Engineering With Nature®
+ Landscape Architecture
S2G

a report identifying design concepts for incorporating Engineering With Nature® and Landscape Architecture approaches into the Sabine Pass to Galveston Bay project

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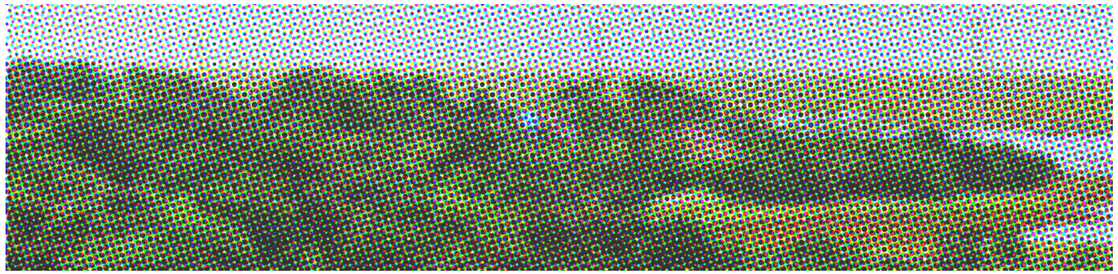

Engineering With Nature®

Dr. Todd Bridges
Dr. Jeff King
Dr. Burton Suedel
Dr. Joseph Gailani
Dr. Tosin Sekoni

Auburn University

Rob Holmes (PI)
Alejandro Ramos

University of Toronto

Justine Holzman (co-I)
Elspeth Holland
Emiley Switzer-Martell
Michael Wideman

University of Pennsylvania

Sean Burkholder (co-I)
Yang Du

Dredge Research Collaborative

Gena Wirth

Participating District

Galveston District (SWG)

Cover Image
Lower Neches WMA (Sean Burkholder)

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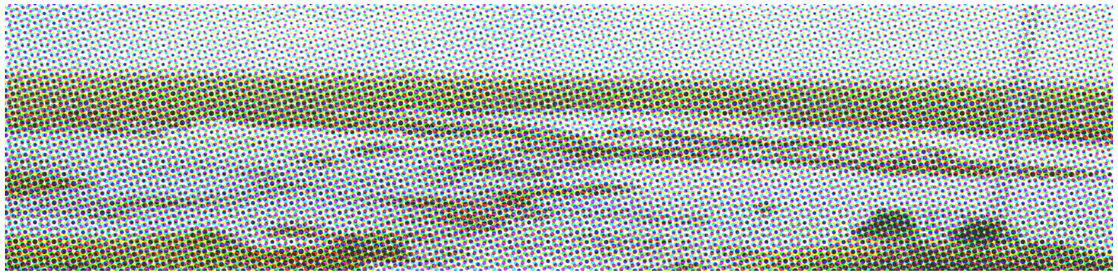
Contact:
Jeff King, Deputy National Lead, Engineering With Nature Initiative®, USACE
Jeff.K.King@usace.army.mil

Rob Holmes, Assistant Professor, School of Architecture, Planning, and Landscape Architecture, Auburn University
rob.holmes@auburn.edu



This report covers findings from research cooperative agreement W912HZ-18-2-0008 **Incorporating Engineering With Nature® (EWN®) and Landscape Architecture (LA) Designs into Existing Infrastructure Projects**, an agreement between the **U.S. Army Engineering Research Development Center** (ERDC) and **Auburn University** (AU) for FY2020.

This report has been prepared by the investigators at **Auburn University**, the **University of Toronto**, and the **University of Pennsylvania** and consultants from the **Dredge Research Collaborative**; it also incorporates research and insights from ERDC's **Engineering With Nature®** project team.

Engineering with Nature® is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes.

Sustainable development of water resources infrastructure is supported by solutions that beneficially integrate engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management.

The Dredge Research Collaborative is an independent 501c3 nonprofit organization that investigates human sediment handling practices through publications, an event series, and various other projects. Its mission is to advance public knowledge about sediment management; to provide platforms for transdisciplinary conversation about sediment management; and to participate in envisioning and realizing preferred sedimentary futures.

http://engineeringwithnature.org
http://dredgeresearchcollaborative.org/

Lower Neches WMA (Sean Burkholder)

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Bridge City and Lower Neches WMA (Sean Burkholder)

Introduction

This report concerns the research and development of innovative design concepts for components of the Sabine to Galveston project (S2G), which is a project of the Galveston District (SWG) of the US Army Corps of Engineers (USACE). These design concepts combine Engineering With Nature® (EWN®) approaches to infrastructure design with landscape architectural (LA) approaches to infrastructure design in order to identify opportunities to incorporate "Natural and Nature-Based Features" (NNBF) into proposed S2G project infrastructure.

As described by the EWN® initiative, NNBF "are landscape features that are used to provide engineering functions relevant to flood risk management, while producing additional economic, environmental, and/or social benefits. These features may occur naturally in landscapes or be engineered, constructed and/or restored to mimic natural conditions. A strategy that combines NNBF with nonstructural and structural measures represents an integrated approach to flood risk management that can deliver a broad array of ecosystem goods and services to local communities."

The components of the S2G project that this study has focused on are coastal storm risk management (CSRM) projects located on the Texas coast in Orange County, Port Arthur, and Freeport. The measures currently identified for these locations are primarily structural, including Hurricane Flood Protection levees, closure gate structures, pump stations, and seawalls that are either proposed for upgrades (as in Port Arthur and Freeport) or proposed as new construction (as in Orange County). This EWN-LA project has aimed to identify opportunities to supplement and augment the proposed structural measures with NNBF. These NNBF have been evaluated and selected for their potential to combine CSRM value with additional ecological and social benefit, such as the provision of marsh habitat and opportunities for recreational use.

This report is divided into four main sections. This **Introduction** frames the report and the study process. **Part I** concerns the S2G project and NNBF approach, generally. **Part II** details proposed NNBF for the three study regions. Finally, **Next Steps** outlines key tasks for moving forward with the refinement and implementaiton of these NNBF.

Waterway in Orange (Rob Holmes)

BACKGROUND

The Engineering With Nature®-Landscape Architecture (EWN-LA) initiative emerged in response to a workshop held at the US Army Corps of Engineers Engineering Research and Development Center in Vicksburg, Mississippi in Summer 2017. In that workshop, personnel from the USACE, members of the Dredge Research Collaborative, and a diverse group of landscape architects identified opportunities to integrate EWN® and LA approaches into USACE water infrastructure projects and operations.

Engineering With Nature® is an initiative of the US Army Corps of Engineers. It is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes.

In the EWN® approach, sustainable development of water resources infrastructure is supported by solutions that beneficially integrate engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management.

EWN® outcomes are “triple-win”, which means that they systematically integrating social, environmental, and economic considerations into decision-making and actions at every phase of a project, in order to achieve innovative and resilient solutions that are more socially acceptable, viable, and equitable, and, ultimately, more sustainable.

As a field, landscape architecture is presently concerned with many of the same issues of infrastructural performance and potential that EWN® is pursuing, including in particular the re-imagination of existing infrastructure to meet more diverse criteria encompassing engineering functions, ecological value, recreational opportunities, and aesthetic benefits (Spirn 1984, Mossop 2006, Orff 2016, Belanger 2017). This overlap in concerns suggests that the design principles and precedent knowledge summarized as EWN® approaches may be beneficially combined with the design principles and precedent knowledge that has been accumulating in landscape architectural approaches to infrastructure, such as the work of landscape architects on recent international design competitions that deal with issues of coastal storm protection, public space, and ecological performance, like Rebuild by Design NYC and the Resilient by Design Bay Area Challenge. Moreover, landscape architects bring additional methods and expertise, including design, representation, and communication skills, that can aid in achieving the shared goals of EWN® and landscape architecture.

The members of the Dredge Research Collaborative, including the DRC-associated faculty from Penn, Toronto, and Auburn working on this project, work in precisely this area of contemporary landscape architecture, with a particular focus on coastal and riverine infrastructures that interact with sediment systems. They are correspondingly able to bring familiarity with both the challenges and the opportunities inherent in deploying EWN® approaches to water infrastructure.

Recreation in the Lower Neches WMA (Sean Burkholder)

Part I

S2G PROJECT AND NNBF APPROACH

The larger S2G project includes measures in a variety of locations on the Texas coast, including Harris and Galveston Counties. For this EWN-LA R&D study, the project delivery team (PDT) has focused on three components of the larger project: CSRM measures in Orange County, Port Arthur, and Freeport.

The PDT's first stage of work was a workshop, hosted by SWG, which took place from June 24 to June 29, 2019. During the workshop, the PDT worked to identify issues and opportunities associated with each of the three main project components as well as general NNBF strategies that might respond to those issues and opportunities. (These issues and opportunities are summarized at the beginning of each of the three "design concept" sections in Part II.) The PDT then split into a series of teams that worked to refine the general strategies into specific features and approaches. Each team presented its individual work to the larger group for comment and review. This work was summarized by the EWN-LA team on the final day of the workshop, and the PDT reviewed the summary to select high-priority features and approaches for further development and inclusion in this report.

Based on this prioritization, the EWN-LA team produced a series of draft products, which were presented to the full PDT via webinar in July. Following the webinar, the PDT worked to refine the draft products and design concepts, arriving at the proposals, drawings, and metrics included in this report.

INITIAL CHALLENGES AND STUDY SCOPE

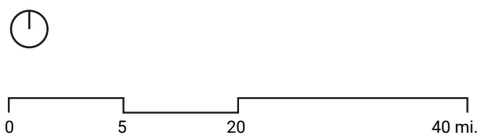
Three major challenges have been identified for the implementation of the NNBF proposed in this report.

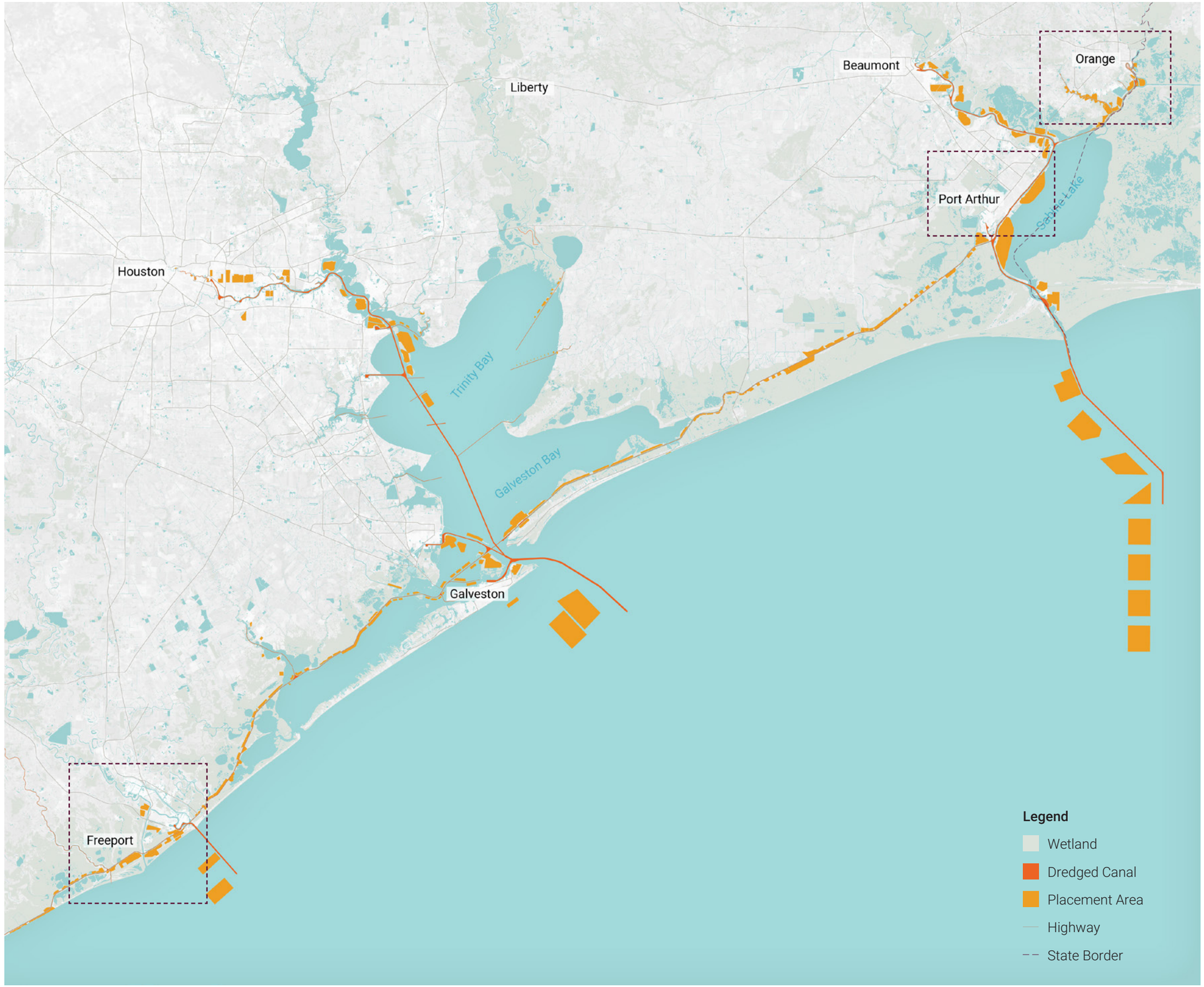
1 Cost-Benefit
Initial quantification of the material needed to construct the proposed NNBF is provided with each feature. Further study will be needed to identify the precise CSRM, ecological, and social benefits of these NNBF, as well as the capital construction costs and operational life-cycle costs associated with these features. See "Next Steps" on page 65.

2 Sediment Needs
Most of the proposed NNBF will require significant sediment for construction. The next four pages look at navigational dredging in the Sabine-Neches Waterway (SNWW) as a potential source of this sediment. These volumes can be compared with the estimated quantities associated with individual NNBF.

3 Plant Community Establishment
The proposed NNBF depend on the successful establishment of appropriate plant communities for their habitat value and long-term viability as CSRM measures. This may require large-scale plant propogation, planting and/or seeding efforts, and some specialized maintenance, particularly during the establishment periods. Further study of this is recommended.

The vicinities of the three major project components are identified in the map at right.



