Returning the Tide

A Tidal Hydrology Restoration Guidance Manual for the Southeastern United States

NOAA

NOAA Restoration Center

and

NOAA Coastal Services Center

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Tidal Hydrology Restoration Guidance Manual

Editors
Leslie Craig, *NOAA Restoration Center*
Krista McCraken, *The Baldwin Group / NOAA Coastal Services Center*
Howard Schnabolk, *NOAA Restoration Center*
Bethney Ward, *NOAA Coastal Services Center*

Contributors:
Melanie Gange, *NOAA Restoration Center*
Mary Swift, *IM Systems Group*

Design:
Milena Viljoen, *IM Systems Group / NOAA Restoration Center*

NOAA Restoration Center *and*
NOAA Coastal Services Center

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LETTER TO THE READER

Along our coastlines, tidal waters have a profound effect on the surrounding landscape and nearby natural and manmade communities. As the tides move through estuaries, water shapes the habitats that provide many services for coastal areas—seagrass habitat that provides refuge for numerous juvenile fish species, salt marsh and mangrove habitat that protect and fortify the shoreline, oyster habitat that filters pollutants. Over time, however, the natural ebb and flow of tidal hydrology around the country has been modified by human development and manmade alterations to the land.

In the Southeastern United States, the restriction and blockage of tidal flow in estuarine ecosystems has resulted in the degradation of thousands of acres of habitat. Activities to impound, dredge and fill estuaries were common in the mid-1900's. In some cases, canals, levees, dikes, causeways and roads were built around and directly through the salt marsh, seagrass, mangroves and oyster reefs that once flourished along the coast. Many examples exist where there was no consideration for preserving tidal flow, resulting in a complete absence of tidal influence into the system. In other areas, some degree of tidal influence was preserved but with restrictions that altered habitats. Altered hydrology has changed the dynamics of entire tidal ecosystems, degrading them or leading to loss of important habitat.

This long history of tidal restriction and vast degradation in the Southeast has created the need for restoration and an opportunity to make a positive impact on an ecosystem-wide scale. Removing barriers and enhancing tidal flow can often naturally restore entire estuarine habitats, and crucial ecosystem services. Tidal flow projects often have a relatively small construction footprint but have a large beneficial impact on the surrounding areas, resulting in extremely cost-effective, estuary-wide restoration.

To improve on techniques and share best practices for tidal hydrology restoration in the Southeast U.S., the National Oceanic and Atmospheric Administration (NOAA) created this manual to focus on "returning the tide". In January 2008, NOAA hosted a two-day *Tidal Hydrology Restoration: Breaking Down Barriers* workshop in Charleston, South Carolina to discuss multiple aspects of tidal hydrology restoration. More than 70 experts, practitioners and coastal managers participated in the event, sharing their expertise and recommending new and established methods. This manual expands upon the Proceedings from the workshop through literature reviews, case studies, and consultation with the experts.

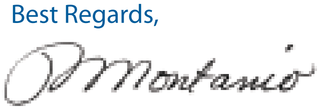
Tidal Hydrology Restoration: Returning the Tide offers guidance to restoration practitioners and coastal resource managers who may not have familiarity with tidal hydrology restoration techniques. Specifically, this manual will help users:

- Identify restoration projects and partners;
- Develop appropriate objectives and quality project design;
- Define and implement construction and maintenance strategies;
- Navigate and optimize the permitting process;
- Determine the meaning of "hydrology restoration success"; and
- Build community support for projects and address typical community concerns.

Unique features of the manual include the *Toolkit* and *Project Portfolios.* The *Toolkit* section is a resource for restoration project planning and implementation. It is designed to be easy-to-use by providing checklists, agency contact information, example project documents, and bulleted to-do lists for every stage of project implementation. The *Project Portfolios* provide details on 13 real-world projects including background, results, and lessons learned. They also reference supporting documents such as financial documents, scopes of work, designs, and permitting information to serve as examples. Projects included in this section are highlighted as examples and case studies throughout the manual. All of the information in this manual can also be found online at *http://www.habitat.noaa.gov/partners/toolkits/tidal_hydro.html*. Resources found in the *Toolkit* and *Project Portfolios* can be downloaded and used in a more interactive way from the online version.

NOAA's strategic plan includes our objective to promote healthy habitats that sustain resilient and thriving marine resources and communities. Returning the tide to estuarine habitats that have been degraded by tidal hydrology modifications in the Southeastern U.S. will help to accomplish this objective, which is even more critical in the face of climate change. NOAA hopes that this manual, and the accompanying on-line resources, will serve as a powerful tool for moving this important restoration technique forward throughout the Southeastern U.S.

Best Regards,



I. **RETURNING THE TIDE:** *GUIDANCE MANUAL*

The goal of this manual is to increase and improve habitat restoration in estuarine environments impacted by the creation of barriers to tidal hydrology. The chapters that follow provide guidance to restoration practitioners and coastal resource managers on the multiple aspects of project implementation.

II. RETURNING THE TIDE: *PROJECT PORTFOLIOS*

The Project Portfolios provide consistent and easily compared information on project-specific components (such as background, goals and lessons learned). Each Portfolio also includes a preview of project documents, including design drawings and permits, available for download in the online version of this manual.

III. **RETURNING THE TIDE:** *TOOLKIT*

The Toolkit provides resources for the multiple phases of project planning and implementation. It includes easy-to-use checklists, agency contact information and summaries of tips from the manual. Many of these tools are available for download in the online version of this manual.

Guidance Manual

for Tidal Hydrology Restoration Projects

Providing guidance to restoration practitioners and coastal resource managers on the multiple aspects of tidal hydrology restoration project implementation.

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

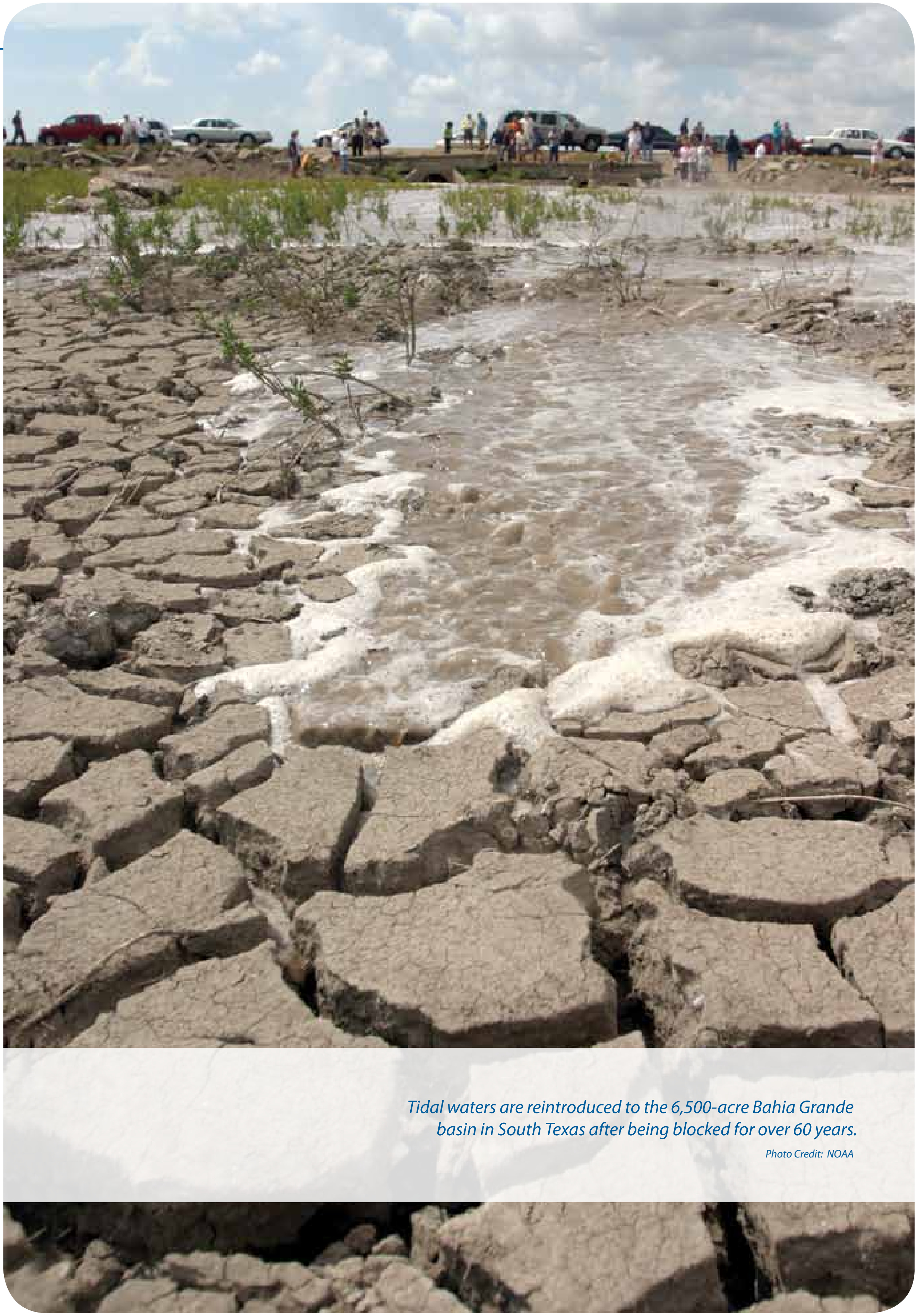
Estuarine habitats such as salt marshes and seagrasses have been adversely impacted by historic tidal hydrology modifications and tidal restrictions. On the east coast of Florida alone, nearly 40,000 acres of coastal marsh are impounded (Rey and Kain1990). In Louisiana, more than 91,000 acres of state 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

Chapter 2: **Project Identification, Feasibility, and Planning**

Project identification is the first step in the strategic planning process. Before spending significant time and resources on a project, restoration practitioners should be able to identify the biological importance and likelihood of restoration success at potential project sites (Battelle 2003). An initial feasibility analysis should also be performed that evaluates how the local or state political climate, permits, funding, or community acceptance might support or impede a project. As project planning proceeds, a team should be assembled that is knowledgeable of the opportunities, complexities, and potential pitfalls of the project. Finally, the development of partnerships and consideration of funding opportunities are also important steps in planning.

This chapter introduces the steps and tools needed to identify tidal hydrology restoration sites and to conduct initial feasibility analysis and project planning. It includes discussion of:

- Recognizing a restoration opportunity;
- Regional-scale planning;
- Characteristics of a potential tidal hydrology restoration site;
- Evaluation of project feasibility; and
- Project identification, feasibility, and planning highlight project: St. Vincent Island Estuarine Habitat Restoration Project, Apalachicola, Florida.

Much of the information in this chapter is a compilation of the experiences of restoration experts and cited literature. Additional project identification, feasibility, and planning resources and summary recommendations can be found in the ***Toolkit*** (page 166).

Opportunistic Action vs. Regional Planning

Identification of a project site can result from **regional strategic planning** or a **discrete opportunity**. Discrete restoration opportunities may arise from a variety of circumstances, such as natural disasters and changes in industrial or commercial land use. Due to potential tax benefits and improved public relations, land owners may also be compelled to donate land or establish conservation easements that may provide a restoration opportunity. At a smaller scale, private landowners often allow for habitat restoration on their land to increase property values or to exercise environmental stewardship.

While discrete opportunities can springboard successful projects, strategic planning helps prioritize regional restoration efforts, allows for widespread restoration support, and may focus available funding on projects that meet larger spatial and temporal goals and objectives. The purpose of long-term regional planning is to develop a strategic plan that identifies ecosystem-based needs, goals, and priorities. Planning at the regional level typically requires an in-depth process that is vetted through local experts, stakeholders, and resource managers. Long-term restoration must be an ongoing process whereby restoration implementation becomes a continuing series of management decisions (Steyer 2000). Comprehensive restoration strategies also lead to the development of long-term expected outcomes, which can instill a sense of commitment and inspire confidence in the local community and potential funding organizations.

An example of a comprehensive, long-term, regional approach to coastal restoration is the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) Program. The CWPPRA program has been a catalyst for large-scale changes in ecosystem-level resource management. The program is mandated to: maintain an interagency Task Force to steer operations; implement intensive planning for the development

Resource managers at St. Vincent National Wildlife Refuge utilized a hydrology study, completed by the U.S. Geological Survey, to identify and prioritize sites in need of hydrologic restoration.

Photo Credit: USFWS

of restoration strategies; develop and implement restoration projects; and implement a comprehensive monitoring program to evaluate the effectiveness of projects. By coordinating efforts, CWPPRA has minimized redundant efforts and conflicting goals, thereby maximizing the long-term productivity of Louisiana's coastal wetlands (Steyer 2000).

For more information about CWPPRA monitoring, see **Chapter 7: Scientific Evaluation and Monitoring**

When planning at a regional scale:

- *Be flexible.* Make the project scale and timeline compatible with concurrent priorities for the larger community.
- *Be open to the public.* Organize public forums to identify priorities and encourage buy-in from a wide range of groups.
- *Be strategic.* Examine the interests of all stakeholders and consider project components that lend themselves to strategic partnerships, leveraging opportunities and public interests. (For instance, it may be important to emphasize economic benefits in terms of property values, recreation, and tourism.)
- *Think broadly.* Advocate for the broadest ecological benefits possible and do not be stifled by political boundaries or by a focus on managing an individual species.

Identifying Sites for Tidal Hydrology Restoration

Structural alterations. Site identification begins by recognizing structural alterations that impede tidal flow. Usual culprits of impeded flow include failing or inadequate culverts, dikes, levees, causeways, and landfills that were implemented without full consideration or understanding of ecosystem impacts. These structures may have initially been installed to enhance the site, but have since lost their functionality and may be damaging ecosystem health. Such structures may need to be removed or re-engineered.

Ecological change. Site identification may also occur through observation of physical and ecological shifts in the associated landscape. These shifts may be observed before the tidal obstruction is apparent. Shifts in an area's ecological health may be evident through singular biological incidents such as fish kills or sudden drops in fisheries harvests. Other distinct events include widespread vegetation die-offs, recurring algal blooms, or invasive species proliferation.

While unique events are relatively easy to observe and document, gradual ecological shifts may also be an indication of ecological impairment due to loss of hydrologic function. Whether ecological change is identified through casual observation or specific evaluation, characterization of the extent of ecological change is important. Long-term monitoring and comparison between historical and current conditions may provide the best evidence that physical alterations to the environment have resulted in ecological change. Information on past conditions can provide valuable information on impacts to the site that may affect restoration actions (Stedman 2003). ***Table 2a*** below identifies indicators of such long-term ecological changes.

A list of questions to consider when evaluating sites for tidal hydrology restoration are available in the **Toolkit** *(page 167).*

Table 2a. Long-term indicators of ecological change.

Common Long-Term Indicator	Impacts Caused by Physical Alteration
Shifts from native to non-native species	Altered hydrology may weaken native species' ability to compete with invasive species.
Shifts in fish assemblages	As physical conditions change, some fish species will prove better adapted to the new environment.
Shifts in benthic assemblages	Species dependent on specific sediment characteristics, turbidity, and water chemistry are impacted by altered hydrology.
Changes in water quality	Reduced tidal flow will alter an area's water chemistry, including salinity, dissolved oxygen, and pH.
Increased flooding and/or shoreline erosion	Blocked freshwater and tidal exchange may lead to increased upland flooding during high rain events. Altered sedimentation due to altered hydrology may increase rates of erosion.
Loss of habitat heterogeneity	Disturbed areas tend to be more homogenous (i.e. vegetation monocultures).

CONSIDER

Effects on Coastal Freshwater Systems

When identifying potential restoration sites, be cognizant that tidal hydrology restoration projects may not be prudent for every location. Breaking down coastal structural barriers inherently enhances tidal connectivity. The potential for saltwater intrusion could actually pose a threat to some low-lying coastal freshwater ecosystems. Alternatively, many estuaries would benefit greatly through improvement to freshwater flows as a means to re-establish oligohaline habitat and an estuarine salinity gradient.

Importance of Reference Sites

Comparing a potential project site to relatively undisturbed or "healthy" reference sites nearby is an effective strategy to understand the impacts of hydrology modification on many ecological indicators (Diefenderfer 2003), including water quality (salinity, dissolved oxygen content, or pH), vegetation, and nekton community composition. Comparisons to reference sites can also help define desired ecosystem services and provide targets for post-restoration monitoring.

For more about reference sites, see **Chapter 7: Scientific Evaluation and Monitoring.**

Tools for Identifying Potential Sites

Project teams can use a variety of low- and high-tech methods and tools for site identification.

In-field investigation. Few tools rival in-person identification of a potential site. While onsite, the team should locate tidal barriers such as roads, ditches, berms, and areas of impervious surface. Other considerations include adjacent land uses, tidal flow rates and timing; water quality, the presence of wetland plants or invasives, whether or not a wetland existed on site, and what factors resulted in wetland loss or degradation.

Desktop investigation. The internet can provide access to a range of resources. A great deal of site information can be rapidly gathered through government agencies or communication with area residents. Information may have been previously gathered by regional or municipal land use plans and studies. Many resource agencies can provide maps on characteristics such as topography, soil, vegetation, and floodplains. Aerial photography can also help identify an area's association with other wetlands and bodies of water, and historical photographs can provide clues to original conditions. All of these data can be incorporated into a geographic information system to aid in site identification and planning.

Geographic information systems (GIS). GIS is a data management tool providing users with an understanding of locations or events based on spatial, or georeferenced (latitude and longitude), data. GIS is used to locate specific features on a landscape, analyze relationships between features, or model landscape processes. With GIS, the team can identify, compare, and prioritize sites, and produce maps based on team-defined criteria. Products supplementing GIS applications often include:

- *Remotely-sensed imagery.* Aerial imagery provides users with a comprehensive aerial view of an environment. Color, infrared, satellite, and digital imagery also fall under this category. Comparing historic imagery with current imagery could provide evidence of landscape changes over time.

- *Digital elevation models (DEMs).* Elevation data (collected from aerial or bathymetric surveys) are critical to understanding how water moves, and thus modeling hydrology. When working with elevation data (or any other spatial data set) it is important to understand how the data were collected and created, including horizontal and vertical spacing, accuracy, and datums. This information is usually found in the dataset's metadata.

- *Maps.* Land cover, land use, and elevation relief maps can help users visualize a site and its surrounding area. Historical maps illustrate previous site conditions while current maps show existing features. Online mapping tools provide users with the capability to create maps specific to their needs.

Ideally, a project team will combine GIS data from a potential restoration site with in-field observation.

Historic charts, aerial photographs, and nautical charts like this 1938 chart of Mullet Key at the mouth of Tampa Bay, Florida (now Fort DeSoto County Park), are useful tools for identifying modifications to hydrology.

The ***Toolkit*** *contains a useful Site Identification Checklist (page 168) for examining potential restoration sites, as well as a list of GIS data portal and online mapping tools (page 170).*

Project Feasibility and Planning

Following the identification of a tidally restricted site, the **feasibility analysis** and planning stage will be initiated. Several factors must be evaluated to determine if restoration of the site is achievable, including landownership, team and partnership opportunities, funding, and permitting needs. During the initial feasibility analysis, such factors should be given cursory consideration. After satisfactory completion of the feasibility analysis, the same factors should be revisited more thoroughly during the planning stage. Ideally, multiple evaluations of the following factors should be produced throughout the project cycle.

A feasibility questions worksheet summarizing the feasibility and planning information below is available in the ***Toolkit*** *(page 173).*

Landownership/land use. Ownership of the potential restoration location will have direct ramifications on the feasibility and expedience of project implementation. Adjacent or regional land uses may or may not be compatible with re-establishing a former wetland (Stedman 2003). Publicly owned land will likely have a management plan that should be reviewed to determine opportunities and restrictions on project implementation. Privately owned land may require negotiations for purchase or conservation easement.

