

Chapter 1. An Introduction to Tampa Bay

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TAMPA BAY IS A LARGE, shallow, Y-shaped embayment located on the west-central coast of the Florida Peninsula (fig. 1–1) which consists of a number of interconnected bays and lagoons that have been grouped into seven named segments for management purposes — Hillsborough Bay, Old Tampa Bay, Middle Tampa Bay, Lower Tampa Bay, Boca Ciega Bay, Terra Ceia Bay, and the tidal reach of the Manatee River (fig. 1–2). The bay receives freshwater runoff from a watershed that covers an area of about 2,200 square miles (mi²) (fig. 1–3). Because of its large size, the gradient of freshwater to saltwater habitats it provides, and its location in a transition zone between warm-temperate and tropical biogeographic provinces, the bay and its contributing watershed support a highly diverse flora and fauna and represent a regionally significant environmental resource, as documented in McCoy and Bell (1985), Lewis and Estevez, (1988), Wolfe and Drew (1990), and the Tampa Bay Estuary Program (TBEP, 1996).

In addition to its environmental significance, the bay is also a critical component of the regional economy. Trade, tourism, development, and fishing contribute about \$55 billion annually to the Tampa Bay economy (TBEP, 2006). Several of these economic activities can be negatively affected by environmental degradation. There is a tacit understanding among bay area policy leaders and the public that improving the environmental quality of the bay makes economic sense. Public agencies contribute about \$250 million to nine different program areas corresponding to Tampa Bay resource-management priorities. These program areas include: pollution control, wastewater and stormwater, living resources, habitat preservation and restoration, land acquisition, dredged material management, regulation and enforcement, public awareness, and administration planning and coordination. About 68 percent of the \$250 million is dedicated to wastewater collection, treatment, and reuse, and other wastewater-related activities (Hazen and Sawyer, 1996). Successful resource management of Tampa Bay has been achieved by scientists, resource managers, citizens, and public agencies working together to balance environmental and economic costs and benefits.

2 Integrating Science and Resource Management in Tampa Bay, Florida

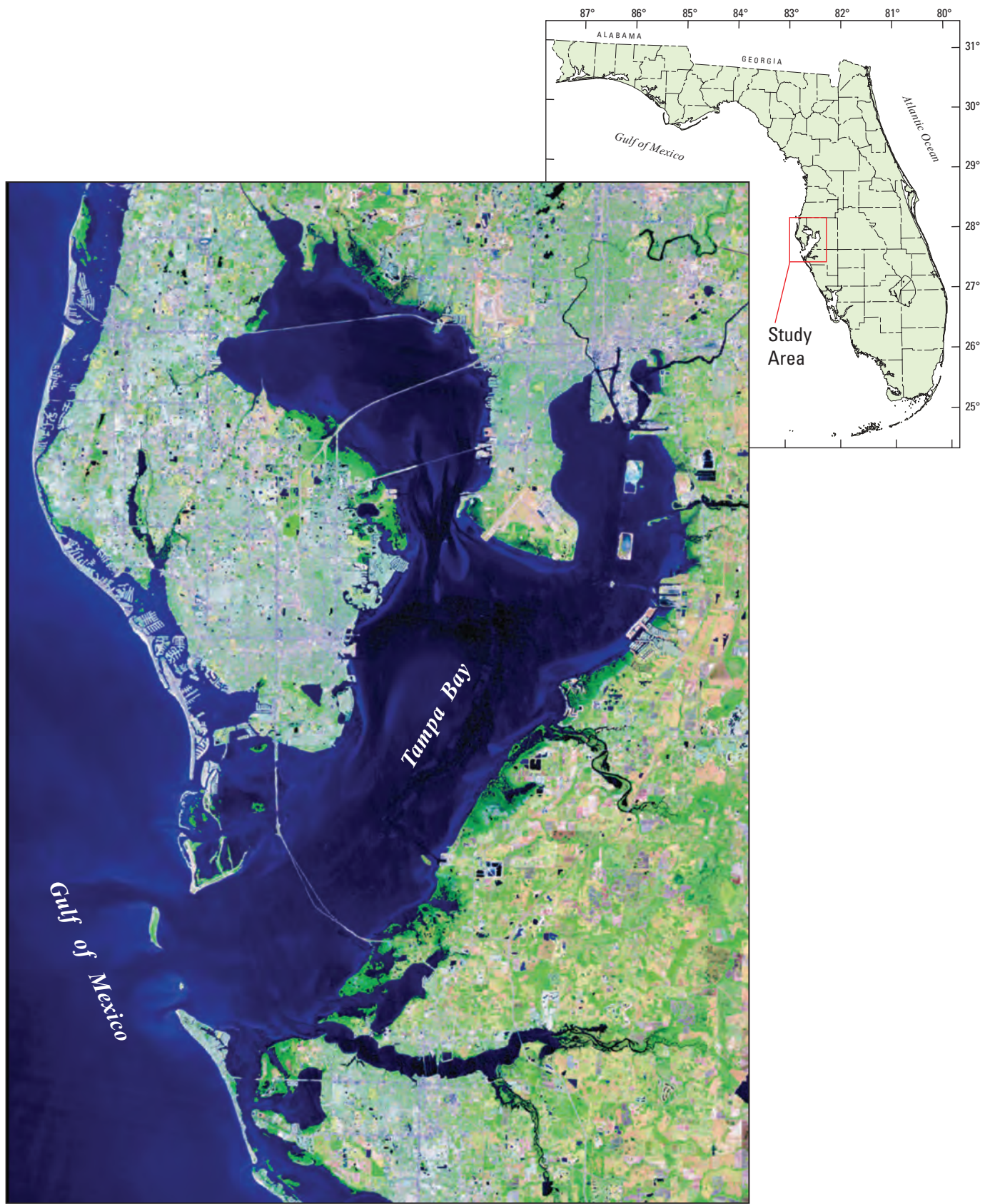


Figure 1–1. Satellite image (LANDSAT) of Tampa Bay located on the west-central coast of Florida. Image by NASA Earth Observatory.



