AUDUBON | JACOBS

Nature Works!

SELECTED CASE STUDIES FOR **NATURE-BASED** SOLUTIONS

NOVEMBER | 2025

Introduction

The National Audubon Society works across the hemisphere, identifying and implementing solutions that create conditions for birds to thrive, thereby creating conditions for people and the planet to thrive as well. As we partner with all levels of government, community members, and other conservation groups, we seek durable solutions to the challenges facing birds and people, including more frequent severe weather, a changing climate, the impacts of development, and the legacy of resources management decisions that only addressed one piece of the puzzle.

Audubon and our partners implement solutions with an eye to the optimization of available resources: identifying projects and programmatic solutions that consider habitat connectivity, economic impact, multi-benefit outcomes, and the inclusion of affected communities in the decision-making process. We seek to make the best use of organizational capacity, funding availability, and innovative approaches to solve multiple challenges with unified and holistic solutions.

In these pages the reader will find shining examples of this sort of approach: implementing nature-based solutions to water management challenges, habitat restoration, wetlands protection, and vulnerability to severe weather events. These solutions feature examples of innovative thinking applied to complex problems, bringing together diverse sets of partners and government agencies to collectively identify and implement solutions that meet multiple goals while achieving local buy-in from the communities most affected.

We believe that this type of collective, cooperative, and innovative action that meets multiple objectives offers a path forward for resource managers and communities across the Americas. We hope that the reader will enjoy and appreciate the geographic reach of this report, and the hard work on the part of managers and communities that these projects represent. As we all chart a path forward toward strategic resource management and creative solutions, we believe that these selected projects represent a great example and opportunity to protect birds and the places they need, today and tomorrow, while safeguarding communities and people across the hemisphere.

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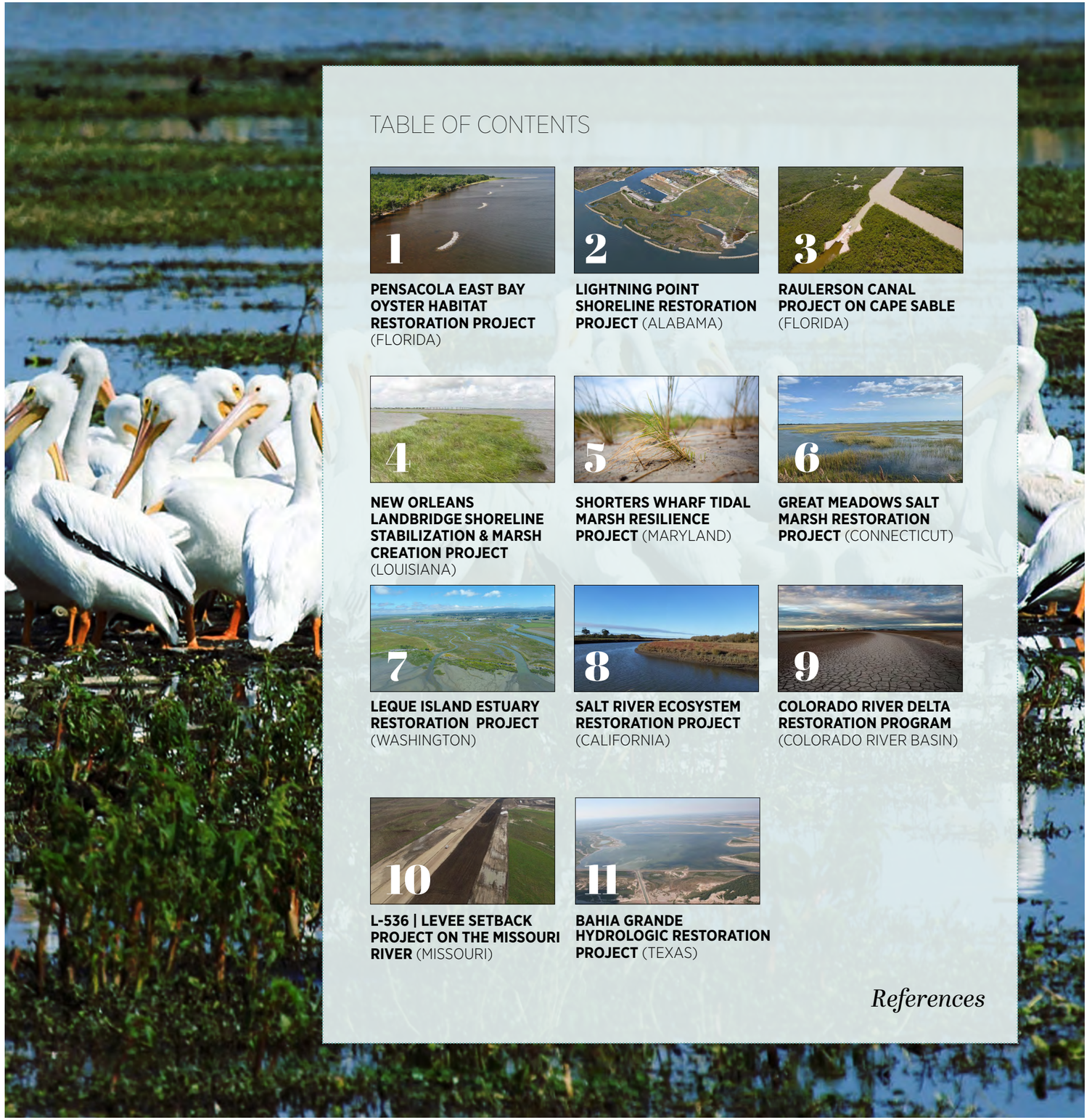
DEFINITIONS

NATURE-BASED SOLUTIONS

Nature-based solutions are defined as "actions to protect, sustainably manage, or restore naturally functioning or modified ecosystems to address societal challenges, while simultaneously providing benefits for people and the environment. Nature-based solutions may include beaches, dunes, wetlands, fluvial flood plains, and oyster reefs, among other solutions. A nature-based feature is a feature that is created by human design, engineering, and construction that works in concert with natural processes or to mimic as closely as possible conditions which would occur absent human changes to the landscape or hydrology to achieve study objectives."

U.S. Army Corps of Engineers Memo: Incorporation of Nature-based Solutions in Civil Works Projects. April 22, 2024.