Land Ownership Impacts on Project Feasibility

The Clam Bayou Tidal Hydrology Restoration Project near Sanibel Island, Florida, was both catalyzed and burdened by adjacent private landowners. Landowners surrounding Clam Bayou helped finance the project and were especially active during the project identification phase. However, intense public interest in the project also resulted in a higher sale price for the privately owned land required for construction. Negotiations with the landowner resulted in construction delays and elevated project costs.

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

Questions to ask about landownership (***Toolkit*** worksheet, page 173):

- *Is the land privately or publicly owned?* Determine whether landowners might be willing participants in the restoration effort, or whether they might be willing to sell their property.

- *Is adjacent land privately or publicly owned?* Consider whether the owners of surrounding areas will be supportive of neighboring restoration.

- *Is there nearby private or public infrastructure?* Identify any infrastructure that could potentially be impacted by restoration, or that might impede construction.

- *Will landownership restrict access to the project area?* Consider whether the project construction efforts will require large equipment, and whether landownership will influence equipment use or movement. If the site is publicly owned, research the management plan governing the property to determine whether public ownership could impose any limitations on project implementation.

Project team. The project team is the core group leading the restoration project, from feasibility analysis through project implementation and subsequent monitoring. Having a well-rounded team is a key factor in determining project feasibility. While building a project team, it is important to assemble a variety of expertise. For example, hydrologists, engineers, biologists and ecologists, regulatory staff, financial experts and accountants, project managers, outreach coordinators, and volunteers may all be valuable assets to a tidal hydrology restoration project team.

The team-building process should include identifying useful skill sets and tools beneficial to project planning and implementation. For instance, it might be useful for the team to include a member with connections to local community groups or with ready access to and understanding of GIS tools, hydrological models, or previous relevant research and datasets.

The project team should include both essential members (due to cost or expertise sharing) as well as strategic members who can facilitate political and community support. Give careful consideration to the specific needs of your project (i.e., engineering needs, hydrologic needs, and biological focus). Tentatively gauge the interests and skills of potential team members. Once there is a clearer understanding of who will participate in the project team, hold a brainstorming meeting and discuss overarching project ideas.

Here are some useful steps to consider in the early stages of project team development:

- Define the project area's known problem(s) and brainstorm potential project goals and objectives.

- Discuss a variety of options or designs for addressing the problem(s).

- Discuss any potential feasibility concerns and funding scenarios.

- Consider team roles and responsibilities. Ensure that people in identified areas of expertise will be available to support the project.

- Identify and rectify gaps in knowledge, skills, and resources.

Questions to ask about the project team (***Toolkit worksheet***, page 173):

- *Does the team possess the range of skills needed to plan a project that will meet restoration goals?* Determine if the project team in place is interdisciplinary with the appropriate representation of engineers, natural resource managers, scientists, accountants, and project managers. Ensure that the project team is prepared to move forward with planning and implementation.

- *Is the team adaptive?* An effective project team will brainstorm potential opportunities as well as roadblocks in order to build in project flexibility and ensure that the project can adapt to shifts in priorities or resources.

Partnerships. Partnerships are those relationships developed with agencies, corporations, and nonprofit groups to provide support and resources to the project team through all stages of project implementation. Some partnering groups may have a relatively small role in project implementation and provide project advocacy, meeting space, or funding. Other partners may be actively engaged in project implementation and provide staff to serve as project team members. Advocacy provided by partners proves especially beneficial to tidal hydrology restoration projects where the footprint of the affected area is large, resulting in high visibility and the potential for direct impact to a wide range of stakeholders.

Questions to ask about partnerships (***Toolkit worksheet***, page 174):

- *What local, state, and federal partners are critical for providing technical support?* What agencies may already have site-specific data to inform decision-making and design? Consider private companies that have a reputation for supporting local restoration efforts. Encourage participation of organizations that may have in-house staff or equipment to help facilitate the project.

- *What local, state, and federal partners may be able to provide necessary funding or in-kind services?* Consider the technical expertise available through such agencies as well as potential funding opportunities. (See ***Potential Funding Requirements and Sources*** below for more information.)

- *What agencies or groups are vital for providing public education, advocacy and support?* Consider local non-governmental organizations (NGOs) with active members and volunteers.

Local involvement. The participation of and coordination among diverse public and private groups is a necessary component of successful restoration (RAE 2002). The most efficient and effective restoration projects are those supported by stakeholders in the local community. This includes support from local residents, nonprofit groups, state and federal agencies, local planning boards, politicians, academics, contractors, and others. One project example emphasizing these ancillary benefits is the Bahia Grande Tidal Hydrology Restoration Project in Texas. Tidal flow to the Bahia Grande basin had been severed, resulting in a vast dry area that was the source of frequent and harmful dust storms that impacted the health of local residents. Returning tidal flows to the area restored 6,500 acres of tidal wetland while also alleviating a source of major health problems and their associated expenses.

For more information about building public support for tidal hydrology restoration projects, see **Chapter 8: Community Support**

Questions to ask about local involvement (***Toolkit worksheet***, page 173):

- *What is the project influence area/geographic extent?* Understanding the geographic extent of the project will help identify both the potential impacts to the local community and all potential stakeholders.

- *Have you consulted project stakeholders?* Make sure to include potential stakeholders such as project partners, landowners, and the interested or affected public during project planning and design.

Potential Funding Requirements and Sources

Though developing reasonable costs estimates can be difficult at the early stage of feasibility analysis, it is a good idea to estimate the scale of project funding required. You should consider categorizing funding needs according to stages of project implementation (i.e., identification, design, construction, etc.). You should also estimate the funding required for a few potential design scenarios (i.e., one large levee breach versus several small breaches with culverts). Contacting the project managers of the example projects included in this manual may be very useful for developing rough budgets (see the ***Project Portfolios,*** page 85).

Once the scale of funding is estimated, outline a general strategy for identifying and securing those funds (Borde et al. 2004). Below are some tips for developing a funding strategy:

- *Accomplish as much as possible with the minimal amount of resources.*
- *Consider how team member contributions will offset funding requirements.* For instance, a project with fewer partners may require hiring a consultant to handle community meetings or design and permitting. Other projects with more strategic partnerships may have team members capable of managing tasks without the need for a consultant.
- *Seek private contributions.* The most likely source is often private organizations or corporations rather than individuals. Sometimes private organizations will have funds set aside for community initiatives.
- *Consider pursuing public funding opportunities (i.e., state or county governments).* For example in Florida, the water management districts can be a source of public funding.
- *Evaluate the niche areas for different grant opportunities and apply for multiple grants.* For instance, NOAA's Community-based Restoration Program gives preference to projects that put the majority of funding toward physical implementation of fisheries habitat restoration activities. The U.S. Fish and Wildlife Service (USFWS) Coastal Program supports a broader array of project activities along the coast.

A list of organizations involved with technical and financial support for restoration is available in the ***Toolkit*** *(page 175).*

- *Approach academic institutions to discuss pre- and post-restoration monitoring ideas and options.* Undergraduate and graduate students can be a useful and cost-effective source of labor and can gain valuable work experiences for future careers through their involvement in pre- and post-restoration monitoring.

A diverse partnership of academic institutions, government agencies, and NGOs led by the Friends of Huntington Beach State Park in South Carolina successfully achieved the goal of reintroducing tidal flow to Sandpiper Pond.

Photo Credit: SC State Parks

- *Keep in mind that different funding agencies and organizations often have different missions, timing, and requirements.*

Questions to ask about funding (***Toolkit worksheet***, page 174)

- *What are the funding needs?* Determine the scale of required funding. Consider possible sources, whether from in-house capital, grants, private capital, or partnerships.
- *What funding strategies should be considered?* Determine what sources and strategies can be used to attain funding.

Regulation and permitting. Determine which agencies you will need to approach to obtain the required permits, and consider the most effective time to engage these agencies in the project process. Based on available information and team input, determine if the permitting environment will be favorable for project implementation.

Questions to ask about permitting (***Toolkit worksheet***, page 174):

- *What permits may be required?* Assess whether the permits are reasonably attainable and estimate the general time frame for receiving local, state, and federal authorization.

See **Chapter 5: Permitting** *for more on permitting tidal hydrology projects.*

PROJECT HIGHLIGHT

St. Vincent Island Estuarine Habitat Restoration Project

St. Vincent National Wildlife Refuge, Franklin County, FL

St. Vincent National Wildlife Refuge (NWR) is a 12,000-acre barrier island located near Apalachicola Bay, Florida. The island is characterized by upland, freshwater, and estuarine habitats. Prior to becoming a NWR, the island was subjected to major hydrology modifications through the construction of 90 miles of road, largely put in place for private hunting expeditions more than 40 years ago.

In 2000, the U.S. Geological Survey (USGS) completed a map report titled *Assessment of the effect of road construction and other modifications on surface-water flow at St. Vincent NWR, Franklin County, Florida*. In this report, USGS comprehensively evaluated the effects of road construction and identified priority restoration options to accomplish surface water–hydrologic wildlife habitat improvements. Field data collection was used to identify areas of road construction and other modifications that may have altered surface-water flow. The sites investigated were (1) road crossings that block creeks (2) road crossings or ditches that connect adjacent creeks; and (3) road crossings that could block saltwater movement in the creeks near the coast. Water flow and water conductivity measurements were collected at these locations and were used to generate a strategic plan for hydrology management and restoration. The goal of the NWR is to use this report to reduce the expanse of roads on the island by 50 percent.

In 2008, the NWR and its largely volunteer workforce implemented part of the plan. An estimated 1,925 acres of estuarine marsh is benefiting from the scrape-down of 4.6 miles of roads historically created on berms through the marsh, the construction of four low water crossings on one remaining 4.2 mile road, and the installation of a culvert under the road bed.

For more information on this project, see the **St. Vincent Island Estuarine Habitat Restoration Project Portfolio** *(page 104).*

Top:
Roads constructed through the estuarine marsh altered tidal hydrology on St. Vincent Island National Wildlife Refuge near Apalachicola, FL. A series of activities, including road removal and the installation of a low water crossing and multiple culverts, were identified and implemented to restore estuarine tidal influence.
Photo Credit: NOAA

Left:
Resource managers at the National Wildlife Refuge conduct an on-site project planning meeting.
Photo credit: USFWS

Chapter 3: **Goals and Objectives**

Goals and objectives (G&Os) are the foundation for all restoration projects. Developing good goals and objectives entails the careful consideration of site-specific characteristics. Often, restoration goals and objectives are shaped not only by the ecological conditions at the site but also by stakeholder interests in the project. Identification of goals and objectives directly informs the project design, construction, and scientific evaluation and allows for a more efficient and focused restoration process.

This chapter of the manual includes discussion of:

- The importance of goals and objectives;
- Methods for establishing goals and objectives;
- Common tidal hydrology restoration goals and objectives; and
- Goals and objectives highlight project: Hopedale Tidal Hydrology Restoration Project, St Bernard Parish, Louisiana.

Additional resources for goals and objectives, as well as a summary of recommendations from this chapter, can be found in the ***Toolkit*** (page 176).

Stakeholder Interests Impact Restoration Goals and Objectives

Goals and objectives of the 15,100-acre South Bay Salt Ponds Project in California have accommodated a range of stakeholder interests. Many project partners focus on bird habitat restoration; NOAA is primarily interested in fisheries habitat, while other stakeholders advocate public accessibility. An example of how these divergent interests were incorporated into the goals and objectives was the creation of areas with varying water depths to support targeted bird and fish species, as well as a range of associated recreational activities.

For more information on setting goals with partners, see **Chapter 2: Project Identification, Feasibility, and Planning**

Importance of Goals and Objectives

Clear goals and objectives provide the project team with the appropriate boundaries necessary to make decisions about the project and to expand the number of alternatives available to achieve the objectives (Steyer 2000).

However, establishing goals and objectives is often overlooked (National Research Council 1992, 1994) due to the misconception that all project team members have the same vision of the restoration project outcomes. However, given the range of potential partners, it is likely that the project team will have divergent interests.

Project G&Os should be referenced during all phases of implementation, as they establish the project priorities and intended outcomes. Failure to define G&Os can result in a number of obstacles to project efficacy and efficiency that will resonate from project design through construction and scientific evaluation.

Why are G&Os important to the design phase?

Goals and objectives:

- Aid in comparison of alternative design scenarios by helping the team create an effective cost-benefit analysis and choose the best design to achieve desired project outcomes.
- Help avoid confusion and disagreement among project team members when choosing a project design.

Community residents, frustrated with declining conditions at Bishopville Pond in Worcester County, MD, teamed up with resource professionals to develop goals and objectives that eliminate aesthetic and water quality issues while restoring tidal flows beyond the existing dam..

Photo Credit: © Google 2007; Satellite imagery by U.S Geological Survey

- Allow for a more efficient design process, saving time and reducing project costs. Communication between the project team and the designer or engineer will be more efficient.

- See ***Chapter 4: Project Design*** for more detail.

Why are G&Os important to the construction phase?

Goals and Objectives:

- Aid in making decisions about the most appropriate on-site design modifications. Delayed decisions can increase costs. Misguided decisions can impact project outcomes.

- Allow the construction contractor to participate in construction modifications through an improved understanding of the desired project outcomes.

- Help the project team choose the appropriate parameters to measure during the as-built monitoring (See ***Chapter 7: Scientific Evaluation and Monitoring***).

- Allow for **adaptive management** approaches for projects, or "learning by doing" (Walters 1986), in a structured rather than haphazard way" (Thom et al. 2005). Adaptive management protocols can increase the likelihood of reaching G&Os since they allow for necessary changes that may occur during or after the construction phase (see ***Implementing Adaptive Management***, page 20). See ***Chapter 6: Construction and Maintenance*** for more detail.

Implementing Adaptive Management

Adaptive management is an iterative approach to managing ecosystems, where the methods of achieving the desired objectives are unknown or uncertain (Holling 1978; Walters 1986). Using this approach, information gained through project monitoring is incorporated into future management actions. During the project planning stage, adaptive management should be used to refine goals and objectives and make changes to design plans as necessary. In the construction stage, adaptive management should be used to evaluate the need for changes to the original plans for specific components of the project, e.g., the number and types of plants, the configuration of channels or grading, or the amount of new soil brought to the site.

The Sandpiper Pond Tidal Hydrology Restoration Project in Murrells Inlet, South Carolina, utilized adaptive management to achieve project goals. The project was originally designed to restore historic tidal flow to a small, isolated estuary by constructing an ocean inlet. After construction, it became apparent that the restored flows were inadequate to meet water quality goals. To address this challenge and meet the original water quality expectations, the project team designed and constructed an additional tidal connection in a new location.

For more information about adaptive management, see the references provided in the **Toolkit** *(page 179).*

Why are G&Os important to the scientific evaluation phase?

- Well defined G&Os will drive scientific evaluation of project outcomes. Reference sites, data collection, target values, and monitoring parameters should reflect specific G&Os (Diefenderfer et al. 2003). Since data collection should begin long before construction, the early development of G&Os is critical to implementation of a strong scientific evaluation plan (see ***Chapter 7: Scientific Evaluation and Monitoring***).

Defining Project Goals and Objectives

- The **goal**, or vision, of a project is a general statement of the desired long-term ecological or biological outcomes (IWWR 2003). A goal statement should be simple and clear. Project **objectives** should be derived from the goal statement, defining specific, measurable targets. One goal may generate multiple objectives. Worksheets to help develop G&Os are available in the ***Toolkit*** (pages 177-178). Below is an example goal statement with three specific objectives statements.

Example:

Goal:

Re-establish a tidal connection through a spoil levee in order to restore salt marsh structure and function.

Objective 1:

Achieve tidal flooding of the marsh at a periodicity and depth comparable to nearby reference marshes within six months post-construction.

Reference marsh:

Semi-diurnal flooding periodicity; average flooding depth 0.4m

Target for restored marsh:

Semi-diurnal flooding periodicity; average flooding depth 0.4m +/- 0.1m

Objective 2:

Achieve an average surface water dissolved oxygen of 7.2 mg/L within six months post construction.

Reference marsh:

Dissolved oxygen 7.2 mg/L +/- 1.0 mg/L

Target for restored marsh:
Dissolved oxygen 7.2 mg/L +/- 1.5 mg/L

Objective 3:
Create habitat for six species of fish within one year post-construction

Reference marsh:
12 species of fish

Target for restored marsh:
Six species of fish within one year

Tips for developing goals and objectives:

- Consider a wide range of project objectives and prioritize those objectives according to the needs or desired outcomes of the specific project. Prioritizing objectives can help the project team analyze the cost-benefit of various design alternatives and determine the best use of limited funds for scientific evaluation. Prioritization can also be used to develop restoration phases in the event that full funding is not immediately available to complete implementation in one phase.

- Do not define G&Os too narrowly. Narrow objectives may result in a project that inadvertently slights one ecological function in favor of another. For example, a culvert of a certain size may be adequate to inundate an area of land, but may not be appropriately sized to allow for fish passage. Blending multiple objectives may result in wider constituent support.

- Consult local stakeholders when defining G&Os. Salt marsh restoration goals should reflect perceptions and values of residents, especially in areas of high population density (Casagrande 1997). Scientific working groups, regional planning documents, universities, and community planning organizations are potential resources.

- Recognize that objectives may change over time as community values or the site itself changes. This is not to suggest that objectives should be easily abandoned, but rather that project proponents should be realistic and flexible. Prioritizing objectives early in project planning will help the project team determine which project objectives can be more easily modified verses those that must be preserved.

Meeting Multiple Objectives

Flooding of private property due to restricted tidal connection spurred the initial interest in the Little River Marsh Restoration Project in New Hampshire. A partnership between the local community and stakeholders representing fisheries habitat resulted in a project design that met multiple objectives, including fisheries habitat restoration and flood control.

For more information, see the **Little River Marsh Restoration Project Portfolio** *(page 158).*

Two side-by-side 6x12 foot culverts replaced a 48-inch culvert connecting the Little River Marsh in New Hampshire to the Gulf of Maine.

Photo Credit: UNH

PROJECT HIGHLIGHT

Hopedale Tidal Hydrology Restoration Project

Yscloskey, St. Bernard Parish, LA

The Hopedale Tidal Hydrology Restoration Project in St. Bernard Parish, Louisiana, was completed in 2004 with funding from the Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA). The total project area is over 3,800 acres with approximately 719 acres of open water and 3,086 acres of brackish and saline marsh, bottomland hardwoods, and bottomland scrub/shrub. An inoperable water control structure installed during the 1950s was adversely affecting wetlands in the project area. The reduced draining capacity of the water control structure resulted in increased depth and duration of flooding events, thereby reducing marsh vegetation and accelerating marsh loss. Extreme tides occasionally entered the project area and became impounded upstream of the structure. The failed water control structure also blocked fisheries access to the wetland.

The goals of this project were clarified early: to re-establish tidal exchange, relieve impoundment conditions, achieve a healthy hydroperiod, provide fisheries access, and reduce wetland loss rates. However, multiple project team meetings were held to identify specific objectives that would influence project design and operational procedures. Specific hydrology objectives identified were to decrease the duration of flooding events to allow high water to stand on the marsh for no longer than one week following a flood event and to mimic the hydroperiod (depth and duration) and salinity regime of a reference marsh. In regard to wetland loss rates, the objective was to maintain 99 percent of the pre-construction acres of vegetated wetland within the project area for 20 years. (Given the rate of wetland loss in Louisiana, most projects set a much lower objective.) In regard to fisheries access, the objective was to maintain or improve fisheries ingress and egress.

The project team also established a monitoring plan that evaluates most of these objectives. Three continuous recorder stations are located within the project area and two are located in reference locations. These stations record water depth and salinity. Results indicate that salinity inside the project area is less than one-half of a part per thousand lower than outside, which does not have a likely biological significance. Water depths have decreased in the project area as compared to depths prior to project construction, and the duration of flooding events meets the established objective. Comparison of the hydroperiod between the project and reference site has proven to be complicated as water depths at reference locations have increased since project construction. Results for wetland loss rates will be analyzed by comparing aerial photography collected in 2000 to photography planned for 2012 and 2022. No specific measures of fisheries utilization are being collected since it is assumed that fisheries access has improved as a result of open fish slots in the water control structure.