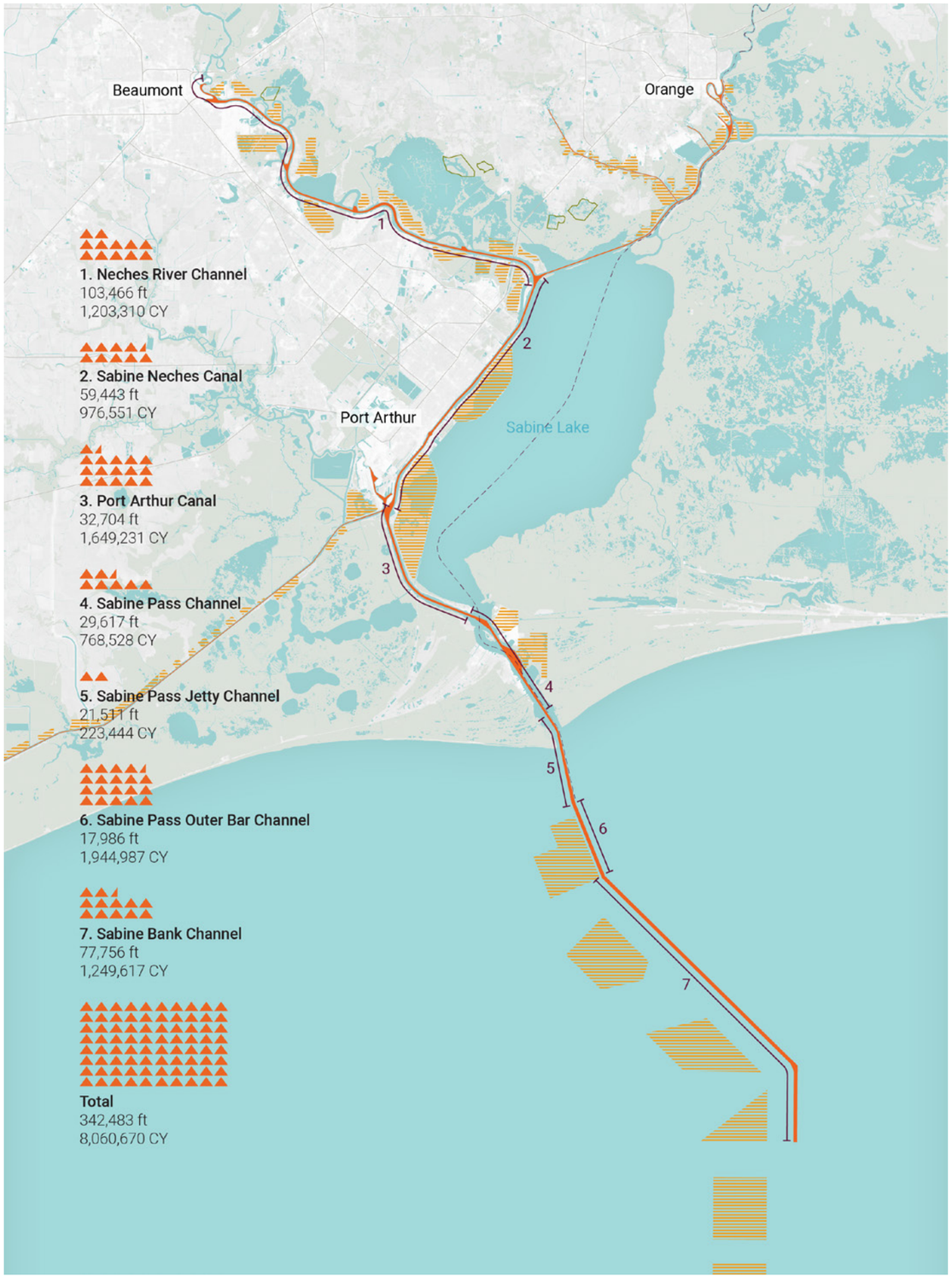


SABINE-NECHES CHANNELS, DREDGING, & PLACEMENT AREAS

For both of the project components associated with the Sabine Lake region, Port Arthur and Orange, the sediment that is dredged from the Sabine-Neches Waterway (SNWW) and its associated channels has been identified as a major potential resource for the construction of NNBF. Sediment is both dredged regularly in maintenance operations and irregularly in channel deepening. One major channel deepening project, the Sabine-Neches Waterway Channel Improvement Project (SNWW CIP), is scheduled to finish by 2026 and would, if properly planned and coordinated, provide a major supply of sediment for the construction of NNBF. At the same time, this beneficial use could play an important role in meeting the SNWW CIP's need to find placement opportunities for its dredged material.

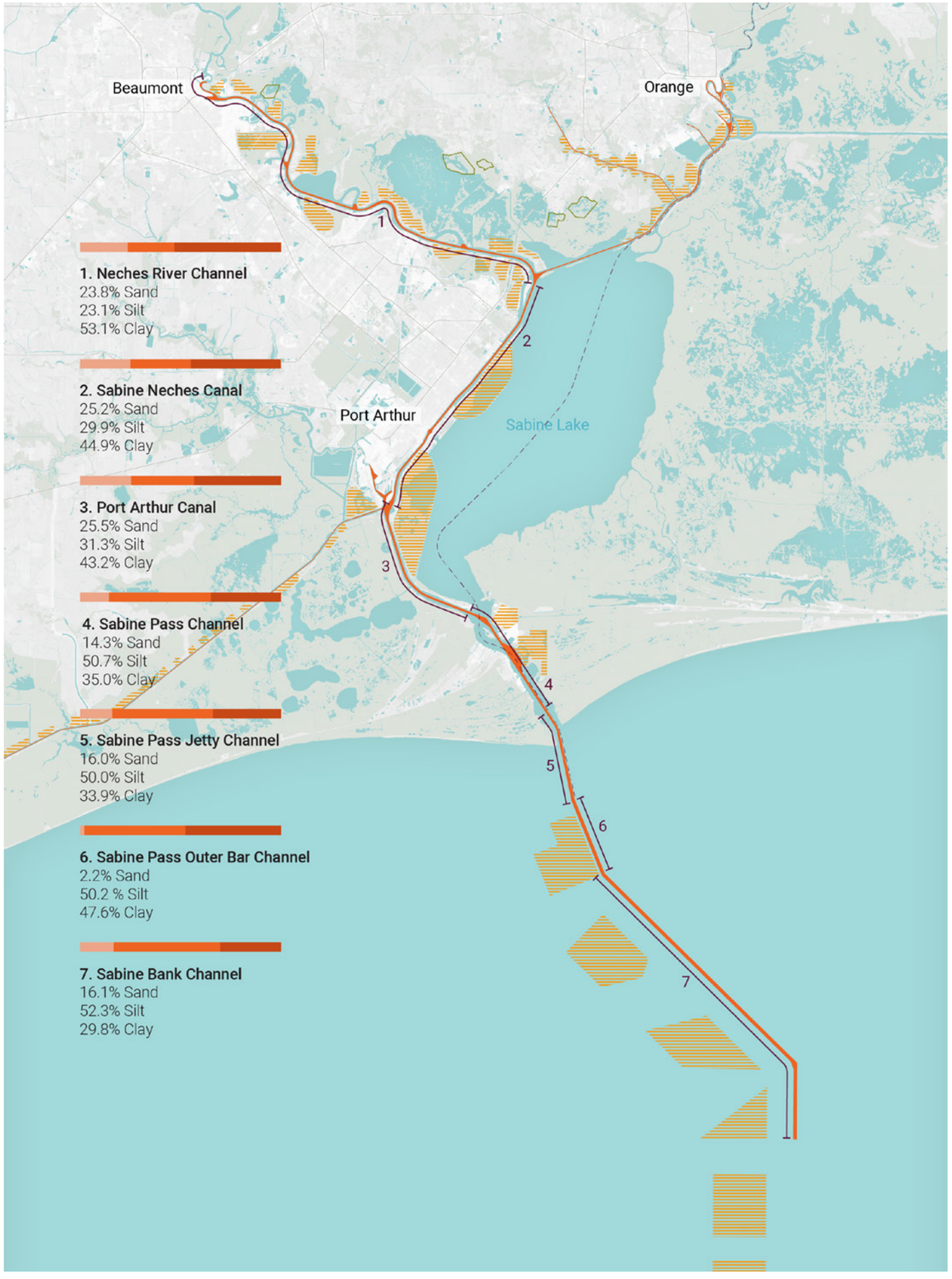
The map at right shows average annual volumes of material dredged from the major reaches of the SNWW. These volumes can be compared with the volumes of material required to construct features described later in the report in order to begin to understand the feasibility of using dredged material to construct NNBF in the Sabine Lake region.

For instance, constructing all four horizontal levee segments using typical section of the recommended alternative (05b) would require approximately 1 million CY of sediment — which is less than the average annual maintenance dredging of the nearby Neches River Channel (reach 1 in the map at right).



SABINE-NECHES CHANNELS, DREDGING, & PLACEMENT AREAS

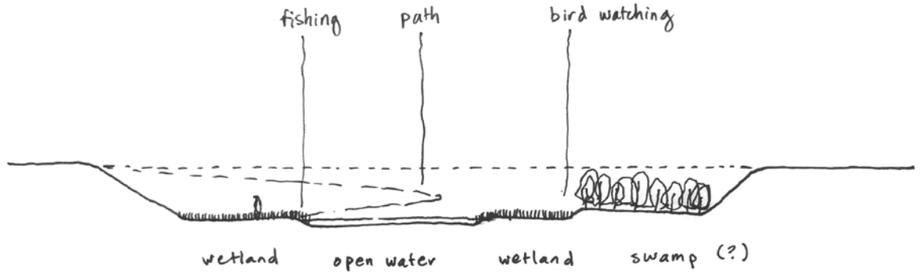
The map at right shows the composition of material in the major reaches of the SNWW. This information can help inform the suitability of dredged material for the construction of features proposed in the report.



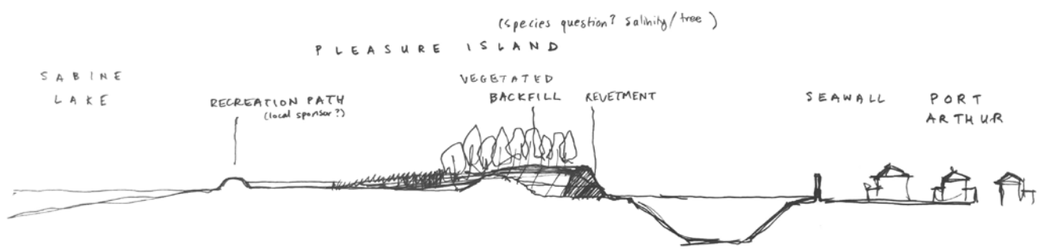
Legend

- Wetland
- Dredged Canal
- Placement Area
- Reach Extent
- Highway
- State Border

0 2.5 5 10 mi.



1 ORANGE
The primary focus in Orange County is a proposed levee system and associated issues of flood risk reduction.



2 PORT ARTHUR
Port Arthur has an existing HFPS, so this study has focused on opportunities to augment this existing system.

3 FREEPORT
Freeport also has an existing levee system and faces potential compound flooding. This study focused on the two natural drainages, the Brazos River and Oyster Creek, on either side.

Part II
DESIGN CONCEPTS

This section addresses specific design concepts that have been explored in this study. The concepts are organized by the three project components that have been a part of this study: first Orange County, then Port Arthur, and finally Freeport.

The main goal of these concepts is to identify the best opportunities for incorporating NNBF into these three components of the S2G project. Consequently, the design concepts prioritize the holistic combination of engineering performance relative to project criteria (in this case, managing flood and storm risk), ecological integration, and the creation of social value through recreational opportunities and aesthetic improvement. Constructability and feasibility have been conceptual considerations, as well, and are discussed where appropriate, but the design concepts have not undergone engineering review or modeling.

The "Next Steps" that follow this section to identify key tasks or issues for consideration if these features are developed further as components of the S2G project.

1 ORANGE

ISSUES AND OPPORTUNITIES

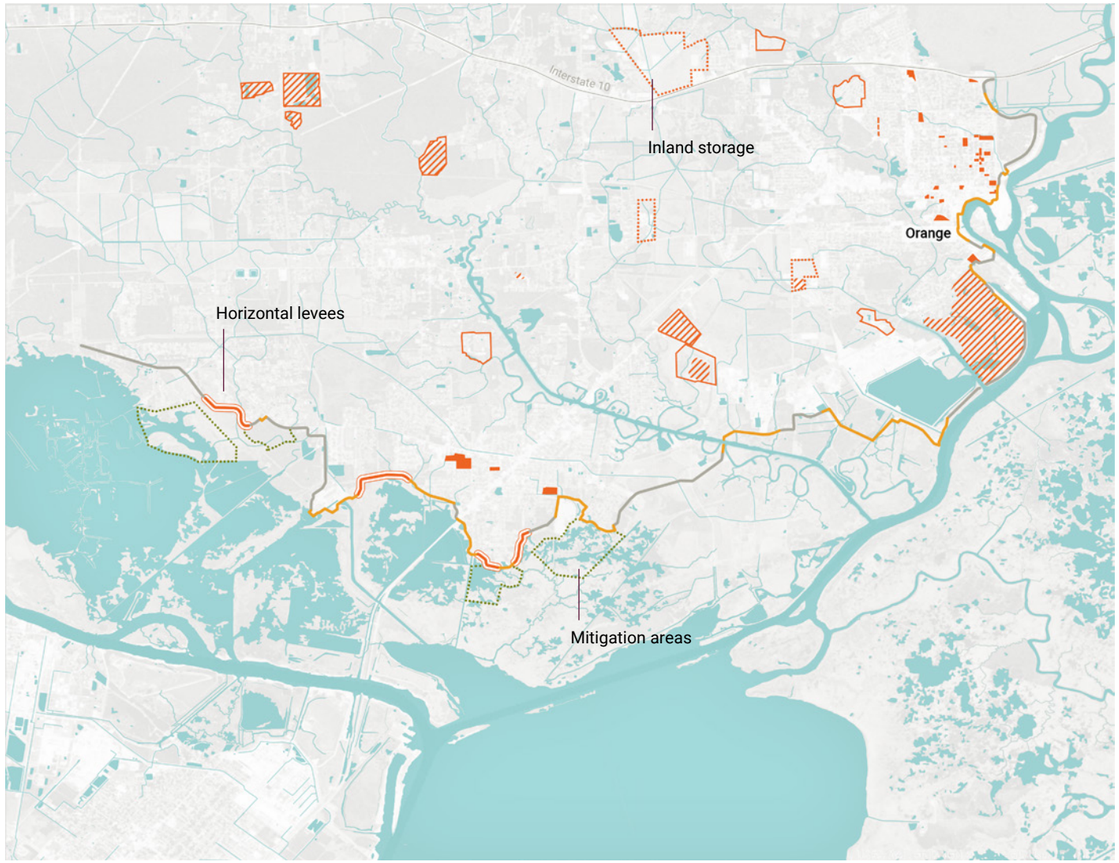
1 Compound Flooding
Due to its low-lying elevation and flat topography, the portions of Orange County that lie behind the proposed Coastal Storm Risk Mitigation (CSRM) system are at risk for both coastal flooding (storm surge arriving at the front of the CSRM across Sabine Lake) and inland flooding (flooding behind the CSRM system resulting from upland rainfall). Flood risk management in areas that may have compound flooding potential requires a bidirectional approach.