Figure 1-2. Interconnected lagoons and bays of Tampa Bay, grouped into seven named segments: Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, Boca Ciega Bay, Terra Ceia Bay, and the tidal reach of the Manatee River.

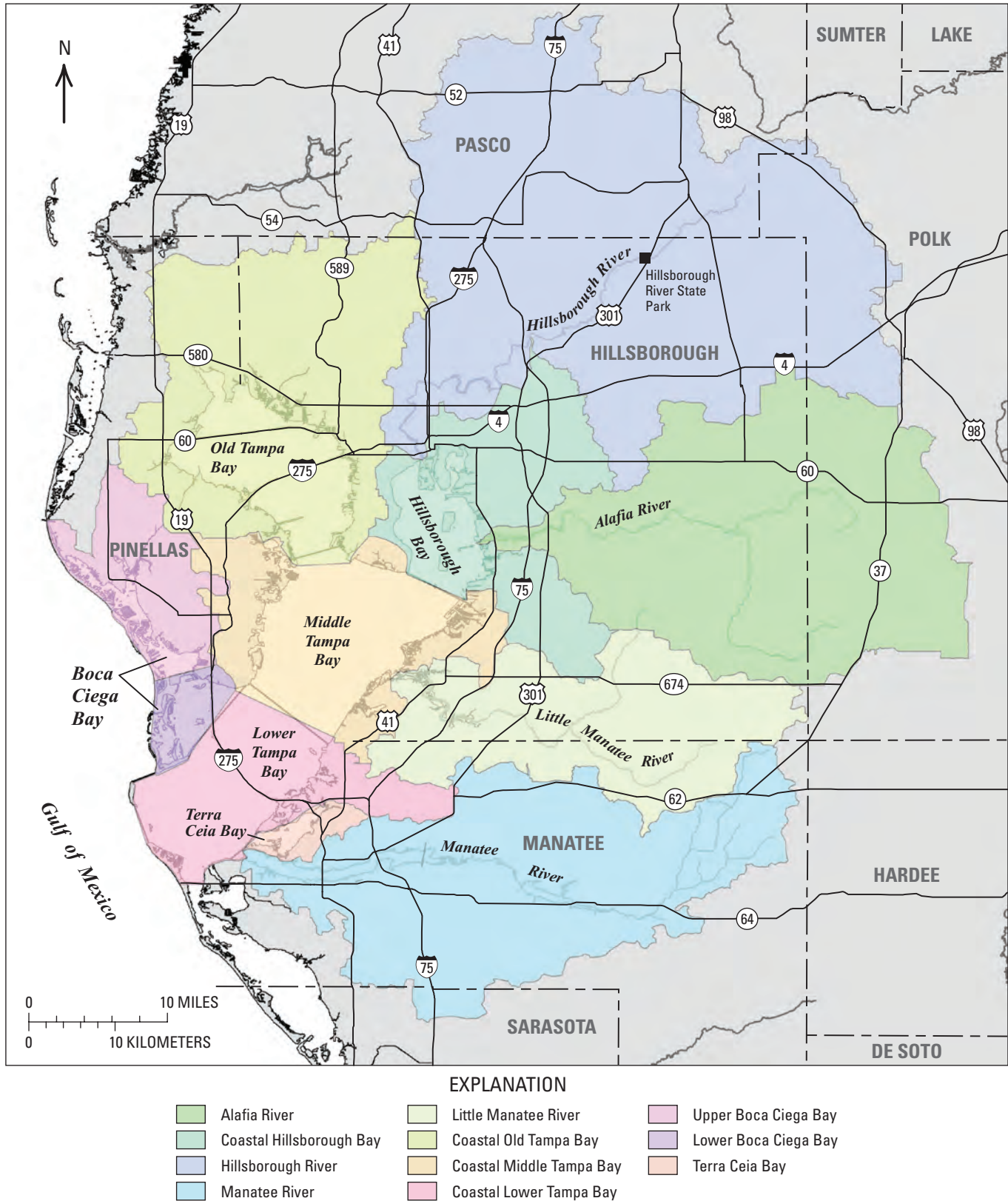


Figure 1-3. Watershed and drainage basins of Tampa Bay showing the geographic extent of land from which the bay receives freshwater runoff.



Figure 1–4. Mouth of the Hillsborough River in downtown Tampa. Photo by Nanette O’Hara, Tampa Bay Estuary Program.