For more information, see the **Hopedale Tidal Hydrology Restoration Project Portfolio** *(page 98).*

Left:
The water control structure installed at the Hopedale Project in Barnard Parish, Louisiana, incorporated three flap gates and two fish gates to improve hydrology and allow for fisheries access to more than 3,000 acres of wetland.

Photo Credit: NOAA

Below:
The goals of the Hopedale project in Barnard Parish, LA, were to re-establish tidal exchange, relieve impoundment conditions, achieve a healthy hydro-period, provide fisheries access, and reduce wetland loss rates.

Photo Credit: NOAA

Chapter 4: **Project Design**

The **design phase** is initiated when the project site has been identified and the restoration goals and objectives defined. The design phase will evaluate the potential range of restoration techniques capable of achieving the desired project objectives. Design options should be continually evaluated against the project goals and objectives.

This section describes multiple design considerations, tools, and tips, including:

- Significant physical, ecological, and feasibility design parameters;
- Design techniques, application, pros and cons;
- Design considerations in context of sea level rise;
- Hydrology modeling as a tool for project design; and
- Project design highlight project: Bahia Grande Tidal Hydrology Restoration Project, Cameron County, TX.

Additional project design resources and summary recommendations can be found in the ***Toolkit*** (page 180).

Ecological and Physical Design Parameters

There are a number of key site-specific ecological and physical parameters that will influence project design (***Table 4a***, opposite). Before developing a design strategy, the project team should have a complete understanding of the historic and current ecological and physical conditions of the site. It is important for the project team to have an understanding of these parameters before the potential results of any design can be evaluated, and before alternative design options can be compared for cost-benefit analysis.

The Importance of a Site Base-Map

A site base-map that highlights habitat types, tidal streams, adjacent land uses, infrastructure, and other key physical parameters is a highly recommended tool for the project design phase (Neckles et al. 2002). Such maps provide the team with an overview for quick reference and comprehensive conceptual planning. The same map will also be useful for implementing effective monitoring or contingency plans.

Design Feasibility Considerations

Design feasibility considerations are the site-specific characteristics that most directly impact the practicality of alternative designs. Site characteristics such as sediment stability, landownership, funding, and stakeholder input can all impact project feasibility and require adjustments to design, goals, and objectives (***Table 4b***, page 26).

Once the project goals and objectives are determined, ecological and physical parameters of the site are known, a base-map is developed, and the feasibility considerations indicate there is potential for successful project implementation, the team should begin an earnest evaluation of the range of design strategies available for tidal hydrology restoration projects.

The necessity of moving all equipment and materials by barge to the island project site resulted in some unique logistical challenges for the St. Vincent National Wildlife Refuge Hydrology Restoration Project.

Photo Credit: USFWS

Table 4a. Ecological and physical site parameters critical to project design.

Ecological Parameter	Importance to Project Design
Tidal prism (range in volume of water from high to low tide)	The volume of water moving through the site under current conditions will influence design components, including size and location of breaches and tidal channels.
Flow velocity	Flow velocity will influence design options with regard to appropriate sizes for breaches or culvert structures.
Salinity regime	Salinity strongly influences distribution of plant and animal communities as well as soil characteristics. Understanding the current salinity regime will aid in developing appropriate targets for post-restoration salinity regimes. Soil or interstitial salinities should also be investigated for proper plant selections.
Tidal footprint	The expanse of area currently influenced by tidal inundation is important information for engineering and modeling efforts. Effects should be modeled for both the existing and projected areas of influence (including trends in sea level rise). It is possible that negative impacts could result from redirecting water flow from its current location.
Freshwater inflows (surface and ground)	Sources, locations, and volumes of freshwater inflows will influence the ecological function in a restored site and must be considered during the design. They will also influence water retention within the site and potential flooding concerns of adjacent property.
Surface elevation	The topography and bathymetry within and around the site will impact the movement and location of water, influencing soil types, plant and habitat types. Project design may entail alteration of existing elevations, as appropriate, to meet goals and objectives. It should also account for any local trends in land subsidence.
Plant communities	Locations and types of plant communities provide insight into soil characteristics and typical flooding patterns. Locations of exotic and native species should also be considered. It may be desirable to design a project that preserves native plant communities (especially coastal upland, maritime forest, and high marsh plant communities – see ***Designing for Sea Level Rise*** on page 30).
Species composition (faunal and vegetation, threatened and endangered)	Vegetation and faunal community composition will be a critical factor in the permitting phase of the project. It is important to understand the community composition so potential impacts of a design can be analyzed prior to submitting permitting applications.
Soil characteristics	Soil characteristics will provide insight into current flooding patterns and can be useful in researching any potential historic soil contamination. Historic data may also help the project team locate the best location for restoring tidal connections or wetland communities based on former hydric soil locations. Soil characteristics are also a critical engineering factor in terms of stability, subsidence, and seepage which could affect structural design and support.
Climate	Seasonal wind and barometric pressure, frequency of droughts and storms, etc. can affect hydrological patterns and wetland survivability. Having an understanding of the local seasonal extremes may be helpful in designing projects.
Adjacent lands	Land cover, use, and ownership of adjacent lands are important design considerations. Land cover (and habitat functionality) will directly influence the ecological outcomes at the project site. Landownership (private or public) and use may provide for a range of design considerations, including public access, adjacent development activities, and future downstream and upstream impacts to the project site.

Table 4b. Key feasibility considerations for project design.

Feasibility Considerations	Importance / Implications
Accessibility for construction equipment	Site location is critical to accessibility of construction equipment. Carefully consider sites on islands, surrounded by or near highly sensitive environments, surrounded by private property, or surrounded by or composed of very soft/wet sediments. These factors can limit or impede project construction and equipment accessibility. Alternatives to typical heavy equipment construction methods may be warranted. For more on construction considerations, see ***Chapter 6: Construction and Maintenance***.
Sediment stability	Sediment stability can impact site accessibility, as well as permitting and turbidity concerns during and following project implementation. It is also important in terms of supporting hard design features such as water control structures. Analysis of sediment samples may be required.
Private landowner and leaseholder issues	Consider landownership and use of both the project site and surrounding land, as well as any effects of the project on landowners and leaseholders, and vice versa. Consider engaging a real estate attorney to address these issues.
Cost and funding availability	Certain designs may be possible, but not practical in terms of cost-benefit analysis. An evaluation of potential funding opportunities may help establish achievable funding ranges.
Timing	The time may or may not be right to pursue restoration at a specific project site. For instance, a specific design may be the best and only reasonable alternative for a site; however, the opportunity to pursue restoration may have to wait for certain issues to be resolved (i.e., permitting concerns, political climate, landownership, development pressures, or pending funding opportunities).
Stakeholder input and concerns	Local residents, the larger community, and other stakeholders may have some specific concerns or interests that must be considered in the project design phase. Frequently, project design can be modified based on public input, but still achieve the stated goals and objectives of the project.

CONSIDER

Location Effects on Project Feasibility

Equipment accessibility to St. Vincent's National Wildlife Refuge was the biggest hurdle to restoring nearly 2,000 acres of estuarine marsh at this site. The Wildlife Refuge is located on an island only accessible by boat. The remote location of the barge docking site in relation to the project, in addition to weight limits on the barge, complicated transport of equipment and materials. Considerations such as these directly impacted feasibility and logistical planning.

Active and Passive Design Strategies

We propose that design strategies for tidal hydrology restoration projects can be categorized as either passive or active. **Passive design strategies** entail a one-time action resulting in a self-sustaining system with little long-term intervention. Tidal hydrology restoration projects of this type typically have a relatively small area of construction activity to reintroduce or enhance tidal flow, allowing a larger area to restore naturally over time. Passive approaches are most appropriate when the degraded site still retains basic wetland characteristics and the source of the degradation is an action that can be stopped. The benefits of passive design methods include low cost and a high degree of certainty that the resulting wetland will be compatible with the surrounding landscape (Stedman 2003). For example, the Fort DeSoto Tidal Hydrology Restoration Project in Pinellas County, Florida, removed a section of causeway and replaced it with a 40-foot span bridge. This action and small footprint of work resulted in the enhancement and rehabilitation of 1,000 acres of seagrass with no hands-on restoration work in the seagrass habitat.

Active design strategies entail more intensive construction activities and are typically characterized by the active operation of structures and regular long-term maintenance needed to achieve project goals. One benefit of active management of projects is that it provides the project team flexibility to manipulate restoration sites over time (Steyer 2000). Examples of active design strategies include the installment of a water control feature such as a tidegate, tidal creek creation, or other major land alterations.

For more details on tidegate installation and tidal creek creation, see the **Hopedale Tidal Hydrology Restoration Project Portfolio** *(page 98) and the* **Little River Marsh Restoration Project Portfolio** *(page 158).*

Sometimes, when a wetland is severely degraded or when goals cannot be achieved in any other way, an active strategy is the only realistic and effective approach. However, passive strategies should be the preferred approach when possible. Even a passive or unmanaged design may require active management initially, but it will ideally evolve to demand little to no active involvement in perpetuity. Keep in mind an individual project may contain both active and passive elements.

When evaluating each design strategy, project managers should consider the life span of each project design technique. For example, after installing a tidegate to manage the hydrologic regime, how long will it function before needing replacement? Certain design strategies will need more frequent monitoring, repair, or replacement. Be sure to incorporate these considerations into the project's long-term design and construction maintenance plan.

For more on incorporating design considerations into construction and maintenance, see **Chapter 6: Construction and Maintenance**

Table 4c on the next page includes a variety of tidal restoration design strategies, a description of when these might be applied, and the pros and cons of each strategy.

Design Strategies and Societal Interests

Societal issues may also be a factor in determining the extent to which you pursue an active design strategy. For example, many areas on the east coast of Florida were impounded for mosquito control in the 1950s and 1960s. The need for mosquito management is still relevant today and restoration of these impoundments often incorporates water control devices and time-of-year operating plans – both of which are examples of active design strategies.

For an example, see the **Wildcat Tidal Hydrology Restoration Project Portfolio** *(page 140).*

Table 4c. Design strategies, application, pros and cons.

Design Strategy	Application
Culvert Placement (Passive)	Useful in situations where water flow has been restricted but passage over the flow point is still required (i.e., roads, walking paths). Multiple culverts can be strategically placed around the site or grouped together. For shallow water sites with the goal of re-establishing sheet flow, multiple smaller pipes are sometimes superior because they more effectively mimic sheet flow characteristics.
Culvert Replacement or Repair (Passive)	This design strategy is typical in situations where the earlier placement of culvert(s) failed due to breakage or inadequate size.
Bridge Installation (Passive)	Useful in situations where water flow has been restricted, but passage over the flow point is still required (i.e., roads, walking paths). Typically this method is used only for small-scale footbridges (inexpensive and easily engineered) or large-scale bridges. Medium-scale projects would likely use a culvert(s) since they are less expensive and easier to engineer than bridges.
Barrier Breach (i.e., holes in the levee) (Passive)	Appropriate for impounded areas where foot or vehicle passage is not required across the impoundment edge (but might be required in some locations around the site). Multiple breaches may be placed strategically around the impoundment and aligned with tidal creeks.
Barrier Removal (i.e., degradation of the entire levee wall) (Passive)	Appropriate for impounded areas where foot or vehicle passage is not required around the site. Especially appropriate in locations where an earthen impoundment was created using borrowed materials from the interior site. Refilling those interior borrow areas with the degraded levee wall will assist in achieving elevation targets.
Ditch Filling or Plugging (Passive)	Used to improve and/or enhance wetland hydrology in areas that have been channelized to facilitate drainage (typically for agriculture and mosquito control).
Tidal Creek Creation (Passive or Active)	Used to facilitate water flow to different points throughout the site. Typically applicable to tidal wetlands. Size (width and depth) will depend on the overall size of the site, the amount of water conveyed, and the tidal range at the location. The width and depth of tidal creeks should be comparable to similar natural systems (Zeff 1999). *Tip: Use the fewest necessary to accomplish project goals.*
Mosaic Habitat Creation (i.e., the incorporation of various microhabitats into the project) (Passive or Active)	Typically applicable to larger tidal wetlands sites where it would be possible to create multiple microhabitats and transition zones.
Sediment Grading and/or Elevation Alterations (Passive or Active)	Grading may be required in sites where excess sediments have been deposited, leaving the site at elevations inappropriate for wetland function. In impounded areas, it might actually be necessary to supply additional sediments since compaction of the sediment over time often results in lower elevation than required to support wetland vegetation.
Water Control Structures (i.e., tide gates and weirs) (Active)	Appropriate for project sites where strict management of water levels is required (i.e., mosquito management, flood control, migratory fowl habitat) or seasonal impacts require the complete control of water regimes for salinity, water level, timing (seasonal objectives), or biological controls.
Broad-crested Earthen Weir (i.e., flat crested or overflow dam, earthen and vegetated) (Passive or Active)	This design strategy is typically incorporated into tidal hydrology restoration projects that seek to increase the residence time of freshwater in low salinity marsh environments, while simultaneously providing a point of overflow.

Pros	Cons
Typically less expensive than a bridge for locations where passage over the flow point is required; often an inexpensive and highly effective way to introduce or enhance flow. Easily installed. Some municipalities have the in-house capability to construct and maintain this work without contracting.	May clog with organic debris, oysters, or fouling organisms. Undersized culverts can restrict adequate flow. Velocities of flow through the restriction point may not be appropriate for fish passage. Sometimes culverts fail or break if exposed to heavy loads. There are also inevitable costs associated with maintenance and replacement .
Same as culvert placement pros above.	Same as culvert placement cons above. If failure occurred previously, consider whether this method is appropriate for the site.
Typically designed to allow higher volume of flow since bridges have less height restriction than culverts. Flow under a bridge may be less restricted than through a culvert, potentially providing lower velocities and increased fisheries access. Allows for tidal exchange between areas where culverts would not be adequate.	Bridges capable of relaying vehicles and equipment are typically expensive, requiring careful engineering and construction techniques. Bridge construction would not be feasible for most municipality in-house capabilities. Long-term maintenance and/or replacement depend on lifespan of materials.
Size of the breach can be variable. Breaches are inexpensive and generally not dependent on material availability (unlike culverts). Long-term maintenance is much lower than culverts or bridges where replacement would eventually be required.	The size of the breach must be adequate to prevent scour, and the design should accommodate for potential scour and sedimentation that would affect the planned invert of the breach.
No long-term maintenance of the wall required. Site experiences fully restored tidal flow. Elevation in borrow areas (area from which sediment was historically removed or "borrowed" to create barrier) is restored (or material can be used to create some transitional high marsh or mosaic habitats).	More expensive than individual breaches of the wall due to handling of soil. Equipment access impacts may be too great to justify complete removal.
Extremely cost effective means to rehydrate large areas.	Must closely model the impounded areas to ensure adjacent property owners will not be directly or indirectly impacted by standing or flood waters (creating wetland communities adjacent to property owners is also a concern).
Facilitates fisheries access into the wetland site and the habitat edge preferred by many species. Facilitates flood and ebb into the site. Also provides avifaunal habitat.	If not properly designed, tidal creeks can fill in with sediment or organic debris. Sheet flow through a wetland is also important, so too many tidal creeks may rapidly drain the site. Appropriate elevation and topography is critical to success. For more information see Williams et al. 2002.
Provides an ecosystem approach that allows for some natural adaptations and potential adjustments in relation to sea level rise.	Use of this design strategy can complicate the design process, as it requires a more careful consideration of short-term management to ensure that invasive vegetation does not exploit some areas.
Sediment grading is typically inexpensive. Can use over-burden to create some transitional high marsh and upland areas.	Adding or removing sediment can be expensive due to material handling costs, and quality soil may not be readily available. Also, the organic content and salinity of the source material must be closely monitored to ensure site objectives. Determining elevations appropriate to support objectives is critical to project success.
Allows for tidal flow and fisheries access during times of year when other issues are not of concern (examples listed at left).	An active management plan is required that describes how and when the water control feature will be operated and who will be in charge of operation and maintenance. Water control structures have a shorter lifespan than other options (due to mechanical complexity). Depending on the management plan, ecological succession within the site may not closely mimic natural conditions and value as fisheries habitat may be compromised.
Low cost to construct. Allow for increased residence time and distribution of water-mimicking sheet flow conditions; virtually maintenance free.	Weirs must be constructed at precise elevations to achieve desired effects. A weak point in the weir could breach and must be built to withstand infrequent (but likely) major rain fall events and water flows; may require use of geoweb materials.

Designing for Sea Level Rise (SLR)

The Intergovernmental Panel on Climate Change (IPCC) has estimated that global SLR (the vertical change in mean ocean level) is occurring at the rate of approximately 1.8 mm/year and will increase to about 3.8 mm/year by 2100 (Meehl et al. 2007). Along most of the Southeastern U.S. coast, the rate of relative SLR will be even greater than the global rate because the elevation of the land is decreasing due to subsidence at the same time that the ocean levels are rising. As a result, rates of relative SLR along the Southeastern U.S. ranged from approximately 3 to 3.5 mm/year during the 20th century (Titus and Narayanan 1995) and likely will accelerate as SLR rates increase through the 21st century.

Tidal wetlands, whether natural, created, or restored, have the potential to grow vertically by accumulating mineral (i.e., sediments) and organic materials (e.g., plant detritus, roots). This vertical accretion is critical to coastal habitats since the distribution of plants across the wetland landscape, and whether plants can persist in the wetland, are largely functions of the depth and duration of flooding of the marsh surface. Thus, insufficient vertical accretion (compared to rates of relative SLR) could result in losses of the functions and services provided by tidal wetlands. Other determinants of tidal marsh quantity and spatial distribution that may be influenced by SLR are the rate of marsh erosion and the potential for the marsh to migrate inland. Depending on local conditions, a tidal marsh may be lost or migrate landward in response to SLR (Shellenbarger Jones et al. 2009).

Coastal resource managers are beginning to promote, and some agencies are even requiring, that predictions about SLR at individual locations be considered in conservation planning efforts. Predicting relative SLR rates and vertical wetland accretion at any given location is a complicated process requiring expert knowledge of geomorphology and sedimentation, organic matter production and retention, sediment budgets, elevation, regional and local-scale subsidence, hydrology, climatology, and other processes/factors. Some experts believe that site-specific model projections of wetland vulnerability to SLR are quite good when information about these local factors/processes that control local accretion (in specific wetland settings) is incorporated (Cahoon et al. 2009).

While it may not be realistic to expect that all potential tidal hydrology restoration projects will have data, models, and resources to make such predictions, there are some effects of SLR that should generally be anticipated and incorporated into tidal hydrology restoration designs.

- **SLR could have secondary effects on the tidal hydrodynamics of coastal and tidal estuaries, inlets, and sounds.** If SLR results in an increase of tidal flow at the entrance, an increase in the tidal range (higher highs and lower lows) and tidal currents could result. The degree of tidal range changes will also be influenced by changes in channel depths or widths, potentially brought about by SLR and other processes (Nicholls et al. 2007). If anticipating changes in tidal range, consider incorporating extreme edge elevations into design plans that are slightly higher and slightly lower than would be the appropriate targets for today.

- **SLR will result in increased frequency and duration of inundation of wetland surfaces during normal tides and present day storm surges.** Yet, the coupling of SLR effects with potential climate change effects on coastal storms is an area of ongoing research. Current research does point to a potential increase in storm intensity due to climate change but not necessarily storm frequency (Trenberth et al.

CONSIDER

2007). Project designs should consider the potential for more frequent and severe storm surge flooding, especially if private property and infrastructure lie adjacent to the project site. Private parties may increasingly resist tidal hydrology restoration if concerns about property protection are not incorporated into project design.

- **Relative SLR at some locations throughout the Southeastern U.S. are already near or greater than 3 mm/yr, and the rate of SLR is expected to increase in the future.** (See NOAA's Sea Levels Online web site at http://co-ops.nos.noaa.gov/sltrends/index.shtml). When possible, especially for larger sites, incorporate gradual slopes and a mosaic of habitats to allow for on-site habitat migration as a hedge against SLR. Incorporation of freshwater, upland, high marsh, and transition zones might allow the site to be more adaptable to changing conditions. This means that you also need to be aware of surrounding land use conditions such as expanses of impervious surfaces that may inhibit habitat migration.

