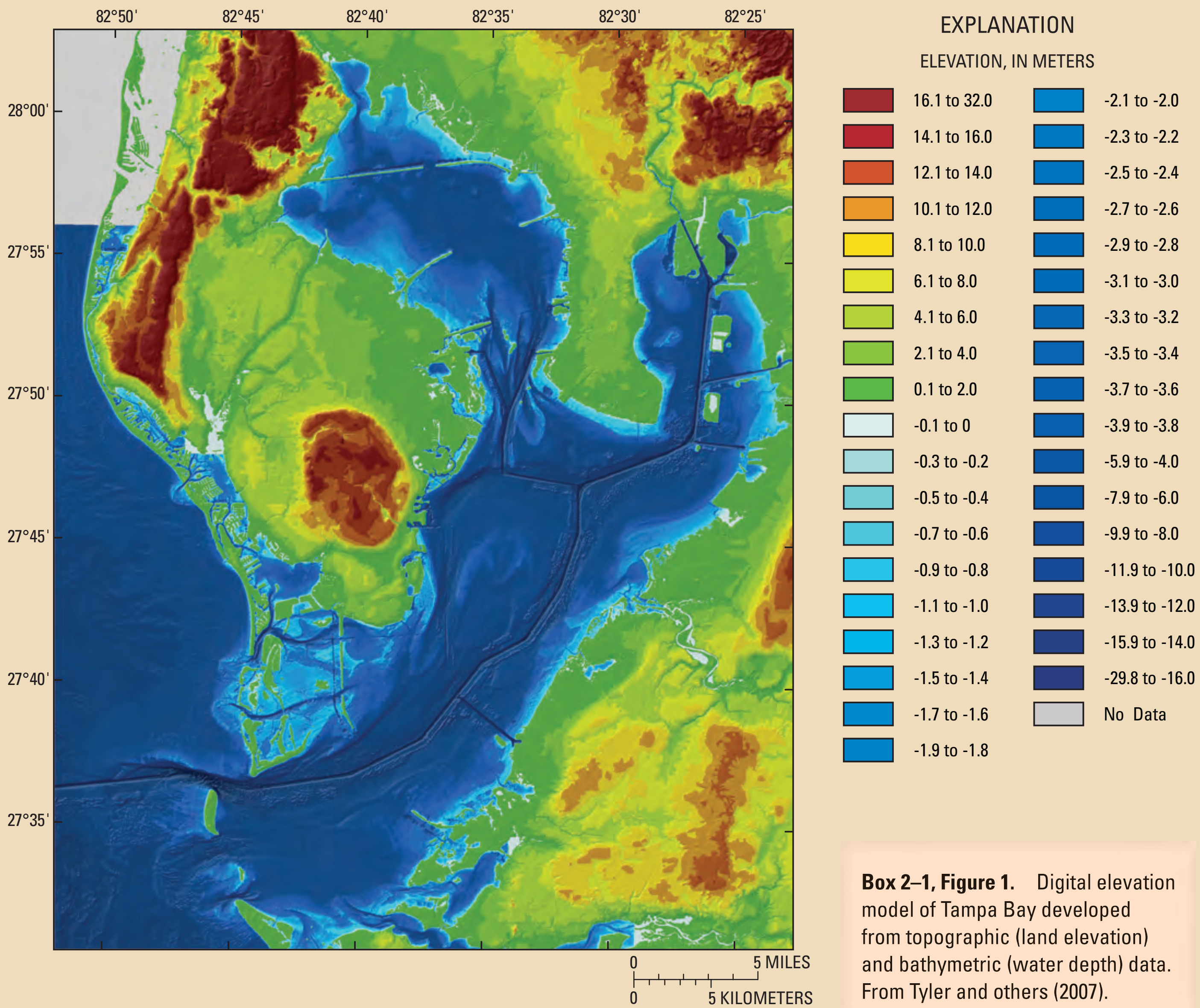
The USGS, in partnership with NOAA and the National Aeronautics and Space Administration (NASA), developed the first seamless digital elevation model of Tampa Bay at 10 m resolution from topobathymetric data. The model, depicted both on the cover of this report and in box 2–1, fig. 1, provided the baseline map for Tampa Bay that has been used for all of the other Tampa Bay Study projects and for generating the bathymetry and model grids for many of the recent numerical, circulation model activities. Topobathymetric data are a merged rendering of both topography (land elevation) and bathymetry (water depth), to provide a single product useful for mapping and a variety of other applications (Tyler and others, 2007). Topography was acquired from the USGS National Elevation Dataset. Bathymetry was provided by NOAA's Geophysical Data System, and from high resolution bathymetry acquired by NASA's Experimental Advanced Airborne Research LiDAR.