2 Excavation for Levee Construction
The proposed CSRM includes significant new levees. Constructing these levees will require locating and excavating suitable fill material from upland sources. The sites of these excavations could potentially become basins for detaining and retaining inland floodwaters, if they are designed properly.

3 New CSRM
Because the CSRM for Orange is proposed rather than existing, it represents a significant opportunity to integrate NNBF directly into the design of features, rather than augmenting or supplementing existing features.

4 Beneficial Use of Dredged Material
The construction of significant NNBF will require large quantities of sediment. Actively maintained navigation channels on the Neches River, on the Sabine River, and in Sabine Lake are potentially major sources of sediment that could link operational demands (the need to place dredged material in a suitable location) with proposed NNBF.

5 Degraded Marshes
The proposed CSRM faces large areas of marsh, particularly in the Lower Neches Wildlife Management Area. This marsh potentially has significant CSRM value in addition to its value as an ecological and social resource. However, the marsh is significantly degraded and in many places has subsided and/or eroded into open water. The Hickory Cove Marsh Restoration and Living Shoreline Project is one on-going initiative that is seeking to address this degradation.



Map showing the vicinity of mitigation areas and proposed NNBF for Orange. Specific features are identified and detailed on following pages.

Legend
- Upland Pit
- Drainage Floodrooms
- Urban Basins
- Degraded Land
- Sea Wall
- Standard Levee
- Horizontal Levee
- Mitigation Areas

1 CONCEPTUAL DESIGN APPROACH TO NNBF FOR ORANGE

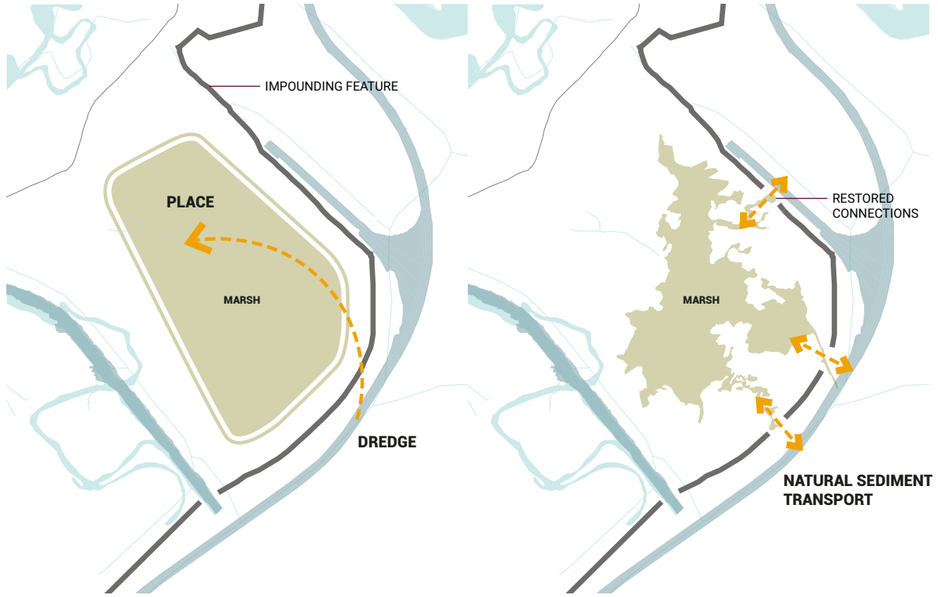
The NNBF that are proposed for Orange on the following pages share several key features.

1 Multi-benefit
Features combine storm risk management, recreational use, and ecological enhancement.

2 Layered approach
Multiple, redundant layers of differing types of features are linked into a system.

3 Augmentation
NNBF augment rather than replace structural measures.

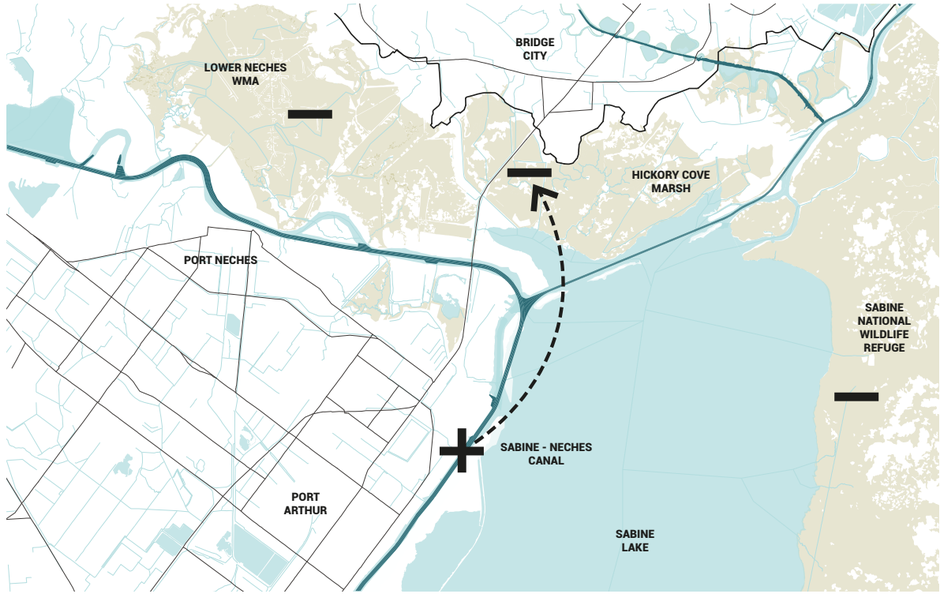
4 Operational Synergies
Strategies that are maintained by natural processes, like marsh accretion, or by Operations and Maintenance from other projects are particularly desirable. The designs seek out opportunities to utilize operational necessities as resources, like excavation for levee construction and maintenance dredging.



Operational synergies and dynamic natural systems

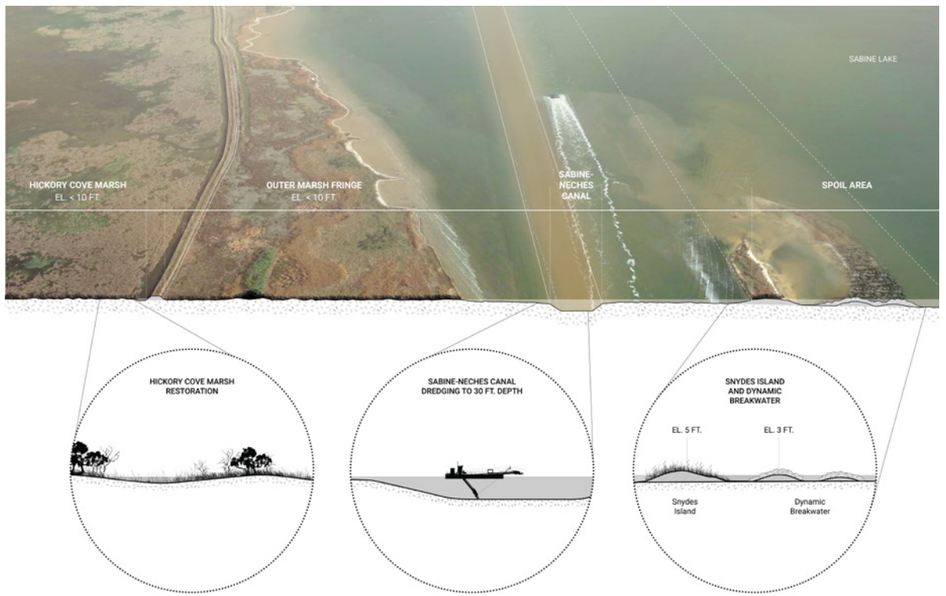
NNBF can be sustainably maintained by taking advantage of operational synergies, like the use of material obtained in maintenance dredging to maintain or restore marshes (as in the diagram at left), or by re-connecting natural systems (as in the diagram at right).

The diagram above shows this distinction abstractly. Similar situations exist in a number of locations within both the Lower Neches WMA generally and Hickory Cove Marsh specifically. The “impounding feature” is typically a small dike that runs around an area of marsh. These dikes are not part of the CSRM.



Choreography

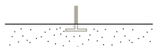
Budgets, operations, and planning should be integrated to balance sediment budgets at a regional scale, across multi-decade time scales. The first step toward this should be scientific study to establish existing sediment regimes in the Sabine Lake region.



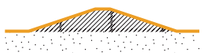
Sydnes Island + Hickory Cove Marsh

The barrier islands along the Sabine-Neches Canal, like Sydnes Island, provide good protection for marshes and, by extension, Orange, but are eroding. They could be reinforced by constructing “dynamic breakwaters” using dredged material.

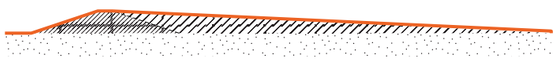
The proposed CSRM for Orange currently includes 10+ miles of floodwalls and 15+ miles of levee. We have identified four segments of levee that offer opportunities to augment the standard levee core with a thickened, vegetated slope, potentially improving risk reduction performance, providing new habitat, and enhancing levee aesthetics. We have studied a series of different approaches for constructing these slopes, ranging from a 'standard' horizontal levee built with solid fill material to 'ecotone ridges' constructed over time by layering dredged material. Our recommended alternative, variation 05B "Dredge Ecotone Ridges", can be found on pages 32-35.



FLOODWALL



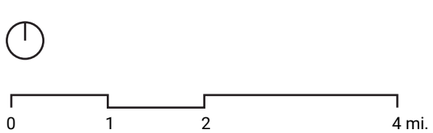
STANDARD LEVEE

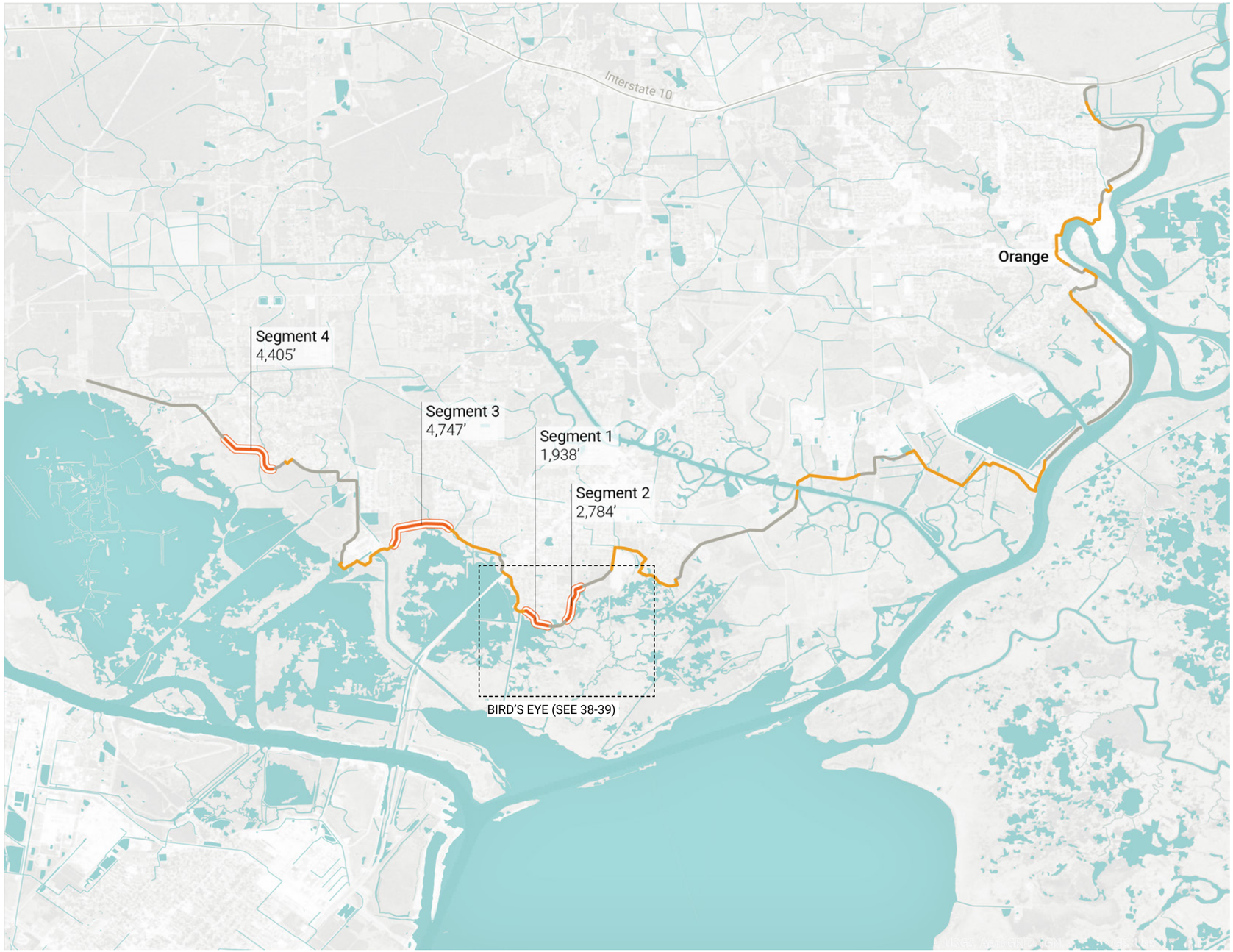


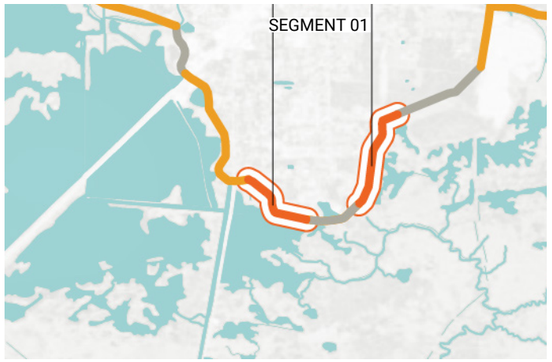
HORIZONTAL LEVEE

Legend

- Floodwall
- Standard Levee
- Horizontal Levee



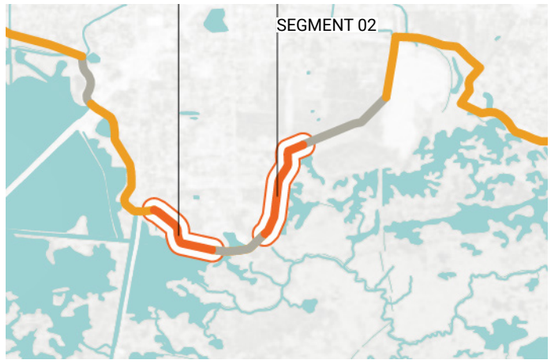




SEGMENT 01
Length: 1,938'