Much of the land area that adjoins the bay is highly urbanized, including the cities of Tampa (fig. 1–4), St. Petersburg, Clearwater, and Bradenton, as well as numerous smaller municipalities. More than 2 million people currently live within the three counties that directly border the bay — a number that has more than quadrupled since the early 1950s (fig. 1–5). The population of the seven-county Tampa Bay region (parts that lie outside the watershed), which was about 3.5 million in 2000, has been projected to increase to more than 4 million by 2013, and to 7 million by 2050. The bay shoreline is dominated by urban land uses on its northern and western sides and by a combination of industrial, agricultural, and rapidly increasing suburban land uses on the east, whereas much of the southern side is natural shoreline. Active port facilities (fig. 1–6) are located on the shorelines of Hillsborough Bay, Middle Tampa Bay, and Lower Tampa Bay, and commercial shipping is an important component of the local economy. Since about 1880, parts of the bay’s shoreline and bathymetry have been modified to support shipping and other economic activities, affecting the estuary’s hydrodynamic characteristics. Population growth and urbanization have also reduced the amount of natural habitat present in the bay and its watershed, with particularly large reductions occurring in the low-salinity stream and marsh, high-salinity salt barren, coastal upland forest, and forested freshwater wetland habitat types (TBEP, 1996; Stetler and others, 2005).

Human activities have also altered the quality, location, and timing of freshwater inflow to the bay. No long-term increases or declines in bay salinity have been detected in water-quality monitoring data collected

Figure 1–5. Population growth in the three-county area (Hillsborough, Manatee, and Pinellas Counties) surrounding Tampa Bay, 1940–2008. Data from U.S. Census Bureau.

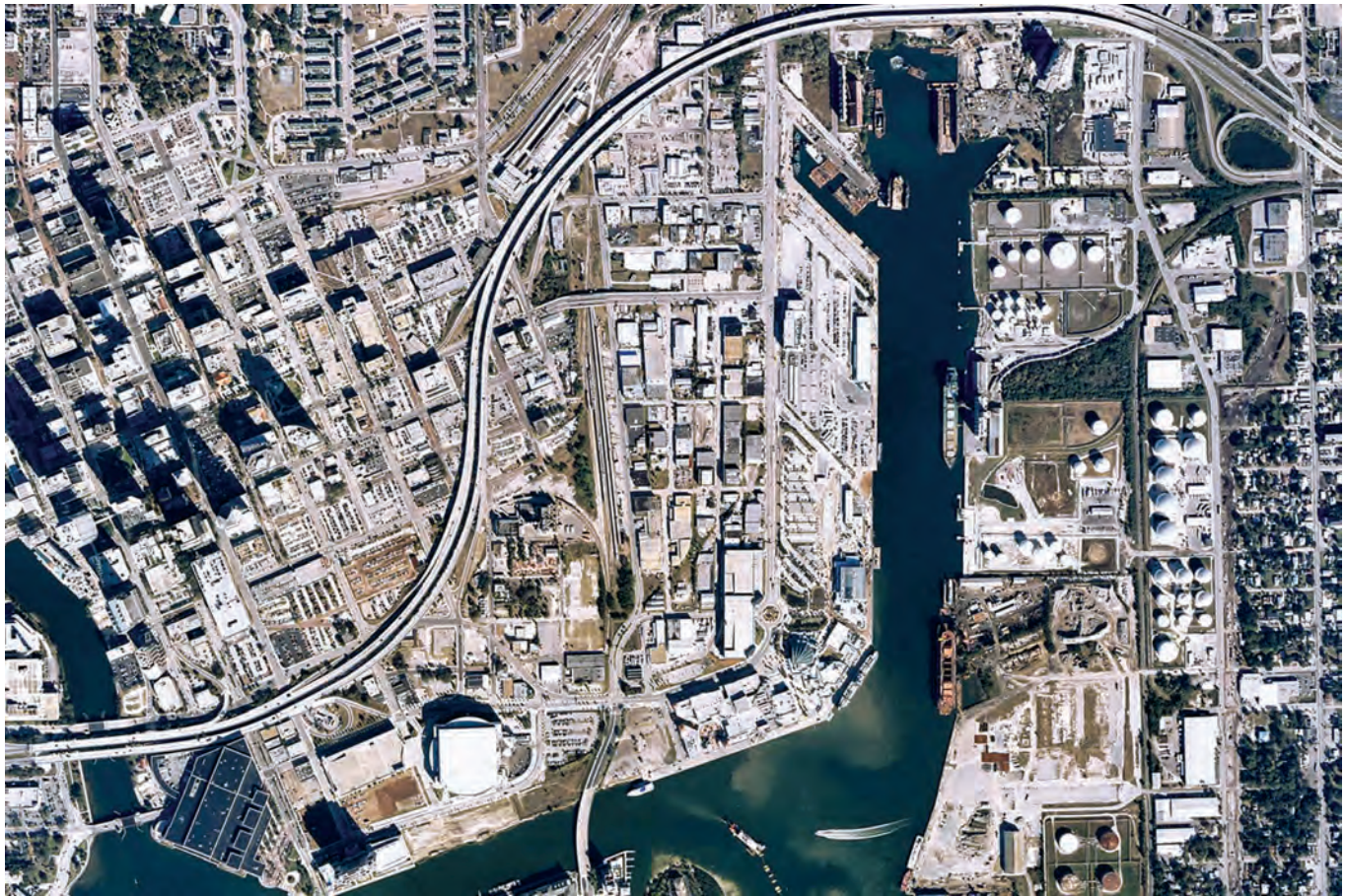
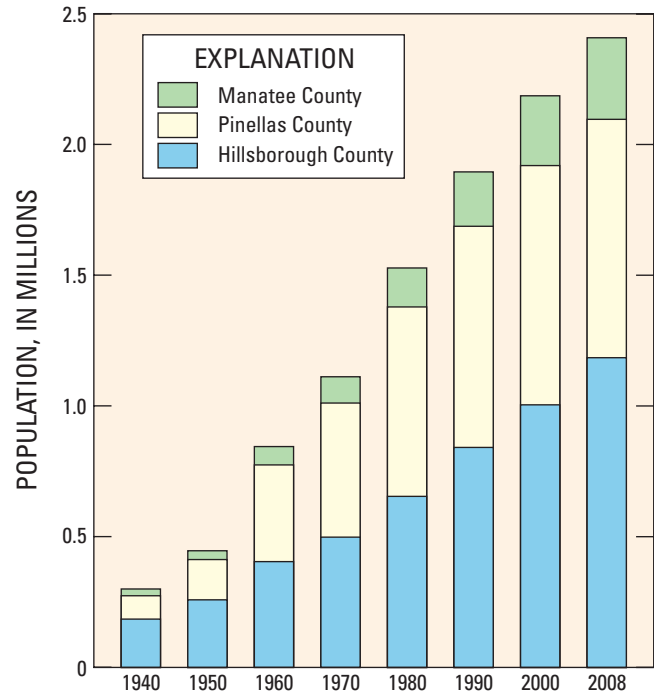