Top:
The red areas above identify a large expanse of Coastal Louisiana that may be susceptible to a 1 meter rise in sea level.
Map by Weiss and Overpeck, University of Arizona

Below:
Modeled sea level rise at Waterfront Park in downtown Charleston, South Carolina. Using CanVis, an image (left) was modified to demonstrate the potential visual impacts of sea level rise (right). CanVis is a free and easy-to-use software program that can help coastal professionals generate visualizations to show the potential impacts of coastal change and development on their communities
Photo Credit: NOAA

Hydrology Modeling in Project Design

Hydrology models are simplified, conceptual representations of a part of the hydrologic cycle including water distribution, movement, and quality. When applied to a restoration design, hydrology models can assist in the evaluation of potential improvements in water quality (i.e., dissolved oxygen and salinity) and habitat types (Boumans et al. 2002) associated with restoration alternatives. However, modeling can also be a complex process involving data acquisition and numerical computer methods that require significant scientific expertise.

Several modeling resources are available in the ***Toolkit*** *(page 180), including recommended modeling inputs, hydrology modeling tips, additional design resources, and hydrological modeling software summaries.*

When is a model needed?

There are a number of reasons why the project team may require a model to evaluate restoration design implications.

- The higher the risk of project failure, the greater the need for a model. For instance, if there is a significant risk that private property might flood with a flawed design – and the evaluation of alternative designs would decrease that potential – then the need for a model increases. Relative risk of project failure may also be a cost consideration. Inexpensive projects that could be easily modified using adaptive management may not require the accurate predictions of a model. However, it might be prudent to rely on some accurate models for projects with high construction costs.

- The more complex the tidal flow is in an area, the greater the need will be for a model to inform the project design.

- The greater the level of uncertainty regarding project benefits and impacts to both existing and planned water receiving basins, the higher the justification for a model.

- Permitting agencies often request modeling results to predict likely outcomes and impacts associated with more complex projects. Similarly, funding agencies may have more confidence in projects that provide modeled outputs.

What kind of site-specific data are required to develop a model?

(See page 181 in the ***Toolkit*** for recommended modeling inputs.)

- Timescale of water pulsing events at the site. This might include river switching (thousands of years), major river flooding (50-100 years), major storms (5-10 years), average river floods (annual), normal storm events (weekly), and tidal periodicity (daily).

- Bathymetry and topography.

- Typical rainfall, evaporation, and runoff.

- Predicted or relative sea level rise.

- For models with water quality prediction capability, current data on salinity, dissolved oxygen, etc. will be required.

What types of models are most appropriate to your needs?

The type of hydrological model used should depend on the scale, size, and complexity of the restoration project. Before engaging modelers and expending project resources, be sure to know what outputs you want from the model so the modeler can determine the appropriate model for your project. For instance, the team may need to know the exact footprint of the area to be flooded, the depth of flooding, and the resultant salinity regime.

Though there are benefits to hydrological modeling, modeling activities for small or simple projects can inflate design costs that might be better applied to construction or monitoring. If modeling is a requirement for securing funding, the project team may want to discuss this issue with funding agency representatives and explain how these types of requests can limit funds available for other more important activities.

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Tips for Modeling for Project Design

Dr. Hassan Mashriqui with NOAA's National Weather Service Office of Hydrologic Development offers the following advice for modeling and project design:

If a model is pursued during design, use the simplest scale model that provides the needed answers for the project. One-dimensional and two-dimensional models are likely adequate for most tidal hydrology restoration projects.

One-dimensional (1D) models are the least expensive, easiest to use, and best models for small project areas. These models incorporate information such as the tidal boundary footprint, elevation, and tidal input. However, one-dimensional models cannot characterize cross-stream conditions.

Two-dimensional (2D) models are needed to depict lateral and over-marsh flow (inputs of tide, freshwater flow, rainwater input, and evaporation).

Information on salt wedge/saltwater intrusion often necessitates the use of **three-dimensional (3D) models**, which require significantly more data than other models.

(Hassan Mashriqui, personal communication, 2009)

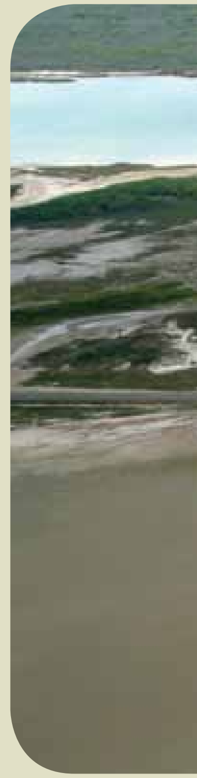
Below are some specific points of consideration when choosing the appropriate hydrology model for your project.

- The simplest scale model that is appropriate and needed for the project should be used.
- Modeling may help the project team decide between alternative project designs.
- Group discussions may be just as useful as a model in terms of predictive power.
- Project risk – or a high cost of failure – may dictate the use of modeling.
- Expensive models may be more precise, but they may not be accurate or necessary for the project at hand.
- Models can be invaluable for helping to get projects approved through the regulatory permitting process, in particularly running models for the 100-year floodplain, potential direct and secondary impacts on federally protected species, and long-term benefits to habitat areas of particular concern.
- Models must address all water input and output, at a minimum. The project team may consider a literature review to help gather these data in the particular project area.
- Bathymetric and topographic data at an appropriate resolution are needed. Recent data are often required given the ever-changing nature of estuarine environments. Models are only as good as the data used to generate them.

PROJECT HIGHLIGHT

Bahia Grande Tidal Hydrology Restoration Project

Bahia Grande, Cameron County, TX



The Bahia Grande is an 11,000-acre complex of three estuarine basins between Brownsville and Port Isabel in Cameron County, Texas. Once a highly productive shallow water system, the tidal flow was cut off in the 1930s by massive spoil banks left over from dredging the Brownsville Ship Channel. The estuarine basin began converting to a salty sand flat. The interruption of the natural hydrologic connection caused a decline in biological productivity of the tidal flats and loss of wildlife dependent on this productivity. The Bahia Grande dried up and its drifting sands caused numerous health and industrial problems for nearby communities. After several decades, a partnership was formed to re-flood the Bahia Grande and restore the health of its ecological systems and its nearby residents.

The project team began the project design process by gathering information to characterize the area. A wealth of baseline biological data was collected to help facilitate the design and evaluation processes. Native American cultural heritage sites were considered before selection of construction locations. A topographic survey was carried out that indicated most of the Bahia Grande basin lies below mean sea level and could be inundated with seawater during low tides. During high tides, storm surges, or periods of high rainfall, additional acreage would also receive tidal flow.

To help create the most efficient design, a hydrologic modeling study was conducted that examined the effects of channel design and wind effects on water flow, circulation, and the mixing needed to achieve biological productivity goals. Individual and multiple breaches and channels at different locations were analyzed. With this information, the project team adopted a passive restoration strategy that involved creating a series of channels through several barriers within the system, designed to take advantage of the normal tidal regime in the area. The small construction footprint provided a great impact to an extensive area for a relatively inexpensive cost.

The final design plan involved the construction of a 2,400-foot-long main channel that connects Bahia Grande to the source of tidal waters. Originally constructed as a pilot channel at 60 feet wide and 9 feet below mean sea level, it will eventually be widened to 210 feet. This channel was also designed so that prevailing winds from the southeast facilitate maximum tidal inundation of the basin. In addition to this main channel, other channels were created to connect Bahia Grande to two adjacent tidal basins: Laguna Larga (1,669 acres) and Little Laguna Madre (1,411 acres). These two smaller basins were also connected by a 5,000-foot-long channel to enhance circulation between the two basins. Other channels have been designed but, due to budgetary limitations and permitting challenges, they have not been constructed to date.

For more information, see the **Bahia Grande Tidal Hydrology Restoration Project Portfolio** *(page 92).*

Top:
A 2,400-foot pilot channel was constructed to return tidal flow after nearly 70 years to the 11,000-acre Bahia Grande Estuary complex in Cameron County, TX.

Below:
Before and after photos show the expansive dry basin that was reflooded when tidal waters returned.

Photo credits: NOAA

Chapter 5: **Permitting and Regulatory Compliance**

Prior to construction, projects that have the potential to impact existing physical and ecological conditions, federally managed fish and invertebrates, or protected species under the Endangered Species Act are subject to regulatory review by federal, state, or local natural resource agencies. Even beneficial barrier removal projects intended to increase tidal circulation patterns are required to undergo regulatory review to ensure the project serves the public interest while balancing a diverse set of physical, ecological, and socioeconomic criteria. Project teams should account for permitting costs and time when planning and implementing tidal hydrology restoration projects.

This chapter provides background information on specific legislation, and provides recommendations to help navigate the regulatory compliance process. Specific topics covered in these pages include:

- General introduction to federal legislation regulating tidal hydrology restoration;
- Coordination between state and federal regulatory agencies; and
- Considerations for successfully navigating the review and permitting process.

Additional permitting resources and summary recommendations can be found in the ***Toolkit*** (page 184).

Useful Acronyms

ACHP	Advisory Council on Historic Preservation
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
EA	Environmental Assessment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FMC	Fisheries Management Councils
JPA	Joint Permit Application
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWP	Nationwide Permit
RHA	Rivers and Harbor Act
SHPO	State Historic Preservation Office
USACE	United States Army Corps of Engineers
USFWS	United States Fish & Wildlife Service

An Introduction to Federal and State Authorization

The **permitting process** (***Figure 1***, opposite) requires coordination across state and federal agencies, as well as interaction between agencies and the people applying for a permit. Permitting processes and regulations vary by state and permitting issue. In general, the five permitting issues for tidal hydrology restoration projects are:

- Community development (i.e., coastal zone compliance);
- Water quality;
- Threatened and endangered species;
- Fish and wildlife; and
- Wetlands.

The permitting process is framed by federal legislation; however, oversight is generally conducted at both the state and national levels. Consequently, most permitting issues have more than one agency that provides regulatory review. For example, restoration and protection of, or impacts to, wetlands are subject to several federal and state authorizations, and therefore are regulated by several agencies. To help simplify regulation and streamline the permitting process for the applicant, federal

The use of sediment curtains to control turbidity was one of the best management practices employed to meet permitting requirements during construction of the Fort DeSoto Park Hydrology Restoration Project.

Photo credit: NOAA

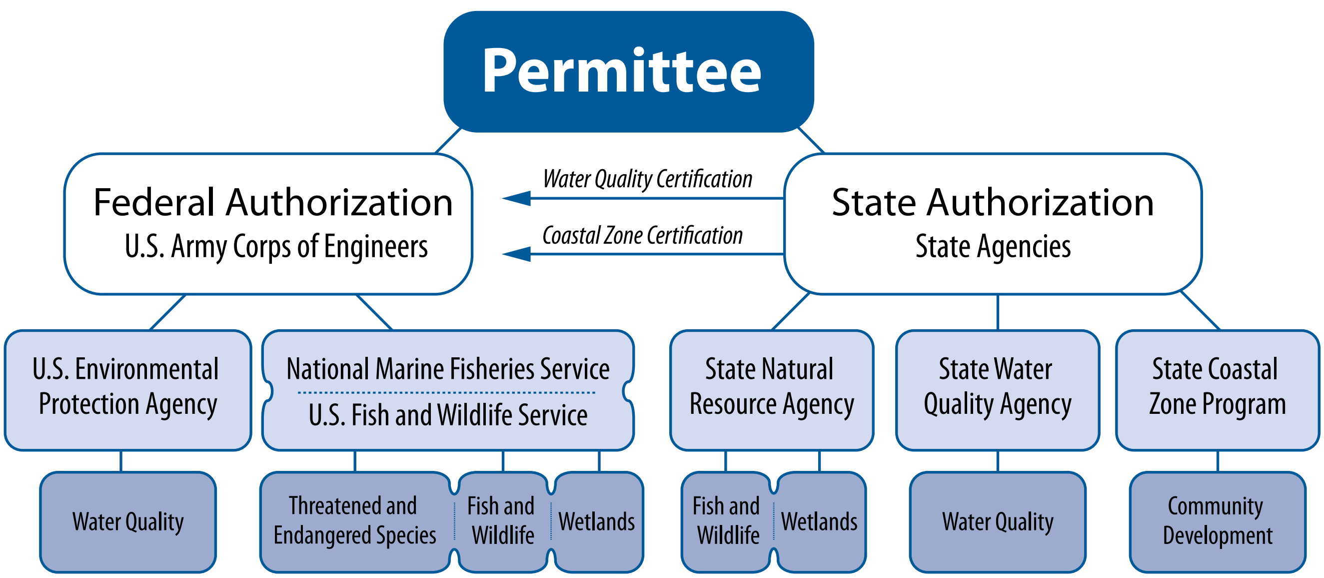


Figure 1. Federal and state permitting.
Simplification of federal and state authorities related to specific resource issues. State regulatory agencies primarily handle coastal zone compliance and water quality issues; federal regulatory agencies handle authorization related to threatened and endangered species; and both state and federal regulators handle authorization related to fish, wildlife, and wetlands.

and state agencies have developed procedures where the submission of a single permit application triggers reviews by multiple state and federal agencies, referred to as a Joint Permit Application (JPA). In order to navigate the permitting process efficiently, the project team should be familiar with the laws that dictate the regulatory process, and the role each agency plays. Below is a list of the major federal legislation typically affecting tidal hydrology restoration projects.

A list of federal policies, websites, and legislative citations is available in the ***Toolkit*** *(page 185).*

Rivers and Harbors Act and the Clean Water Act. Cornerstones of the hydrology restoration federal permitting process are the Rivers and Harbors Act (RHA) and the Clean Water Act (CWA). Compliance with these acts requires authorization from the Secretary of the Army, acting through the U.S. Army Corps of Engineers (USACE). Under the RHA, authorization is required for the construction of any structure in or over navigable waters of the United States. Under Section 404 of the CWA, authorization is required for discharge of dredged or fill material into any waters of the United States, including wetlands. In almost all cases, USACE addresses both authorizations by issuing a single permit (for example, via Nationwide Permit 27, see sidebar, opposite). However, before a permit is issued, in most cases, USACE coordinates with other federal and state agencies that have mandates to provide oversight and key contributions in their respective areas of expertise. Some of the more relevant acts that mandate the oversight roles of these federal and state agencies are described below.

Magnuson-Stevens Fishery Conservation and Management Act. This act mandates NOAA's National Marine Fisheries Service (NMFS), regional fishery management councils (FMCs), and other federal agencies to identify and protect important marine and anadromous fish habitat, known as "essential fish habitat" (EFH). Federal or state action agencies that fund, permit, or carry out activities that may adversely affect EFH are required to consult with NOAA regarding the potential impacts of their actions on EFH, and respond in writing to any NOAA or FMC EFH conservation recommendations. Where appropriate, NOAA uses existing interagency coordination processes to fulfill EFH consultations with action agencies.

Endangered Species Act. The Endangered Species Act (ESA) intends to protect species threatened with extinction and the critical habitat upon which they rely. The U.S. Fish & Wildlife Service (USFWS) administers ESA review for freshwater and terrestrial species, while NMFS administers review for marine species. Both agencies may be involved for species that migrate between habitats or spend portions of their life cycle in water and on land. Under Section 7 of ESA, federal agencies such as USACE cannot issue a permit for activities that adversely affect threatened or endangered species or their critical habitat.

An example template used for ESA consultation is available in the ***Toolkit*** *(page 186).*

Coastal Zone Management Act. The Coastal Zone Management Act (CZMA) requires that any federal action inside or outside of the coastal zone that affects any land or water use or natural resources of the coastal zone shall be consistent, to the maximum extent practicable, with the enforceable policies of approved state management programs. It states that no federal license or permit may be granted without giving the state the opportunity to concur that the project is consistent with the state's coastal policies. State coastal zone agencies provide their certification either through interagency coordination processes, the federal permitting agency or, in some instances, directly to applicants or other state agencies representing public interest in the project.

State agencies also play additional roles beyond those established by the CZMA. For example, for a project to be authorized under the CWA, it must receive a water quality certification indicating the project will not contravene established water quality standards. These standards are set by the states and the certification is provided to USACE by the state water quality agency, all with oversight from the U.S. Environmental Protection Agency (EPA).

National Historic Preservation Act. Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires federal agencies to take into account the effects of their undertakings on historic properties. Consultations with the State Historic Preservation Office (SHPO) are usually initiated through the interagency coordination process and assist in determining a project's impact on properties included in or meeting the criteria for the National Register of Historic Places. The historic preservation review process mandated by Section 106 is outlined in regulations issued by the Advisory Council on Historic Preservation (ACHP). Where tidal hydrology restoration projects take place in areas of human settlement, there exists the possibility of impacts upon historic properties or artifacts.

National Environmental Policy Act. The National Environmental Policy Act (NEPA) requires agencies to consider environmental impacts of proposed federal actions, including the issuance of permits. The analysis must include reasonable alternatives to the action. NEPA review may require the preparation of an environmental assessment (EA) to determine whether an environmental impact statement (EIS) is required. Federal agencies require EISs for actions that may have a significant impact on the environment. An EIS documents existing conditions, proposed actions and alternatives, and the impacts that may result from implementation of alternatives, including those on natural, cultural, and historic resources. EISs must go through formal, detailed public review and comment. Generally, USACE will administer NEPA analysis for a tidal hydrology restoration project. In most cases, USACE's normal coordination of the permit will satisfy NEPA's requirements so an EIS will not be necessary.

An example checklist used to guide the analysis of environmental impacts under NEPA is available in the ***Toolkit*** *(page 190).*

The Role of the U.S. Army Corps of Engineers

Any individual, firm, or agency engaged in an activity (including restoration) that involves jurisdictional navigable U.S. waters or wetlands must obtain a permit from USACE and/or the appropriate state regulatory agency. USACE supplies general permits for "minor" activities, but typically an individual, project-specific permit is required for barrier removal as part of a tidal hydrologic restoration project. The process for a general permit may take three to four months, while individual permits may require up to 12 months for completion.

What is Nationwide Permit 27?

Certain restoration actions may qualify for USACE's Nationwide Permits (NWP). These "umbrella" permits streamline review and are defined for regionally specific actions. Using an NWP allows applicants to forgo many elements of a detailed analysis typically required for individual permits. An additional benefit is the abbreviated time required for USACE project review.

NWP 27, which serves as a CWA and RHA permit, covers activities resulting in "net increases in aquatic resource function and services"; however, multiple conditions must be met to apply. Pre-construction coordination with USACE is required, as differences may exist depending on regional conditions.

Activities authorized by NWP 27 include but are not limited to:

- Removal of accumulated sediments;
- Installation, removal, and maintenance of small water control structures, dikes, and berms;
- Removal of existing drainage structures;
- Installation of current deflectors;
- Enhancement, restoration, or establishment of riffle and pool stream structure;
- Placement of in-stream habitat structures; modifications of streambed/banks to restore/establish stream meanders;
- Backfilling of artificial channels and drainage ditches;
- Construction of small nesting islands;
- Construction of open water areas;
- Construction of oyster habitat over unvegetated bottom in tidal waters;
- Shellfish seeding; and
- Activities needed to reestablish vegetation, including plowing or disking for seed bed preparation and planting of appropriate species; mechanized land clearing to remove non-native invasive, exotic, or nuisance vegetation; and other related activities. Only native plant species should be planted at the site.

Building Successful Relationships with Permitting Agencies

Developing positive working relationships with permitting agency staff eases the overall permitting process, reduces miscommunication, and can increase efficiencies. Establishing a local contact within appropriate regulatory agencies can also help the team determine the appropriate permits required and the recommended process for completing permit applications. Additionally, many regional offices have applications and example permits available online.