Box 2–1, Figure 1. Digital elevation model of Tampa Bay developed from topographic (land elevation) and bathymetric (water depth) data. From Tyler and others (2007).

In the absence of large-scale cold fronts or tropical storms, the Atlantic Ocean and Gulf of Mexico become primary influences on the region's weather. During the day, heat from the sun is absorbed by both the land and water, with the land heating faster. As the warmer air over land rises, it is replaced by cooler air blowing off the water, creating a sea breeze (Fernald and Purdum, 1998). The flat topography of the low-lying Florida Peninsula provides a relatively unobstructed path for the sea breezes, which converge over land in summer to form massive convective thunderstorms capable of producing heavy local rainfall amounts and frequent cloud-to-ground lightning. Lightning strikes associated with summer thunderstorms can reach impressive densities, averaging almost four strikes per square mile (Hodanish and others, 1997).

Surrounded by water on three sides, Florida's location also increases its vulnerability to hurricanes. Four hurricanes struck the state in 2004, the most affecting any state since Texas experienced four in 1884 (Sallenger and others, 2006). Three of those hurricanes — Charley, Frances, and Jeanne — impacted the bay area. Wind speeds during Hurricane Charley were reported by the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center to have reached 125 miles per hour (mph) south of the Tampa Bay area. Altogether, 29 hurricanes have struck Tampa Bay between 1852 and 2006, according to the National Hurricane Center. Of those, 11 (38 percent) were major category 3 or category 4 storms (fig. 2–4).