Figure 1–6. The Port of Tampa is located on the northern shoreline of the Hillsborough Bay segment of Tampa Bay. Photo by Southwest Water Management District.

since the mid-1970s indicating that overall freshwater inflows have not changed appreciably over the past three decades (Zarbock and others, 1995). A number of tributaries have been impounded to create water-supply reservoirs, however, and water has been withdrawn from several of the free-flowing tributaries to provide raw water for the public supply system. As a result of these withdrawals, freshwater discharges to the tidal reaches of some tributaries have been reduced. At the same time, urbanization has increased the imperviousness of large parts of the watershed (Xian and Crane, 2005; Xian and others, 2007; fig. 1–7), a process that typically leads to more rapid stormwater runoff and less infiltration of rainfall to recharge groundwater aquifers (Schueler and Holland, 2000). Although modern stormwater management practices can help reduce these effects, much of the urbanization in the immediate vicinity of the bay (for example, in the cities of Tampa, Clearwater, St. Petersburg, and Bradenton) occurred prior to the mid-1980s, when the State of Florida began requiring the installation of stormwater management systems as a condition for new development. As a result, many of the older urban areas currently discharge untreated or minimally treated stormwater, containing large amounts of nutrients and other contaminants, to the bay or its tributaries. Recent studies indicate that these changes can have important effects on the ecology and habitat quality of small tidal streams, which are important nursery areas for numerous fish and shellfish species (Tampa Bay Tidal Tributary Research Team [TBTTRT], 2008).

