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.

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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.

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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