Dredged Material Required: 150,000 CY
Estimated Marsh Area Produced: 13.6 acres

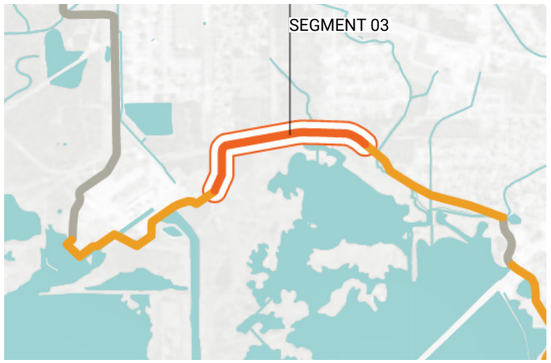
Notes:
- behind highly degraded marsh
- Segment 01 and Segment 02 are separated by a stretch of floodwall
- adjacent marsh has been identified as a mitigation area
- adjacent to community and in area used for significant recreation



SEGMENT 02
Length: 2,784'

Dredged Material Required: 220,000 CY
Estimated Marsh Area Produced: 19.6 acres

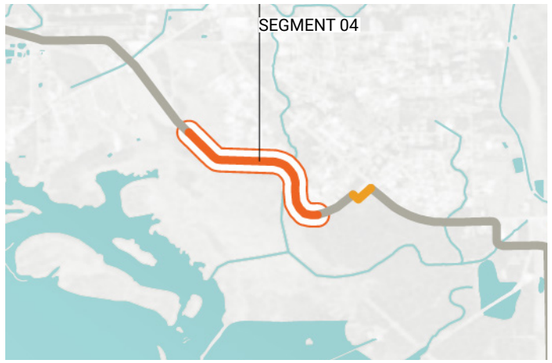
Notes:
- marsh appears to be moderatedly degraded
- hydrologically disconnected, likely lacking sediment supply and suffering subsidence
- more significant marsh community than Segment 01
- adjacent marsh has been identified as a mitigation area
- significant forest to east of this segment



SEGMENT 03
Length: 4,747'

Dredged Material Required: 370,000 CY
Estimated Marsh Area Produced: 33.3 acres

Notes:
- this segment has been identified as the location with the least constraints by SWG
- land on the floodside is at higher elevation than the land on the floodside of segments 01 and 02
- marsh appears somewhat degraded but less degraded than marshes to the east or west



SEGMENT 04
Length: 4,405'

Dredged Material Required: 343,000 CY
Estimated Marsh Area Produced: 30.9 acres

Notes:
- segment is somewhat upland of actual marsh edge; consequently a shallow slope (at least 1V:200H) would be necessary for a modified levee to reach the marsh interface
- adjacent marsh is highly degraded; some tree stands are present but appear to be in decline

The following considerations have informed the selection of the four segments:

- Degradation and/or absence of marsh in front of the proposed segment. (Intact habitat should not be displaced by slope construction.)
- Absence of developed private property.
- Land ownership (public ownership of parcels where the slope would be constructed was preferred).

Additional design concerns for these vegetated slopes that should be considered if these features are advanced to further design and implementation:

- The electrical line pylons (slope design would need to acknowledge and accommodate the footings of these large pylons)
- Tie-ins to standard levee segments and/or floodwalls (these need to be designed)
- Constructability using dredged material (needs to be engineered)
- Plant community procurement, establishment, and maintenance (appropriate species would need to be obtained, planted, and in some cases, such as meadow, maintained; invasive species recruitment would need to be discouraged through the establishment period)

General Quantification Notes:
- these estimates assume the preferred alternative, Variation 05B
- dredged material requirements and marsh area produced are relative estimates, not absolute estimates, as they are based on linear extrapolation from the study transect (see following pages).
- dredged material requirements have been calculated using the formula *[requirement] = [cross-section area of material placed] x [length of levee segment]*
- marsh areas have been calculated using the formula *[marsh area] = [width of marsh along transect] x [length of levee segment]*

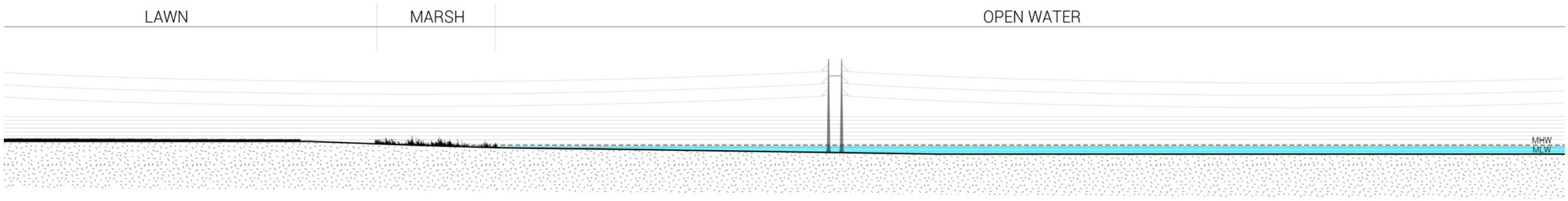
1 ORANGE:
LEVEE VARIATIONS

These two pages and the four that that follow them show a range of alternatives for construction of a thickened, vegetated slope. Differing possibilities in terms of construction method, areas of habitat (both marsh and upland) produced, planting strategies, and proposed slopes are shown. The current spread shows existing conditions (00) and the condition with a traditional levee (01) as in the current proposal for the CSRM.

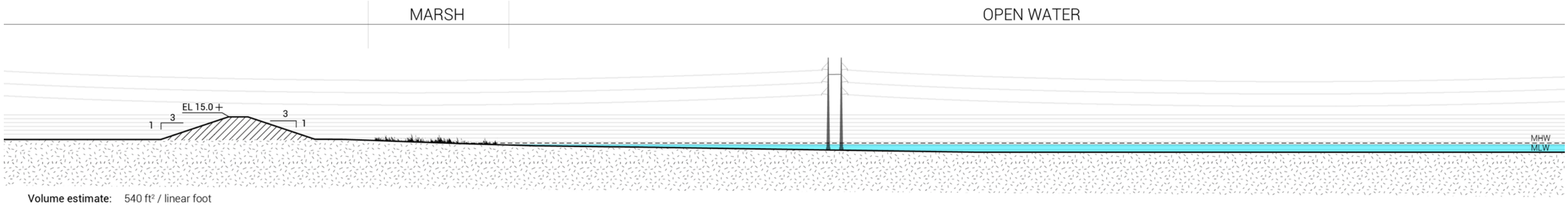
EXISTING CONDITIONS AND A STANDARD LEVEE

For comparison's sake, each section is drawn along the same transect, which intersects Segment 01 as shown in the bird's-eye perspective on pages 38-39.
Each section is also drawn with a levee crown elevation of +15.0' (NAVD88). Note that the actual authorized elevations vary along the CSRM from +12.0' to +17.5' (NAVD88).

00 EXISTING CONDITION



01 STANDARD LEVEE (PER CURRENT CSRM PROPOSAL)



Volume estimate: 540 ft² / linear foot
(h.l. one) 39,000 CY of dredged material

Marsh estimate: 60 ft. wide
(h.l. one) 16,000 ft² (2.67 acres)

Note: this underestimates existing marsh along length of segment as this section is drawn through narrowest segment of marsh.

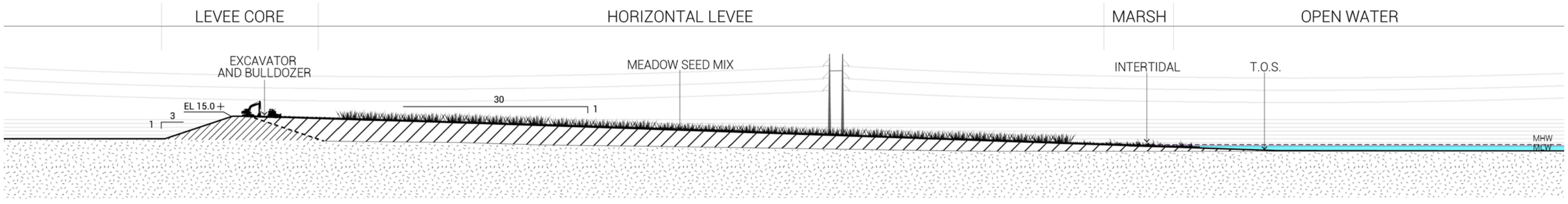
1"=50'

1 ORANGE: LEVEE VARIATIONS

A typical horizontal levee would have a slope of at least 30:1, as shown in variation 02. This variation has the disadvantage of requiring a tremendous amount of additional fill material, which would need to be obtained from upland sources. One alternative would be to begin the horizontal levee from a lower crest elevation, as shown in 03.

TYPICAL HORIZONTAL LEVEE CONFIGURATIONS

02 HORIZONTAL LEVEE



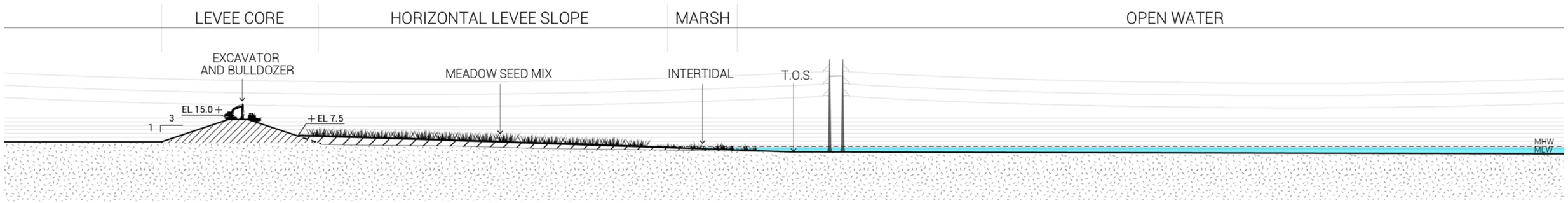
Volume estimate: 3,600 ft² / linear foot of levee (Including levee core)
(h.l. one) 260,000 CY of dredged material

Marsh estimate: 35 ft. wide
(h.l. one) 67,900 ft² (1.56 acres)

Note: Meadow seed mix requires annual mowing

1"=50'

03 LOWER HORIZONTAL LEVEE



Volume estimate: 470 ft² / linear foot of levee (in addition to levee core)
(h.l. one) 34,000 CY of dredged material

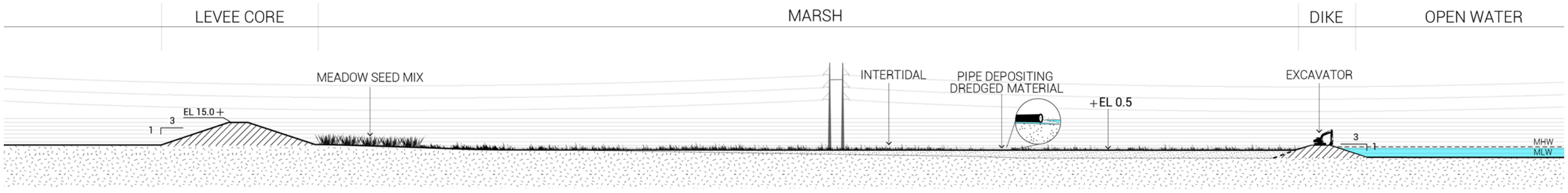
Marsh estimate: 35 ft. wide
(h.l. one) 67,900 ft² (1.56 acres)

1"=50'

1 ORANGE: LEVEE VARIATIONS

An alternative to the use of upland fill is the beneficial use of dredged material from local navigation projects. One option, shown in 04, would be to construct a dike in the open water, using a small amount of upland fill, and then to pump slurried sediment behind that dike, dewater, and repeat until marsh elevation is achieved. The primary disadvantage of this approach is that it would require the construction of the dike in open water, on presumably soft soils. **Variation 05**, which **is the recommended alternative**, shows the construction of an 'ecotone slope' by pumping unconfined slurry. The slurry would be allowed to settle, forming gently-sloped ridges as pipes are moved over time.

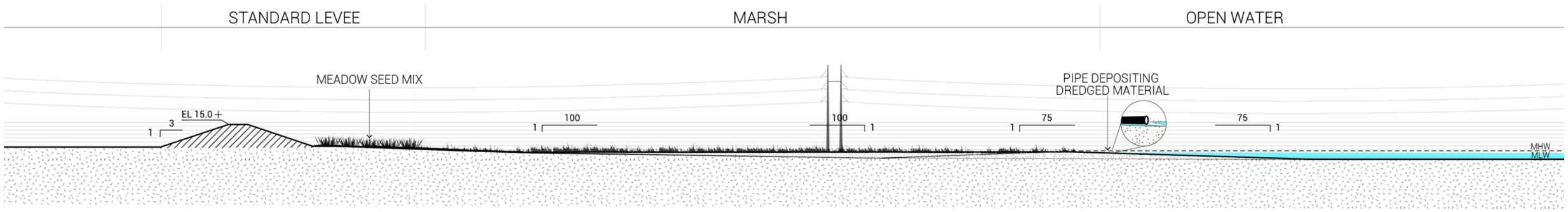
04 DIKED MARSH AND LEVEE



Volume estimate: 200 ft² for dike + 1,180 ft² of dredged material / linear foot of levee
(h.l. one) 14,300 CY of dredged material

Marsh estimate: 460 ft. wide
(h.l. one) 20.49 acres

05 DREDGE ECOTONE SLOPE **RECOMMENDED ALTERNATIVE** STAGE I



Volume estimate: 1,000 ft² / linear foot of levee
(h.l. one) 72,100 CY of dredged material

Marsh estimate: 355 ft. wide
(h.l. one) 15.81 acres

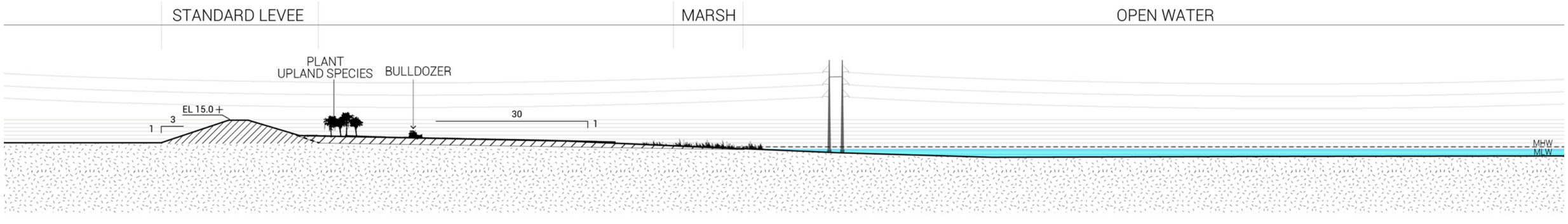
1"=50'

1 ORANGE: LEVEE VARIATIONS

MAINTAINING ECOTONE OVER TIME USING DREDGED MATERIAL

These diagrams show how an 'ecotone slope', as shown in variation 05, could be maintained to enhance its value over time while providing a use for O+M dredged material. In 05a, the sediment that settles out from the initial placement shown in 05 is reshaped into a 30:1 slope, which is then planted with upland species. In 05b, additional 'ridges' are placed by pipe, using more dredged material, forming a wide expanse of marsh and a differentiated habitats.