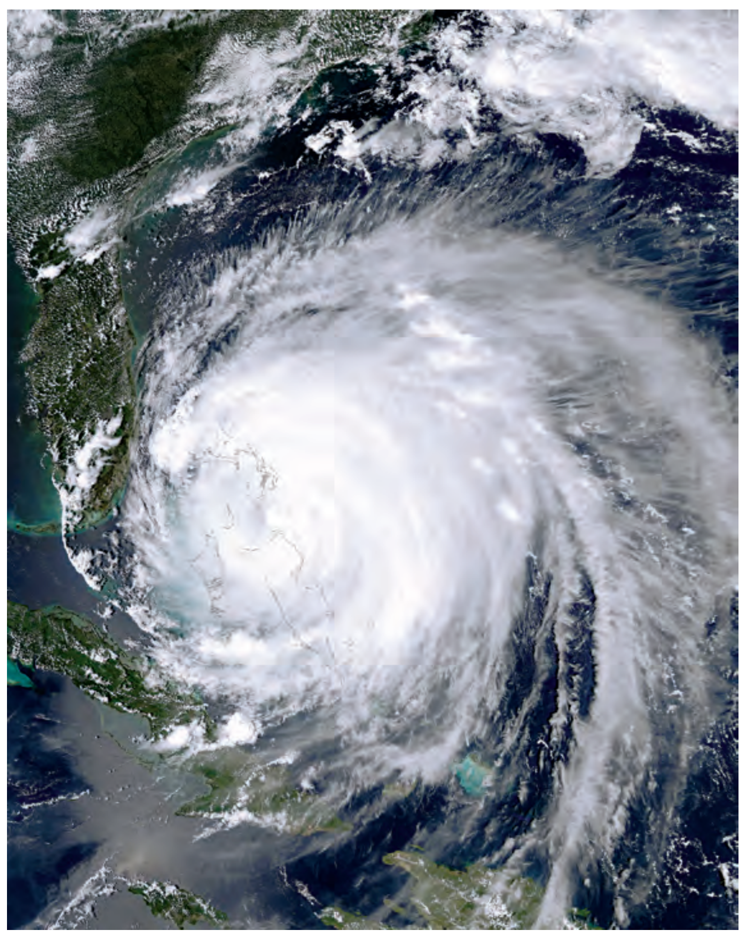
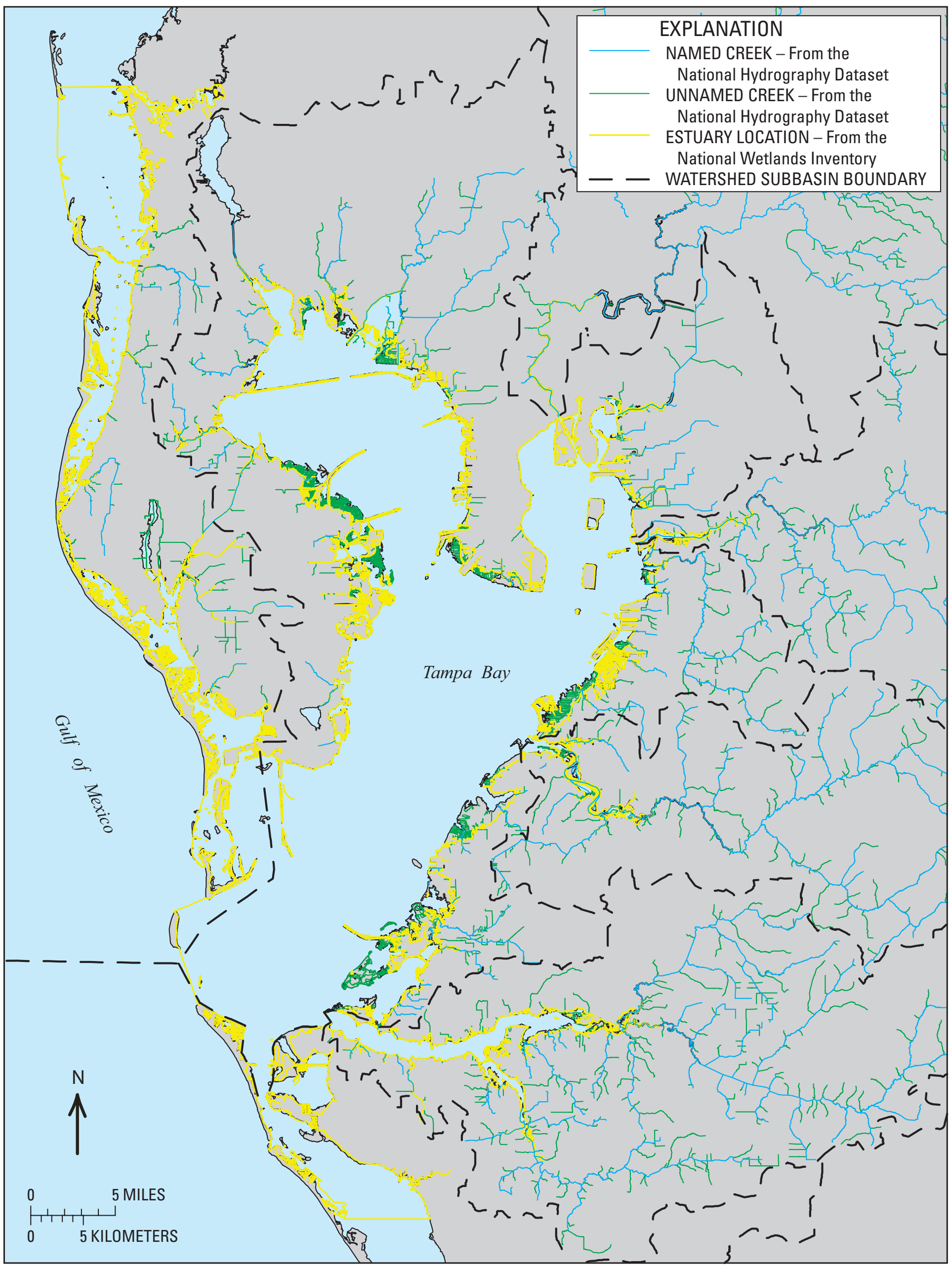


Figure 2–4. Satellite image of Hurricane Frances as it approached the east coast of Florida on July 24, 2004. Image credit from National Aeronautics and Space Administration.

Tributaries and Freshwater Inflow

The Tampa Bay watershed contains a well-defined drainage network that includes four rivers (the Hillsborough, Alafia, Manatee, and Little Manatee) and more than one hundred smaller tributaries and bayous (Lewis and Robison, 1996) (fig. 2–5). Average annual freshwater inputs have been estimated to range between 1,200 and 2,200 million gallons per day (Mgal/d) in recent decades, with rain falling directly on the bay surface (43 percent of contribution) and surface-water inputs from rivers and streams (41 percent of contribution) representing the largest source categories (Zarbock and others, 1995). Estimated inputs of fresh and brackish groundwater are subject to considerable uncertainty (for example, Kroeger and others, 2007; Swarzenski and others, 2007). Freshwater inflows are discussed in more detail in Chapter 6.



