Chapter 1: **Background**

Barriers to natural surface water movement and tidal flow such as levees, dikes, causeways, and other barriers can result in the degradation of estuarine habitat, particularly in sensitive ecosystems in the Southeast United States. These tidal barriers can precipitate conversion to a predominantely freshwater habitat, which changes the dynamics of an entire ecosystem.

This chapter discusses reasons for historic **tidal hydrology modifications**, the impacts of those modifications on different estuarine habitats found in the Southeastern U.S., and the benefits of removing these tidal barriers. More specifically, this chapter describes the following information:

- Scale and geographic extent of tidal modifications;
- Reasons for historic tidal modifications in the Southeastern U.S.;
- Characteristics of estuarine habitats and impacts from modified tidal hydrology;
- Ecological and socio-economic benefits of tidal hydrology restoration;
- Cost-effectiveness of removing tidal hydrology barriers; and
- Example tidal hydrology restoration projects.

Old rice fields in coastal South Carolina are now managed impoundments.

Photo Credit: NOAA

Tidal Hydrology Modifications in the Southeastern United States

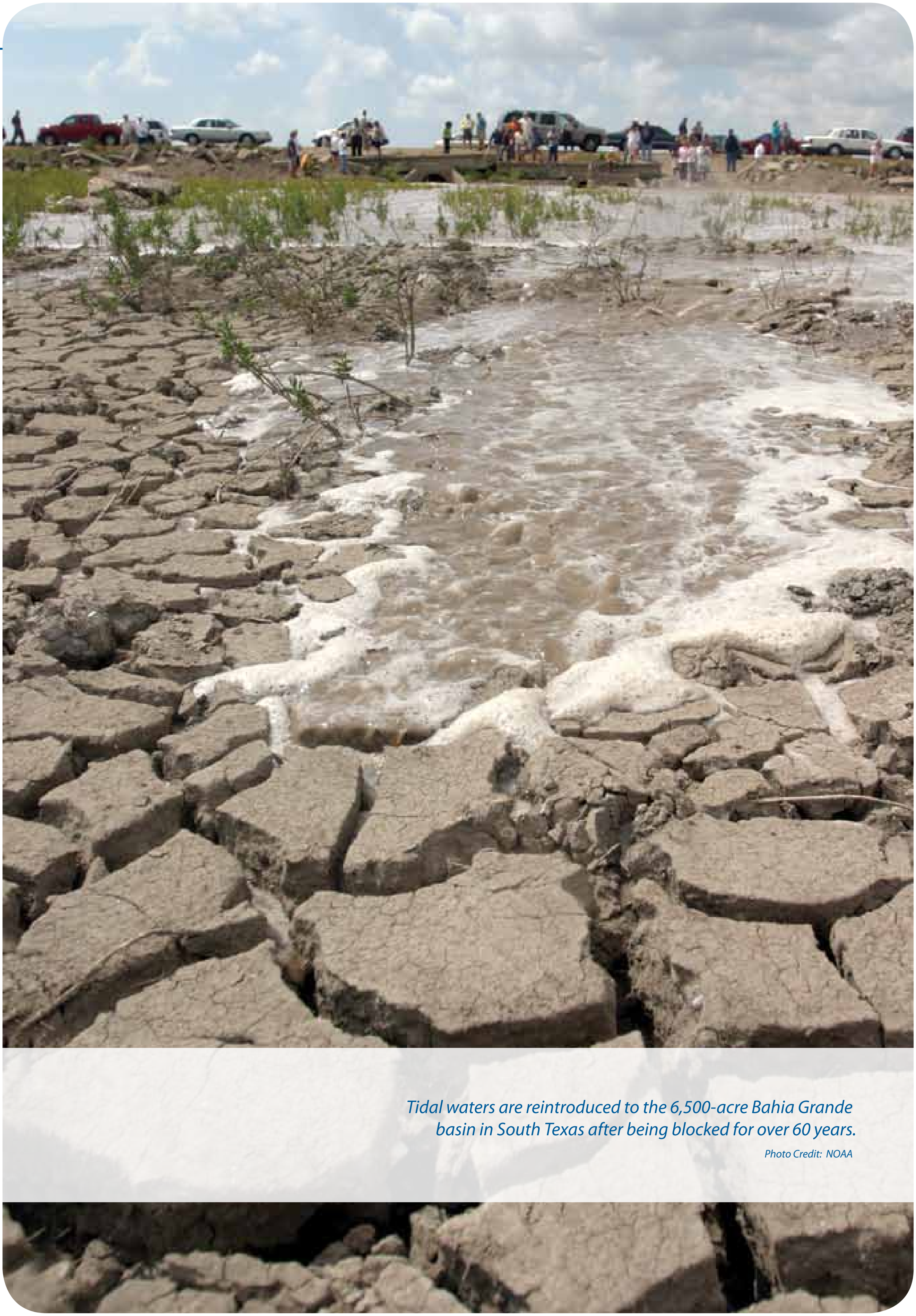
Estuarine habitats such as salt marshes and seagrasses have been adversely impacted by historic tidal hydrology modifications and tidal restrictions. On the east coast of Florida alone, nearly 40,000 acres of coastal marsh are impounded (Rey and Kain1990). In Louisiana, more than 91,000 acres of state and federally owned land are impounded (Day et al. 1990), and in South Carolina, there are over 70,000 acres of rice field impoundments (NOAA 1979). Some hydrologic modifications have been in place for so long that it is impossible to recognize that these locations once functioned as estuarine habitat. Over time, many modifications have lacked maintenance and failed, resulting in partial impoundments containing various forms of degraded habitat.