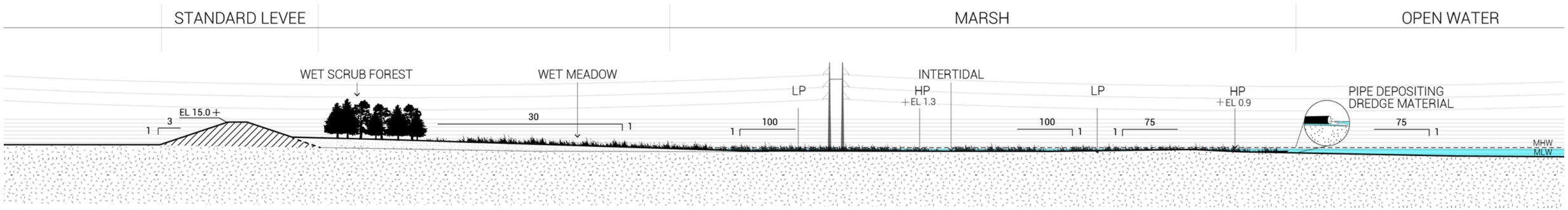
05a **RECOMMENDED ALTERNATIVE** STAGE II



1"=50'

Note: Use bulldozers and excavators to reshape dewatered dredged material into new slope

05b DREDGE ECOTONE RIDGES **RECOMMENDED ALTERNATIVE** STAGE III



Volume estimate: 1,100 ft² additional placement / linear foot of levee
(h.l. one) 79,000 CY of dredged material (total including 05: 151,000 CY)

Marsh estimate: 306 ft. wide
(h.l. one) 13.62 acres

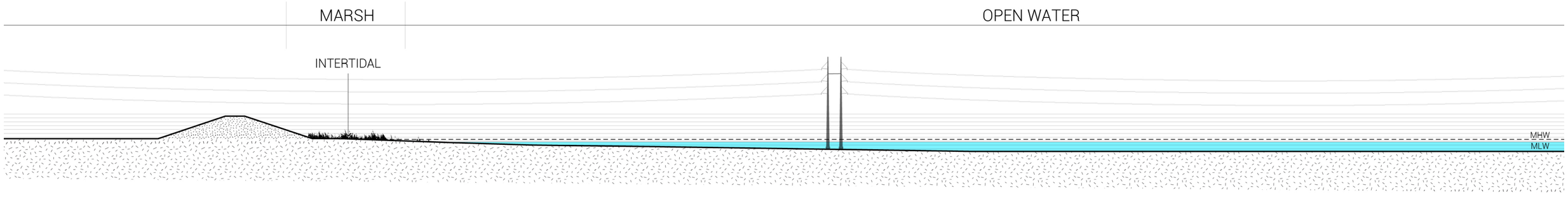
1"=50'

1 ORANGE: LEVEE VARIATIONS

PERFORMANCE WITH SEA LEVEL RISE

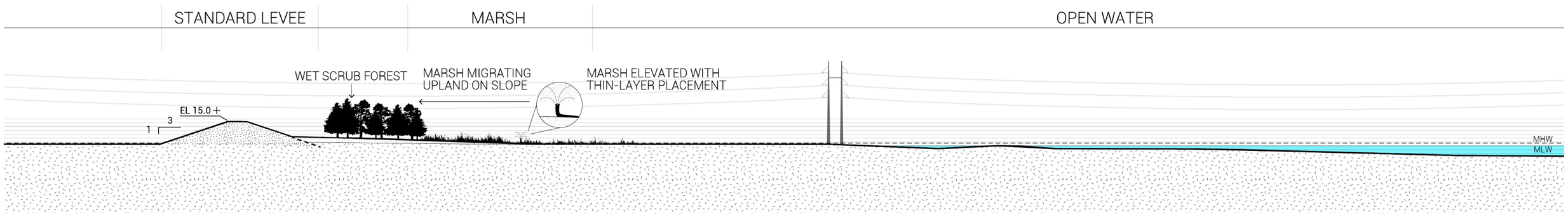
One of the primary advantages of Variation 05 is its potential adaptability in the face of RSLR. Under the USACE's intermediate scenario for RSLR in the Sabine Lake region, a traditional levee in this location can be expected to find that the edge of the intertidal zone has migrated to its toe by 2070 (as shown in variation 01.1). In the decades following that, as the intertidal zone continues to move up, the levee's performance may be compromised. (The USACE Sea Level Change Calculator shows 1.961' of RSLC in 2070 under the intermediate scenario and 3.004' of RSLC in 2100. Both of these calculations use data for the Sabine Pass North gauge, the nearest NOAA gauge, and both use LMSL as the output datum, because NAVD88 is not available at this gauge.) The Dredge Ecotone Slope, however, provides a wide, gentle slope that can offer room for the marsh to migrate upland (as shown in variation 05b.1), while buffering the toe of the levee. Thin-layer placement on the ecotone slope could further mitigate RSLR, extending the operational lifespan of the levee and the viability of the marsh.

01.1 STANDARD LEVEE WITH SLR



1"=50'

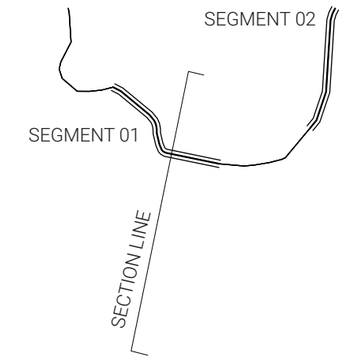
05b.1 DREDGE ECOTONE SLOPE WITH SLR **RECOMMENDED ALTERNATIVE** IV



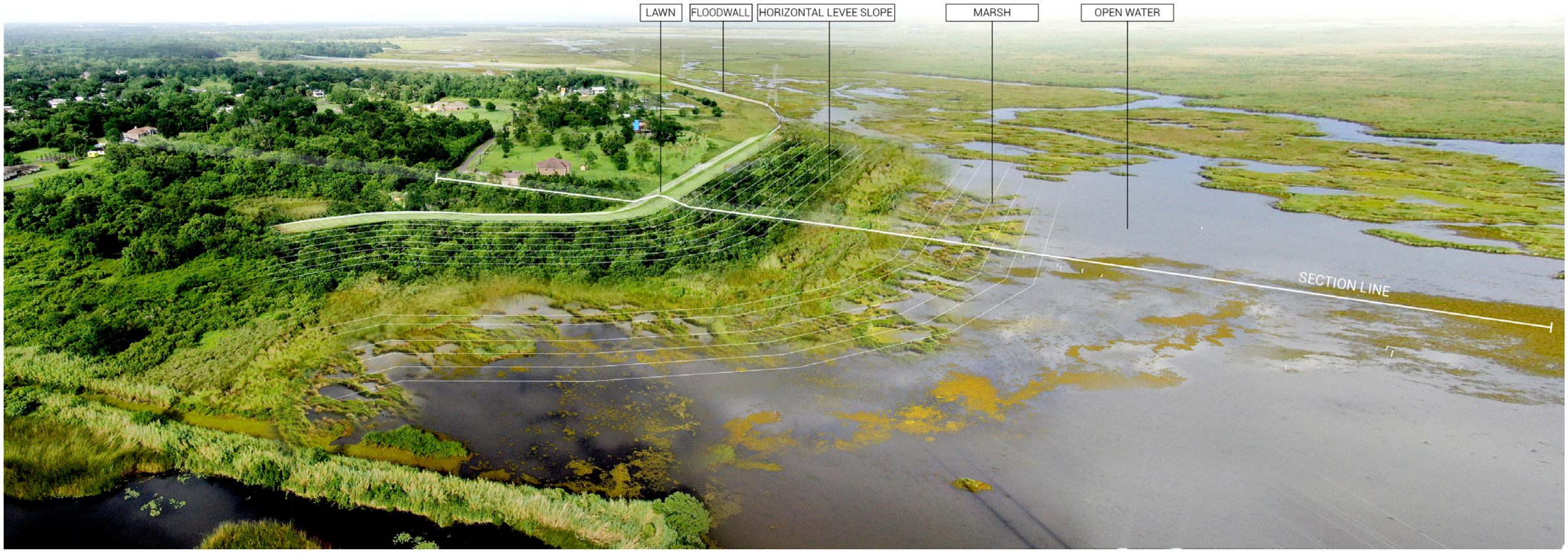
Volume estimate: 450 ft² additional placement / linear foot of levee (in addition to 05 + 05b)
(h.l. one) 320,000 CY of dredged material

Marsh estimate: 177 ft. wide
(h.l. one) 7.88 acres

1"=50'

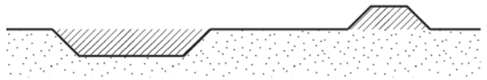


LOCATION KEY PLAN

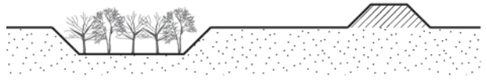


Bird's eye view of Horizontal Levee Option 05b "Dredge Ecotone Ridges"

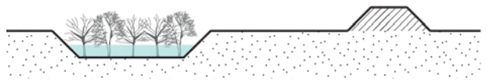
The other major NNBF proposed for Orange is a system of inland floodwater retention basins. These basins would take advantage of the need to excavate fill material for levee construction. The pits made by this excavation would be designed to connect to the regional drainage system, providing storage capacity. They would also be designed as habitat and for recreational use, enhancing their value during the long periods when they are not in use for floodwater storage. This would have the effect of reducing pressure on pump stations during flooding and, correspondingly, could lower pump station costs, which are the most expensive part of the CSRM.



A. EXCAVATION AND LEVEE



B. BASIN VEGETATED

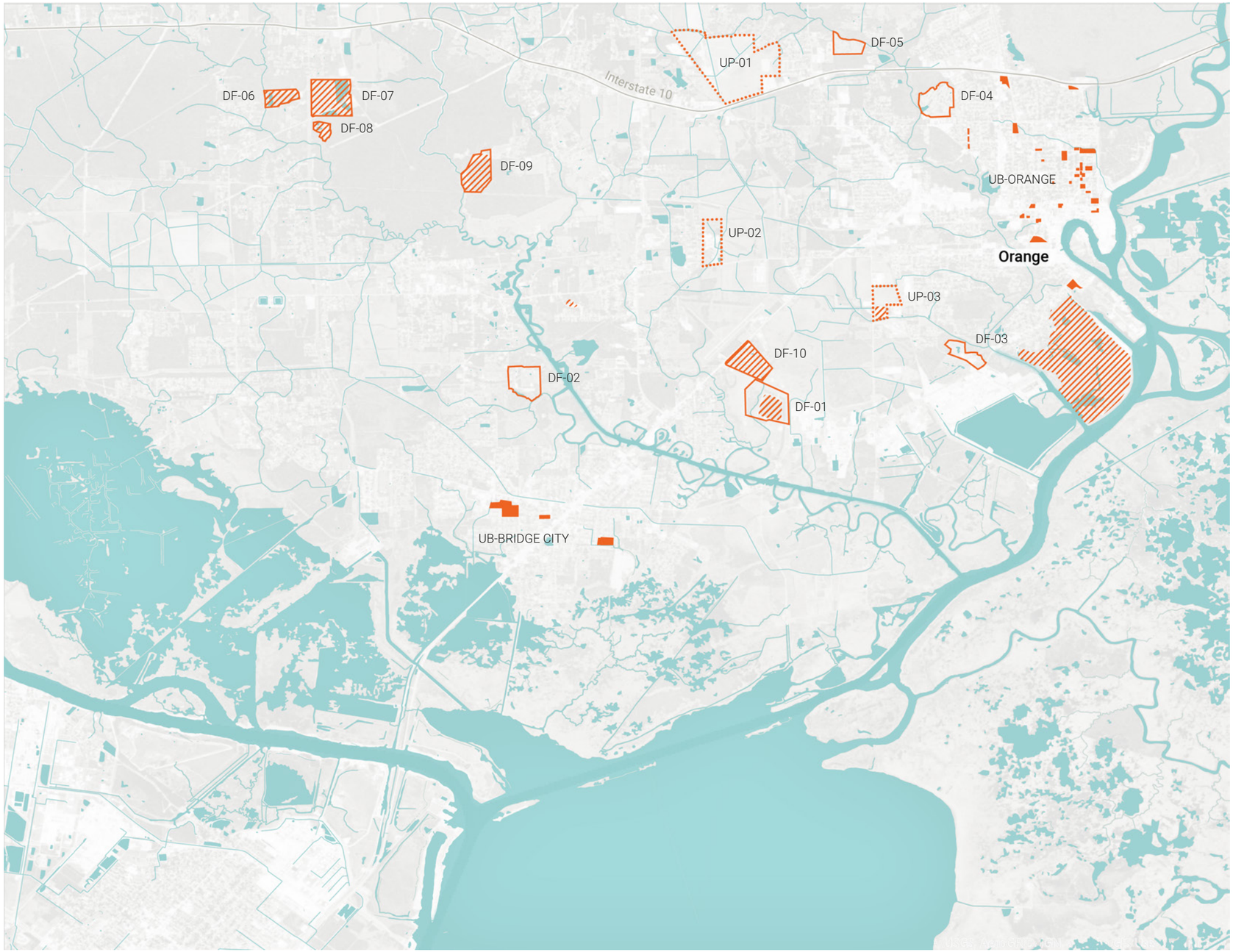


C. FLOOD RETENTION

Legend

- Upland Pit
- Drainage Floodrooms
- Urban Basins
- Degraded Land

0 1 2 4 mi.