Local contact information for USACE offices and state permitting agencies in the Southeast U.S. can be found in the ***Toolkit*** *(page 195-197).*

Coordinate early with USACE staff, as the process for securing permits varies by jurisdiction and project type. USACE and state regulatory staff are often divided between geographic areas or application type, so multiple agencies may be involved in project review. Due to the complexities of interacting with multiple regulatory agencies, time and experience are needed to master this stage of restoration planning.

Below are some tips to ease the permitting process once the team has contacted the local permitting agency and USACE office:

- Provide background information, including a detailed project description and site location prior to any formal meetings;
- Plan site visits and face-to-face meetings far in advance;
- Prepare visual aids such as PowerPoint presentations or digital maps to help communicate project details;
- Be prepared to discuss the types of permits needed through each agency, and whether supplemental information is required; and
- Provide electronic files whenever possible to ease transferability and review.

Joint Agency Meetings

Participating in a Joint Agency Meeting is recommended as an option to streamline communication between a project proponent and the many permitting agencies. These meetings allow the details of a project to be vetted by regulators in an informal setting before project plans are submitted for permits. Meetings are often held monthly and are arranged by USACE or relevant state agencies.

Aside from establishing clear lines of communication with regulatory agencies, the project team can further expedite the regulatory process by keeping permitting issues in mind throughout all stages of the restoration project planning process. A project team that anticipates opportunities and challenges with permitting early in the development of the project is likely to save time and resources. Here are some variables to consider early in project development to expedite the permitting process:

- Align restoration projects within larger regional efforts, such as a larger watershed management plan that has been developed in conjunction with the USACE.
- Determine if easements, liens, covenants, water-rights issues, cultural resources, or other parcel aspects may restrict site availability.
- Solicit public input and support early in the project design process.
- Participate in joint inter-agency meetings that involve permitting processes and collective reviews of local or regional permit requests.

Table 5a (opposite) summarizes the various permitting requirements of various tidal hydrology restoration projects in the Southeast U.S.

Table 5a. Example project permitting summary

Example Project	Federal Permitting	State Permitting	ESA/ NEPA issues	Notes
Bahia Grande *Texas*	USACE NWP 27	Environmental Assessment (EA) required due to archaeological issues	None	A contractor was hired to draft the EA to expedite the process. See the Bahia Grande Project Portfolio on page 92.
Hopedale *Louisiana*	USACE CWA Section 404	Coastal Use and Water Quality permits	None	See the Hopedale Project Portfolio on page 98.
Fort DeSoto *Florida*	USACE NWP 27	FL's Environmental Resource Permit (ERP) process coordinates state and USACE permits; SWFWMD permit	Manatee habitat	Permit to include "stop-work" order with manatee sightings. See the Fort DeSoto Project Portfolio on page 110.
Don Pedro *Florida*	USACE NWP 27	Southwest Florida Watershed Management District (SWFWMD) required significant technical and engineering data	None	The SWFWMD permit was submitted with letter requesting Nationwide Permit 27 approval; permit was issued within days See the Don Pedro Project Portfolio on page 122.
Clam Bayou *Florida*	USACE NWP 27	FL's Standard General Permit	Manatee habitat	Designed permits to provide movement for manatees See the Clam Bayou Project Portfolio on page 128.
Wildcat Cove *Florida*	USACE NWP 27	FL's Standard General Permit	None	The permitting process only took 90 days due to team's familiarity with permitting staff (compared to a typical six-month processing time) See the Wildcat Cove Project Portfolio on page 140.
Sandpiper Pond *South Carolina*	USACE CWA Section 404	SC's Department of Health and Environmental Control coordinated state permits	Project area once contained threatened species (seabeach amaranth)	Permit stipulates that no work is to occur during sea turtle nesting season. See the Sandpiper Pond Project Portfolio on page 146.
North River Farms *North Carolina*	USACE CWA Section 404	Coastal Area Management Act permit (through NC's Department of Environment and Natural Resources – DENR)	None	An Erosion Control Plan was required through the DENR's Land Quality division See the North River Farms Project Portfolio on page 152.

Chapter 6: **Construction and Maintenance**

The project construction phase involves construction preparations, actual construction, and post-construction management. During the construction phase, the project team will carry out the design, while referring back to project goals and objectives. Consulting the project goals and objectives is important for keeping construction on track.

This chapter focuses on:

- Pre-construction considerations, including selecting a construction contractor, budgeting and cost analyses, scheduling, and final plans;
- Construction implementation, including site preparation, removal or installation, and contingency planning;
- Post-construction management, including "as built" monitoring and maintenance; and
- Construction and maintenance highlight project: Sandpiper Pond Tidal Hydrology Restoration Project, Murrels Inlet, South Carolina.

Additional construction and maintenance resources and summary recommendations can be found in the ***Toolkit*** (page 198).

Pre-Construction Preparation

During the **pre-construction stage**, a project team will develop a budget and estimate costs for construction, develop a statement of work, select a construction contractor, determine a schedule, and finalize construction plans (Diefenderfer and Thom 2003). Some of these efforts may overlap with design and permitting phases. For instance, developing an initial cost estimate during the design and permitting phase allows the team to plan and provide budgets to potential funding agencies. However, once the project has reached the construction phase, the contractor may recommend modifications to the design, which may require adjustments to the permit and the project budget.

A brief outline of the overall construction process can be found in the **Toolkit** *(page 199).*

Estimating construction costs.
Costs and methods of tidal hydrology restoration projects vary widely within and between ecosystems and regional economies. Costs result from factors including project location, size, time of year or day (because of tidal regimes), site accessibility, equipment and material needs, site contaminants, earth moving, erosion control, and the amount and type of vegetation to be planted. Current market conditions will directly impact all costs. Though there are no standard construction costs for restoration, the following recommendations may be useful when developing a budget:

- *Work closely with contractors to estimate costs.* Discussions with local contractors and experienced engineers may help provide rough cost estimates expected for that area.
- *Research similar projects.* It may be helpful to start pricing based on estimates derived from other similar projects, especially if they are in the same region.
- *Leverage resources.* Pooling resources and partnering may be the most cost-effective approach to any project. In-kind contributions can help defray costs and is also viewed favorably in federal grant applications. However, having more partners also elevates the need for effective coordination and communication.

CONSIDER

Budgeting for Contingencies

Restoration practitioners along the Gulf Coast have had first-hand experience with cost increases due to weather. Hurricane seasons and resulting demand on construction resources have more than doubled some material costs. Some smaller restoration projects have had difficulty attracting competitive construction bids, given the high demand for contracting services on much larger, expensive post-storm projects. Although changes in market conditions are generally unforeseeable, budgeting for contingency may help cover unplanned cost increases.

Replacement of a portion of the causeway with a 40-foot span bridge at Fort DeSoto Park in Tampa Bay, FL, involved a range of heavy equipment including cranes, a long-arm excavator and dredge pumps.

Photo Credit: NOAi

- *Be aware that estimated costs may differ from actual construction costs* because of uncertainties about site condition and implementation.

- *Identify construction needs and incorporate realistic expectations into the budget.* If specific expertise or technologies are deemed necessary for the project, then budget for them.

- *Budget for construction and monitoring contingencies, or unforeseeable cost requirements.* This typically ranges between 15 and 25 percent of total construction costs.

Developing an independent cost estimate. There are two reasons to develop an independent cost estimate, or line item budget. First, it will assist the project team in considering costs associated with all potential aspects of the contract, which in turn, ensures that an appropriate budget has been allocated. Second, it may prove useful during contract negotiation.

Project costs can be categorized in various ways. For instance, teams can organize their budget by specific restoration tasks, restoration phase (e.g., design, construction, monitoring), construction stage (e.g., site preparation, planting,

Table 6a. Potential budget line items for construction phases.

Pre-Construction	Active Construction	Post-Construction
Baseline data collection	Mobilization	As-built assessment/survey
Site surveys	Materials (i.e., culvert, plants)	Physical and biological data collection
Phase I or II Environmental Assessment (survey for potential contaminants)	Labor (heavy equipment operators, manual labor, etc.)	Maintenance
Employee briefing/training	Construction activity (i.e., clearing and grubbing, excavation, planting)	Removal of temporary structures
Project management and oversight	Sediment and erosion control	Grant administration/ report generation
Meeting space for team and public meetings	Road demolition and repair/ traffic management	Permit-required report generation
Communications/public relations staff time	Project management and oversight	Adaptive management (if possible to budget)
Volunteer coordination/ education/outreach activities	Independent oversight and inspection	Project management and oversight
Plant Propagation (if preferable to existing nursery stocks)	Contingency costs (i.e., budget overruns, unanticipated circumstances)	Communications/public relations staff time
Development of work/ implementation plans	Non-traditional labor ("paid" volunteers)	Volunteer coordination/ education/outreach

installation/removal), or input (e.g., labor, equipment, materials). Construction budgets are most often itemized by:

- *Labor and equipment* – where the cost of labor is separated from the cost of the equipment for any given activity; or
- *Construction activity* – where the cost of the labor and equipment is included in an overall cost of the activity (e.g., excavation).

Table 6a (above) includes potential budget line items common for tidal hydrology restoration construction. Project teams should consider which of these budget items are critical and realistic to incorporate. Some may be included in a Statement of Work (see ***Writing a Statement of Work***) for any individual phase of the project for which a contractor will be hired. Project partners may also commit to certain budget items, if they have the expertise on staff to complete them.

Example financial documents, independent cost estimates, and a match analysis tool can be found in the **Toolkit** *(page 200-203).*

Writing a statement of work. The statement, or scope, of work (SOW), developed by the project team, is a narrative description of the deliverables and services required to meet the contract requirements. It provides the basis on which contractors develop proposals and bids. A SOW will be drafted for any project phase for which a contractor is required to complete a task. For instance, a SOW may be required for the design phase, the scientific monitoring phase, etc. The process described here focuses on development of a SOW for construction, but much of the process is applicable to the development of any SOW.

Construction contractors need a clear SOW in order to detail the work plan and expectations for project success. Specifically, the SOW should establish a chain of command, especially if multiple partners are involved, and require a communications plan (i.e., establishment of a main point of contact for both the contractor and the project team and a time line when communication is anticipated.). If there are any special grant, NEPA, or permit conditions to the project, they need to be specified in the SOW. Safety is also a critical consideration for construction, so the SOW should require a written safety plan for all construction related activities, including management of volunteers (if applicable). Below are some additional tips to keep in mind when writing a construction SOW.

- *Describe the project background, goals and objectives.*
- *Provide a template of the project design.* This can save time and reduce costs.
- *Include as many project requirements as possible* in the SOW to help avoid change orders on contracts.
- *Incorporate a construction activity schedule that shows required timing* (e.g., on-site construction must occur between November and March to avoid bird nesting season) and request that bid proposals incorporate a detailed scheduled of all activities. More detail is provided below in the *Scheduling* subsection (page 46).
- *Request consultations with all parties involved* at each stage of the construction process to reduce confusion, redundancy, and unnecessary costs.
- *Require all parties to visit the site before bids are submitted,* if possible. In instances where pre-bid site visits are not possible, require on-site meetings during cost negotiations.
- *Request all projected expenses to be explicitly identified by the contractor.* Consider whether to request line item cost estimates (such as those in ***Table 6a***) versus lump sum bids, and consider per hour or a lump sum for labor costs.
- *Be explicit about the tasks to be delivered by project partners* so the contractor does not budget for those tasks.
- *Reference example projects* comparable in size and scope to your project.
- *Do not be too rigid in your requirements.* Ask for and be willing to consider alternative potential techniques, design modifications, and construction methods posed by the contractor. Their previous experience could save time and money.
- *Request information on the contractor's prior experience with similar projects.*
- *Ask for qualifications of and references for key staff* to be assigned to the project and prior notification of any changes made to key staff.

Selecting a contractor. Once proposals and bids are received in response to the SOW, the team will evaluate responses to choose the most appropriate contractor. The goal is to hire a knowledgeable and experienced contractor who can provide expertise and resources not found in the initial project team. Before selecting a contractor, be sure they are bonded and fully insured. Typically, state contractor licensing boards will know if issues have been reported for a contractor. Other tips to keep in mind when selecting construction contractors include:

- *Consider hiring companies that have experienced teams* of biologists, engineers, and construction personnel.
- *Hold pre-construction meetings on-site with potential contractors if possible;* viewing the site allows contractors to prepare better bids and may reduce later bid addendums. Site visits are especially prudent for non-local contractors.

(continued on page 46)

- *Use local contractors for small-scale projects* because they will be more knowledgeable of site conditions and appropriate construction techniques for the area. However, this may narrow the pool of qualified contractors.

- *Closely evaluate any alternatives and techniques* that have been proposed by contractors: they may have some innovative and cost-effective ideas.

- *Be cautious if considering using marine contractors who specialize in building docks and bulkheads.* Their experience working in coastal areas may not be relevant to the construction of restoration projects.

Keep in mind that there may be alternatives to hiring a contractor for all phases of project construction, especially when specialized skills are not necessarily required for the project at hand. For example, consider using non-traditional labor resources such as local prison-work programs, youth corps organizations, or local volunteer service clubs. These alternatives can also help keep construction costs down.

Finding Experts

The Society of Wetland Scientists (SWS) can help project teams locate trained wetland science professionals. SWS has created a certification program "aimed at serving the public's need to identify qualified individuals to assess and manage the Nation's wetland resources." An online database is available to search for certified individuals in your city or state. The SWS Professional Certification Program also offers a Vendor Listing to help you locate "sources of state-of-the-science technology and information pertinent to wetland science."

For more information, visit http://www.wetlandcert.org

Negotiating with contractors. Once a preferred contractor has been identified, the team will enter into formal negotiations to finalize elements of the proposal and bid.

The independent estimate generated during budgeting may be a tool used to assist with negotiating cost, manpower, and expertise required for specific project elements. Two example negotiating points follow.

- The contractor may have budgeted to lease a staging site that could be provided by the project team.

- The project team anticipated (and budgeted for) one senior and one junior engineer to be on site during construction, but the bid from the contractor proposes two senior engineers (at a higher rate).

In both instances the team can negotiate anticipated requirements, roles of contract staff, and related costs. The contract is finalized when all services, deliverables, and an associated schedule are agreed upon through the negotiation process.

Scheduling. The SOW will include a rough schedule for implementation; however, this schedule will be revised through negotiations and discussions with the construction contractor and will ultimately be determined by some factors outside the project team's

Table 6b.
Construction scheduling considerations.

Construction Factor	Timing/Scheduling Consideration
Biological	Seed germination, invasive species removal, species migration or nesting seasons
Physical	Tidal regime, water flow and velocity, erosion, weather conditions
Funding	Grant cycles
Legal	Permitting, land acquisition, conservation easement
Climate	Hurricane season, wet/dry seasons
Local circumstances	Traffic volumes, tourist seasons, local events, equipment and labor availability

CONSIDER

Construction Challenges in Estuaries

Tidal hydrology restoration in estuarine or brackish environments presents several challenges to the construction stage. First, activities may need to be timed around tide levels. In many instances, construction can only take place during low tide to allow full access to the site, yet as-built monitoring may need to occur at high tide to determine if maximum flow is being achieved. Second, saltwater and sediment conditions of estuaries will play a big factor in the type of equipment which can be used at the site and for how long. For example, heavy metal machinery may sink in soft-ground conditions or rust if continually exposed to the saltwater. Although the contractor should ultimately be responsible for any damage to the site, make sure that potential contractors are knowledgeable of estuarine ecosystem characteristics and specialized equipment.

Low ground pressure equipment, characterized by wider treads to spread the weight of the machinery, is sometimes desired to reduce soil compaction. In other cases, soft tires may be preferred.

Photo Credit: NOAA

control. Such factors include the availability of funding (e.g., grant award expiration), time needed to procure required permits, and the specifications of those permits. Compliance with the Endangered Species Act (ESA), National Environmental Policy Act (NEPA), Magnuson-Stevens Act (MSA), and other permitting regulations can dictate the timing of construction. For example, regulations may prohibit in-water construction during certain seasons due to threatened species presence.

For more information on scheduling and permits, see **Chapter 5: Permitting**

Societal interests can also impact scheduling. For instance, culvert construction at Clam Bayou was completed during off-peak tourist season to minimize traffic congestion since construction impacted traffic flow to Sanibel Island, Florida.

Scheduling for biological, physical, and engineering considerations are important to take into account when constructing tidal hydrology restoration projects. ***Table 6b*** (opposite) describes some of these factors.

Developing construction plans. After entering into the contract, there are typically implementation details that need to be finalized before construction can begin. Most contractors will develop **construction plans**, or field protocols, that incorporate written guidelines for field crews to follow. At a minimum, field protocols should include (IWWR 2003):

- Descriptions of site preparation needed;
- Specifications/diagrams for construction features;

(continued on page 48)

- Descriptions of how to install features, such as culverts or plants;
- Specifications of equipment to be used;
- Inventories and locations of all plant species, if applicable;
- A safety plan and a communications plan;
- Plans to prevent construction impacts on other resources, such as a Sediment and Erosion Control Plan and a Tree Protection Plan;
- Indemnification language, in case there are accidents or damage to property;
- Plans for site maintenance during construction;
- A construction schedule with terms for terminating the construction; and
- Plans for monitoring key environmental features while construction is underway, such as tidal flow and velocity, water depth, and groundwater swells to determine if any adjustments in construction need to be made.

Construction plans, or field protocols, can be complicated, as they typically require input from hydrologists, engineers, ecologists, and community leaders. As these plans are developed, work closely with the contractor to make sure the plan is as specific and intelligible as possible to avoid confusion. Review the engineering drawings and specifications with the contractors; by doing so the team can visualize the project and understand project specifications relating to water flow/velocity, elevation, slope, erosion protection, substrata composition, and schedule. Have hydrologists and ecologists review construction plans to make sure the structures and related functions are consistent with scientific goals and objectives of the project.

Construction Implementation

Construction is the action of restoring the site, whether the aim is habitat restoration, habitat enhancement, or outright creation of new habitat. The construction phase often receives public attention because the activities are visible and community members may serve as volunteers. Construction activities for tidal hydrology restoration usually include physical alterations, such as dike, dam, or levee removal; grading; culvert installation, cleanout, or removal; channel cleaning; erosion control; and vegetation planting (see ***Table 6c,*** page 50). Construction activities can disturb and even harm the ecosystem and should be limited in duration and scale as much as possible. Try to reduce the footprint of activities by controlling the number of people and pieces of equipment on site and by having the appropriate environmental protection plans in place.

Implementation stages. There are several stages involved with construction implementation (IWWR 2003):

- *Plant preparation.* This stage typically begins during the Pre-Construction Phase and carries through to the Construction Phase. It may involve identifying native seed banks, collecting seeds, and propagating plants. If purchasing plants from a nursery, *(continued on page 51)*

CONSIDER

Reducing the Negative Impacts of Construction

At the Don Pedro Tidal Hydrology Restoration Project in Florida, the Florida Department of Environmental Protection has been careful to control the footprint of activity by stipulating the types of equipment that may be used on site, specifically in regard to tire type. They recommend using soft track and soft tires. Otherwise "the damage done is often not worth the benefit of the project." – *Annette Nielson, FDEP.*

Implementation of the Tarpon Bay Tidal Hydrology Project required careful coordination with local utilities regarding pipes and other right-of-way issues.

Photo Credit: Florida Department of Environmental Protection

Table 6c. Design strategy considerations related to budget.