Courtesy of Tampa Bay Estuary Program

Figure 2–5. Locations of Tampa Bay tidal tributaries. Map credit: Florida Fish and Wildlife Research Institute.

Tides

On average, water levels in the bay vary daily by about 2.3 feet (ft) due to tidal fluctuations (Lewis and Estevez, 1988). The bay experiences a combination of diurnal (solar) and semidiurnal (lunar) tides, leading to highly variable tidal cycles that consist of two unequal high and two unequal low tides on most days (fig. 2–6). On some days, however, tides are predominately diurnal (one high and one low tide per day) or semidiurnal (two equal high and low tides per day). On a single tidal cycle roughly 160 billion gallons of water flow in and out of the bay (Goodwin, 1987). Seasonally, the difference between summer (relatively high) and winter (relatively low) average water levels is about 1 ft (Galperin and others, 1991).

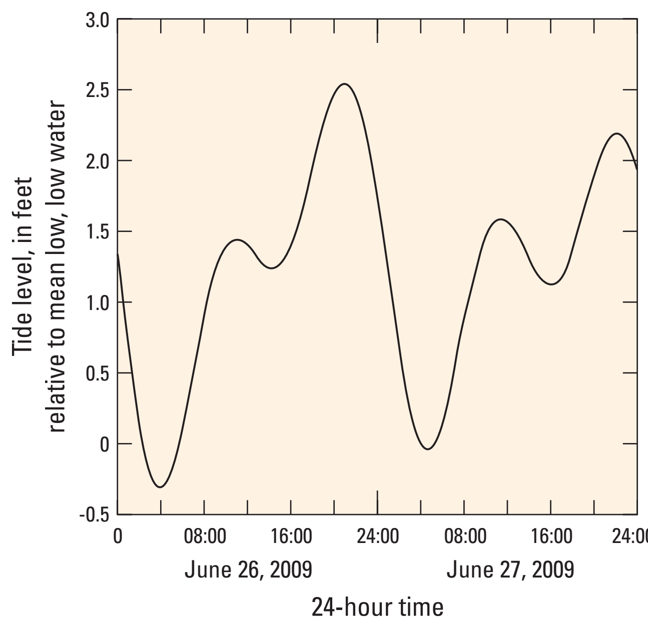


Figure 2–6. Example of tide data for a semidiurnal tide in Tampa Bay near St. Petersburg. Data from Physical Oceanographic Real-Time System; *http://ompl.marine.usf.edu/PORTS/*.

Circulation

Circulating water transports nutrients, planktonic plants and animals, sediments, and other particulate and dissolved matter throughout the estuary. It affects water quality, the distribution of fish and shellfish larvae, and the structure of the bay itself through sediment transport, erosion, and deposition. Over time the bay's circulation has itself been affected by bathymetric changes brought about by anthropogenic activities, such as dredging, filling, and spoil disposal (Goodwin, 1987; Burwell and others, 2000; Burwell, 2001). Historically, natural forces, such as hurricanes and other large storms, have also influenced circulation patterns by altering the shapes and locations of passes that connect the bay to the Gulf of Mexico.

Estuarine circulation is driven by a number of physical forces and processes. Tampa Bay is relatively wide and shallow, facilitating wind-driven mixing. It receives relatively small volumes of freshwater inflow, which reduces the likelihood of salt-wedge formation, and the bay water column tends to be vertically well-mixed with little density stratification

(Goodwin, 1987; Galperin and others, 1991). Salinity levels are relatively high, with average surface values ranging from 12 to 33 ppt in the upper parts of Hillsborough Bay and Old Tampa Bay — which receive much of the bay's freshwater input — and from 33 to 36 ppt near the bay mouth in Lower Tampa Bay (Meyers and others, 2007). When viewed over multiple tidal cycles, this horizontal (head to mouth) salinity gradient encourages the development of a baroclinic residual circulation pattern whereby fresher water flows seaward on the bay surface whereas more saline water flows landward at depth (Galperin and others, 1991; Jakobsen and others, 2006; Weisberg and Zheng, 2006a,b; Meyers and others, 2007). This classic two-layered circulation pattern appears to be most pronounced in the vicinity of the dredged shipping channels, where highest current velocities occur (Jakobsen and others, 2006), and can be enhanced or inhibited by variations in wind speed and direction, freshwater inflow, and bay bathymetry (Galperin and others, 1991; Burwell and others, 2000; Burwell, 2001; Weisberg and Zheng, 2006a, b; Meyers and others, 2007).