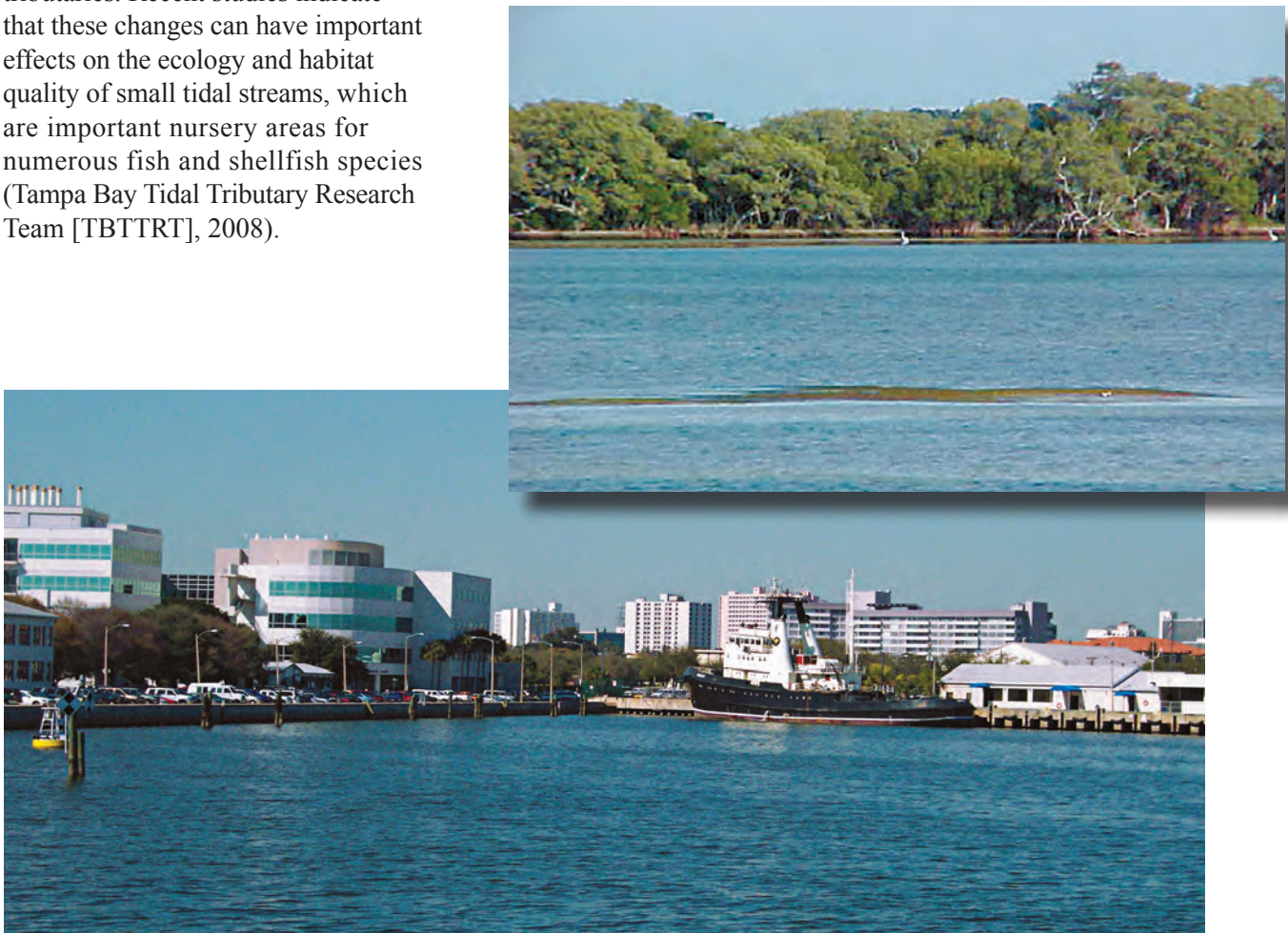


Figure 1–7. *Top*, an undeveloped area of shoreline located along the southeastern shoreline of Lower Tampa Bay; and *bottom*, the urbanized shoreline of Bayboro Harbor located along the western coastline of Middle Tampa Bay depicting increased urban structures and seawalls. Photo by Renee Koenig, U.S. Geological Survey.

Despite these and other management challenges, Tampa Bay remains a valuable and highly productive natural resource and has undergone a sustained period of recovery since the early 1980s. Following a period of degraded water quality that became increasingly evident during the 1970s, State legislation prompted improvements in municipal sewage-treatment practices that reduced nutrient discharges to the bay. Beginning in the late 1970s, some municipalities, including the City of Tampa, upgraded their sewage-treatment plants to provide higher levels of treatment. Others, including the City of St. Petersburg, diverted larger amounts of the treated effluent that had previously been discharged to the bay into reuse systems, providing water for landscape irrigation and other purposes (TBEP, 2006). Improved stormwater management practices and more stringent regulation of dredge-and-fill practices also provided benefits, and by the early 1980s dramatic improvements in water quality were observed (Johansson, 2005).

The water-quality improvements and habitat protection and restoration efforts that have occurred since the early 1980s have made Tampa Bay one of the most notable success stories in the management of urban estuaries (Greening and Janicki, 2006; Duarte and others, 2009). Site-specific chlorophyll *a* and water clarity targets have been met in most of the last 15 years (Chapter 5). Seagrass coverage has also increased substantially, with almost 8,000 acres recovered since 1982. At this rate, the seagrass recovery goal of 38,000 acres, which represents the estimated extent of seagrass that occurred in the bay during the early 1950s, may be reached by 2045 (Chapter 4).

Tampa Bay Study — Integrating Science and Management

In 1991, the Tampa Bay National Estuary Program (now the Tampa Bay Estuary Program; TBEP) was established to assist in developing a comprehensive plan for bay restoration and protection. This plan, called the Tampa Bay Comprehensive Conservation and Management Plan (TBEP, 1996, 2006), was developed and initiated in partnership with Hillsborough, Pinellas, and Manatee Counties; the cities of Tampa, St. Petersburg, and Clearwater; the Southwest Florida Water Management District (SWFWMD); the Florida Department of Environmental Protection (FDEP); and the U.S. Environmental Protection Agency (USEPA). The Comprehensive Conservation and Management Plan, published in 1996 and updated in 2006, summarized the goals and priorities for bay restoration and protection, outlined action plans for addressing these priorities through partnership and community participation, and provided a mechanism for building upon the resource-management approach that had initiated improvement in the Tampa Bay ecosystem.

Some of the key elements of the resource-management strategy outlined and implemented through the comprehensive management plan process include:

- Focusing on the protection and restoration of specific living resources, such as seagrasses, in the development of water-quality targets and habitat restoration goals;
- Establishing quantitative management goals that are clearly defined, measurable, and ambitious but achievable (for example, restoration of seagrass cover to the acreage levels estimated to have been present in the early 1950s);

- Developing and implementing science-based strategies for achieving the goals;
- Obtaining commitments of partners through an inter-local agreement to achieve the goals; and
- Tracking and reporting both the outputs (projects completed) and outcomes (progress made toward achieving the quantitative goals) of the management process.

Over time, the TBEP has evolved into a collaborative, flexible, multientity, and multidisciplinary effort that is able to adapt to changes in technology, data availability, and scientific understanding. To address the inherent uncertainties and complexity of the bay's responses to changing contaminant loads and other environmental conditions, the program has adopted the widely recommended "adaptive management" approach (Holling, 1978; Lee, 1993; National Research Council, 2000; Greening and Elfring, 2002). The goal of adaptive management is to improve managers' understanding of, and their ability to address, a set of well-defined ecological objectives, through the implementation of carefully designed management interventions and monitoring programs. Environmental outcomes are monitored on a regular basis, and the information provided by the monitoring programs is used to update and refine management actions (Gregory and others, 2006). An example of this approach can be seen in the Tampa Bay nutrient management strategy (Chapter 5), which includes annual evaluations of monitoring data and redirection of nutrient load management actions on an as-needed basis based on those evaluations.

In 2001, the TBEP and its partners identified a need for U.S. Geological Survey (USGS) participation to provide multidisciplinary expertise and a regional-scale, integrated science approach to help address unresolved research issues and fill critical data gaps necessary for continued restoration and preservation of Tampa Bay (fig. 1–8). The USGS Director responded by charging USGS scientists with the task of developing a science and management strategy to engage in fully integrated science across the Nation, beginning in the Tampa Bay Estuary as a pilot study.



