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.

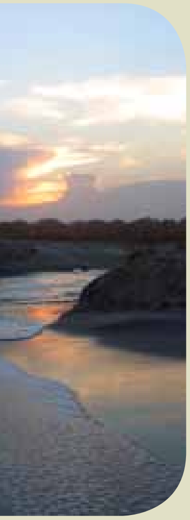
For more details on baselines, see **Chapter 7: Scientific Evaluation and Monitoring**

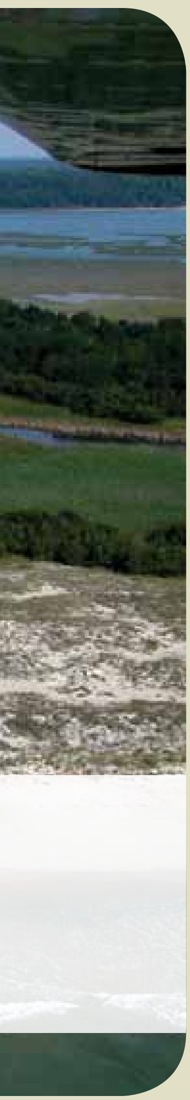
Construction maintenance. Maintenance of a tidal hydrology restoration site involves structure repair; plant replacement (if planting was part of the original project); and control or elimination of invasive species, herbivores, and predators. Local entities will likely be the most accessible and cost 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).*