Due to the complex interactions that can occur among these factors, numerical simulation models are helpful tools for understanding and visualizing estuarine circulation patterns. The ability of models to provide accurate, detailed simulations is constantly improving due to increases in computing power and improvements in model algorithms. Also, as the results of independent modeling investigations converge over time, confidence in model predictions increases. All computer models represent simplifications and simulations of reality, however, meaning that even the best circulation models are approximations of actual bay dynamics.

Early bay circulation models, which were developed in the 1970s and 1980s, relied on two-dimensional, vertically integrated simulations (Ross and Anderson, 1972; Ross, 1973; Goodwin, 1977, 1980, 1987, 1989). These models could not provide highly accurate simulations of tidal currents and were incapable of predicting complex material fluxes in and out of the bay through the surface and bottom layers. They were useful, however, for predicting tidal stages at different locations in the bay, and for investigating the potential effects of dredge and fill activities on average salinity levels and flushing rates in different bay segments.

In 1990 efforts to improve forecasting of tides and currents resulted in the deployment of the Nation's first Physical Oceanographic Real-Time System (Appell and others, 1994) and the development of three-dimensional hydrodynamic models of Tampa Bay (Galperin and others, 1991; Hess, 1991). Real-time information on tidal stage and currents was deemed essential for safe navigation in the bay, due to its relatively narrow channels and frequent use by shipping traffic. Tide prediction tables published annually by NOAA furnish information on astronomical tides and currents based on the movement of the sun and moon, but do not account for the effects of wind, river flow, and other meteorological forces that can cause substantial deviations from the predicted values.

Developed by NOAA's National Ocean Service in cooperation with the Greater Tampa Bay Marine Advisory Council, the Physical Oceanographic Real-Time System (fig. 2–7) includes an array of acoustic Doppler current profilers, water-level gages, anemometers, atmospheric temperature and barometric pressure sensors, a directional wave gage, packet radio transmission equipment, data acquisition technology, and an information distribution system. The system is managed by the Marine Advisory Council under a

Figure 2–7. Physical Oceanographic Real-Time System station located in Tampa Bay. Photo by Mark Luther, University of South Florida.

cooperative agreement with National Ocean Service and the University of South Florida (USF). In addition to safer navigation, the system provides improved levels of hazardous material/oil spill prevention and response, and improved search and rescue and scientific research capabilities.

Such improvements in the acquisition of physical oceanographic data, along with more accurate and detailed bay bathymetry maps (see box 2–1) and improvements in computer hardware and software, have enabled the progressive refinement of three-dimensional numerical circulation models. Building on the earlier two-dimensional approach, these models have been used to analyze the bay's response under a wide range of scenarios, providing managers and policymakers with additional tools for planning and decisionmaking. Together, the models have helped in the evaluation of several proposed projects, from a 1970s plan to convert Old Tampa Bay north of the Courtney Campbell Causeway into a freshwater reservoir, to a 2000 study examining the effects of a proposed (and since constructed) desalination plant. They have also been employed to predict the potential environmental impacts of freshwater withdrawals, develop regulatory minimum flow recommendations for rivers, examine oil spill trajectories, and gage the effects of harbor deepening and channel construction. Table 2–2 provides a list of existing Tampa Bay circulation models and their applications.

A number of insights and working hypotheses have been provided by the models, including the following:

- Dredge and fill activities conducted during the 1950s and 1960s led to increased flushing rates and salinity levels in some parts of the bay, relative to predevelopment conditions (Goodwin, 1987, 1989);

Table 2-2. Tampa Bay circulation models and representative applications.