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CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

OFFSHORE REEFS

Pensacola East Bay Oyster Habitat Restoration Project (Florida)

1

The bays of Santa Rosa County, Florida, once teemed with oysters. The stories told by local watermen reveal a history of plentiful oysters that supported a vibrant fishery and thriving wildlife. However, because of water quality degradation and other challenges, the oyster population sharply declined, along with the once-flourishing seagrasses in East Bay and Blackwater Bay. Communities throughout the watershed are making strides to improve the bays' water quality. This means once-abundant oysters in these bays can make a comeback — with a little help. The Nature Conservancy and partners completed the **construction of 33 reefs** designed to perfectly suit the local conditions and attract Eastern oysters along 6.5 miles of shoreline in the East and Blackwater bays. These reefs, made of **limestone rock and oyster shells,** were designed to attract Eastern oysters, providing them with an ideal habitat for settlement. The Pensacola East Bay Oyster Habitat Restoration Project is funded by the National Fish and Wildlife Foundation's Gulf Environmental Benefit Fund.

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The Nature Conservancy

ECOSYSTEM SERVICES

Oysters play a crucial role in our estuaries because they form reefs that can provide valuable ecosystem services. These unique marine species **filter water, protect shorelines from erosion**, and serve as an important **food source and nursery habitat for many species**, including commercially and recreationally significant fin-fish, crabs, shrimp, and birds.

The health of the estuary and its species is dependent on having healthy oyster habitat. Like many places throughout the world, oyster populations in Escambia and Santa Rosa counties have declined significantly in recent decades.

PARTNERSHIP

The construction of these reefs is part of a broader initiative by The Nature Conservancy, partners, and the community to restore oysters throughout the Pensacola Bay system to support both the wild harvest oyster fishery and the ecosystem services provided by reefs.

© Russell C. Mick

Four of the eight reefs in Blackwater Bay.

1

PROJECT AREA

Location of Pensacola East Bay Oyster Habitat Restoration Project

COSTS AND FUNDING SOURCES

$11 million construction cost.

Funded by the National Fish and Wildlife Foundation's Gulf Environmental Benefit Fund.

© Darryl Boudreau/Northwest Florida Water Management District

© Darryl Boudreau/Northwest Florida Water Management District

Pensacola East Bay Oyster habitat restorations reefs.

PROJECT TIMELINE

- **2016 to 2020**
  Reef design, permitting, construction bids, and pre-construction monitoring
- **2021 to 2022**
  Reef construction
- **2021 to 2026**
  Post-construction monitoring

Measuring Impacts

To evaluate the success of the project, monitoring began 2 years before construction of the oyster reefs. Monitoring will continue until 2026 to measure oyster recruitment to new reefs and the increase in abundance of fish, crabs, and water birds. The project's progress will be measured quarterly or annually using metrics such as oyster density; oyster size frequency; density and size of invertebrates; and water quality parameters, including temperature, salinity, and dissolved oxygen.

© Whitney Scheffel/Pensacola and Perdido Bays

Oysters on a rock from a recent constructed reef in East Bay, Florida.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

LIVING SHORELINE

MARSH CREATION

HYBRID SOLUTION

Lightning Point Shoreline Restoration Project (Alabama)

The Lightning Point Shoreline Restoration Project is located in the southwest corner of Mobile County, Alabama, on the northern shore of Mississippi Sound where Portersville and Grand bays meet. It is home to a thriving community that lives off the waters for seafood processing, ship building, fishing, and marine construction. The project started in 2016 with the acquisition of 89 acres obtained through the National Fish and Wildlife Foundation's (NFWF's) Gulf Environmental Benefit Fund and 44 acres through Coastal Impact Assistance Program funds. In 2017, efforts were initiated to design a diverse habitat restoration project, including 1.5 miles of breakwaters with two jetties aimed at enhancing the protection of the Bayou La Batre Channel. The project used 300,000 cubic yards of dredged sediment to build more than 43 acres of marsh and create more than 2.5 miles of tidal creeks. In addition, a low-impact parking lot was designed to help manage stormwater runoff, along with trails and a pavilion to support the managed access needs of the Bayou La Batre community. The project involved more than 25 partners to make it a reality. Habitat monitoring is planned through 2025.

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The project is designed to achieve multiple restoration goals for the Bayou La Batre coastline.

SHORELINE PROTECTION
More than a mile of overlapping, segmented breakwaters was constructed along the shoreline on both sides of the navigation channel to provide a buffer from waves and boat wakes. Two jetties (700 and 800 feet long, respectively) were also built at the mouth of the channel to maintain access to the navigation channel for all types of vessels.

HABITAT CREATION
Almost 40 acres of marsh, over 2 miles of tidal creeks, and approximately 4 acres of scrub-shrub habitat were created to support a wide range of fish, shellfish, and birds.

MANAGED ACCESS
Walking paths and a lookout point were added for community use and enjoyment, along with interpretive signage, view finders, and an ADA-accessible fishing platform.

BENEFICIAL USE OF DREDGED MATERIAL
More than 300,000 cubic yards of dredged material were beneficially used to create marsh habitat and to help expand the existing shoreline to buffer the town from future coastal hazards.

Lightning Point shoreline restoration aerial.

2

PROJECT AREA

Location of Lightning Point Shoreline Restoration Project

COSTS AND FUNDING SOURCES

Total project costs **approximately $22 million ($7 million - land acquisition, baseline monitoring, stewardship, and engineering and design + $15 million - restoration construction and post-monitoring)** funded by a unique blend of federal, state, and private capital.

The project's primary funding source was **the NFWF Gulf Environmental Benefit Fund**. Additional sources of funding included the Gulf of Mexico Energy Security Act, Alabama Power Foundation, and Restore America's Estuaries-CITGO.

PROJECT TIMELINE

- **2016**
  Project started with land acquisition
- **2017 to 2018**
  Project designs
- **2019 to 2020**
  Construction
- **2020 to 2025**
  Habitat monitoring of the restoration project will occur for 5 years

Students from Alma Bryant High School replanted native grasses at Bayou La Batre's Lightning Point as part of a conservation project.

Measuring Impacts

To assess the overall ecosystem and economic values of the project, the initial construction investment was compared with the value generated by the newly created tidal marsh and scrub-shrub habitats over the 25-year design life of the project. The project is expected to produce a total value of nearly $66 million, representing **a threefold return on investment**. This calculation does not include the **additional benefits from improving bird habitats and providing recreational opportunities for visitors, which bring in more dollars and value to the local area.**

Additionally, the project is expected to help **mitigate the impacts of coastal storms on local Gulf communities and support their livelihoods.**

To ensure the project's long-term success, a sustainability plan was developed, outlining the need to periodically add thin layers of sediment from nearby navigational channels that require regular maintenance dredging to nourish the marshes and **counter the effects of climate change, particularly sea level rise and subsidence.**

In addition to its environmental benefits, the success of the project can be attributed in part to the effective collaboration between The Nature Conservancy, the engineering firm, the prime contractor and its subcontractors, most of which are local to the Bayou La Batre region.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

Raulerson Canal Project on Cape Sable (Florida)

3

The Raulerson Canal Project is located within the southern Everglades in Monroe County, Florida. The site falls within the boundaries of the Greater Everglades Restoration Act and the Comprehensive Everglades Restoration Plan (CERP). This project complements **the largest hydrologic restoration project ever undertaken in the CERP** authorized by Congress. The habitats of Cape Sable, the CERP project area, and the greater Everglades ecosystem are linked by their waters and wildlife; thus, Everglades restoration relies on both designated CERP projects and non-CERP projects like this one to accomplish overarching goals.