Design Strategy	Relative Cost	Equipment Needed	Considerations
Culvert placement (pipe or arch)	Low to Moderate	Corrugated metal or pre-fab concrete pipes, gravel, rip-rap, excavator	Causeways, berms, and other barriers often contain electrical, gas, and sewer lines. Coordinate with utility companies prior to construction.
Culvert placement (box)	Moderate	Excavator or crane for placement of pre-fab culvert or molds for pouring on-site; gravel, rip-rap	See above consideration. Also, for culverts under roadways, timing of construction must be carefully coordinated to minimize road closures.
Culvert replacement or repair	Low to Moderate	Culvert cleaning tools, "sleeve" inserts, mesh benders, mesh flatteners, gravel, rip-rap	See above culvert considerations. Velocity of flow and scour are both ecological and safety considerations; construct during low flows and use armoring materials to protect culvert.
Bridge installation	Very High	Cranes and hoists, concrete pouring stations, piles, pile driver	For smaller spans, consider the use of pre-fab modular bridges that reduce costs by eliminating the need for concrete form work or pours.
Barrier breach (berms, dikes, levees, dams)	Low	Backhoe/excavator, bulldozer, dump truck, rip-rap	If possible, distribute soil to on-site locations to reduce costs.
Barrier removal (berms, dikes, levees, dams)	High	Backhoe, excavator/ cranes, dump truck	Erosion control is imperative; loosening large amounts of soil/sediment can make sediment flow into gutters, storm drains, and the ocean. Cost may be controlled if soil can be redistributed on site.
Ditch filling or plugging	Low	Bulldozer, backhoe	Plug ditches at their lowest point at an elevation 20% to 33% above grade to allow for soil settling (Reis, personal communication, 2009). Utilize original spoils if available.
Tidal creek creation	High	Trailers, bulldozer, backhoe and gardening machines, dump truck	Excavation levels must be precise and monitored as-built. Use of amphibious or low ground pressure tracked vehicles may be necessary for working in sites with existing wetland conditions.
Mosaic habitat creation	Moderate	Backhoe/excavator, bulldozer	May increase design costs or on-site costs due to extra time and care needed to implement precise elevations. This technique is most applicable at large sites or areas prone to sea level rise.
Sediment grading and/ or elevation alterations	Moderate to High	Backhoe/excavator, bulldozer, dump truck, silt fences, straw bales, compost berms or filter socks, and sediment control basins	When raising elevations over a large area in proximity to dredging operations, consider use of dredge spoils. When lowering elevations (scraping), coordinate with construction sites in need of fill to reduce transportation and disposal costs.
Water control structures (i.e., tide gates and weirs)	Moderate	Gates, molds for concrete wingwalls, culverts, rip rap	Consider structures with fish slots or variable-crested weirs to optimize fish passage and water management options. Use low-maintenance structures able to withstand extreme hydrological and climactic events, such as hurricanes.
Broad-crested earthen weir	Low	Excavator, bulldozer, geoweb materials	Weir heights must be precise to be effective.

the origin of the stock should be considered. Always use native species and cuttings or seeds from local plants. Locally adapted seeds and plants will have a better chance of surviving the conditions at your site than plants or seeds of the same species that come from another area (Stedman 2003).

Acclimation to local salinity gradients prior to planting can also increase success. Although re-establishing vegetation is a common practice, not all tidal hydrology restoration projects will necessitate it. Consider negotiating a warranty with your plant supplier that will ensure a minimum survival period for transplants. The IWWR 2003 report, cited in the References, includes more information on this activity.

- *Site preparation.* This stage may involve installing temporary tide controls; removing and/or bringing in dirt; plugging or removing drains; breaching levees; staging heavy equipment; preparing and/or installing erosion control devices; clearing access to the site (e.g., brush removal); and removing invasive species.

- *Construction (removal or installation).* This stage involves constructing essential project components such as water control and stabilization structures, soil gradations, and habitat structures. Different design strategies require different equipment, costs, and environmental and logistical considerations. Based on the restoration design strategies presented in Chapter 4: Project Design, ***Table 6c*** (opposite) offers construction considerations for each strategy.

Vegetation considerations. If vegetation planting follows earth-moving operations, here are some tips to keep in mind:

- Sand is a good substrate to use for building a marsh platform because it is easier to manipulate during construction, to plant healthy vegetation, and to fertilize (sand will need fertilizing since it lacks nutrients and organic matter). With correct plant spacing, using sand will generally result in a two-year grow-out to vegetate the site completely.

- Consider preserving or stockpiling topsoil on site as it may contain a valuable seed source that can be distributed near project completion.

- Restoration experts generally agree that bare root vegetation is most cost-effective in intertidal areas, while three-gallon pots (or larger) are typically recommended in upland areas.

- Most practitioners agree that at least three to five years of maintenance is required to combat non-native vegetation on a site, so plan accordingly.

Ensuring quality implementation. There are numerous actions a project team can take to ensure the quality of construction. Restoration experts offer the following advice:

- *Ensure quality construction through independent oversight, and budget appropriately for this expense*. Hold weekly construction oversight meetings that include input from the construction manager and project team. Create agendas for meetings, conduct site visits, and take notes to keep a careful record. For example, the Hopedale Tidal Hydrology Restoration Project in Louisiana budgeted approximately 10 percent of total costs for on-site, independent oversight and inspection.

- *Consider keeping the permit process separate from the construction contracting process, but maintain communication about permit specifications.* This approach provides the project team with more control over final design, scheduling, and costs. However, it will require clear communication with the contractor to ensure construction elements comply with permitting requirements.

- *Do not implement changes to the construction plan without thorough evaluation by the planning and design team.*

When Implementation does not go as planned. Restoration experts know that construction does not always go as planned and offer the following advice:

- *Have a* ***contingency plan*** *and funds to implement it.* Know when to cut your losses, and modify the contingency plan if necessary during the project.
- *Engage design experts* throughout the entire project so you can adapt quickly to changes.
- *Communicate with persistence,* even when the team, contractors, or stakeholders are reticent. Help the team translate their expertise to others. For example, biologists need to understand how construction equipment works, and engineers need to understand the ecology of the site to participate effectively on a project team.

CONSIDER

Budgeting for Construction Monitoring and Maintenance

It is a good idea to budget for construction monitoring and maintenance to ensure the funds are available for these activities. Some funding sources even require it. For example, projects completed under the federal Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA) must budget for these costs at project outset. For instance, the project team for the Hopedale Tidal Hydrology Restoration Project in Louisiana set aside a budget of $500,000 prior to construction of this large-scale project for all construction monitoring and maintenance over a 20-year period.

For more information, see the **Hopedale Tidal Hydrology Restoration Project Portfolio** *(page 98).*

Post-Construction Management

Post-construction management of tidal hydrology restoration projects includes maintenance and monitoring of the physical construction (IWWR 2003). It is critical to the project's value over time, especially for projects that involve engineered structures. Because of its importance, post-construction management should be planned and budgeted from the outset of the project, along with funds for corrective action.

Construction monitoring. The project manager should monitor the site during and after construction to ensure work is progressing and completed as planned. An example of monitoring during construction might be measuring and adjusting invert elevations of culverts to achieve maximum flow.

An **as-built survey** should be completed immediately following construction, ideally before the contractor removes their equipment and leaves the site. The as-built survey records

Cutting Your Losses

The Tarpon Bay Tidal Hydrology Restoration Project in Florida encountered many challenges during construction that resulted in unplanned daily oversight of the construction contractor by the project team. In addition to safety and site maintenance issues, the contractor attempted to use equipment that was insufficient to complete construction. The project lost time and resources before the team decided to cut their losses and select a new contractor who successfully completed the project.

For more information, see the **Tarpon Bay Tidal Hydrology Restoration Project Portfolio** *(page 134).*

Construction underway to breach the dikes at the Eden Landing Salt Pond Restoration Project on the eastern shore of San Francisco Bay, CA.

Photo Credit: NOAA

post-construction physical structure, elevation, soil type, and other relevant parameters. The survey should be closely compared to the design (goal and objectives) and construction specifications. In fact, many project managers suggest having an independent contractor complete the post-construction evaluation to ensure compliance with design.

Be realistic about the project team's expectations for construction, but if there are major problems with the final construction results, request that the contractor make specific corrections if it is within the contract or if it is otherwise cost-effective to amend the contract. Use the as-built assessment as a baseline for monitoring and evaluation needs.

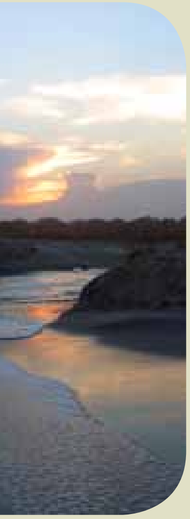
For more details on baselines, see **Chapter 7: Scientific Evaluation and Monitoring**

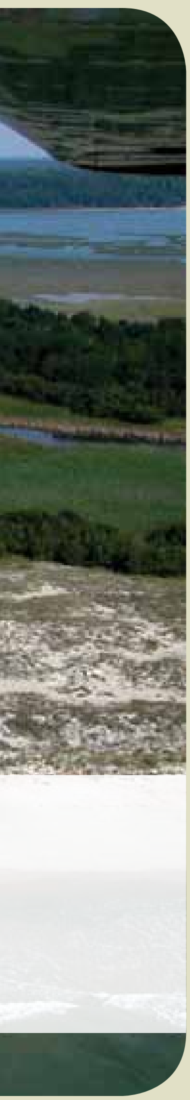
Construction maintenance. Maintenance of a tidal hydrology restoration site involves structure repair; plant replacement (if planting was part of the original project); and control or elimination of invasive species, herbivores, and predators. Local entities will likely be the most accessible and cost effective for administering long-term maintenance of the project site; however, local priorities may shift in the future and diminish their ability to follow through with construction maintenance. Consider contracting for long-term maintenance if the project budget allows.

Construction and Maintenance

Top left: *Increased sedimentation due to coastal modifications led to the loss of an inlet through coastal dunes that provided tidal flow to Sandpiper Pond in Murrells Inlet, SC.* **Top right:** *Tidal flow moves through the restored inlet at high tide.* **Bottom:** *The restored tidal inlet at low tide. Annual maintenance is required to sustain tidal flow through the dune system.*

Photo Credit: SC State Parks





PROJECT HIGHLIGHT

Sandpiper Pond Tidal Hydrology Restoration Project

Huntington Beach State Park, Georgetown County, SC

Sandpiper Pond at Huntington Beach State Park is a thriving coastal wetland system. System health relies on tidal flushing and circulation from a short inlet that meanders through coastal dunes and connects to the Atlantic Ocean. In 1989, the inlet was blocked due to years of increased sedimentation along the coast caused by the construction of a nearby jetty and a powerful storm surge associated with Hurricane Hugo. The lack of tidal circulation resulted in lower salinity levels, an influx of invasive plants, and a series of major fish kills.

In an effort to restore the health of the pond, the Friends of Huntington Beach State Park (a nonprofit group) along with Park officials sought to breach the newly formed dunes and reintroduce tidal flushing to the system. In order to mimic original conditions and maintain a natural appearance to the dune system, detailed engineering plans with specific elevations were created that called for the movement of sand only. Unlike many tidal hydrology projects, no hard structures, culverts, or armoring were used to convey tidal waters. Although this construction technique was simple and low impact, it required planning for intensive on-going maintenance.

Prior to construction, volunteers removed dune vegetation from the project area and transplanted it nearby. Shortly after, Park employees used two rented bulldozers over a one-week period to create a 40-foot-wide swath through the sand to allow ocean tides to reach the Pond. Volunteers with engineering expertise closely monitored elevations, and the final stages of earthwork were timed to coincide with low tides. Now after several years of tidal flows into Sandpiper Pond, salinity levels have increased and native estuarine species such as *Spartina*, sheepshead, and blue crab have returned.

With the constant accretion of sand and the shifting dynamics of the dune system, the inlet to Sandpiper Pond requires consistent maintenance that was anticipated and incorporated into long-term Park management plans. Park staff must rent bulldozers annually and allot time for clearing the inlet. As stipulated in the project permit, this work must be completed in April before turtle nesting season.

Through the many years of experience acquired by the inlet maintenance staff, construction maintenance techniques continue to become more effective and efficient. Originally, the created inlet was a straight channel built at a right angle to the pond. Over time, the channel has meandered, forming an indirect route to the pond. During annual maintenance, construction crews work with this naturally defined course. Crews have also learned that sands excavated from the channel must be graded at an angle less than was previously thought.

Perhaps as a benefit from the constant attention required to maintain Sandpiper Pond, a high degree of familiarity with the site dynamics now exists among the project team. After the initial breach, the project team recognized an opportunity to further enhance the tidal flushing and circulation of the Pond. A culvert was installed under a nearby road to create another access point for flow in the Pond.

For more photos, details, and example project documents, see the
Sandpiper Pond Tidal Hydrology Restoration Project Portfolio *(page 146).*

Chapter 7: **Scientific Evaluation and Monitoring**

Scientific monitoring is the systematic collection of data that provides information on changes in environmental conditions of the project area. The data collected will indicate problems and/or progress toward achieving restoration project goals and objectives (IWWR 2003). Monitoring requires measuring certain habitat attributes or physical parameters at regular intervals before and after project implementation. This record of habitat changes, along with comparison to a reference condition, will indicate if objectives are being met.

Monitoring and project evaluation are important components of systematic project management.

A monitoring plan should be developed in concert with project goals and objectives and strive to evaluate the effectiveness of achieving those goals and objectives.

For more information, see **Chapter 3: Goals and Objectives.**

This chapter will provide:

- General introduction to the issues of monitoring and scientific evaluation;
- Discussion of what and how to monitor;
- Discussion of where and when to monitor;
- Guidelines for how to determine tidal hydrology restoration effectiveness;
- Possibilities for how a practitioner can contribute to furthering the science and understanding of tidal hydrology restoration; and
- Scientific evaluation and monitoring highlight project: Fort DeSoto Tidal Hydrology Restoration Project, Pinellas County, Florida.

Additional scientific evaluation and monitoring resources and summary recommendations can be found in the ***Toolkit*** (page 204).

Background and Reasons for Monitoring

Reasons for implementing scientific monitoring plans have been detailed in numerous publications (Kentula et al. 1992; Thom 2000; Wilber et al. 2000; Diefenderfer 2003; Thayer et al. 2003; Thayer et al. 2005; Thom et al. 2005) and include:

- *Evaluation of project effectiveness.* It is important that specific parameters are measured to evaluate progress toward meeting project goals and objectives. Often public support and agency funding depend on the demonstration of achieving project goals and objectives.
- *Maintenance.* Monitoring indicates needs for maintenance, including invasive species removal, turbidity curtain positioning, floating debris removal, signage, fence maintenance, and repair of engineered structures (e.g., culvert flap-gates).
- *Adaptive management.* Project monitoring allows the practitioner to observe the project area evolution carefully and to employ adaptive management practices when needed (Walters 1986; Steyer and Llewellyn 2000; Thom 2000; Thom 2005). Typical mid-course corrections for tidal hydrology restoration projects might include tidal creek channel modification, vegetation re-seeding or planting, grading, ditch plugging, or even planning for the future construction of additional tidal exchanges.

Additional goals and objectives references are available in the **Toolkit** *(page 176).*

- *Enhancement of science and management understanding.* Data are needed to improve our understanding of the effects of tidal restrictions and of tidal hydrology restoration. The synthesis of information from restoration sites can aid future restoration efforts (Neckles et al. 2002). Practitioners learn from both the successes and failures of past projects.

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A flow meter is used to monitor the effectiveness of the culvert installation at St. Vincent National Wildlife Refuge Tidal Hydrology Restoration Project in the Florida Panhandle.

Photo Credit: USFWS

Major Components of a Monitoring Plan

For an overview of the most common components included in a monitoring plan, see the monitoring plan template in the ***Toolkit*** *(page 205).*

The monitoring plan should be developed concurrently with the design and construction plans and should flow directly from the goals and objectives of the project, including both structural and functional objectives. For each objective, a corresponding measureable **parameter** will be selected. Each parameter will have an associated **baseline** (condition of the site prior to restoration activities), **reference** (condition of a representative site with characteristics desired to be achieved at the restoration site), and **target** (realistic target to be achieved during a specified period of time). Establishment of appropriate parameters and targets allows for implementation of a monitoring plan that will indicate whether the project goals and objectives have been achieved.

Execution of the monitoring plan entails data collection related to each of the selected parameters. (Example Monitoring Data Collection Forms and and example Wildlife Monitoring Datasheet are available in the ***Toolkit*** on pages 206-210.) The methods and timing of data collection will be influenced by numerous factors, including project goals, targets, geographic location, and site-specific conditions. The frequency of data collection and number of samples required is determined by development of a robust statistical and experimental design. With the exception of goals and objectives (see ***Chapter 3: Goals and Objectives***) and experimental design and analysis (beyond the scope of this manual), each of these monitoring plan components, as they relate to tidal hydrology, are described more fully in the subsections that follow.

What and How to Monitor

There are numerous scientific monitoring parameters that can be measured to examine the ways a tidal system might change following tidal hydrology restoration actions. The goal of a scientific evaluation plan is to select key measurable parameters and create a sampling strategy for those parameters that will provide the most reliable and useful data to help the restoration team determine the project's effectiveness in reaching project objectives.

Examples of useful parameters include:

- *Fauna* (e.g., community composition, diversity, density, presence/absence, biomass, size/age frequency, secondary production, etc.);
- *Water quality* (e.g., dissolved oxygen, pH, nutrients, temperature, etc.);
- *Tidal flooding patterns* (e.g., extent, tide height, tidal prism, periodicity, water velocity, etc.);
- *Soils* (e.g., redox, pore water salinity and chemistry, organic content, vertical accretion, etc.);
- *Native vegetation* (e.g., community composition, percent cover, stem density, underground/above ground biomass, Carbon/Nitrogen ratios, primary production, etc.); and
- *Invasive vegetation* (e.g., presence/absence, percent cover, number of seedlings, stem density, ratio of native to invasive cover, etc.).

Restoration practitioners generally agree on four core categories of scientific monitoring parameters that are applicable for almost all tidal hydrology restoration projects: **hydrology**, **vegetation**, **soil**, and **nekton** (NOAA 2008). Within each of these four categories are specific parameters, or characteristics, that may be appropriate to monitor for an individual restoration project. ***Table 7a*** (page 60) includes specific recommended parameters and related monitoring techniques.

Structural and Functional Objectives

Structural objectives are objectives focused on the physical aspects that define the habitat, such as the percent cover of vegetation.

Functional objectives are objectives focused on the processes occurring within and between habitats, such as fish utilization or vegetative growth.

NOAA has developed several useful resources to aid restoration practitioners choose appropriate structural and functional objectives and monitoring parameters for their restoration projects:

Science-Based Restoration Monitoring of Coastal Habitats (Volumes 1 and 2) provide a framework and set of tools for developing restoration monitoring plans.

NOAA's Restoration Monitoring Planner is an interactive online tool to assist in developing a basic monitoring plan for restoration efforts in salt marsh, shellfish, or riverine habitats.

These resources can be accessed online at *http://www.era.noaa.gov/information/monitor.html*.

Setting target values. Once specific parameters have been selected, target values should be set that relate back to each project objective. A target value is the desired numerical metric to be achieved within a specified period of time.

For more on relating target values back to goals and objectives, see **Chapter 3: Goals and Objectives.**

For example, a project objective might be to restore percent cover of wetland vegetation to that of a healthy wetland, or to the reference system. The parameter measured is percent cover of wetland vegetation. For instance, the target value may be 80 percent of reference within three years. Keep in mind that data collected from the reference site allow you to set pre-construction targets – but continuing to monitor the reference site after construction allows you to modify targets as conditions change. (See ***Relying on Reference Sites*** for more information on choosing reference sites.)

Other methods for choosing target values include literature review and collecting information from similar restoration projects completed in the past. Be aware, however, that methods used previously to collect data from earlier restoration sites may not provide appropriate comparison to more current data collection methods. Data collection from nearby reference sites is the preferred approach for setting target values.

In ecological systems, it is not always reasonable to achieve target restoration values (based on pristine conditions) during the monitoring period which is sometimes dictated by funding agency reporting (See ***Principle Monitoring Periods***, page 62) (Thom and Wellman 1996; Simenstad and Thom 1996). Instead, it may be more beneficial to chart the project's trajectory (Kentula et al. 1992; Simenstad and Thom 1996) toward targets and perhaps set intermediate targets, also known as success criteria or performance standards. For example, while the project objective may be to achieve 80 percent cover of marsh vegetation (similar to the reference marsh), it may not be reasonable for the site to reach this high threshold in only one to two years of monitoring before a final report is due to a funding agency. In this case, an intermediate target of 40 percent cover after two years may be more appropriate and satisfy funding agency requirements.