Along the Gulf Coast, it is common to drive from the mainland to barrier islands along earthen causeways built through marshes and seagrass habitat between the 1940s and 1960s. For example, in South Florida, a causeway was constructed in the 1950s to provide access from the mainland to Sanibel and Captiva Islands, blocking all tidal flow through Dinkins Bayou into Clam Bayou. Clam Bayou became completely impounded, resulting in the loss of 150 acres of mangroves, 120 acres of seagrass, and 20 acres of oyster reef habitat.

For more, see the **Clam Bayou Tidal Hydrology Restoration Project Portfolio** *(page 128).*

As early as the 1930s, impoundment activities were used along the Atlantic coast to create agricultural land and migratory bird habitat, and to control mosquitoes. An **impoundment** is an area created by the placement of earthen barriers around its perimeter, which exclude or control the influence of tidal flow.

While many of these activities are not in common practice today, the results of these historic modifications have significant impact on present-day coastal ecosystems. These changes were made for the following reasons:



Tidal waters are reintroduced to the 6,500-acre Bahia Grande basin in South Texas after being blocked for over 60 years.

Photo Credit: NOAA

Background

- *Agriculture.* As coastal populations increased, marsh areas were drained of tidal waters and used as fields for crop plants, such as rice impoundments. These areas would also be used to graze cattle and other livestock.

- *Roads.* To allow for direct access through tidal systems, elevated road beds were constructed by borrowing sediments from adjacent areas. It is common to see ditches along the length of a roadbed through a coastal system as a result of the "borrowed" material. Although small culverts were typically placed intermittently under the road to relieve flooding concerns, tidal flows remained restricted.

- *Causeways.* Dredge materials were used to create elevated roadbeds from the mainland to barrier islands, between islands, or bisecting an embayment. The dredge material was typically removed from nearby habitat and placed in a manner where tidal flow was completely inhibited, or restricted to narrow bridges or culverts.

- *Duck habitat.* The exclusion of tidal flow and freshwater impoundment created areas for important migratory bird habitat and hunting opportunities.

- *Mosquito control (impoundments).* Water levels in coastal areas were, and still may be, seasonally managed to minimize mosquito populations. The impoundments often included water control devices with the primary goal of controlling mosquito populations and coastal flooding.

- *Mosquito control (ditching).* Checkerboard patterns of ditches were dug through mangrove and marsh systems to facilitate drainage and deplete mosquito populations. This technique altered tidal flow through the system by creating routes for rapid flooding and drying. The excavated ditch sediments were typically piled near the ditches, creating additional hydrology modifications.

- *Dredge spoil disposal.* Dredge spoils resulting from the construction of navigation channels were often disposed of in estuarine habitats, resulting in elevations that did not support the historic ecosystem functions or restricted tidal flow into or through the estuary.

Sandpiper Pond in Murrells Inlet, SC, was tidally influenced before shoreline modifications and Hurricane Hugo blocked tidal flow, turning the area into a lagoon.

Photo Credit: SC State Parks

Influence of Tidal Hydrology Modifications on Estuarine Habitats

Tidal hydrology is one of the main factors influencing the location and function of estuarine habitats. In general, estuarine ecosystems are created from the natural influx of seawater interacting with freshwater. The salinity, volume, exchange, temperature, and velocity of water; flooding frequency; and elevation all influence coastal habitat types and ecological functions. For example, a high marsh is flooded with seawater less frequently than a low marsh, allowing fish to utilize the high marsh less frequently than the low marsh. Conversely, seagrass beds are almost always inundated with seawater and are adapted to specific depths, salinity, and water clarity. If the amount or type of water (i.e., saline or fresh) entering the ecosystem is altered by a tidal barrier, a shift in habitat type will likely follow.