Specifically, the human-made canals in Cape Sable, created in the early 1900s to drain freshwater wetlands in the interior, have had drastic effects on the landscape. These effects include fragmentation of the wetlands' vegetative footprint and conversion of vegetation to open water through erosion and peat loss. Additionally, high salinity variability lowers the abundance of forage fishes, potentially reducing prey availability for wading birds and game fish and affecting their survival. In turn, the reduced food sources may affect higher trophic level animals, such as crocodiles.

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Audubon

All of these factors have degraded the Cape habitats and ecological productivity for freshwater herbaceous marshes (grasses and sedges), intertidal scrub-shrub wetlands, mangroves, seagrasses, and tidal flats. Recognizing that the canals allowed saltwater intrusion that degraded interior freshwater marsh habitats, the **National Park Service** (NPS) made repeated efforts to plug many of the canals in the 1950s, 1990s, 2011, and 2016. These effects and planned remedies for enhancement are detailed in documents developed by **Everglades National Park** (ENP) staff and its partners such as the University of Miami Department of Geological Sciences. This historic due diligence culminated in an Environmental Assessment in 2016 in which alternatives were described for the engineered closure of each of the canals.

Raulerson Canal is the last Cape Sable canal in need of closure following previous efforts conducted by ENP and its partners to close the other canals.

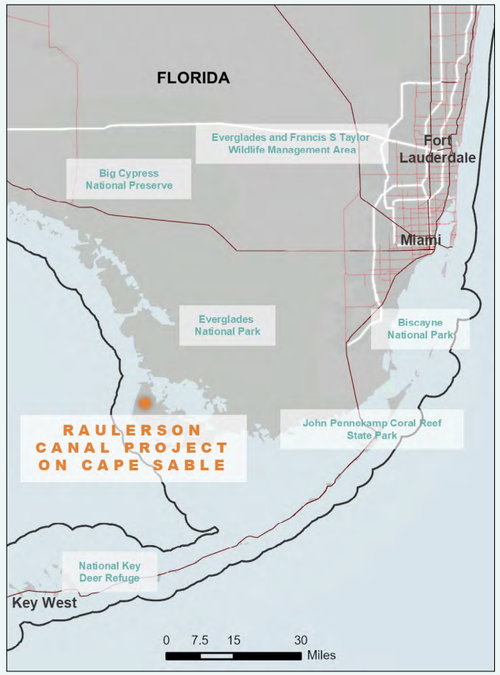
The canal is now widening at a rate of ~2 feet annually as its bank erodes from tidal inundation and storm activity. ENP staff and partners such as Audubon Florida have conducted the necessary due diligence for the planned closures of all Cape Sable canals including the 2016 Environmental Assessment, which outlined the **benefits of these projects to fish and wildlife habitats as well as to water quality.**

A canal at Cape Sable.

3

PROJECT AREA

Location of Raulerson Canal Project on Cape Sable



COSTS AND FUNDING SOURCES

The **total estimated project cost is $5.3 million**, as outlined in a 2020 budget analysis by Audubon. Additional partner funds will address final design, permitting, personnel, travel, and extra materials. Grant and match funds will create a water control structure (earthen plug with sheet pile weir) similar to those at nearby Homestead and East Cape Extension canals. Grant funds will primarily cover installation costs, with partner funds covering the remainder.

ENP, Florida Fish and Wildlife Conservation Commission (FWC), Audubon, Ducks Unlimited (DU), and other partners are collaborating to secure the necessary funding. ENP has already obtained funding from the National Fish and Wildlife Foundation, while FWC has in-house funds and has applied for a National Coastal Wetland Grant to support additional funding, which would be managed by DU.

Aerial view of Cape Sable.

PROJECT TIMELINE

- **2021**
  Project started
- **2022-2024**
  Permitting and design
- **2025**
  Construction by early 2025

Accomplishments to Date

In 2011, the first phase of the Cape Sable Dam Restoration was completed. This phase reestablished the natural coastal ridge across canals, which helped prevent saltwater intrusion and reduce erosion. Six years later, Hurricane Irma tested the effectiveness of wetlands when it passed just west of Cape Sable. After the storm, Audubon scientists documented the impacts on both restored and non-restored wetland areas, revealing a significant difference. In the restored wetlands, where earthen dams replicated natural conditions, the habitat withstood the storm's forces exceptionally well, showing virtually no further erosion or loss of vegetation. In contrast, areas that had not yet been restored experienced notable loss of shoreline and mangroves due to storm surge. This provides direct evidence that an intact coastal ridge and healthy mangrove habitat offer strong protection against extreme storm conditions and rising sea levels.

Roseate Spoonbills and other wading birds.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

New Orleans Landbridge Shoreline Stabilization & Marsh Creation Project (Louisiana)

The New Orleans Landbridge Shoreline Stabilization & Marsh Creation Project aims to **restore and protect 283 acres of brackish marsh and to safeguard 15,900 linear feet of shoreline** by armoring lakeshore containment dikes. The specific objectives of the project are to create and nourish brackish marsh habitat; stabilize the shoreline to reduce erosion; maintain the integrity of the East Orleans Landbridge and Lakes Pontchartrain and Borgne; protect fish and wildlife trust resources, particularly at-risk species and species of conservation concern; and provide protection for a major hurricane evacuation route.

The project area, flanking U.S. Highway 90 along the east shore of Lake Pontchartrain and areas surrounding Lake St. Catherine, has experienced significant marsh loss because of tropical storm impacts, especially during Hurricane Katrina. This loss has necessitated the restoration and protection of these vital marsh habitats.

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The project is designed to achieve multiple restoration goals:

SHORELINE PROTECTION
Approximately **15,900 linear feet of articulated concrete mats** will be added as a shoreline stabilization feature placed on the earthen containment dikes along the shorelines of three of the four marsh creation areas to ensure shoreline stability during and after construction.

HABITAT CREATION
To meet the project's habitat creation goals, the dredge slurry in all marsh creation fill areas will need to initially be placed to a constructed fill elevation above the functional brackish marsh range and settle into the range over the 20-year design life. To accomplish this, marsh creation areas will be pumped to an elevation of +2.0 feet NAVD88. Le Batre's Master Plan includes walking paths and lookout points for the community. In addition, a low-impact parking lot employing green infrastructure techniques, such as pervious pavers, bioretention cells, and bioswales, to aid in stormwater management was designed to improve water quality in the area.