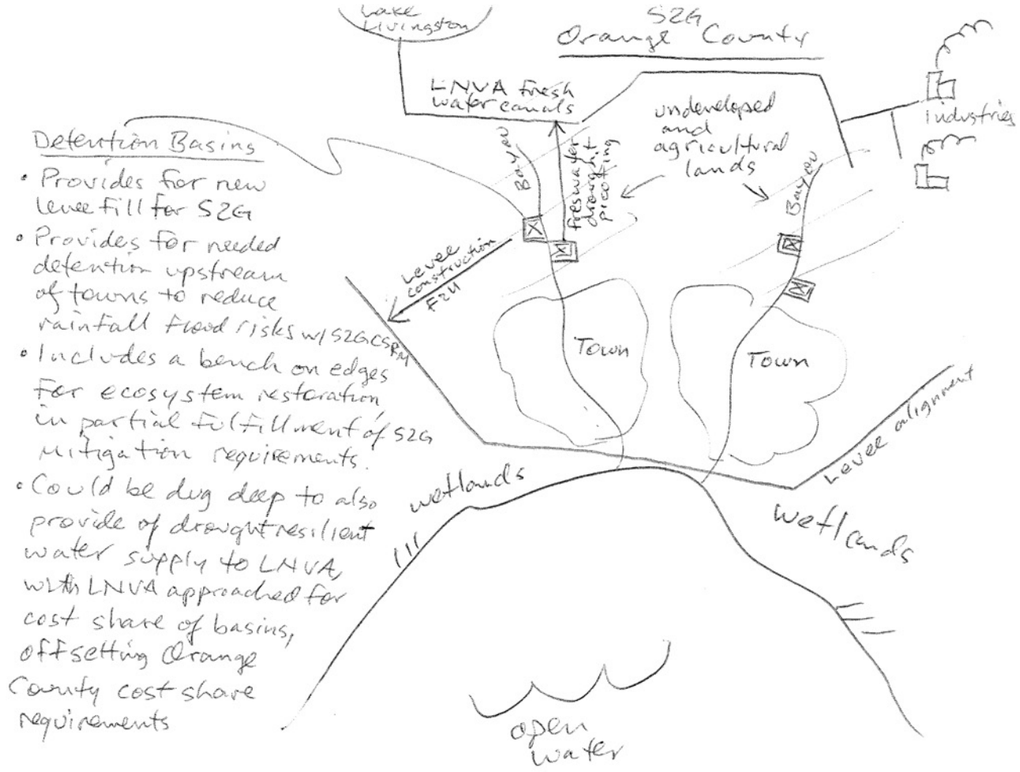


FEATURE ID	PROP. DEPTH (FT)	EST. VOLUME (AC/FT)	NOTES
UPLAND PITS			
01	10	508	Fields appear to be mined for sand, mostly as yet unmined
02	10	92	Fields appear to be mined for sand
03	10	76	Part sand mine owned by a construction company, part field owned by Chevron
DRAINAGE FLOODROOMS			
01	5	161	Partially excavated already, owned by a real estate company
02	5	103	Combines several private parcels, mostly cleared land with a mix of unclear land uses, potentially some extracation; located immediately off Cow Bayou
03	5	53	Three connected parcels of cleared and light industrial land; buildings appear to be abandoned and land is held by a holding company based in Delaware
04	5	103	Private land, seems actively used; large parcel of land with low ecological value
05	5	52	Cleared but moderately degraded land (clear evidence of erosion on eastern half of parcel); appears to be grazed by livestock, some agricultural structures on site; privately held.
06	5	52	Cow Bayou watershed
07	5	159	Cow Bayou watershed
08	5	25	Cow Bayou watershed
09	5	103	Cow Bayou watershed
10	5	104	Cow Bayou watershed
URBAN BASINS			
ORANGE	5	397	Thirty small parcels; primarily vacant parcels in/around older residential and commerical districts
BRIDGE CITY	5	265	Three medium-sized parcels; undeveloped land

General Design Notes

Sites have been selected with primary criteria including:

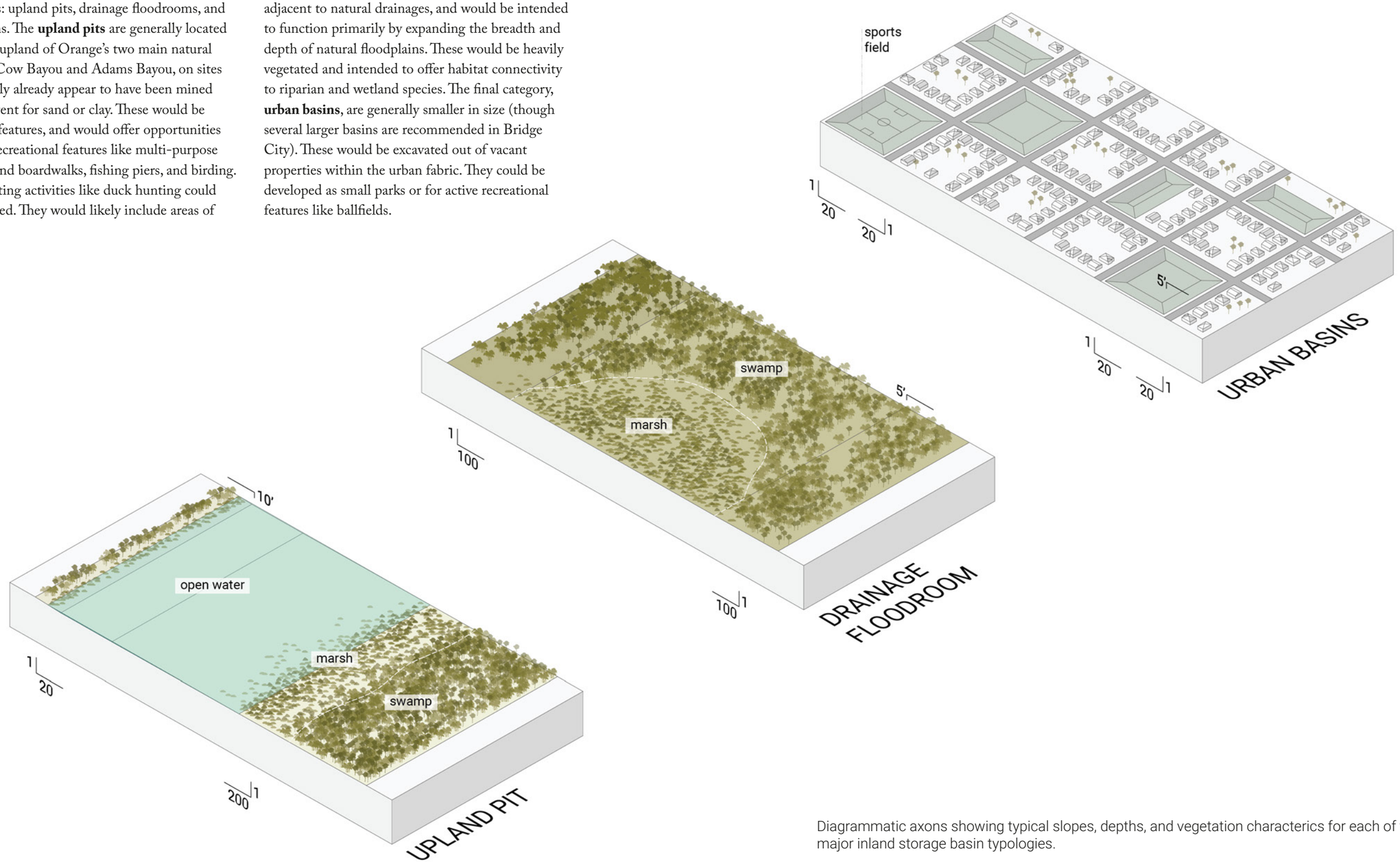
+ Disturbance of existing landscape (evidence of existing excavations, clearings, etc.)
+ Evidence of vacancy and/or disuse (abandoned lots, abandoned buildings, etc.)
+ Connection to existing drainages (canals, natural waterways)



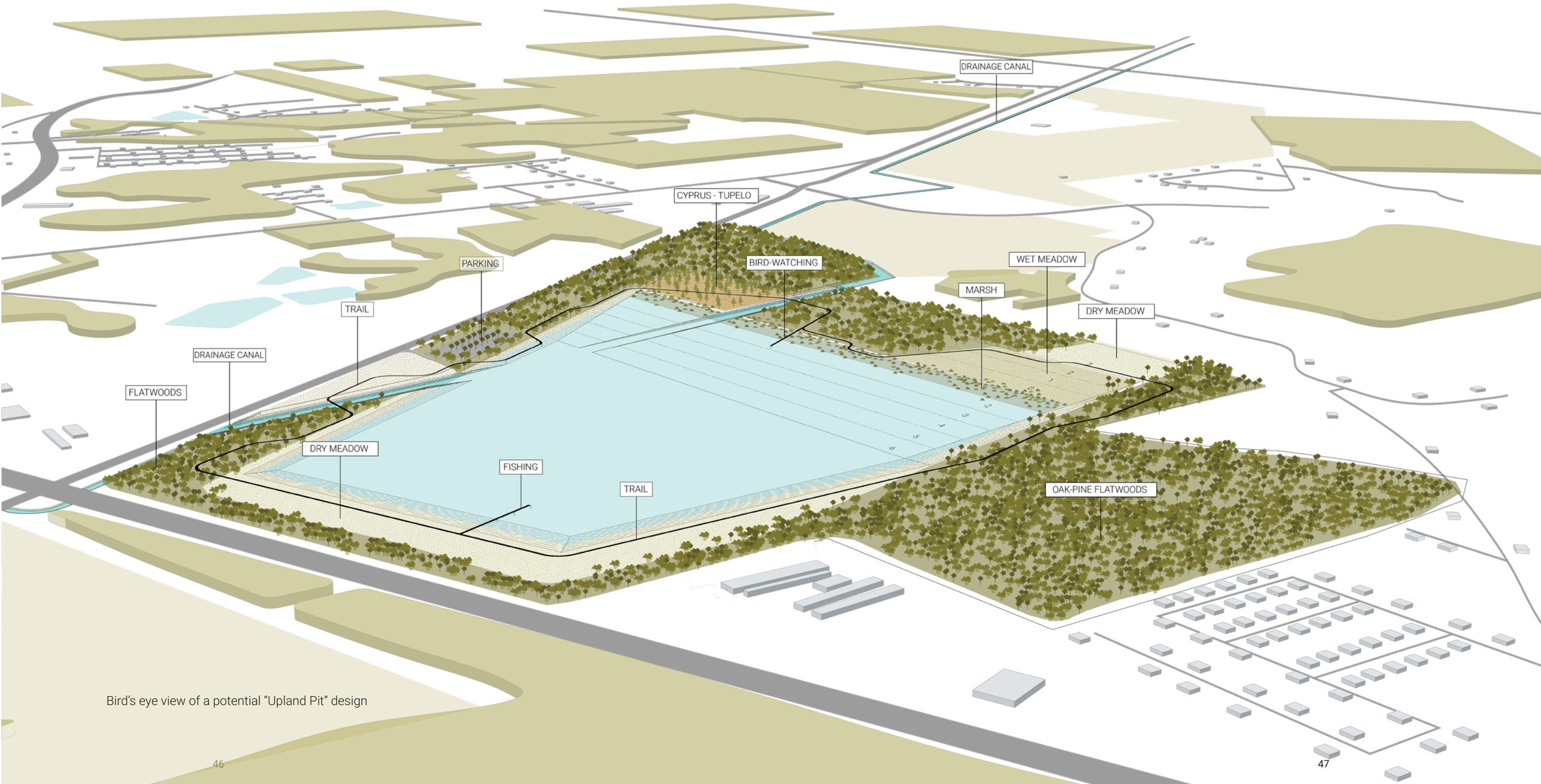
Initial sketch diagram by Dr. Edmund Russo, Jr., Deputy District Engineer for SWG, showing the potential synergy between excavation for levee construction, detention, ecosystem restoration, and water supply for local industry.

1 ORANGE: INLAND STORAGE

The inland storage basins have categorized by three major types: upland pits, drainage floodrooms, and urban basins. The **upland pits** are generally located inland and upland of Orange's two main natural drainages, Cow Bayou and Adams Bayou, on sites that typically already appear to have been mined to some extent for sand or clay. These would be the largest features, and would offer opportunities for major recreational features like multi-purpose trails, wetland boardwalks, fishing piers, and birding. Other sporting activities like duck hunting could be considered. They would likely include areas of open water. The **drainage floodrooms** are sited on or adjacent to natural drainages, and would be intended to function primarily by expanding the breadth and depth of natural floodplains. These would be heavily vegetated and intended to offer habitat connectivity to riparian and wetland species. The final category, **urban basins**, are generally smaller in size (though several larger basins are recommended in Bridge City). These would be excavated out of vacant properties within the urban fabric. They could be developed as small parks or for active recreational features like ballfields.



Diagrammatic axons showing typical slopes, depths, and vegetation characterics for each of the major inland storage basin typologies.