Some habitat types are more sensitive to altered hydrology and changes will occur rapidly, often resulting in dramatic shifts in the composition of faunal and vegetation communities. Other habitat types will shift more slowly – and perhaps will look the same (e.g., the same species still occur) but may not function the same (e.g., will not provide the same ecosystem services) (Turner and Lewis 1997).

A variety of specific tidal habitats in the Southeastern U.S. are susceptible to damage from tidal hydrology modification. These include:

Open water/soft bottom. Open water plays a critical role in establishing a common link between habitats through its ability to transport both solid and dissolved materials, in addition to plankton and other organisms. The physical and chemical characteristics of open water affect all associated habitats, including soft bottom estuarine areas (NOAA 2003). Soft bottom habitats host a wide range of bacteria, plants, and animals from all levels of the food web, known collectively as benthic organisms. These organisms are among the most important component of coastal ecosystems (NOAA 2003). They provide an important link in the food chain by consuming phytoplankton before they are, in turn, consumed by larger organisms such as finfish (Lenihan and Micheli 2001). Open water and soft bottom habitats sustained by tidal influence degrade in functionality when water flow is blocked. These areas, commonly called lagoons, are characterized by low salinity (less than 10 parts per million) and contain less than one-third seawater. As a result, lagoons are less able to sustain species that thrive under the more saline conditions. Additionally, restricted tidal flow can result in reduced oxygen concentrations and increased nutrient loading. This can allow for vigorous growth of algae and other microorganisms that further deplete oxygen, often leading to fish kills and rapid changes in benthic and vegetation composition (Gönenç and Wolflin 2005).

Tidal wetlands. Tidal marshes, or tidal wetlands, in the Southeastern U.S. include salt marsh (low salinity to high salinity) and mangrove. Marshes under the influence of tidal ebb and flow maintain high water quality (Adam 1990); support biodiversity, fisheries, and high biological productivity for smaller organisms; sustain wildlife habitat for birds and waterfowl; mitigate the impacts of storm surges, flooding, and sea level rise; control erosion; and attract people for recreation (Ellison and Farnsworth 2001; Adam et al. 2008; Zedler et al. 2008). However, these tidal marshes are on the decline and the functions they serve are being lost due to degradation caused by pollutants, urban runoff, invasive species, and dredging for commercial and recreational use (Weinstein and Kreeger 2000). More than half of all tidal marshes in the U.S. have been destroyed by human development activities through draining, diking, dredging, and filling (Kennish 2001). With the absence or restriction of tidal influence, tidal wetlands will eventually give way to a different habitat type. Depending on the degree of tidal restriction, elevation, and amount of freshwater input, the tidal marsh may become severely degraded through peaks of high and low salinity and invasion of non-native vegetation, or it may convert completely to a freshwater wetland, an open water pond, or dry upland (Montalto and Steenhuis 2004).

Background

Seagrass. Seagrasses are marine flowering plants and typically grow in shallow coastal waters, including protected bays and inlets (Hemminga and Duarte 2000; Larkum et al. 2006). In the Southeastern U.S., marine seagrasses are found from the Gulf of Mexico to the eastern Florida coast, and along the North Carolina coast. Seagrasses provide structured habitat for shallow marine and estuarine soft bottoms, offering refuge for many commercially and recreationally important fish and invertebrates. Water depth and clarity are critical for seagrasses since they live in anoxic sediments and generally require more light than other marine plants (Williams and Heck 2001). Seagrass habitat is often fragmented into patches resulting from natural processes, such as waves and currents, but also from human activities including boating, dredging, and coastal development (e.g., docks and piers). Some of the most common impacts to submerged aquatic vegetation (SAV) beds have been the draining and diking of coastal wetlands for agriculture, heavy industry, and recreation (Jude and Pappas 1992; Edsall and Charlton 1997). The distribution and quality of seagrass habitat can also be adversely affected by water diversions, dams, impervious surfaces, and other activities that alter natural hydrologic drainage patterns, water levels, salinity regimes, erosion/sedimentation rates, temperature, and water quality. For instance, restriction of tidal flow may result in decreased water velocities, allowing sediment to settle on grass blades and thereby inhibiting photosynthesis.