BENEFICIAL USE OF DREDGED MATERIAL
Approximately **1.5 million cubic yards of material dredged** from three borrow areas in Lakes St. Catherine and Pontchartrain and from flotation access dredging will be used to restore approximately 283 acres of brackish marsh in three marsh restoration areas: a 111-acre area west of U.S. Highway 90 (MC1), an 112-acre area east of U.S. Highway 90 (MC2), and a 60-acre area known as Nine Mile Island (MC3).

New Orleans Landbridge Marsh

4

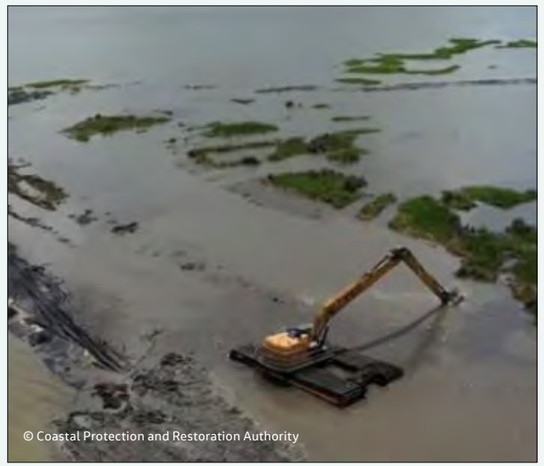
PROJECT AREA

Location of New Orleans Landbridge Shoreline Stabilization & Marsh Creation Project

COSTS AND FUNDING SOURCES

~$25.4 million construction cost funded by the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA)

Sponsors: U.S. Fish and Wildlife Service Energy Security Act ; Alabama Power Foundation; and Restore America's Estuaries-CITGO



Marsh creation construction.

PROJECT TIMELINE

- **2015**
  Funding approved
- **2015 to 2022**
  Project design
- **2022 to 2025**
  Construction
- **2024 to 2029**
  Habitat monitoring

Measuring Impacts

One of the greatest influences of marsh loss in the area can be attributed to tropical storm impacts. Wetland losses were accelerated by winds and storm surge caused by Hurricane Katrina, which converted approximately 70 acres of interior marsh to open water.

To assess the overall ecosystem and economic values of the project, the Coastal Protection and Restoration Authority compared the $25.4 million initial construction investment to the value provided by the newly created tidal marsh and habitats. **The project will produce a net benefit of 283 acres restored.** Additionally, stabilizing the shoreline and protecting the remaining marsh would protect natural coastal resources dependent on this important estuarine lake, communities that thrive on those resources, the Fort Pike State Historical Site, and infrastructure, including U.S. Highway 90.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

OFFSHORE REEFS

MARSH CREATION

HYBRID SOLUTION

Shorters Wharf Tidal Marsh Resilience Project (Maryland)

5

Blackwater National Wildlife Refuge (NWR) is situated on Maryland's Eastern Shore, approximately 12 miles south of Cambridge. Covering more than 29,000 acres, the refuge includes a mix of tidal marsh, hardwood and pine forests, freshwater wetlands, and agricultural land. The Blackwater River, a tidal tributary of the Chesapeake Bay, runs through the refuge and encompasses one of the largest brackish marsh areas in the Chesapeake Bay watershed.

Unfortunately, the tidal marsh system of the Blackwater River has suffered considerable wetland loss and degradation over the decades. Research by Stevenson et al. (1985, 2000) and Scott et al. (2009) indicates that around 5,028 acres of tidal marsh have converted to open water since 1938, marking a significant ecological loss for the Chesapeake Bay.

The primary cause of this marsh loss is the fragmentation of previously contiguous marsh areas, leading to the formation of ponds that expand through wave erosion (Whitbeck et al. 2019). Contributing factors include sea level rise, land subsidence, and plant consumption by nutria, all of which accelerate marsh fragmentation.

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CHALLENGE

Salt marsh plants, although adapted to the intertidal zone, have limits to their tolerance for prolonged flooding. A marsh's "elevation capital" — the difference between its surface elevation and the minimum elevation required for plant survival during tidal fluctuations — plays a crucial role in maintaining these ecosystems. Much of Blackwater's marshland was below optimal elevation for plant growth, and the vertical growth of these marshes was failing to keep pace with sea level rise (Whitbeck et al. 2019).

In 2013, the Blackwater Climate Adaptation Project (BCAP) was launched through a partnership of The Conservation Fund, Audubon Maryland-DC, and the U.S. Fish and Wildlife Service, and was supported by additional organizations. The project aimed to implement climate adaptation strategies for the region's tidal marsh ecosystem and create habitats for at-risk salt marsh birds.

With support from the Maryland Department of Natural Resources, BCAP utilized the Sea Level Affecting Marshes Model (SLAMM) to assess potential marsh losses due to sea level rise, predicting up to 1.03 meters of submersion without intervention. To counter this, BCAP encouraged strategies for the inland migration of marshes to enhance resilience. The Shorters Wharf Tidal Marsh Resilience Project aimed to enhance the resilience of about 40 acres of tidal marsh in Blackwater NWR against rising sea levels and storms. By restoring marsh elevation, it sought to boost the productivity of marsh grasses, promoting below-ground growth to help the marsh keep pace with rising waters. This intervention would provide valuable habitat for salt marsh birds, preventing the area from likely converting to open water.

Planting at the project site.

5

PROJECT AREA

Location of Shorters Wharf Tidal Marsh Resilience Project

COSTS AND FUNDING SOURCES

Approximately **$1.1 million construction cost**. Funding was provided by a grant from the NFWF's Hurricane Sandy Coastal Resiliency Competitive Grants Program to The Conservation Fund.

The project was implemented by: Audubon Maryland-DC, The Conservation Fund, U.S. Fish and Wildlife Service, and Sustainable Science, LLC.

Sediment placement.

PROJECT TIMELINE

- **2014**
  Fundraising – funding proposal submitted
- **2015-2016**
  Project design and baseline data collection
- **2016**
  Project construction (November-December)
- **2017**
  Vegetation replanting
- **2017 to Today**
  Post-construction monitoring

IMPLEMENTATION

Dredging commenced on November 1, 2016, and concluded on December 21, 2016, placing approximately 26,000 cubic yards of material. Surveys indicated a loss of 15,073 cubic yards due to natural erosion between October 12, 2016, and January 12, 2017. During operations, dredge material spread about 150 feet from the discharge point, and once target heights were achieved, the nozzle was moved 300 feet away for further pumping, resulting in circular patterns of sandier centers transitioning to finer sediments.

Three-square, a native marsh sedge, re-established itself by May 2017 across much of its pre-construction coverage. Bare soil areas, primarily from materials placed in historical marsh holes, were planted with saltmeadow cordgrass (*Spartina patens*). Following aerial imagery obtained on June 13, 2017, a total of 217,050 two-inch *Spartina patens* plugs were installed in varying densities across the project site during June and July 2017 by Ecological Restoration and Management.