[2D, two dimensional; 3D, three dimensional; NOAA, National Oceanic Atmospheric Administration; USGS, U.S. Geological Survey. Model types: POM, Princeton Ocean Model; GNOME, General NOAA Oil Modeling Environment; FVCOM, Finite Volume Coastal Ocean Model; ICM, Integrated Coastal Model]

Developer	Date	Model type	Grid type	Elements	Application	Driving forces	References
Ross and Anderson	1972	Vertically integrated	Rectangular	2D	Examination of tidal flushing in upper Old Tampa Bay	Tides, winds, freshwater runoff	Ross and Anderson, 1972
Goodwin	1987, 1989	Vertically integrated	Rectangular	2D	Examination of changes in circulation and flushing caused by dredge and fill operations in Tampa Bay	Tides, winds, freshwater runoff, salinity	Goodwin, 1987, 1989
Galperin, Blumberg, and Weisberg	1991	POM	Curvilinear orthogonal	3D	Examination of relative importance of the density- and wind-induced residual circulation	Tides, winds, freshwater runoff, salinity	Galperin and others, 1991
Hess	1991	POM	Curvilinear orthogonal	3D	Estuarine and Ocean Physics Branch (EOPB) of NOAA's National Ocean Service (NOS) Tampa Bay Oceanography Project (TOP) - Physical Oceanographic Real-Time System (PORTS) for safe navigation	Tides, winds, freshwater inflows, water temperature and salinity	Hess, 1991
Luther, Vincent, and Meyers	1990s and 2000s	POM/ECOM-3D	Curvilinear orthogonal	3D	Piney Point, desalination, minimum flows	Winds, freshwater inflow, tides	Vincent and others, 2000
Sheng	1997	CH3D-IMS	Curvilinear orthogonal	3D	Effects of reduced freshwater and nutrient loadings on salinity, dissolved oxygen, and seagrass	Tides, freshwater inflows, winds	Sheng and others, 1997
Burwell, Luther, Vincent, and Galperin	2000	POM/ECOM-3D	Curvilinear orthogonal	3D	Residence times (Eulerian and Lagrangian)	Winds, freshwater inflow, tides	Burwell and others, 2000
NOAA	2002	GNOME	Grid independent	Based on input information	Oil spill trajector	Currents, winds, diffusion	NOAA Office of Response and Restoration, Hazardous Materials Response Division, 2002
Weisberg	2006	FVCOM (with flooding and drying capabilities)	Vertical σ-coordinate, horizontal nonoverlapping unstructured triangular grid	3D	Storm surge simulations	Prototypical hurricane winds, atmospheric pressure fields, supported by a merged bathymetric-topographic dataset	Weisberg and Zheng, 2006 a, b
USGS	2009	ICM, DHI	Triangular bathymetry-following flexible mesh (bffm)	3D	Wave impacts, sediment transport	Wind, tides	Jakobsen and others, 2006

- The density-induced two-layer residual circulation pattern is sensitive to wind speed and direction, becoming enhanced when winds are blowing down-bay (to the south or southwest) and depressed when winds are blowing up-bay (to the north or northeast) (Galperin and others, 1991; Weisberg and Zheng, 2006a, b; Meyers and others, 2007);
- Residual circulation is also sensitive to freshwater inflow, enhanced during wet-weather, higher-flow periods and depressed during dry-weather, lower-flow conditions (Meyers and others, 2007);
- Interactions between winds and freshwater inflow rates are also important. Circulation can be disrupted, going to near zero or even reversing, when the freshwater inputs are low and winds are to the northeast (Meyers and others, 2007);
- Model-based estimates of flushing rates and residence times depend on the modeling approaches used to estimate them. In general, estimated bay-wide residence times range from 75 days (using the Eulerian approach) to 159 days (using the Lagrangian approach) (Burwell and others, 2000). Estimated residence times are shortest (15 to 30 days) in the vicinity of the dredged shipping channels, and longest (up to three months or more) in nearshore areas and in the vicinity of persistent eddy features (Burwell and others, 2000); and
- Preliminary results of wave and sediment transport modeling indicate that sediment transport near the shoreline is caused primarily by waves, sediment transport in the middle of Tampa Bay is caused primarily by currents, and deposition of mud in the navigation channels may be orders of magnitude larger than sand deposition (Jakobsen and others, 2006).

Although the accuracy and speed of computer models have improved dramatically in recent decades, future refinements will focus on resolving important questions more quickly and at finer spatial scales. Such improvements are necessary, for example, to better predict the effects of wind-generated and ship-generated wave action on longshore bars, potential impacts of sea-level changes and storm surges, and effects of water-supply withdrawals on bay salinity and water quality.