Figure 1–8. Scientists, managers, and congressional liaisons at the southeast shoreline of Tampa Bay to discuss the potential impacts of sea-level rise on Florida wetlands and resource management actions that scientists and managers are taking. Photo by Renee Koenig, U.S. Geological Survey.

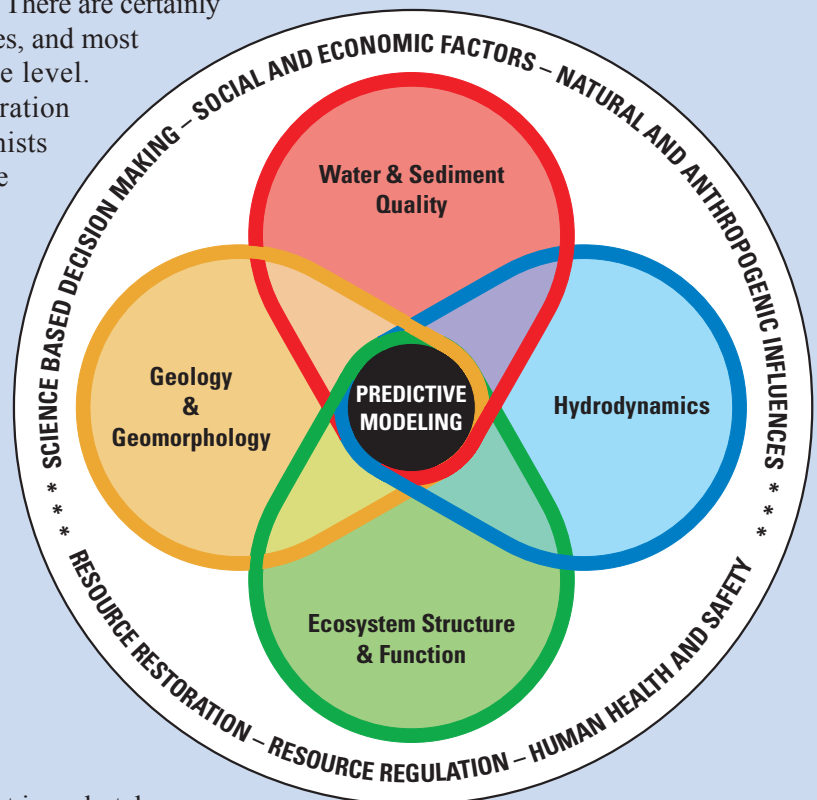
Box 1–1. Integrated Science

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The USGS broadly defines integrated science as “multidisciplinary teams of scientists working together, across their scientific disciplines, to understand complex relations among the biology, geology, chemistry, and physical structure of an ecosystem” (Yates, 2003). There are certainly various levels of integration within science studies, and most multidisciplinary studies are integrated at some level. For example, the simplest level of project integration may be demonstrated when biologists and chemists work together in the same location to study the effects of various pollutants on the health of marine organisms. The most complex level of project integration, termed “fully integrated,” includes integration of:

- People (scientists, resource managers, citizens, educators, and government officials) who work together using a partnership approach;
- Multiple science disciplines;
- Science culture from each discipline;
- The science planning process;
- Common business practices for carrying out science;
- Data collection and analysis; and
- Product development and distribution.

Additionally, a fully integrated science project is undertaken in response to social and economic factors, science-based decision making, resource conservation, restoration, and regulation, human health and safety, and in the context of both natural and anthropogenic impacts to the ecosystem as shown in the outer ring of the integrated science logo in box 1–1, figure 1. The integrated science process is both interactive and iterative among scientists and resource managers. As such, it requires that a high degree of flexibility and communication be maintained in planning and execution of science activities and development of science information products to respond to the changing needs of resource managers. Often projects and tasks in the Tampa Bay Study were modified as resource-management issues evolved or as linkages among estuarine system components were understood and modification of projects was needed to characterize them. Throughout the following chapters, highlight boxes describe some key research projects that exemplify the essence of integrated science. These represent only a few of the many projects that demonstrate the value of the integrated science process for the advancement of science and resource management. These research efforts were made possible by the dedication of scientists and resource managers from multiple agencies whom embraced true partnership and pushed forward the challenging frontier of integrated science.



Box 1–1, Figure 1. Integrated science logo for the U.S. Geological Survey Tampa Bay Study shows the four critical categories of science gaps that correspond to ecosystem components (labeled in each of the colored loops), and the factors and issues to which integrated science responds (labeled in the outer ring of the logo). Design by Renee Koenig, U.S. Geological Survey.

The USGS is a multidisciplinary organization consisting of four research disciplines, including Geologic (GD), Biological Resources (BRD), Water Resources (WRD), and Geography, and has a long history of engaging in large-scale multidisciplinary research. As such, the USGS has the capability to develop and coordinate fully integrated science strategies for ecosystem-scale research founded on partnerships and collaborative efforts, multidisciplinary teams of scientists, integrated fieldwork, data analysis and interpretation, and product development. The USGS was, thus, well-poised to respond to this request and was able to build upon the foundation of integrated science and adaptive resource management that the Tampa Bay science and resource-management community had established over the previous decade. This level of project integration in Tampa Bay represented a new approach for the USGS to “the business of doing science” and a cultural change for its scientists, managers, administrators, and technical staff.