Measuring Impacts

In 2018, approximately 32.5 acres of the project area were surveyed. In the surveyed area, 25.5 acres had an elevation exceeding 0.65 feet NAVD88. Of this, 18.7 acres were situated at elevations between 0.79 and 1.11 feet NAVD88. These observations align closely with the project target elevation range of 0.65 to 0.98 feet NAVD88.

Monitoring of vegetation cover, breeding bird communities, below-ground biomass, and marsh elevation change is ongoing. The U.S. Geological Survey is tracking marsh elevation and biomass, while the University of Delaware monitors breeding birds through Saltmarsh Habitat and Avian Research Program. Blackwater NWR, Salisbury University, and Audubon Maryland-DC are assessing vegetation cover and composition. Results will be shared publicly as they become available.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

HYBRID SOLUTION

Great Meadows Salt Marsh Restoration Project (Connecticut)

Great Meadows Marsh (GMM) is in the Stewart B. McKinney National Wildlife Refuge and is one of Connecticut's largest salt marshes. It contains the largest remaining mostly un-ditched marsh in the state.

The Great Meadows Unit consists of approximately **225 acres of un-ditched marsh, tidal wetland, ditched salt marsh, filled wetland, and upland.** The area also has small fresh or brackish ponds, salt pannes, and tidal mud and sand flats. GMM is connected to Long Beach by Lewis Gut, an estuarine embayment fed from several freshwater creeks and the waters of Long Island Sound through Bridgeport Harbor. The marsh was historically more than 1,400 acres, but because of land use changes since the mid-1800s, it has been reduced to less than 700 acres.

Even though it used to be much larger, GMM still provides **critical habitat for a diverse range of wildlife species,** including rare plant species, various finfish, and approximately 270 bird species. The birds, including many federal and state species of concern, use GMM for nesting, overwintering, and as a stopover during migration.

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Audubon

EARLY IMPLEMENTATION

In November 2021, the $4.65 million project to restore 34 acres of salt marsh and adjacent upland areas at GMM began. Before any soil was moved, a controlled burn was carried out to clear standing vegetation, particularly non-native common reed (*Phragmites australis*). Construction crews then removed excess soil piles, or berms, as well as tons of topsoil containing pieces of common reed that could resprout.

REPLANTING THE MARSH

After the site was cleared of common reed and modified to accommodate tidal flow and wildlife, volunteers, local high school students, contractors, and **project partners planted more than 165,000 grasses and other non-woody plants.** The planted species included "high marsh" grasses such as salt meadow cordgrass (*Spartina patens*) and spike grass (*Distichlis spicata*), "low marsh" smooth cordgrass *(Spartina alterniflora)*, and other species like seaside goldenrod (*Solidago sempervirens*), switchgrass *(Panicum virgatum*), and soft rush (*Juncus effusus*).

Controlled burn at Great Meadows Marsh.

Volunteers planting spikegrass plugs at Great Meadows Marsh.

Salt marsh restoration assessment at Great Meadows Marsh.

6

PROJECT AREA

Location of Great Meadows Salt Marsh Restoration Project

COSTS AND FUNDING SOURCES

Approximately $4.8 million construction cost. The primary project partners for the GMM restoration were Audubon Connecticut, U.S. Forest Service, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, Connecticut Department of Energy and Environmental Protection, and the Town of Stratford.

Restoration volunteers included Avalon Park and Conservancy, Connecticut's Beardsley Zoo, Norwalk Maritime Aquarium, Sacred Heart University, Southern Connecticut State University, National Oceanic and Atmospheric Administration, Northeast Fisheries Science Center, and hundreds of community members.

PROJECT TIMELINE

- **2004 to 2019** Planning
- **2019 to 2021** Fundraising
- **2021 to 2022** Implementation
- **2022 to 2026** Adaptive management

Measuring Impacts

A healthy GMM will produce more small fish and invertebrates, increasing the food supply for larger fish, birds, and other animals that live in and around the marsh. More than 270 bird species, including waterfowl, shorebirds, and wading birds, use GMM for foraging, nesting, resting, or as a home during the winter. Several rare species, including saltmarsh sparrow, American kestrel, great egret, and American black duck, rely on the marsh and surrounding area. The marsh provides important foraging and nursery habitat for horseshoe crabs, blue crabs, and fish like Atlantic silverside, Atlantic menhaden, striped bass, winter flounder, and bluefish.

The restoration work at GMM aimed to **increase community interest in the salt marsh and improve public health.** Goals included reopening a trail that had been closed for several years and installing two new accessible viewing platforms. These efforts have made the marsh more welcoming to visitors.

"The most exciting part of the project, from the perspective of protecting birds, is testing a fairly new strategy to ***create nesting habitat*** *for the saltmarsh sparrow. This critically threatened bird relies on healthy high-marsh habitat to survive, and unfortunately our coastlines and their associated marshes are being squeezed by rising sea levels and human development,"* said **Corrie Folsom-O'Keefe**, director of conservation for Audubon Connecticut.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

HYBRID SOLUTION

Leque Island Estuary Restoration Project (Washington)

Leque Island, west of Stanwood between Port Susan and Skagit bays, was originally a tidal marsh. In the late 1800s, early settlers constructed dikes around the island, transforming the area into farmland and homesteads. However, over time, the land became increasingly waterlogged and subsided, posing challenges for agricultural activities.

The Washington Department of Fish and Wildlife (WDFW) began acquiring properties on Leque Island in 1974 and currently owns the entire island as part of the Skagit Wildlife Area. In 2013, WDFW collaborated with Ducks Unlimited (DU) to explore **new management options for the site**. To facilitate decision-making, WDFW involved local stakeholders and formed a committee of outdoor recreationists, local jurisdictions, tribal representatives, and farmers.

A juvenile Chinook salmon counted in the canals of Leque Island

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CONSTRUCTION BEGINS

On October 14, 2019, the dikes at the island were breached, and after more than a 100 years, salt water flowed freely into the 250-acre swath of land. In the summer of 2019, WDFW, DU, and construction partners completed the project south of Highway 532. The team **removed over 2.4 miles of levee, excavated over 5 miles of new tidal channels, and constructed a berm to protect the city of Stanwood from waves** while also supporting a walking trail.

WDFW and partners completed the removal of an **additional 0.6 mile of dike** to the north of Highway 532 during summer 2022. This initiative aimed to restore full tidal exchange and enhance access to 26 acres of salt marsh for juvenile salmon.

The newly restored habitat was expected to help **juvenile salmon and birds,** while the newly integrated flood protection infrastructure and recreation features were meant to **benefit the local community**. Scientists who have been monitoring the site since its construction have found that the project is well on track to meet these objectives.