Bird's eye view of a potential "Upland Pit" design

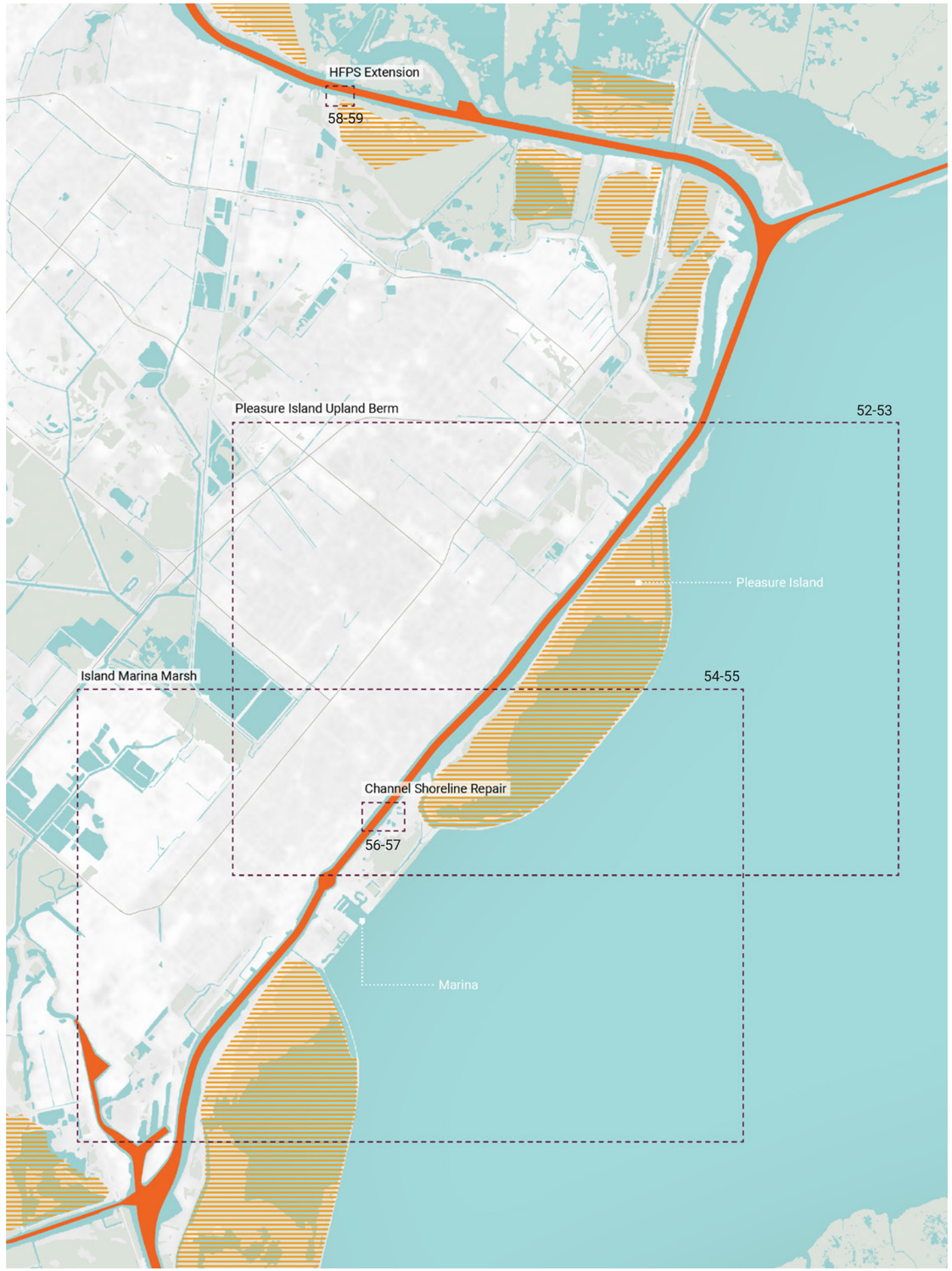
2 PORT ARTHUR

ISSUES AND OPPORTUNITIES

1 Pleasure Island as Storm Buffer
Pleasure Island is a significant feature in Lake Sabine that protects and buffers Port Arthur from coastal storm impacts. Unfortunately, the island has suffered from significant degradation, including erosion on its channel side along the SNWW.

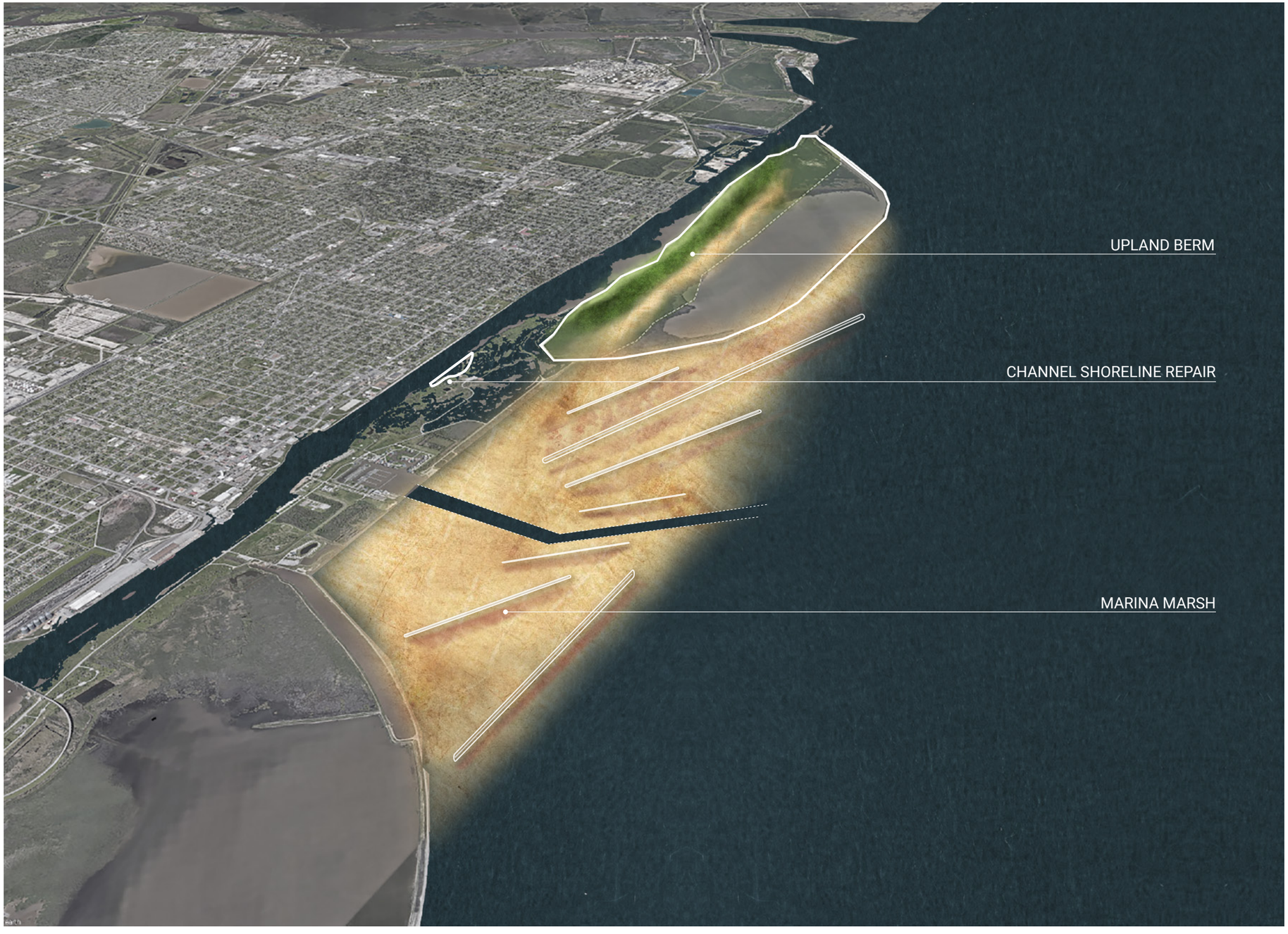
2 Beneficial Use of Dredged Material
As in Orange, the construction of significant NNBF for Port Arthur will require large quantities of sediment. The actively maintained navigation channels of the Sabine-Neches Waterway are potentially major sources of sediment that could link operational demands (the need to place dredged material in a suitable location) with proposed NNBF.

3 Levee Extension
While the majority of Port Arthur's HPS is already existing, one new segment is proposed near Port Neches. This segment represents an opportunity to consider how a levee could be integrated into its ecological and social context.



2 PORT ARTHUR: PLEASURE ISLAND

Three distinct NNBF are proposed for Pleasure Island: an enhanced upland berm along the island's northwestern edge, a marsh that would protect the thinnest portion of the island in front of the marina, and repair of eroded shoreline along the navigation channel. Each of these projects would require significant sediment for implementation, making linking them to channel improvements and maintenance dredging a high priority.



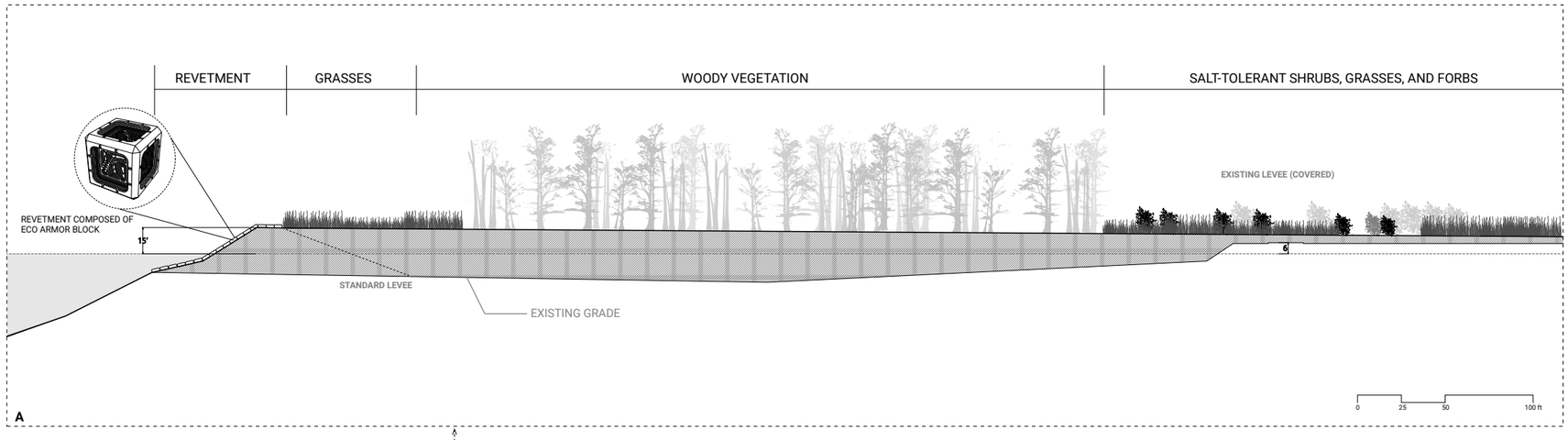
2 PORT ARTHUR: PLEASURE ISLAND UPLAND BERM

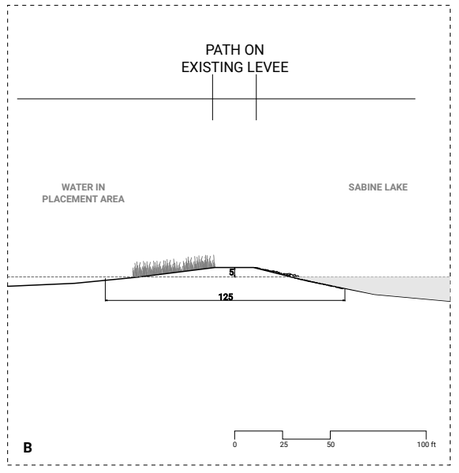
This proposed berm would line the northwestern edge of the island. A traditional levee core would be constructed along this edge, and it could be backfilled with dredged material to produce a shallow slope, covering the existing grade and the low existing levee, then dying into the open water of the existing dredged material placement area. This landside slope would be vegetated with both perennial salt-tolerant vegetation and woody salt-tolerant vegetation for both habitat value and to increase the wave energy reduction value of the feature. On the channel side, the levee revetment would be constructed using a segmented ecoblock with demonstrated habitat value and shellfish recruitment potential.

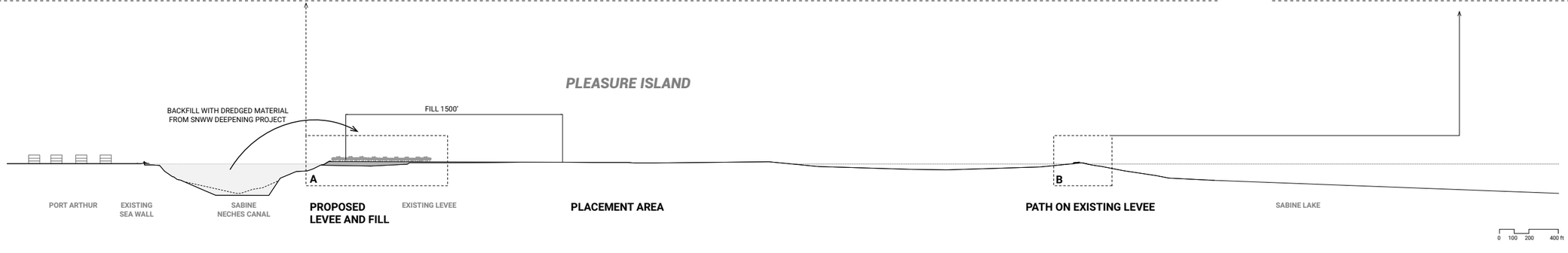
ESTIMATES

Habitat	574 acres
Fill Required	4.5 MCY*
Revetment	910,000 sq ft

* some upland fill required, majority to be dredged material as shown in section below







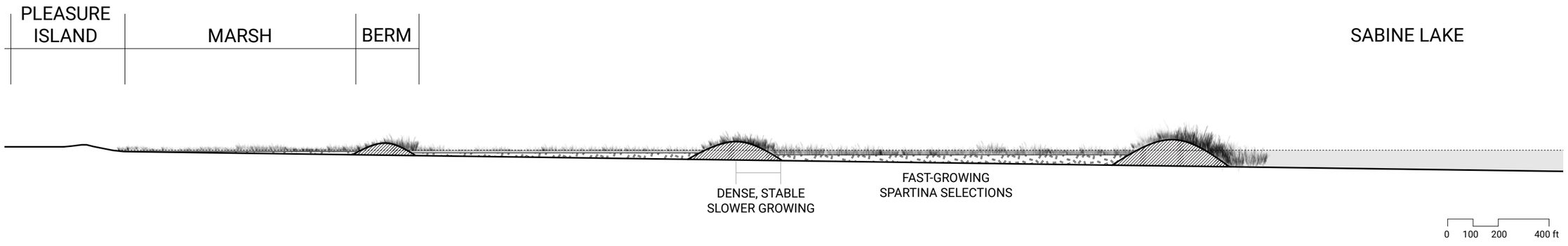
2 PORT ARTHUR: PLEASURE ISLAND MARINA MARSH

This feature is a constructed marsh that would protect the thinnest (and most developed) portion of Pleasure Island, in front of the marina. A series of berms would be built using the highly plastic, immobile clay material that will be obtained during the SNWW channel deepening. The space between these berms would then be brought up to marsh elevation using looser dredged material. Dense, slow-growing Spartina would be planted on the front edges of the berms to secure them, while faster-growing but less resilient Spartina would be planted in the gaps between berms. A navigation channel would be maintained between marsh segments for access to and from the marina.