The primary role of the USGS in Tampa Bay research was defined with TBEP and its science and management partners based upon USGS capabilities to address estuarine issues using an integrated science approach with a regional perspective and within a national context. USGS research complemented the numerous ongoing science efforts by State and local agencies that address local issues within Tampa Bay. Four categories of critical science gaps that needed to be addressed by the USGS were identified. These critical gaps correspond to ecosystem components and include: (1) water and sediment quality, (2) hydrodynamics, (3) geology and geomorphology, and (4) ecosystem structure and function (box 1–1, figure 1). Six tasks, encompassing 39 linked projects, were developed to address issues within these categories with the common goal of “establishing relations among estuarine system components to develop conceptual and predictive models that describe the natural and anthropogenic changes impacting estuarine health” (Yates, 2003). The primary objectives of the Tampa Bay Study and a summary of key findings are listed in box 1–2.

The Tampa Bay Study has encompassed process-oriented research to understand fundamental processes within each component of an estuarine system and to develop conceptual and predictive models that establish links among system components to aid adaptive management practices. This research was performed by: (1) integrating fieldwork among science disciplines and data among tasks, (2) building on previous results and information, (3) partnering with the many science and resource-management agencies working in Tampa Bay, (4) responding to the needs of resource managers and adaptive management, and (5) integrating interpretation of data and product development among USGS scientists and their partners and collaborators. In partnership with the TBEP, the USGS launched the Tampa Bay Study in 2001, supported by 120 collaborators and partners from 56 different agencies, municipalities, universities, private entities, nongovernmental organizations, and all four disciplines of the USGS.

The purpose of this report is to provide an overview of the science-based process that has been used to guide the bay management effort in recent decades, to point out some of the obvious challenges that remain to be faced, and to outline some anticipated challenges that may arise in the near future. This document represents the first comprehensive synthesis of integrated science and management from the USGS, TBEP, their partnering agencies, and from the numerous participants in Tampa Bay research, monitoring, and resource management, including a variety of State, local,

and Federal agencies, universities from across the Nation, community groups, and many private and nongovernmental entities. The remainder of the report is organized into chapters that provide overviews of the physical characteristics of Tampa Bay (Chapter 2), the geological origins and changes in the bay over time (Chapter 3), seagrass management (Chapter 4), water quality (Chapter 5), freshwater inflows and instream flows (Chapter 6), sediment quality and benthos (Chapter 7), and habitat protection and restoration (Chapter 8).

Technical material in the report was collated from information provided by the TBEP and its partner organizations, and by the USGS. Most of the technical reports and other agency documents cited here are available in electronic form through the TBEP website (<http://www.tbep.org/>) or through the digital library maintained by the USGS and several partners (<http://gulfsci.usgs.gov/library/index.html>) as part of the USGS Tampa Bay Study. Results from the Tampa Bay Study are providing a stronger scientific framework in a number of estuary management areas. It is anticipated that the integrated science strategy developed through the Tampa Bay Study will be used as a model for USGS integrated science in other Gulf of Mexico estuaries and coastal ecosystems throughout the Nation.

Box 1–2. The U.S. Geological Survey Tampa Bay Study

By Kimberly K. Yates (U.S. Geological Survey—St. Petersburg, Florida)

Historically, science programs of the TBEP and its partners have focused primarily on biological, surface-water, and sediment-quality monitoring and research in Tampa Bay. Four areas of critical science gaps were identified for USGS research, and these gaps correspond to the ecosystem components. Box 1–2, figure 1 shows a diagrammatic conceptual model that depicts the distribution of six project tasks among the four categories of critical science gaps:

- Geology and Geomorphology
- Water and Sediment Quality
- Hydrodynamics
- Ecosystem Structure and Function

USGS Tampa Bay Study science tasks were numbered according to the order of priority research elements defined among partnering agencies, and reflect the Tampa Bay scientific community's greatest need for USGS expertise in the physical sciences:

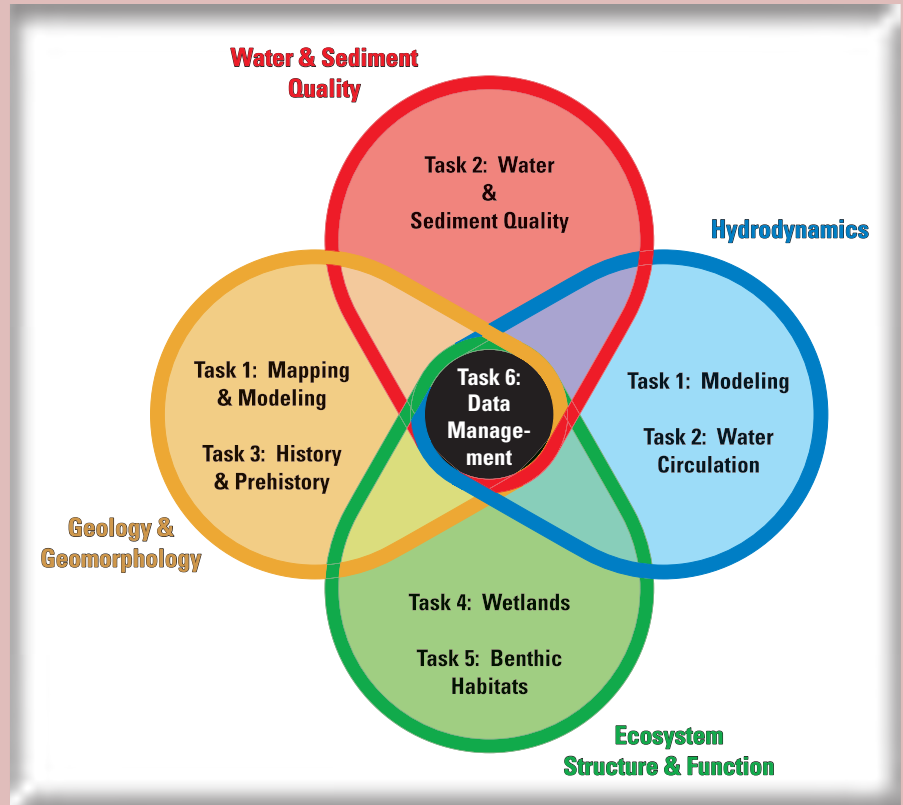
- Mapping and Modeling
- Water and Sediment Quality
- History and Prehistory
- Wetlands
- Benthic Habitats
- Data Management