Restored intertidal marsh and estuary habitat at the Leque Island Unit of Skagit Wildlife Area near Stanwood.

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PROJECT AREA

Location of Leque Island Estuary Restoration Project

COSTS AND FUNDING SOURCES

Approximately $6.4 million construction cost funded by a unique blend of federal and state capital.

PROJECT TIMELINE

Years of planning and securing grant funding from state and federal programs:

- **2019**
  Construction
- **2022**
  Removal of additional dike to restore the entirety of 276-acre project footprint

Birders use the trail along the top of the wave protection berm.

Measuring Impacts

The removal of the dikes has resulted in the **restoration of 276 acres of tidal marsh habitat in the Stillaguamish River watershed,** which is particularly significant because 85% of the historical tidal marsh in the area had been displaced. Tidal marshes play a critical role in providing habitat for juvenile Chinook salmon during their transition from fresh to salt water, as well as for shorebirds, waterfowl, and various other species. Because Puget Sound's Southern Resident orca rely on Chinook salmon for sustenance, this initiative is closely aligned with orca recovery efforts.

Since the restoration, fish scientists have documented 15 different species using the newly restored area, including Chinook, chum, and coho salmon, as well as adult bull trout. Bird scientists have noted a **greater diversity and increased abundance of birds** on the site following restoration when compared with pre-restoration data.

In addition to the benefits associated with habitat restoration, the wave protection berm has **enhanced the city of Stanwood's resilience against storm damage.** The project created additional amenities such as a walking trail, parking lots, and a paddle boat launch on Davis Slough, providing visitors with opportunities to continue enjoying the area.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

Salt River Ecosystem Restoration Project (California)

The Salt River watershed, which feeds into the Eel River delta, has been significantly affected by **changes in land use.**

These changes began in the late 19th century and have led to a reduction in acres of estuary lands and a decrease in its natural function. The alteration of the landscape, construction of levees and tide gates, and sediment buildup in the river channels have caused several issues. These include a **loss of natural hydraulic function, chronic flooding, and a decline in water quality.** Agricultural producers have also faced difficulties because of overland flow and the need for supplemental measures to manage flood conditions.

During the summer, **water flow in tributares is disconnected from the hyrdologic system because sediment causes** surface water to disappear in some areas. Culverts along roadways have also been obstructed by sediment, leading to further water management challenges. **The poor fish passage in the Salt River watershed has contributed to the decline of salmon populations in the Eel River watershed** and the loss of wetlands and habitat diversity.

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PROJECT COMPONENTS

The Salt River Ecosystem Restoration Project main components are:

River Restoration: This element involves increasing the hydraulic capacity, improving in-stream fish habitat, and enhancing water quality for approximately 7 miles of the Salt River and lower Francis Creek.

Estuary Restoration: The project aims to restore Riverside Ranch, a 400-acre property, by converting it into a tidal marsh while preserving 75 acres of short grass habitat**.**

Upslope Sediment Reduction: This element involves collaborative efforts with private landowners in the Williams, Francis, and Reas creek tributary watersheds to implement erosion control projects, reduce sediment, and restore riparian habitat.

Adaptive Management Plan: This component focuses on initiating a long-term process for monitoring and managing the project to ensure ongoing performance within a working landscape.

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Salt River California

PROJECT AREA

Location of Salt River Ecosystem Restoration Project

COSTS AND FUNDING SOURCES

~$1.8 million Integrated Regional Water Management funds

~$24.9 million leveraged funds

~$26.7 million total funds

PROJECT TIMELINE

The project is being implemented in **several phases. Phase 1, completed in 2013,** restored tidal marsh and enhanced tidal prism in the area known as Riverside Ranch.

Phase 2, was completed between 2014 and 2019.. Of the 7 miles of Salt River channel planned for restoration, 6 miles have been completed. The remaining mile is slated for restoration in the future.

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Aerial view of post-project Salt River tidal marsh and lower channel restoration area.

Measuring Impacts

Throughout the lifespan of this project, more than $5.4 million in estimated savings has been achieved by avoiding various projects. In addition, an estimated annual savings of $60,000 has been realized by avoiding wastewater violation fines. The project has led to **improved agricultural production** in the Eel River delta, **enhancing water quality** and benefiting various uses, including migration of aquatic organisms; rare, threatened, and endangered species; wetland habitat; water quality enhancement; and cold freshwater habitat. Watershed rehabilitation efforts have successfully restored 15 miles of migration routes and rearing habitat, as well as wetland habitat and floodplain function. These initiatives have also contributed to reducing the flooding risk for the city of Ferndale.

There have been **recreational benefits** such as improved opportunities for the fishing and tourism industries. The project has also increased agricultural viability by minimizing losses from chronic flooding and sediment accretion. Notably, almost $18 million was spent locally, benefiting the state's goals for environmental justice and social equity. The project has also created and maintained approximately 100 jobs while reducing the economic impacts of annual flooding for agricultural producers in the area. The **economic benefits** also include an annual reduction of approximately $160,000 in expenses for flood-related activities. Additionally, the project has saved Humboldt County and the City of Ferndale from having to expend funds to protect and repair roads and other infrastructure damaged by annual flooding.

HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

HYBRID SOLUTION

Colorado River Delta Restoration Program (Colorado River Basin)

In 2012, the United States and Mexico signed a historic agreement, formally known as Minute 319, **to tackle longstanding issues in the Colorado River Delta**. These issues pertain to binational water management during prolonged droughts, as well as the historic loss of freshwater flows and degradation and loss of the delta.

The agreement not only provided incentives for leaving water in storage but also emphasized collaboration between the United States and Mexico. Both countries are committed to partnering with a binational coalition of nongovernmental organizations (NGOs) to initiate habitat restoration efforts in the delta. The agreement delineated specific commitments from all three parties— the United States, Mexico, and the NGOs— to allocate water for environmental flows, in addition to securing funding for habitat restoration and initiatives focused on monitoring and scientific research.

Established in 2012, Raise The River (RTR) is a unique partnership of six U.S. and Mexican non-governmental organizations. These organizations work together to conduct scientific studies, implement restoration programs, and raise funds to bring water and life back to the Colorado River Delta and reconnect the river to the sea.

You can find more information at https://raisetheriver.org/.

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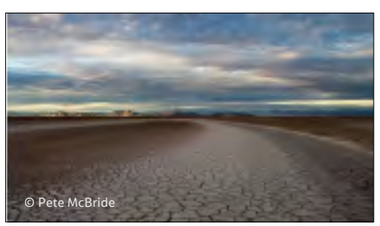
RESTORATION
The important binational agreement signed in November **2012** was a significant milestone that accelerated restoration efforts. Subsequently, the signing of its successor agreement, **Minute 323**, on **September 27, 2017**, ensured that their efforts would not only continue but also expand.