To address these issues, scientists and managers participating in a 2007 workshop recommended that future generations of Tampa Bay hydrodynamic models should seek to:

(1) Establish links between the watershed, the estuary, and the coastal Gulf of Mexico;

(2) Better predict how circulation is influenced by water quality and freshwater inflow, sediment transport and other physical and biological processes;

(3) Include socioeconomic data to help assess impacts of human population on the watershed; and

(4) Incorporate short- and long-term climate patterns.

Accomplishing this will require additional remote sensing data (airborne and satellite surveys, hyper-spectral scanning of habitats, and bio-sensing), better data on benthic habitat and distribution, and increased spatial/temporal resolution of water-quality data. Bay managers also stressed the need to establish common databases and metadata reporting formats, and improve communication between modelers and decision-makers who may make use of modeling results (Center for Science and Policy Applications for the Coastal Environment, 2007).

Coming Challenges — Climate Change and Sea-Level Rise

Anthropogenic climate change is now widely regarded as one of the most pressing challenges facing society. Its potential consequences are profound and far-reaching: melting terrestrial and polar ice, rising sea level contributing to coastal flooding and erosion, increased frequency of severe weather, increases in ocean temperature and acidification, and rising incidences of marine diseases and harmful algal blooms that can devastate fisheries (Intergovernmental Panel on Climate Change (IPCC), 2007; Florida Oceans and Coastal Council (FOCC), 2009). With 1,200 mi of coastline and billions of dollars invested in coastal real estate and tourism, a warming climate with higher sea levels places Florida at risk. Higher average sea temperatures and changing precipitation patterns may have dramatic and widespread effects on coastal property and habitats. One possible result is the development of more frequent and intense hurricanes (Elsner, 2006) and hurricane-related flooding.

Average air temperatures have risen by about 2 °F in parts of Florida since the 1960s, with precipitation decreasing in southern Florida and increasing in central Florida and the Panhandle region (USEPA, 1997). By 2100 summer temperatures in Florida could rise an additional 3 to 7 °F (Twilley and others, 2001). Warmer temperatures are expected to shift the geographic areas where freezes occur, enabling subtropical plant species such as mangroves, many that cannot tolerate freezing temperatures, to expand their ranges northward.

On a statewide basis, Glick and Clough (2006) assessed the potential impacts of sea-level rise on coastal habitats and fisheries in nine areas along Florida's coast, including Tampa Bay. The study predicts that many of Florida's shoreline and subtidal habitats will be inundated by 2100 due to sea-level rise from global warming, with potentially grave implications. For the nine sites combined, the report predicts losses of nearly 50 percent of critical salt marsh (22,956 acres) and 84 percent of tidal flat (166,572 acres) habitats during this century. Additionally, dry land would decrease by 14 percent (174,580 acres), and roughly 30 percent (1,000 acres) of ocean beaches and two-thirds (5,879 acres) of estuarine beaches would disappear (Glick and Clough, 2006).

In Tampa Bay a 15 in. rise in sea level by 2100 is projected to result in a 96 percent loss of existing tidal flats (42,689 acres) and an 86 percent loss of salt marsh (2,552 acres), with a 10 percent overall loss of dry land (34,676 acres) — an area comparable in size to the city of St. Petersburg. Mangrove extent would more than double under the mean sea-level rise scenario (Glick