Oyster reefs. Oyster reefs are composed of densely packed individual oysters that form a highly productive and complex three-dimensional habitat (Zimmerman et al. 1989). These reefs are abundant throughout the estuaries of the southeast United States and can be found in both shallow inter-tidal areas such as creeks, lagoons, and embayments and deeper sub-tidal areas. In addition to improving water quality through the filtering activity of oysters (Newell 1988), reefs provide feeding, breeding, and nursery ground for benthic invertebrates and numerous fish and bird species. Significant economic value is generated by reefs from the many recreationally and commercially valuable animals that rely on reefs such as fish, crabs, and oysters. Additionally, the hard structure of the oyster reef stabilizes sediments, providing shoreline protection for adjacent fringing marshes (Meyer et al. 1997). The health and survival of an oyster reef is highly dependent on tidal currents to import food sources from surrounding habitats, maintain water quality characteristics such as temperature and salinity levels, and flush away smothering sediments (Dame 1996; Kennedy et al. 2006). Similar to other estuarine habitats, oyster reefs have been negatively impacted by human activities, including those associated with hydrologic modifications. For instance, the construction of dikes or levees in intertidal zones can lead to the direct destruction of reefs, while salinity changes due to altered hydrology can create unfavorable conditions that lead to degraded reefs and the potential for complete loss.

Benefits of Tidal Hydrology Restoration: Breaking Down Barriers

Numerous ecological and socio-economic benefits can be achieved by removing hydrology barriers to restore or enhance tidal flow.

Examples of ecological benefits include:

- Creation/enhancement of fish and wildlife habitat;
- Improved habitat longevity and sustainability;
- Reduction of shoreline erosion;
- Storm surge attenuation and flood mitigation;
- Adaptation to or accommodation of sea level rise;
- Storm water management (reducing rate and quantity of runoff);
- Reduction/control of invasive species; and
- Improved ground water and surface water quality (dissolved oxygen, nutrient loads, sediment loads, contaminants, salinity, temperature).

Examples of socio- economic benefits include:

- Enhanced fisheries productivity for commercial/recreational harvest;
- Improved shoreline/infrastructure protection; and
- Increase in surrounding property values.

Often a single tidal hydrology restoration project can achieve a combination of these benefits and affect more than one habitat type, making barrier removal an attractive and efficient restoration technique.

Cost-Effectiveness of Returning the Tide

Relatively small physical barriers to tidal flow can negatively impact large areas of habitat. Consequently, the large-scale restoration of these habitats on an ecosystem level can be achieved from a relatively inexpensive (on a cost/acre basis), small footprint of work. For example, removing a section of dredge-and-fill causeway and replacing it with a 40-foot bridge enhanced more than 1,000 acres of seagrass habitat in the Pinellas County Florida Aquatic Preserve near Fort DeSoto. Removal of the relatively small barrier (in relation to the size of the impacted adjacent habitat) allowed the water flow to naturally restore the surrounding seagrass habitat.

For more information on this project, see the **Fort DeSoto Tidal Hydrology Restoration Project Portfolio** *(page 110).*

Table 1 (below) lists some examples of tidal hydrology restoration projects throughout the Southeastern U.S. with associated acreage, habitat type improved, and cost per acre restored. Despite the funding required for engineering studies and construction, projects such as these demonstrate the cost-effectiveness of tidal barrier removal on a per-acre-restored basis.

Full descriptions of the efforts listed below can be found in the **Project Portfolios** *(page 85).*

Table 1. Example tidal hydrology restoration projects.

Name	Modification/ solution	Acres	Habitat type	Total Cost	Cost/acre
Bahia Grande *Brownsville, TX*	Dredge-fill/Breach	6,500	Soft bottom, sand	$1,800,000	$277
Hopedale *St. Bernard Parish, LA*	Levee/Water control structure	3,086	Salt marsh	$2,140,000	$693
St. Vincent Island *St. Vincent Island, FL*	Road construction/ removal and culverts	1,925	Salt marsh	$46,000	$24
Fort DeSoto *Pinellas County, FL*	Causeway/Bridge	1,140	Mangrove, soft bottom, seagrass	$1,600,000	$1,403
Don Pedro *Charlotte County, FL*	Road construction and dredge-fill/ Culvert and scrape down	32	Mangrove, salt marsh	$104,800	$3,275
Clam Bayou *Sanibel Island, FL*	Causeway/Box culverts	290	Mangrove, oyster, seagrass	$1,000,000	$3,448
Tarpon Bay *Naples, FL*	Causeway/Box culverts	360	Water column	$1,300,000	$3,611
Wildcat Cove *St. Lucie County, FL*	Culverts	100	Mangrove, upland	$84,000	$840
Sandpiper Pond *Murrels Inlet, NC*	Sedimentation/Breach	35	Salt marsh	$81,000	$2,314