Since 2013, RTR actively managed restoration sites, regularly releasing water to **restore more than 1,000 acres of riparian habitat** along the river's main channel. Hundreds of thousands of **native cottonwoods and willow trees were planted** at key sites. RTR also actively engages in the scientific monitoring of the environmental water flows. Their primary objective is to replenish the delta with water and restore its ecosystem. The collaboration among NGOs, the United States, and Mexico serves as a model for international river restoration projects.

PARTNERSHIP
RTR established a water trust in Mexico to permanently acquire water rights from voluntary sellers in the Mexicali Valley. This initiative was funded by **raising more than $50 million** (as of November 2024) for restoration and water acquisition from foundations, corporations, federal agencies, and individuals in both countries. **Annually, more than 6,000 residents, school children, and volunteers** from around the world are involved in onsite restoration work and environmental education programs. The project also **created more than 140 jobs in 2016 alone**, related to completing the restoration work. RTR's successful habitat restoration under Minute 319 helped lay the foundation for Minute 323.

This program demonstrates how governments and stakeholders with diverse interests can collaborate to manage the river for the benefit of people and nature, particularly in the face of drought. The success of this project across international borders provides inspiration for similar efforts in the rest of the Colorado River Basin and other parts of the world.

Colorado River Delta near the Hardy River in 1904.



Colorado River Delta 2010.

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PROJECT AREA

Location of Colorado River Delta Restoration Program

Measuring Impacts

The project aims to produce a range of significant benefits for the entire basin, including the delta. Habitat restoration is a key component of the Colorado River agreement that improves water security and resilience for 40 million people who rely on the river. It also enables reductions in water use and establishes a model for long-term, binational cooperation over shared water resources, with the potential for replication in other transboundary river basins.

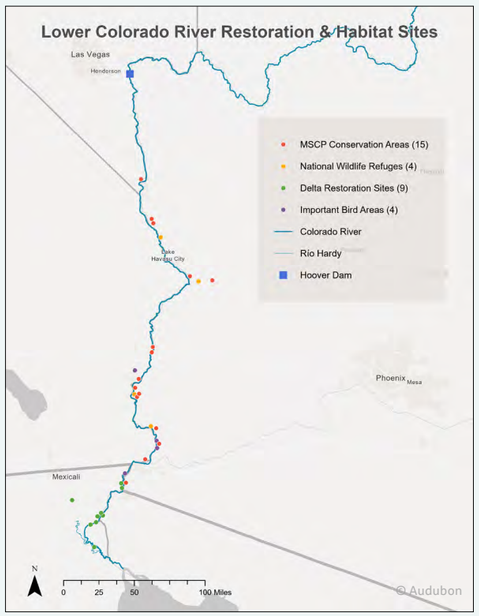
Additionally, the program promises tremendous benefits to the delta region, such as **restoration and protection of habitats for around 17 million birds, reconnection of the river to the sea, restoration of cultural value to the Cucapá People**, and increased resilience of the Mexicali agriculture industry.

COSTS AND FUNDING SOURCES

- **$33 million in funding raised** in federal and private funds for restoration efforts

IMPLEMENTATION

- **12 years of collaboration** between the United States, Mexico, and NGOs to revive the delta, including establishment of two historic agreements - Minutes 319 and 323 to the U.S. and Mexico 1944 Water Treaty, which allocate water to the delta
- **A decade of operational success** implementing water flows; restoration activities; and making financial investments in science, monitoring, and education including environmental flows in 2014, 2021, 2022, and 2024
- **Established governance and implementation model** including a binational Environmental Working Group with federal, state, NGOs, and university representatives; binational Science Team; and on-ground implementing partners
- 1,305 acres have already been restored, and there are plans for approximately 2,000 acres of additional restoration



HABITAT/ECOSYSTEM RESTORATION

EROSION REDUCTION/STORM SURGE AND FLOOD PROTECTION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

HYBRID SOLUTION

L-536 | Levee Setback Project on the Missouri River (Missouri)

In 2019, the Missouri River suffered from severe flooding, causing breaches and overtopping of more than 100 levees. This resulted in 1.2 million acres being inundated and **significant damage to infrastructure, including farms, railroads, and highways.** The flooding also led to **the closure of approximately 470 roads.** Specifically, levee L-536 in northwest Missouri, located in Atchison and Holt counties, was partially or fully breached in seven locations and suffered significant damage along its entire 11-mile length.

After conducting a levee repair alternative analysis, the U.S. Army Corps of Engineers (USACE) determined that the construction of a **levee realignment** (commonly referred to as a "setback") was the most cost-effective option compared to repairing the levee at its original location.

The L-536 Levee Setback Project is a remarkable example of a diverse team working with a devastated community to achieve a **large-scale, nature-based solution** following a major flood in the region.

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US Army Corps of Engineers

COLLABORATION

This project was carried out between 2019 and 2024 under the authority of USACE Public Law (PL) 84-99 levee rehabilitation assistance program. The project involved **extensive collaboration, transparency, dedication, creativity, and a shared vision** among all partners to bring it to fruition. After a 2019 flood, the L-536 levee sponsor and the surrounding community considered various options.

Through discussions among the project partners, a strategy was developed to **leverage habitat conservation programs to facilitate land acquisition and for sourcing borrow material for new levee construction**.

INNOVATION

The project demonstrated the impact of **innovative engineering** and how modern methods can result in **significant accomplishments.**

In -20° Fahrenheit conditions, the team set up heated tents to keep clay materials workable, ensuring the levee was flood-ready for the 2021 flood season. They strengthened the levee and contributed to ecosystem restoration by working together to source borrow materials. To save time and money, they **transformed borrow pits into floodplain wetland habitats.** The team also used dredge-discharged sand from the Missouri River to build the seepage berm, proving it to be the **most efficient and cost-effective** method.

Large woody debris placement and fine grading at borrow pit wetland site.