Project tasks were developed to complement, not duplicate, efforts of partners. Thus, although seagrass recovery, wetland protection and restoration, and surface-water quality are high priorities of the TBEP, these areas represented smaller research components of the Tampa Bay Study, because much of the research in these areas was already being addressed by partnering agencies.

USGS Science Task Objectives

- Task 1: Mapping and Modeling — Characterize and model natural and anthropogenic changes in the physical structure of Tampa Bay and their impact on ecosystem health.
- Task 2: Water and Sediment Quality — Quantify and assess the source, quality, and impact of ground-water, sediment, and surface water on benthic and coastal habitats.
- Task 3: History and Prehistory — Model the historical and prehistorical evolution of the bay to develop the structural setting for estuarine processes, provide the basis for predictive modeling, and serve as a guide for restoration planning.
- Task 4: Wetlands — Assess the current ecological status of wetlands, and characterize natural and anthropogenic factors impacting wetland health and restoration.
- Task 5: Benthic Habitats — Identify, quantify and model the impacts of urbanization on benthic-habitat distribution, health, and restoration.
- Task 6: Data and Information Management — Develop and maintain a decision support system to facilitate science information exchange, product development and delivery, modeling exercises, and public outreach.

The Mapping and Modeling task (Task 1) was designed to develop the regional, spatial, and physical context of the Tampa Bay Region for all other research and monitoring components. The baseline maps and models produced in this task provided the foundation for all other efforts. The most important results from this work were the development of a seamless digital elevation model (10 m resolution) and the development of urbanization and integrated coastal models for Tampa Bay (See Chapter 2). The model results assist resource managers in predicting the future of urban extent and its impact on the environment, and provide critical information on the effects of urbanization, ship traffic, and anthropogenic modifications on water circulation and sediment dynamics within Tampa Bay.



Box 1–2, Figure 1. U.S. Geological Survey Tampa Bay Study tasks are listed under the four critical science gaps, corresponding to ecosystem components, as indicated in the integrated science logo.

Some of the most significant results from the Water and Sediment Quality task (Task 2) included the identification of groundwater sources in Tampa Bay. This was achieved by combining resistivity mapping results from Task 2 with seismic mapping results from Task 1. Resistivity mapping showed the location of freshened water masses below the seafloor, and seismic mapping identified geologic features on the seafloor that may act as conduits for freshwater flow into the bay. Additionally, the amount of groundwater coming into Tampa Bay was quantified for the first time and shown to be a significant source of nutrients to Tampa Bay (See Chapters 5 and 7).

The History and Prehistory task (Task 3) collected and analyzed over 100 sediment cores taken along seismic mapping track lines throughout Tampa Bay. Data from these analyses have provided the first comprehensive look at preanthropogenic and anthropogenic environmental conditions in the bay with respect to sediment accumulation rates, climate change, sea-level rise, trace metals, nutrients, and floral transitions. Characterization of surface sediments in the cores also provided critical information for sediment transport modeling in Task 1. Additionally, results from these analyses have shed new light on the controversies over how Tampa Bay originated (See Chapter 3).

The Wetlands task (Task 4) focused on providing data to resource managers that quantified impacts to flora and fauna from historical manmade alterations to wetland areas. This information has been used to assist with development and monitoring of wetland restoration activities in Tampa Bay. Significant results from this task include information on use of manmade and natural wetland ditches by 76 species of economically important fish for nursery habitat. Resource managers are using this information as a guide to make sure they achieve the intended results with their restoration plans. Additionally, methodologies and minimum standards were developed for wetland restoration techniques that have now been adopted in other estuaries around the world (See Chapter 8).

The Benthic Habitats task (Task 5) focused on the development of an Urban Extent/Seagrass distribution model that shows the relationship between urban development and changes in extent of seagrass over time. Other significant results of this task include the first measurements of community productivity in seagrass habitats in relation to available light, and the first documentation of bioaccumulation of metal contaminants in seagrass tissues within Tampa Bay (See Chapter 4).

The Data and Information Management task (Task 6) was designed to support rapid and efficient dissemination of science information and completed products to all collaborating scientists, stakeholders, and the general public, to facilitate communication among scientists and resource managers, and to collect and provide relevant historical research information required for Tampa Bay study projects. Significant products from this task include development of a web-site (<http://gulfsce.usgs.gov>) that provides online access to research information from the Tampa Bay Study, and has been expanded to include all USGS Gulf of Mexico research activities. The website also features a digital library containing data products from individual projects, and an interactive map server that allows the public to view and analyze geospatial data from the study.

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