Relying on reference sites. Typically, a reference site represents an "ideal" undisturbed habitat and has characteristics similar to the goals and targets of the restoration project. For project evaluation purposes, the restoration site should be compared with the reference site(s) with the goal of increasing similarity over time. Reference sites provide information about the natural range of values for the parameters used in the monitoring program and show the annual variation in these parameters. The monitoring plan should incorporate data collection at the reference site for as long as possible both before (minimum one year) and after project construction (minimum five years) to account for variations in habitat and tidal flow.

Tips for selecting reference sites:

- *Select both up-estuary and down-estuary reference sites for wetland tidal hydrology restoration projects.* This will allow for better comparison of more saline down-estuary or more freshwater up-estuary conditions.

(continued on page 62)

CONSIDER

National Estuarine Research Reserves as Reference Sites

Frequently there are no pristine or nearby reference sites available for comparison and practitioners must seek out suitable surrogates for reference conditions. To this end, consider sites within the National Estuarine Research Reserve (NERR) system. Examination of the data available at NERR sites (or from other reference sites) may help practitioners select the parameters to include in a monitoring plan . Since NERR sites are relatively undisturbed and have on-going monitoring programs (especially focused on water quality), these programs provide data meant to be indicative of pristine conditions. NERR sites can be found in every coastal state (including the Great Lakes) except Louisiana. The Eden Landing Salt Pond Restoration Project in California, part of the South Bay Salt Ponds Project, is utilizing China Camp (a portion of the San Francisco Bay NERR) as a reference site.

For more information on NOAA's network of National Estuarine Research Reserves, visit the NERRS website at http://www.nerrs.noaa.gov/

Table 7a. Core monitoring parameters with recommendations for monitoring specific characteristics.

	Characteristic	As-Built
Core Parameter: Hydrology	**Water depth** (Neckles and Dionne 2000)	Above ground: use staff gauge; below ground: use shallow well (slotted PVC pipe)
	Flow pattern	Direct observation to indicate major pathways and channels on map
	Flow rate	Measure inflow or outflow with flumes or weirs; measure interior flow with current meters
	Tidal flooding extent	GPS edge at spring high tide
	Tidal prism (volume)	Combine site survey and water height to calculate prism
Core Parameter: Vegetation (Native and Non-native)	**Community composition** (Kent and Coker 1992; Neckles and Dionne 2000)	Map planting areas and measure density
	Coverage (Elzinga et al. 1998)	Estimate or measure percent cover
	Survivorship (when native planting part of design)	Number and type of vegetation planted
	Height	Estimated or measured height of plants
	Reproduction	N/A
Core Parameter: Soils	**Soil salinity** (Neckles and Dionne 2000)	N/A
	Soil texture	N/A
	Organic matter (Craft et al. 1991)	N/A
	Sedimentation (Cahoon and Turner 1989 for marker horizons; Boumans and Day 1993; Cornu and Sadro 2002 for SET)	Survey topography, establish elevation stakes or Sediment Erosion Table (SET) for later comparison
Core Parameter: Nekton	**Species diversity and/or relative abundance** (Note: relative abundance can only be compared for samples collected using same gear)	N/A
	Density or abundance (#/m2)	N/A
	Species survivorship	N/A
	Growth	N/A
	Secondary production	N/A
	Size	N/A

(Some information reproduced here from IWWR 2003)

Qualitative Method	Quantitative Method
Record observations of high-water marks, drift lines, etc.	Above ground: use automatic water level gauge; below ground: use shallow well with automatic recorder
Direct observation to indicate major pathways and channels on map	Datalogger
Estimate as high or low based on visual observation and compared to other nearby sites	Measure inflow or outflow with flumes or weirs; measure interior flow with current meters
Walk edge and mark on map	GPS edge at spring high tide
N/A	Combine site survey and water height to calculate prism
Identify common species and map dominant community types; note invasive species and vigor	Establish transects and/ or quadrats; identify all species; map dominant communities
Estimate percent cover	Collect percent cover along permanent transects
Visually estimate percent of plants alive	Count plants and determine percent of plants alive
Estimate heights of plants compared to previous year's height	Measure height of plants
Estimate percent of dominant plants flowering/seeding	Determine percent of plants flowering/seeding by species in plots
Taste	Hand-held refractometer at established stations
Use soil texture triangle to classify based on feel (Horner and Raedeke 1989)	Particle size analysis of the different soil horizons (Folk 1974)
N/A	Soil moisture and organic matter in top layer at stations
Establish pre-marked elevation stakes at critical points across site; estimate depth increase or decrease in sediment	Survey topography; SET with marker horizons
Seine and/or trap fish to determine presence/absence and relative abundance; identify species	Use purse seines (Hartman and Herke 1987), combination seine and block nets (Weinstein 1979), pop nets (Connolly 1994), lift net (Wenner et al. 1996), throw traps (Jordan et al. 1997, Raposa and Roman 2001); fyke nets (Neckles and Dionne 2000); count and identify all species. General information on, and comparison of, different capture techniques (Murphy and Willis 1996, Kneib 1997, Rozas and Minello 1997).
N/A	Use purse seines, combination seine and block nets, pop nets, throw traps, or other enclosure gear to determine density by species. Papers that describe use of gear to determine density (Rozas and Minello 1999, Raposa and Roman 2003, Piazza and La Peyre 2007).
N/A	Mark and recapture study (van Montfrans et al. 1991; Murphy and Willis 1996).
N/A	Otolith analysis (Murphy and Willis 1996); field growth experiments (e.g., Stunz et al. 2002; Posey et al. 2005; Shervette and Gelwick 2008).
N/A	Use density, growth, and survivorship data with production model (Roth et al. 2008)
N/A	Use variety of quantitative gear to sample most common fish; measure (Murphy and Willis 1996, Kneib 1997, Rozas and Minello 1997).

- *Consider including a reference site that represents the impaired condition of the project (Cornu & Sadro 2002).* For instance, consider an adjacent impounded wetland that has not yet been restored to serve as a baseline condition over time. This site can show how much the restored habitat has changed, which might be especially important if no pre-restoration data can be collected.

- *Choose reference sites that are close in time and space* and have as many similar characteristics to the disturbed (to-be-restored) habitat as possible.

- *Try to identify several reference wetlands, because wetlands of the same type can vary considerably in their characteristics.* Looking at multiple wetlands of the type you hope to establish can help you understand the natural range of variation of the wetland type (Stedman 2003).

Qualitative vs. Quantitative Data

Time and budget constraints generally do not allow every aspect of a project to benefit from quantitative data collection. However, qualitative data collection can be informative. Neither quantitative nor qualitative data alone can provide a comprehensive evaluation of how the site conditions at a restored site are evolving to match the target design objectives.

Qualitative data that can be useful for evaluating project restoration effectiveness include (IWWR 2003):

- *Aerial photographs* to show general hydrology, evidence of channelization, and the extent of plant covering at the site;

- *Ground-level photographs* (preferably photo stations) for identification of some plant species, general degree of plant growth, general water levels. Methods also exist to transform repeat photography into a quantitative analysis through techniques such as grid analysis (Hall 2002); and

- *General observations* such as water clarity, floating vegetation or macroalgae, presence of trash, evidence of human use, bird species presence, vegetation condition (stressed, flowering, healthy), presence of invasive plants, evidence of erosion, and the integrity of structures.

Local community volunteers can be invaluable in terms of gathering qualitative assessment data such as ground-level photographs and general site observations.

For more ideas on ways to involve volunteers in monitoring activities, see **Chapter 8: Community Support**

> "Monitoring is an investment in the future of the next project – it is not a report card on the current project."
>
> - **Tom Cuba,** *Delta Seven, Inc.*

Principal Monitoring Periods

There are three principal periods of effective project monitoring and evaluation: baseline ecological conditions, as-built assessment following construction, and scientific monitoring of the ecosystem response to barrier removal.

Baseline assessment. The first period is often termed pre-restoration monitoring and establishes the conditions prior to construction work. It provides the baseline to which all future data can be compared. Ideally, baseline data are collected under a range of conditions over a long period of time – at least one year of pre-construction data is critical at both project and reference sites.

As-built assessment. The second period requires the team to survey and record the actual construction results, then compare the results to the design and construction plans. For tidal hydrology restoration, the construction plans and the as-built

Quadrat surveys of seagrass were taken both before and after installation of the new bridge at the Fort DeSoto Park Tidal Hydrology project in Florida.

Photo Credit: NOAA

assessment will likely include information on the openings for water flow (types, numbers, size, invert elevation), velocities of flow across a tidal range, duration and frequency of inundation, and (if constructed or altered) the width, depth, and number of tidal channels. For projects with plantings or invasive species control, assessment would include planting density, invasive species remaining, or other measurable outcomes. As-built data provide the starting point to allow the tracking of the site's evolution, allows resource managers to make strategic adjustments to projects, and provides invaluable knowledge to inform planning and funding of future projects.

If the as-built characteristics do not meet the expectation of the design, then corrections may be possible early in the monitoring phase. The project team should continue to monitor these construction characteristics to determine if corrections are needed in the future.

For more information on construction monitoring, see **Chapter 6: Construction and Maintenance**

Scientific monitoring and evaluation. The third period of monitoring entails assessing those parameters that indicate if a site can sustain key ecological and biological functions. This stage generally uses the same methods and tracks the same parameters as baseline monitoring and as-built assessments. This monitoring period relates specifically to the goals and objectives of the project and allows for careful comparison of the project site to the baseline condition and reference site(s) over time. It may examine changes in water quality, fish assemblage and biomass, soil characteristics, sedimentation processes, and vegetation composition and coverage.

A water gauge is used at the Little River Marsh Restoration site in New Hampshire to measure restored water flow through the tidal creeks.

Photo Credit: UNH

Considerations for Developing Scientific Evaluation Plans

Monitoring strategies should be developed for all three principal phases of monitoring. However, developing a plan for the scientific evaluation phase will take the most time and consideration. Below are some tips for developing effective strategies for short- and long-term monitoring; monitoring frequency and duration; determining the "footprint," or area of impact, of the restoration project; meeting regulatory monitoring requirements; and funding monitoring activities.

Short-term monitoring. Monitoring for short-term indicators of effectiveness allows the team to employ adaptive management actions based on actual changes observed. Short-term monitoring of hydrology can be used to verify that construction actions resulted in the desired site changes caused by water movement and the spatial extent of tidal inundation. Vegetation is also an effective parameter for short-term monitoring, especially if the removal of invasive vegetation was part of the project. Both parameters may require frequent data collection in the initial weeks and months following construction, and again periodically throughout the long-term monitoring phase (see below). It may be helpful to consider the short-term plan as a more intensive monitoring period nested within the larger, comprehensive monitoring plan.

Long-term monitoring. Long-term monitoring allows for the most robust comparison to the baseline (Thom 2000; Watson and Novelly 2004). The long-term monitoring plan will include the full monitoring strategy – from pre-construction data collection to some time after construction (minimum five years, ideally 20 years or longer) and will collect data under a wide range of environmental conditions. Long-term monitoring will require data collection at given intervals or times of year most appropriate for each parameter. Vegetation and faunal community composition, as well as soil characteristics, can take several years to begin to resemble natural site conditions (Gray et al. 2002, Thom et al. 2002). Budgets are often limited, so decide carefully which parameters

Determining the Restoration Footprint

As part of monitoring and assessing the impact of a project, restoration practitioners and funding agencies often try to determine the actual area restored by the project (e.g., acres/hectares restored).

For projects where tidal waters are reintroduced to a previously "dry" area, determining the **footprint**, or extent of the site restored (e.g., flooded area), is not difficult. Determining if the objectives of the project have been achieved and over how large an area, however, can be a challenge.

For projects where flow of tidal waters is improved rather than reintroduced, determining the footprint of restored area becomes more complicated. Collecting pre- and post-construction data at *multiple locations* throughout the reference and project sites is critical to determining restored acreage.

Data collection for multiple locations at both sites will provide a spatial component to monitoring that will make it possible to scientifically examine the extent of the site impacted by the project activities.

to measure, the intensity of measurements, and how long the monitoring should continue.

Frequency and duration. Natural variability, rate of site change, funding and project timelines, and project goals and objectives determine how often and how long to monitor. Natural variability is more likely to hinder the ability to identify problems or trajectories toward functional habitat conditions in less frequently monitored project and reference sites. However, if funds are inadequate for more frequent monitoring, most parameters should be monitored at least once a year: vegetation during the growing season and animals during breeding, nesting, and/or migration seasons. Hydrologic characteristics should ideally be monitored during maximum and minimum flood and ebb tides, but need not be measured each year. Changes in sedimentary characteristics are often slower than changes to other parameters (Simenstad and Thom 1996), so it is reasonable to monitor these less frequently (every two to three years) but for a longer time (10 to 20 years). Additional recommendations for frequency of monitoring are included in ***Table 7a*** (page 60).

Funding scientific monitoring. The funding available for scientific monitoring is typically a small proportion of the total funds allocated to a project. Costs have been found to average 13 percent of total project costs, ranging from 3 to 62 percent (Thom and Wellman 1996). Decisions related to parameters, techniques, frequency, and duration of sample collections are often the product of budgetary constraint, so the team must plan carefully to ensure the scientific validity of the evaluation process and its utility in informing future decisions. Resources devoted to monitoring may reduce the funds available to restore the project site, but this challenge can be mitigated. For instance, choosing parameters and data collection techniques that are similar to those used in other projects may make data more comparable across sites and improve understanding of the project effectiveness.

Surrogate indicators may provide more cost-effective and feasible options for measuring project effectiveness in the future. For example, monitoring fish populations can be expensive, but it may be possible to estimate fish production by analyzing data for surrogate indicators such as hydrology and vegetation growth (Haas et al. 2004, Weinstein et al. 2005). Additional ways to control costs include using volunteers to collect data and choosing reference sites that have on-going data collection funded for other purposes (e.g., NERRs), with parameters of significance to the restoration site.

For more on how to defray project costs by using volunteer labor, see **Chapter 8: Community Support**

Regulatory-required monitoring. It is important to note that permits issued by regulatory agencies will also specify required monitoring parameters and reporting schedules. Pre-permit discussions with appropriate regulatory personnel about these requirements allow the team to incorporate these requirements into the evaluation plan, rather than duplicating effort later.

Advancing the Science of Tidal Hydrology Restoration

It may not be practical, or even efficient, for all projects to receive the level of scientific evaluation described above. All projects should receive basic monitoring to provide some degree of confidence that the design criteria were met. However, practitioners overseeing or partnering on many projects might more efficiently enhance overall understanding of restoration ecology by intensively monitoring a carefully selected subset of projects and evaluating their functionality in comparison to reference sites.

What constitutes basic data as opposed to more in-depth scientific evaluation may be a product of the intensity, frequency, and precision of data collection efforts. For instance, the same type of data may be collected from two sites – focusing on similar core parameters – yet one project may only collect data on an annual basis, using a simple, precise technique for each core parameter, while another site may collect data several times a year, using multiple techniques (of differing precision and accuracy) to describe each core parameter. These two levels of effort would both yield informative results. One provides information about general site conditions in comparison to a reference site, while the other yields much greater information that could aid the advancement of habitat restoration science.

In order to apply the approach of comparison among project sites over time at a regional level, it is recommended that region-specific core parameters (more specific than the four included in this document) be agreed upon and adopted. The Gulf of Maine provides an example of this kind of core characterization (Neckles et al. 2002), resulting in the Global Programme of Action Coalition for the Gulf of Maine (GPAC; see *http://www.gpac-gom.org*) Protocol.

Core variables include:

- Base map;
- Hydrology (including at least the two week lunar cycles, spring, and neap tides);
- Marsh surface elevation data;
- Soils/sediment (pore water salinity);
- Vegetation (percent cover by species, invasive species height, and density);
- Nekton (species composition and richness, abundance by species, length, biomass); and
- Birds (species composition and richness, abundance by species, breeding behavior).

Mimicking this type of regional planning effort to establish core parameters and data collection protocols could greatly enhance the science of tidal hydrology restoration. The Coast-wide Reference Monitoring System (CRMS-Wetlands), developed in Louisiana, is another model that could be utilized and adopted to improve scientific evaluation of restoration projects.

Baseline (pre-restoration) trawling surveys followed by twice-yearly post-restoration surveys allow for comparison of species composition at the Tarpon Bay Hydrology Restoration Project in Florida.

Photo Credit: Florida Department of Environmental Protection

Coast-wide Reference Monitoring System (CRMS-Wetlands) and Barrier Island Comprehensive Monitoring (BICM) Programs

CRMS-Wetlands provides long-term data from hundreds of established reference sites throughout the various vegetated habitats of coastal Louisiana. The sites span the range of habitat health, from disturbed to pristine. Monitoring sites were intentionally placed both inside and outside boundaries of existing and planned restoration projects. At each site, aspects of ecosystem structure and function (including elevation dynamics, vegetative assemblage, and hydrologic parameters) are measured (Steyer et al. 2003). The data are made available on-line to the public after thorough quality assurance/quality control. The State Office of Coastal Protection and Restoration (OCPR) works with the U.S. Geological Survey on the management of the CRMS-Wetlands program.

A complementary program to CRMS-Wetlands is the Barrier Island Comprehensive Monitoring (BICM) program, which monitors the mainland shoreline of the Louisiana coast with special emphasis on sandy beaches and barrier islands. Specific parameters monitored include bathymetry, topography, shoreline change, land loss, habitats, and storm impact.

As these program databases grow, they will allow for both project-specific evaluations and cumulative evaluation of the effects of projects on a hydrologic basis and coastwide level (Steyer 2000), and could serve as a model for evaluating wetland ecosystems in other locations as well.

For further information, please visit the following websites:
http://www.lacoast.gov/crms2/Home.aspx
http://dnr.louisiana.gov/crm/coastres/project.asp?id=CRMS-WETLANDS
http://dnr.louisiana.gov/crm/coastres/project.asp?id=BICM

Scientific Evaluation and Monitoring

Two areas of causeway were identified for replacement with bridges at the Fort DeSoto Park Project. Only the location identified by the larger circle was completed, including extensive before and after monitoring in the surrounding bays.

Photo Credit: Pinellas County

PROJECT HIGHLIGHT

Fort DeSoto Tidal Hydrology Restoration Project

Fort Desoto Park, Pinellas County, FL

Tidal flow between bays in the Fort DeSoto Park Aquatic Habitat Management Area in Pinellas County, Florida, was severed due to the construction of a dredge-and-fill causeway designed to connect the island chain in the late 1950s. The lack of tidal flow between the bays resulted in extreme summer water temperatures, low dissolved oxygen, high sediment hydrogen sulfide concentrations, stress to seagrass meadows, and low faunal habitat suitability. To relieve these conditions and improve tidal circulation, a portion of the causeway was replaced in 2005 with a 40-foot span bridge. (Plans to construct a second bridge were curtailed due to cost.)

The project's scientific evaluation plan incorporated both impact and reference sites, two years of pre-construction data, and three years of post-construction data (to date), with an estimated cost of $100,000 per year. Indicators of all four core parameters were monitored, including hydrology (temperature, salinity, dissolved oxygen), vegetation (community composition, seagrass density, shoot counts, lengths and widths, epiphytes), soil (hydrogen sulfide concentration), and fauna (macrofauna identification, length, width, weight).

Only three years after construction, a few parameters do indicate a response to the bridge construction. These include improved water quality conditions in terms of extreme temperatures, salinity, and dissolved oxygen. Data suggest epiphytic growth on the seagrass is decreasing in the impact area. It also appears fish populations are responding positively, but the extreme natural variability of this measure makes results somewhat inconclusive. Multiple data set trends toward reference site conditions provide evidence that the project goals are being achieved. Based on this work, project partners agree that construction of the second bridge may be necessary to yield the most complete restoration possible at the park.

Natural variability has made it very difficult to follow a signal of change for any one parameter. Four major tropical storm events followed the bridge opening, and a major red-tide occurred the next year. Comparing pre-construction data to data collected during extreme events is challenging and supports the position that long-term data collection both before and after construction is the only valid way to follow a trajectory of change.