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PROJECT AREA

Location of L-536 | Levee Setback Project on the Missouri River

2019 Flood Impact on Atchison County*

- 56,000 ACRES UNDERWATER
- 14 COMMERCIAL BUSINESSES UNDERWATER
- 166 HOMES FLOODED
- 278 CITIZENS FORCED TO EVACUATE
- 1,295 AGRICULTURAL BUILDINGS FLOODED
- $25 MILLION (EST.) IN LOST AGRICULTURE REVENUE
- 121 MILES OF ROAD DESTROYED
- I-29 CLOSED FOR APPROXIMATELY 187 MILES BETWEEN ST. JOSEPH, MO & OMAHA, NE
- US HWY 136 BRIDGE CLOSED FOR 216 DAYS
- MAJOR DISRUPTION OF BNSF RAILROAD

*Data from Atchison County Levee District #1

COSTS AND FUNDING SOURCES

$103.5+ million total cost
(levee construction + real estate)

Partnership funding

PROJECT TIMELINE

- **April 2019 to October 2019:**
  Damage assessment and preliminary planning
- **October 2019 to July 2020:**
  Detailed planning and design
- **July 2020 to March 2021:**
  Construction to "flood ready" status
- **March 2021 to November 2024:**
  Construction substantially complete

Measuring Impacts

The proposed project offers a range of benefits, including **hydrologic and geologic improvements**, potential **economic advantages**, and indirect **ecosystem benefits**. It is expected to **decrease flood velocities, reduce erosion and scour**, lower levee repair and maintenance costs, **minimize damage to infrastructure, and create floodplain habitat for fish and wildlife**. Additionally, it could contribute to increased groundwater recharge and improved water quality. As of September 2024, researchers and levee setback practitioners from the USACE and University of Georgia are studying this and other levee setbacks to quantify various ecosystem service benefits and to develop innovations in modeling and predicting benefits to make these kinds of projects easier to justify in the future.

LESSONS LEARNED

Developing a **real estate acquisition strategy** necessitates the **involvement of proficient partners well-versed in real estate**, motivated sellers advocating for the project, and conservation partners capable of purchasing land from willing sellers. This approach is crucial to avoid delays in land acquisition and ineligibility for conservation programs.

When relying on onsite material for construction, it is imperative to identify the **location of each material** before commencing construction, preferably before the detailed design phase. This is essential to preventing interruptions in construction and cost escalation resulting from transporting material from offsite locations.

HABITAT/ECOSYSTEM RESTORATION

CLIMATE RESILIENCY, ECONOMIC AND SOCIAL BENEFITS

MARSH CREATION

HYBRID SOLUTION

Bahia Grande Hydrologic Restoration Project (Texas)

The Bahia Grande complex is a recovering estuarine system within the Laguna Atascosa National Wildlife Refuge. Tidal exchange between this system and the Lower Laguna Madre was interrupted in the 1930s, effectively converting the basin into a dust bowl. The ecosystem dried up, resulting in massive **"dead zones,"** and the bay became the source of dust storms and fish kills.

This condition remained until a **pilot channel** was dredged in 2005, connecting the system to the Lower Laguna Madre, allowing the water to flow and limited tidal exchange. The 2005 pilot channel was 2,250 feet long, 15 feet wide at the bottom, and approximately 3 feet deep. This intervention successfully mitigated the dust storms by allowing an estimated **2.5% tidal exchange,** but did not provide enough circulation to the system and salinities stayed high.

This project is considered to be **one of the largest coastal wetland restoration projects in Texas history**.

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PROJECT HISTORY

In 2007, the Texas Department of Transportation constructed the Highway 48 bridge. The construction involved replacing culverts with a **large trapezoidal channel** that was 150 feet wide at the bottom and 9 feet deep. This new channel increased the estimated tidal exchange from 2.5% to 9%.

In 2011, the Coastal Impact Assistance Program funded engineering and design aimed at achieving several goals. These goals included **enabling 16-30% tidal exchange, reducing salinity levels, and restoring vital wetland habitat.** This was to be achieved through enlarging and stabilizing the pilot channel, removing approximately 220,000 cubic yards of material, and installing scour protection near the bridge. Unfortunately, there was insufficient funding for the subsequent construction phase.

In 2017, following the devastating Deepwater Horizon oil spill and the resulting widespread environmental damage, the Bahia Grande Hydrologic Restoration Project was selected as the preferred alternative for environmental restoration. In 2021, a Notice to Proceed for a conservation initiative was issued, and on July 30, 2022, the construction was successfully completed, marking **a significant milestone in environmental restoration efforts.**

Bahia Grande aerial view.

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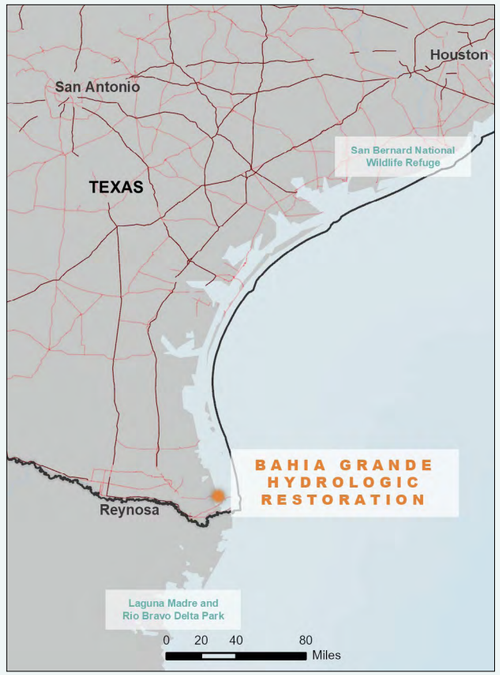
PROJECT AREA

Location of Bahia Grande Hydrologic Restoration Project



COSTS AND FUNDING SOURCES

Approximately $5,050,000 was allocated for the project through the Deepwater Horizon Natural Resource Damage Assessment fund.
The allocated budget was used for:

- Engineering and design
- Construction
- 5-year monitoring
- Implementing trustee costs
- Trustee oversight costs
- Contingency

In addition, **$3,000,000** was designated for construction under the Gulf of Mexico Energy Security Act (GOMESA) program.

UNFORESEEN CHALLENGES

During the construction phase, the project encountered several unforeseen challenges. On March 24, 2021, a fatal car accident resulted in the car becoming wedged against a bridge piling, requiring extensive coordination with authorities to safely remove the car, which was achieved on July 7, 2021. The low-clearance bridge and high flows through the newly widened channel necessitated a change in the installation method to ensure worker safety, with temporary closure of lanes required. Finally, the day before the final walk-through, geogrid failure necessitated re-engineering new anchors to spread the load and tension, which ensures long-term project success.

Measuring Impacts

The Bahia Grande Project is an outstanding example of environmental restoration that **benefits ecosystems and communities** in various ways. Current monitoring involves assessing water quality and hydrology to ensure the project is performing as designed and that the benefits will continue for the project's duration.

The project has implemented **adaptive management practices** following the completion of construction. Flow velocities are being measured to assess tidal exchange between the systems, estimate accretion, and control potential erosion. Water quality data, including conductivity, dissolved oxygen, pH, and temperature, are being measured to document induced changes to water quality and confirm continued hydrological connection between the Brownsville Ship Channel and the Bahia Grande.

Annual monitoring plans have confirmed post-construction improvements in water quality, including decreasing salinity and a reduction in incidents of low dissolved oxygen and pH fluctuations compared to baseline conditions.

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