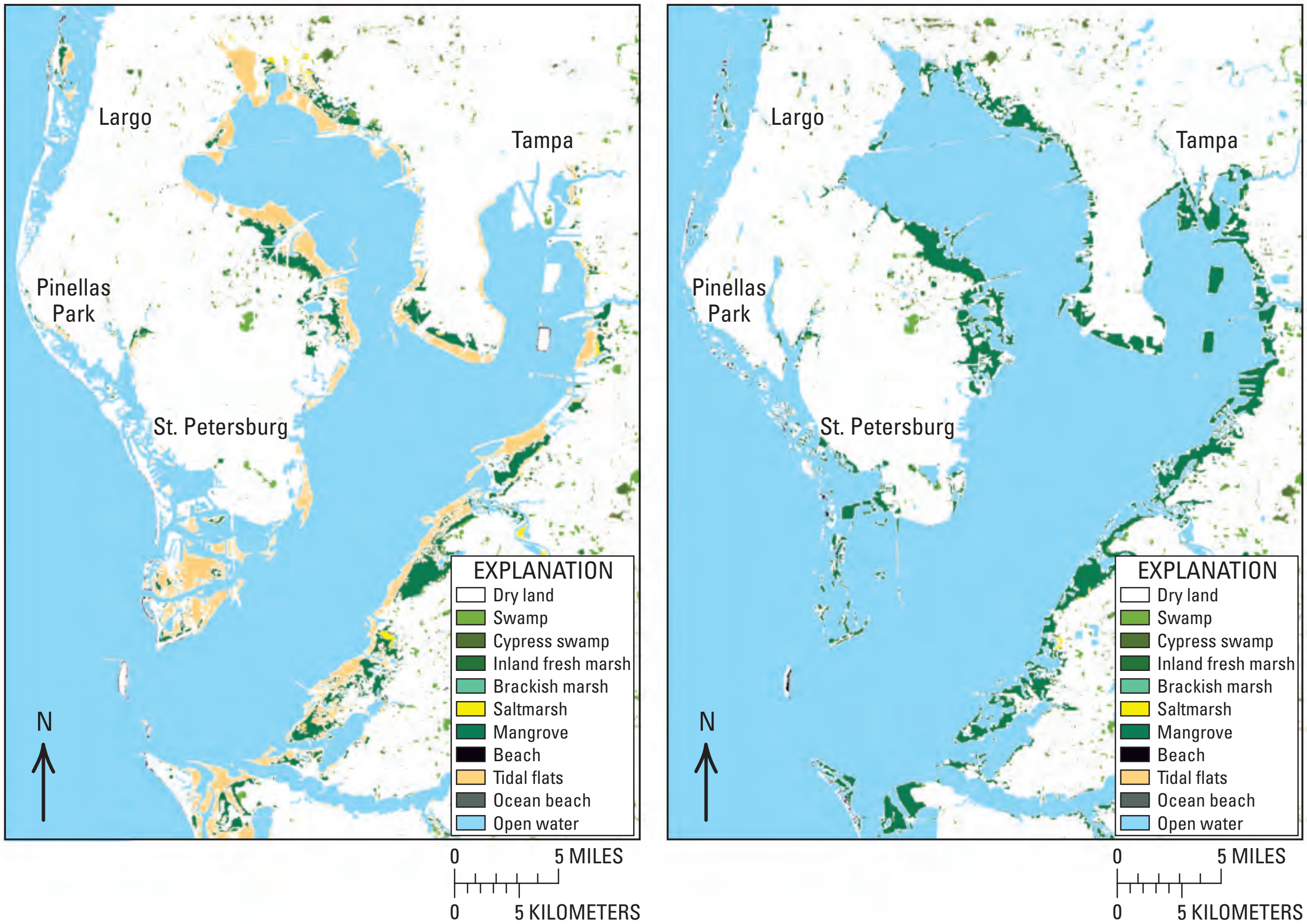


Figure 2–8. Potential changes in shoreline habitat in Tampa Bay by 2100, assuming a 15-inch increase in sea level. From Glick and Clough (2006). Left panel depicts current conditions; right panel depicts conditions possible in 2100.

and Clough, 2006; fig. 2–8). The deeper water would also alter the distribution and composition of seagrasses, which require sunlight to grow. Implications for fisheries, although difficult to forecast, are likely to be profound. Although the prognosis for individual fish species rests on a combination of factors, it is reasonable to deduce that those fish most dependent on vulnerable habitats, such as salt marshes, are at greatest risk. For Tampa Bay, that would include some of the estuary's most prized game fish — common snook, spotted sea trout, red drum, sheepshead, and tarpon. Other implications of climate change and sea-level rise on Tampa Bay habitats and habitat management are discussed in Chapter 8.

Climatic variability, including the potential for relatively abrupt (for example, decadal) climate change, also has important implications for coastal habitat restoration projects in which sizeable investments have been made (Cronin and Walker, 2006). Although there is still significant uncertainty surrounding the timing and magnitude of these changes, habitat restoration teams led by the SWFWMD are now designing and constructing restoration sites in the Tampa Bay region with maximum amounts of high marsh to allow up-slope recruitment as sea-level rises. Ongoing planning will require closer consideration of these factors and adaptive management as new information becomes available.

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