Interestingly, the parameter that will likely have the largest impact on the long-term condition and habitat suitability of the site will also take the longest to respond. Elevated sediment hydrogen sulfide concentrations, which directly impact infauna and seagrass conditions, may require several decades to respond to the improved hydrology and dissolved oxygen concentrations, thereby improving ecosystem health.

For more information, see the **Fort Desoto Tidal Hydrology Restoration Project Portfolio** *(page 110).*

A non-toxic dye was released near the newly constructed bridge when the final barrier to tidal flow was breached. The dispersion of dye is evidence of the tidal flow moving through the new bridge opening.

Photo Credit: NOAA

Chapter 8: **Community Support**

Often the general public is not well informed about historic tidal modifications and their associated ecological impacts. Consequently, vast areas of tidally restricted aquatic and estuarine habitat remain degraded despite the potential to be restored to productive estuaries. Developing public awareness of the need for restoration and gaining public support for projects are challenges that require the development of community relations programs. Governmental and non-governmental organizations, including environmental non-profit groups, must adopt strategies that nurture the development of an informed and politically active constituency in order to realize the widespread restoration of tidal areas.

Building organizational capacity and dedicated staff in the areas of education, advocacy, and volunteer coordination may be the most important investments toward the restoration of healthy estuaries in the Southeast U.S. This section provides:

- Recommendations for developing long-term community support;
- Information about establishing and maintaining a volunteer base;
- Resources for building community support; and
- Community support highlight project: Clam Bayou Tidal Hydrology Restoration Project, Sanibel Island, Florida.

Additional community support resources and summary recommendations can be found in the ***Toolkit*** (page 212).

A local class participated in data collection activities at the Little River Marsh Project in New Hampshire.

Photo Credit: UNH

Building Programmatic Support for Restoration

Ensuring that all the resource groups understand and appreciate the significance of productive coastal estuaries and the urgency for a long-term coastal restoration strategy is important (Steyer 2000). Organizations adopting a long-term, programmatic approach to restoring tidal hydrology on a regional scale must employ multiple public involvement strategies. Some of these strategies include:

- *Securing political involvement.* Adequate resources and the appropriate policy mechanisms needed to address restoration opportunities at a meaningful scale can often only be generated through public interaction with legislative bodies. Support at the legislative level can result in direct comprehensive funding of sustained programs rather than the piecing together of smaller efforts and initiatives. These political activities are often undertaken by environmental nonprofit organizations.

For a list of related environmental nonprofit organizations, see the ***Toolkit*** *(page 213).*

- *Marketing completed projects.* Utilize media during construction and volunteer events to provide visibility of project activities. After the project is complete, well-maintained interpretive signs at accessible locations can educate the public in perpetuity. Producing videos to air on local cable channels can provide a cost-effective means for reaching large audiences to demonstrate project benefits.
- *Hosting public tours and celebrations.* Invite the public to participate in planned site tours hosted through all phases of project implementation. Consider having a project dedication celebration that includes partners, dignitaries, and members of the public.
- *Engaging the public in hands-on activities.* See the ***Volunteers and Monitoring*** section below (page 74).

Volunteers prepare to plant red mangroves at the Clam Bayou Tidal Hydrology Restoration Project in Sanibel Island, FL. This project was initiated by local citizens interested in reversing the negative impacts caused by restricted tidal flow.

Photo Credit: NOAA

Building Project-Level Support

When developing plans for tidal hydrology restoration projects, it is important to account for concerns of the affected community. Neighborhoods, government agencies, private consultants, and industry must all participate in planning, implementation, and evaluation of the restoration as equals. Otherwise, the local community is not likely to develop a sense of ownership (Cassagrande 1997). Projects that may be technically sound risk never getting off the ground if the project team ignores or overlooks public perceptions and needs. When a project team addresses community concerns and the project receives widespread support, expedited planning, permitting, and project implementation can result.

The project team should develop a thorough strategy regarding how and when to engage the public in the project planning process, depending on project aspects such as landownership, the project scope, and the proximity of the project to populated areas. Typical community concerns often focus on the expected construction timeline and footprint, as well as on new tidal flooding patterns—especially projections about potential flooding during extreme weather events.

For more on identifying appropriate sites and project feasibility considerations, see

Chapter 2: Project Identification, Feasibility and Planning

Chapter 4: Project Design

While each tidal hydrology restoration project will present unique community outreach challenges, ***Table 8a*** (next page) outlines some basic aspects of a public involvement strategy to consider.

Community Support

Table 8a. Strategies for successful public support.

Strategy	Guidance
Engage early	Communicate early with the community to help gain approval from landowners directly affected by or adjacent to the project area. Having affected stakeholders serve as project proponents can help build public support.
Hold public meetings	Provide the public an opportunity to weigh in on the project idea long before plans have been finalized. It is also helpful to make field trips to restored ecosystems, so that community members can envision a finished product in their neighborhood (Casagrande 1997).
Clearly translate project goals and objectives	Avoid complex science jargon during public meetings and when developing outreach materials. Use non-scientific language, well-versed speakers, graphics, and charts to avoid confusion and educate your audience. Modeling activities can be especially challenging to describe. Remember that the ecological benefits of restoring tidal flow are not necessarily obvious to the general public.
Incorporate community interests	Understand community interests related to the characteristics and history of the project location. On occasion, restoration projects can be designed to meet primary ecological goals while simultaneously satisfying community goals with limited additional expense. For instance, aesthetic benefits realized from a project may provide increases in adjacent property values.
Utilize success stories	Enable community understanding of the project. Utilize simple schematics and visualizations of similar projects during meetings, in outreach materials, and when working with the media.
Address misinformation	Use the media to disseminate correct information that directly addresses community concerns if misinformation is widespread.
Reexamine the project	Reexamine the project if substantial and valid community opposition exists. Incorporate community concerns into subsequent plans, or if opposition is insurmountable, accept that the project may not be viable.

Volunteers provided needed manpower to remove invasive plant species at the Eden Landing Salt Pond Project in California.

Photo Credit: NOAA

Developing Volunteer Strategies

Developing and implementing a comprehensive volunteer strategy is a key step toward effectively building public support. The inclusion of volunteers for a one-time task may be a simple undertaking, but investing resources in a sustained community involvement strategy to implement education, outreach, advocacy, and volunteer coordination can provide an exponential increase in project benefits. The ultimate goal of such a volunteer and involvement program is to educate and inspire citizens to take ownership of their public resources and to serve as a voice for future restoration and protection actions and policies.

Some specific benefits of an effective volunteer strategy include:

- *Financial benefits.* At the project level, volunteers can be very useful for reducing costs while helping meet matching funds requirements for grants. Some granting programs accept a standard value for volunteer contributions. In 2009, volunteer service was valued at $20.85 per hour.

For up-to-date valuations, visit http://www.independentsector.org/programs/research/volunteer_time.html

- *Project maintenance.* Engaging volunteers in tidal restoration project construction and maintenance may inspire them to continue in a long-term stewardship role.
- *Expanded capacity.* Dedicated volunteers sometimes take on more complex roles, including recruitment and management of new volunteers, as well as initiation and management of their own projects.
- *Stronger grant proposals.* Grant proposals with volunteer, education, and outreach components are typically ranked higher by funding agencies during the review process than similar projects that omit these components.

CONSIDER

Utilizing the Professional Capacity of Volunteers

Investigate the skill sets of available volunteers. Biologists, engineers, heavy equipment owners/operators, teachers, graphic designers, and grant administrators can provide particularly valuable volunteer services. Individuals living in proximity to a project site may have professional backgrounds that can assist with complicated aspects of project implementation.

For example, the management of the Sandpiper Pond Tidal Hydrology Restoration Project in South Carolina was enhanced by the expertise of a local retired environmental administrator. The resident led recruitment and coordination of partners and volunteers, secured grants, and completed project reports. The grant matching funds associated with these complex tasks were commensurate with the value of the service provided, rather than a standard volunteer hourly rate based on manual labor.

For more, see the **Sandpiper Pond Tidal Hydrology Restoration Project Portfolio** *(page 146).*

- *Public exposure.* Volunteer events often gain the attention of media outlets and local politicians.

Volunteer coordination is a well-documented practice featured in several guidance manuals. A list of these resources is provided in the ***Toolkit***, page 213. Despite the benefits of volunteers, it is important to consider the cost and time required to train volunteers, the need for oversight, and the potential liability if volunteers are injured (IWWR 2003). There are also many dangerous and complex elements of tidal hydrology restoration, such as heavy equipment operation and technical design components, that can not be readily undertaken by volunteers.

Investing resources into developing a volunteer monitoring program can provide numerous benefits to restoration organizations and their projects.

Photo Credit: Dave Burdick

Volunteers and Monitoring

One resourceful way to engage volunteers is to involve them in long-term scientific monitoring activities. This can provide multiple benefits, as monitoring is usually a requirement associated with the use of grant funds and is necessary to gauge project outcomes. Often the burden of monitoring can be decreased by utilizing volunteers who live close to the project.

Using volunteers for frequent monitoring also allows for more rapid response to potential project performance issues, such as tidal blockages from organic debris or sedimentation, invasive vegetation, vandalism, or illegal dumping. High-frequency scientific monitoring is typically not financially feasible; however, an "adopt a wetland" style program, in which volunteers assist with scientific monitoring, encourages both long-term volunteer involvement and ensures consistent qualitative assessment.

Members of the public, academics, and state or federal resource managers sometimes question the validity of monitoring data gathered by volunteers. However, volunteer monitoring data is often as accurate and valid as the data gathered by academics and professionals (Fore et al. 2001; Canfield et al. 2002; Ringvall et al. 2005). The key to ensuring data quality is to provide thorough training for volunteers in standard monitoring protocols.

Some points to consider when developing a volunteer monitoring program:

- *Volunteering capabilities.* Acknowledge the skill set of your volunteers. Limit volunteer involvement with complicated techniques such as vegetation monitoring or fish counts. Consider tasks associated with bird, mammal, and other megafauna monitoring.

- *School programs.* Involve local schools in monitoring programs. Schools are helpful in amassing long-term data sets over multiple years. When compiling this data, be sure to check quality and discard outlier data points.

- *Academic oversight.* Involve university researchers in the development of monitoring plans and provide these researchers with the best data collection volunteers. Dr. David Burdick, with the University of New Hampshire, implemented a monitoring plan incorporating volunteer data collection for the Little River Marsh Restoration Project. He found that their contribution has been beneficial for long-term repeated measures.

For more information, see the **Little River Marsh Restoration Project Portfolio** *(page 158).*

Below are some monitoring activities critical for evaluating effectiveness of tidal hydrology restoration projects that may more easily apply to volunteers.

- *Invasive vegetation.* Consider training volunteers to identify one or two types of specific invasive plants. Provide them with the appropriate tools to document the species' presence or absence and removal, if applicable. It is generally advisable not to assign volunteers activities requiring percent cover estimates, since the results require calibration and may create problems with data analysis.

- *Hydrology.* By establishing permanent stations at the project site, certain tools, such as a staff gauge, allow for data collection on tidal height and period, requiring only periodic visual observation and recording of information.

- *Salinity.* Simple tools (e.g., refractometer and data sheets) allow for the collection of many relevant data points.

- *Water quality.* Many companies sell inexpensive water quality kits that are very simple to use in the field with straightforward training techniques and instruction manuals. Typical water quality kits test for dissolved oxygen, salinity, pH, and more.

- *Bird counts and identification.* Bird lovers enjoy watching, identifying, and counting birds.

- *Photopoint.* Visual markers such as numbered wooden posts can be established throughout the project site. Volunteers can then use a compass for orientation, a camera, and a data sheet indicating the direction to take photos from any given post. It is also useful to provide an example photo taken from each photopoint to allow for a refinement of orientation. While typically qualitative in nature, a photo can often provide more information than quantitative data points.

For more information on volunteers and monitoring, see **Chapter 7: Scientific Evaluation and Monitoring.**

Staff gauges are easily used by volunteers to determine tidal height.

Photo Credit: NOAA (Steve Block)

PROJECT HIGHLIGHT

Clam Bayou Tidal Hydrology Restoration Project

Sanibel Island, Lee County, FL

During the South Florida population boom of the 1950s and 1960s, local developers used dredge and fill construction activities to create vehicular causeways connecting Sanibel and Captiva Islands to the mainland. Unfortunately, these causeways bisected Clam and Dinkins Bayous, halting all natural tidal flushing between the two mangrove-dominated systems. The impoundment of freshwater resulted in the loss of more than 150 acres of mangroves, 20 acres of oyster reefs, and 120 acres of seagrass beds. Fish kills and algae blooms were also common occurrences following causeway construction.

Private landowners surrounding the bayous formed the Clam Bayou Preservation Association to investigate the problems and identify solutions for the system. The Association used private funds to hire a consultant to study the flow and bathymetry at the site. The Association also prompted the City of Sanibel into action with the results of this study and partnered with the city to obtain the remaining information needed to develop a project design.

The city took the lead in 2006 with the installation of three 10x10-foot box culverts under the causeway. Citizens have remained actively engaged, planting more than 5,000 mangroves over the course of multiple volunteer days to help repopulate mangrove islands within the Bayou. Rob Loflin, City of Sanibel project manager, acknowledges that local citizens “drove and sped up” the process.

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

Citizen volunteers planted over 5,000 mangroves following installation of the box culverts at the Clam Bayou Tidal Hydrology Project in South Florida.

Photo Credit: NOAA

GLOSSARY

Active restoration design strategy
Construction activities across a large area relative to the overall size of the area to be restored (as compared to passive design strategies) and/or characterized by regular and scheduled long-term maintenance. *Examples include the installment, maintenance, and operation of a water control structure, tidal creek creation, or other major land alterations.*

Adaptive management
A management approach that involves monitoring the outcomes of a project or issue and, on the basis of the monitoring, improving the way the project is managed.

As-built assessment
Measurement and assessment of the actual constructed or installed project design components immediately following final construction activities; describes physical and/or functional characteristics in comparison to the final design.

Bathymetry
Measurement of depths of water in oceans, seas, and lakes; also the information derived from such measurements.

Benthic
Pertaining to the bottom (bed) of a water body.

Construction footprint
The actual area or boundary of physical construction activities; the actual project area affected by construction activities may be much larger than the "construction footprint."

Culvert
A conduit used to allow passage of water below ground level. *Often a large diameter metal, concrete, or polyvinyl chloride (PVC) pipe used to allow water to pass underneath a road, railway, or embankment, for example.*

Ecosystem
A conceptual unit comprising organisms interacting with each other and their environment. An ecosystem has the major attributes of structure, function, complexity, interaction and interdependency, temporal change, and no inherent definition of spatial dimension.

Estuary
Regions of interaction between rivers and nearshore ocean waters, where tidal action and river flow create a mixing of fresh water and saltwater. These areas may include bays, mouths of rivers, salt marshes, and lagoons.

Field protocols
A formal plan describing the standardized procedures and techniques to be used in conducting construction activities.

Floodplain
Typically flat land areas adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding. This area, if left undisturbed, acts to store excess floodwater. The 100-year floodplain, or lands that have a 1 percent chance of flooding in any given year, are typically regulated for protection by federal, state, and municipal agencies.

Flow velocity
Distance traveled by a packet of fluid in a unit of time. *Influences the options for project design, specifically in regard to appropriate sizes for breaches, culverts, etc.*

Geographic Information System (GIS)
A data management tool that provides users with a spatial understanding of locations or events based on georeferenced data. *GIS is often used to locate specific features on a landscape or analyze relationships between features. Successfully implemented, GIS aids goal setting, data analysis, and monitoring ecosystem integrity.*

Global Positioning System (GPS)
A system based on satellites that allows a user with a receiver to determine precise coordinates for their location on the Earth's surface. These are a primary source of spatial data used in GIS systems.

Hydric soil
Soils that remain saturated year round.

Hydrology
Study of water and its properties, including its distribution, movement, and quality.

Hydrologic model
Simplified, conceptual representations of part of the hydrologic cycle; primarily used for hydrologic prediction and for understanding hydrologic processes. *Allows for analysis of current site hydrology and prediction of potential impacts from alternative restoration project designs.*

Impoundment
A body of water confined by a dam, dike, floodgate, or other barrier used to exclude or control the influence of water flow.

Invasive species
A species that does not naturally occur in a specific area and whose introduction is likely to cause economic or environmental harm.

Land cover
The physical material at the surface of the Earth. Land covers include grass, asphalt, trees, bare ground, water, etc. *There are two primary methods for capturing information on land cover: field survey and thorough analysis of remotely sensed imagery.*

Land use
The manner in which a parcel of land is used or occupied.

Lagoon

A shallow body of water that usually has a shallow restricted inlet from the sea; typically characterized by low salinity (less than 10 parts per million) and containing less than one-third seawater.

Levee

A large dike or embankment built to prevent inundation, often having an access road along the top, which is designed as part of a system to protect land from floods.

Mosaic habitat

Multiple microhabitat types patched together potentially providing for a range of ecosystem services and allowing for on-site habitat migration as a hedge against sea level rise. *For example, incorporation of freshwater, upland, high marsh, and transition zones might allow the site to be more adaptable to changing conditions.*

Nekton

Organisms that swim freely in the ocean.

Passive design strategy

One-time construction activity resulting in a self-sustaining system with little long-term intervention; typically characterized by a relatively small area of construction activity that reintroduces or enhances tidal flow, allowing a larger area to restore naturally over time. *For example, the small footprint of construction through removal and replacement of a section of causeway that enhances a large area of seagrass with no hands-on restoration work in the seagrass habitat.*

Reference sites

An "ideal" undisturbed or relatively undisturbed healthy habitat that has characteristics similar to a potential restoration project. *Reference sites can help practitioners understand hydrology modification impacts on many ecological indicators, including water quality (salinity, dissolved oxygen content, or pH), vegetation, and nekton community composition. Comparisons to reference sites can also help define desired ecosystem services, and provide targets for post-restoration monitoring. Reference sites provide information about the natural range of values for the parameters used in the monitoring program and show the annual variation in these parameters.*

Restoration (Habitat)

Process of re-establishing a self-sustaining habitat that closely resembles a natural condition in terms of structure and function. Does not focus on a single species, but rather strives to replicate the original natural ecosystem to support numerous species.

Returning the tide

Restoring or enhancing flow of tidal waters to estuarine habitats in areas that have been historically degraded as a result of tidal barriers such as levees, dikes, causeways, and failed or undersized culverts. Barriers are breached or removed to provide a more natural tidal regime with the ultimate goal of restoring estuarine habitat functionality.

Salinity regime

The prevailing pattern or normal set of conditions for salinity in an ecosystem. *Salinity strongly influences distribution of plant and animal communities as well as soil characteristics. Understanding the current salinity regime will aid in developing appropriate targets for post-restoration salinity regimes. Soil or interstitial salinities should also be investigated for proper plant selections.*

Sheet flow

A thin layer of water movement over the land surface with no identifiable channels.

Tidal footprint

The expanse of area influenced by the tidal ebb and flow. *Important for any engineering or hydrology modeling effort used to forecast the effects of hydrology modification at the site.*

Tidal hydrology restoration

Re-establishing or enhancing movement, distribution, and quality of waters in an estuarine environment with the purpose of re-establishing habitat that closely resembles a natural condition in terms of structure and function.

Tidal prism

Range in volume of water from high to low tide.

Tidal regime

The prevailing pattern or normal set of conditions of the tides.

Topography

The physical features of the land.

Turbidity barrier

A device used to contain and control the dispersion of sediments and siltation in association with nearshore or in-water construction activities. *Examples include turbidity curtains, silt curtains, and silt barriers.*

Wetlands

Permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions. *Examples of wetlands include freshwater and saltwater estuaries, fens, bogs and swamps, tidal marshes, prairie potholes, seagrass beds, mangroves, and forested wetlands. Cowardin et al. (1978) provides an in-depth discussion of wetland definition and classification.*

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NOAA Restoration Center
1315 East-West Highway
Silver Spring MD, 20910

NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405

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