ESTIMATES

Berms	32,400 linear feet
Marsh	1377 acres
Dredged Material	3.3 MCY*

* assumes placement thickness of 1.5'

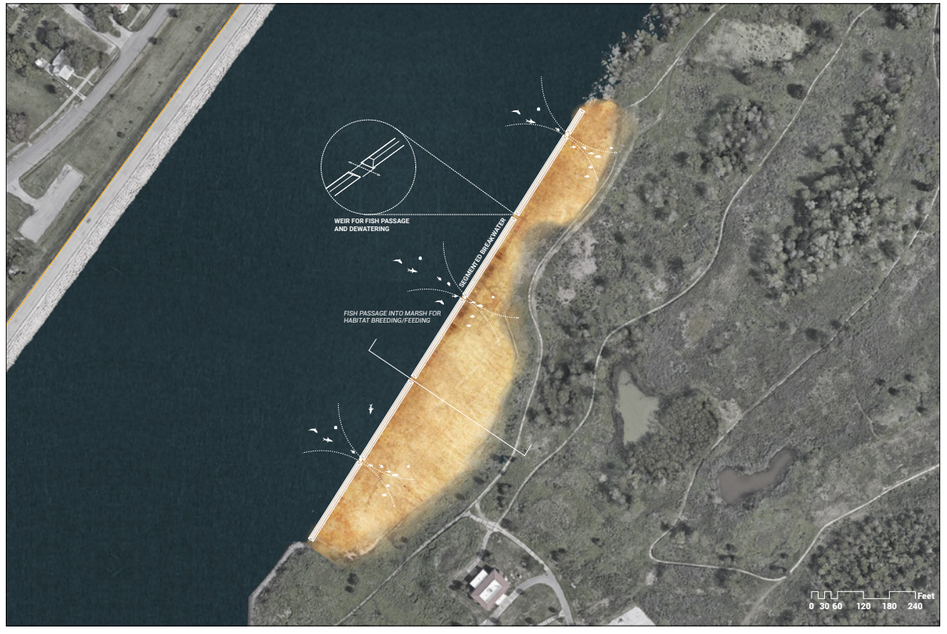


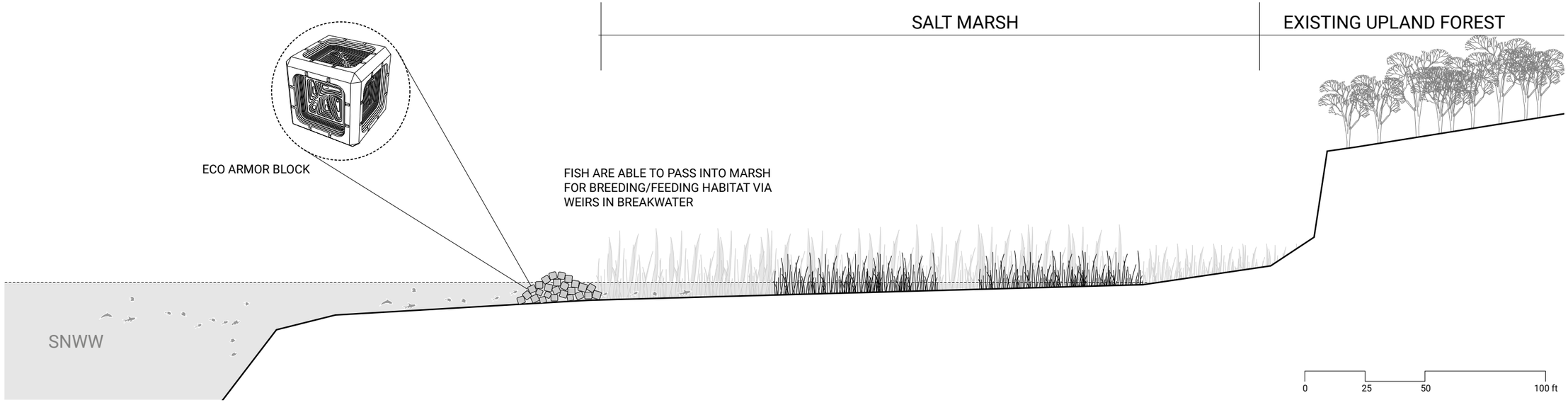
2 PORT ARTHUR: PLEASURE ISLAND CHANNEL SHORELINE REPAIR

In a number of places, the channel shoreline along the western edge of Pleasure Island is highly degraded. This feature proposes to construct a segmented breakwater using ecoblock along these eroded 'scallops', and then to bring the area behind those breakwaters up to marsh elevation using dredged material. Small weirs in the breakwaters could facilitate access in and out of these marshes for juvenile fish.

ESTIMATES

Breakwater	1,190 linear feet
Marsh	4.1 acres



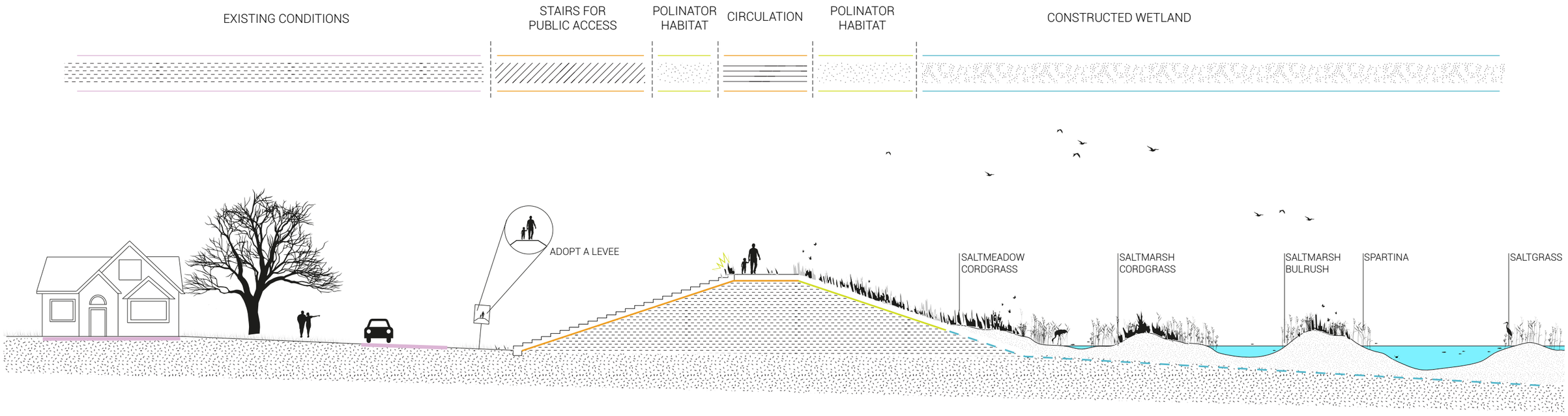


2 PORT ARTHUR: HFPS EXTENSION

Near Port Neches, the existing HFPS may need to be extended. This segment could be constructed as a NNBF. The plan diagram at right indicates how local borrow pits could be orchestrated to create habitat variation and a constructed wetland in front of the proposed levee. In places, the levee design could incorporate stairs for public access. Circulation atop the levee would permit the public to observe pollinator habitat (meadow species) on the outboard side of the levee and the constructed wetland. An "adopt-a-levee" program might be able to engage the community in the development and maintenance of this NNBF.

ESTIMATES

Length	1,900 linear feet

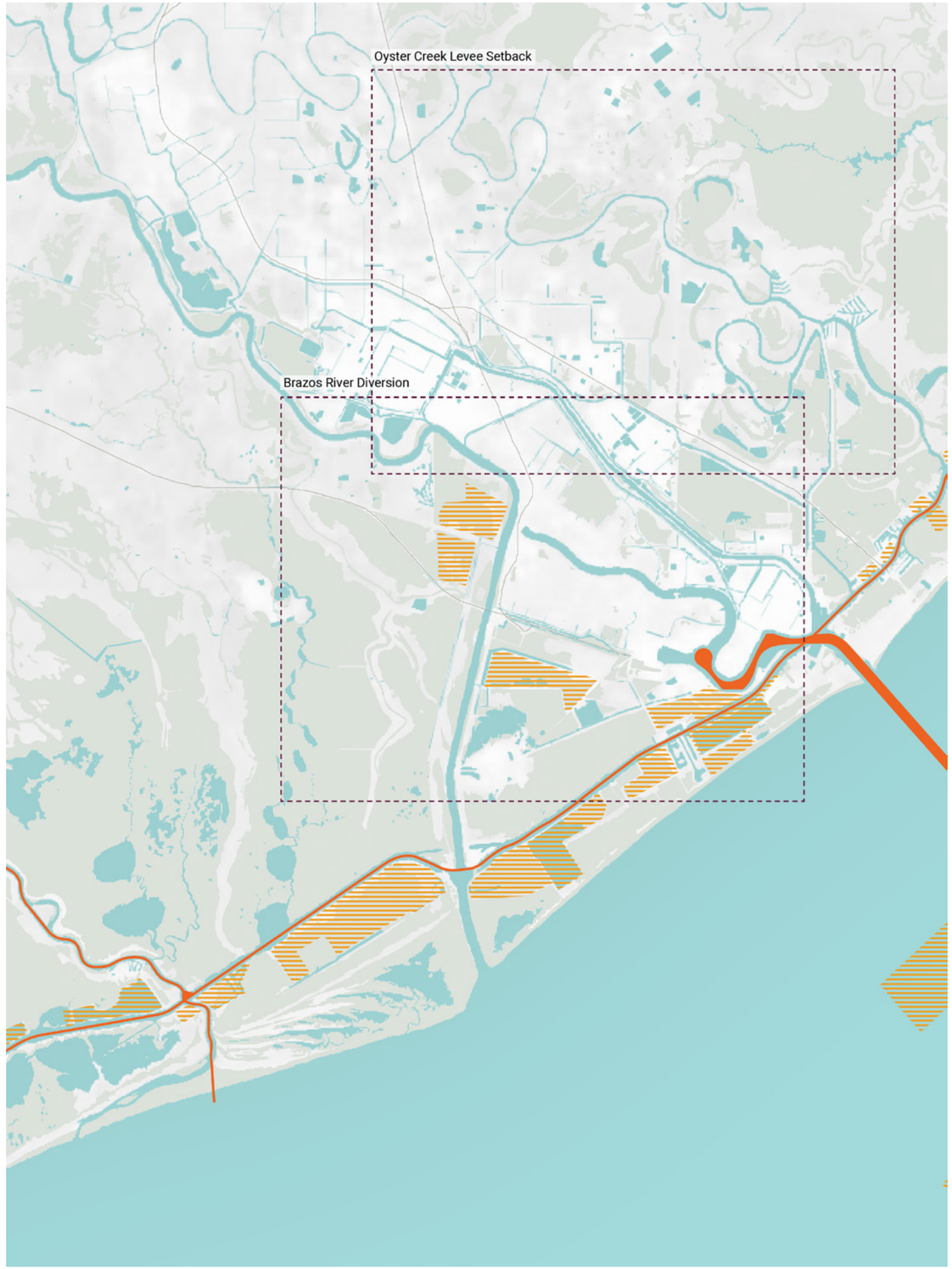


3 FREEPORT

ISSUES AND OPPORTUNITIES

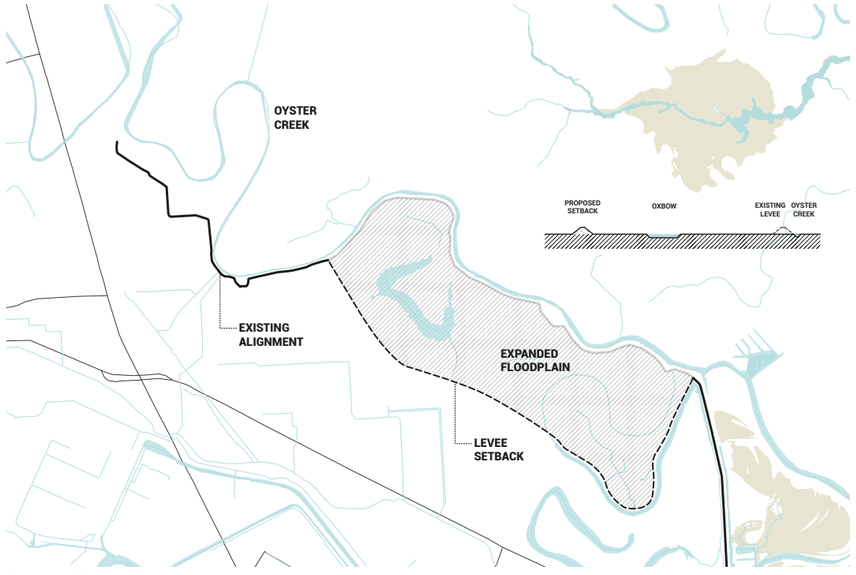
1 Compound Flooding
Like Orange, Freeport is low-lying and flat, and similarly at risk of compound flooding. Where Orange is drained primarily by two bayous, Cow and Adams, Freeport lies between two major drainages, the Brazos River and Oyster Creek. This means that a different approach to alleviating bidirectional storm risk is required, but this risk is recommended to be addressed regardless.

2 Adjacencies to Major Natural Systems
Major coastal ecosystems, including marshes and coastal prairies, lie just on the other side of those two drainages. Consequently, Freeport is flanked by broad expanses of active, dynamic natural systems. An NNBF approach can and should take into account opportunities to actively engage these systems, supporting them and enhancing their CSRM value, habitat value, and long-term sustainability.



3 FREEPORT: OYSTER CREEK LEVEE SETBACK

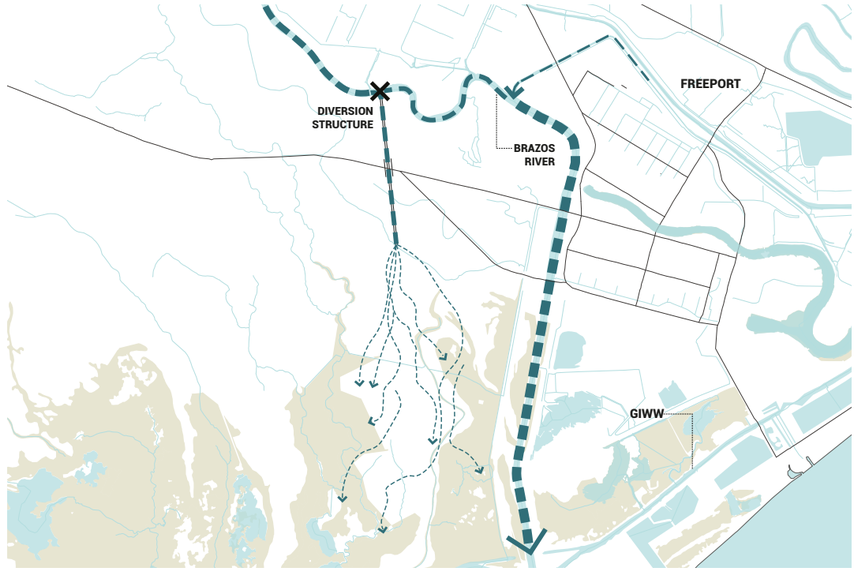
During the workshop, several 'high-level' options were identified as potential NNBF that could improve the management of floodwaters during storm events in the Freeport region. Those options included levee setbacks along Oyster Creek (below) and study of a potential hydrological and sediment diversion on the Brazos River (at right). The general consensus during the workshop was that these concepts are not presently feasible for S2G due to the scope of the authorized project and scheduling constraints, so they are presented here only as documentation of the workshop process and information regarding potential future options. Their feasibility, constructability, and design have not been evaluated in detailed.



Oyster Creek Setback Levee

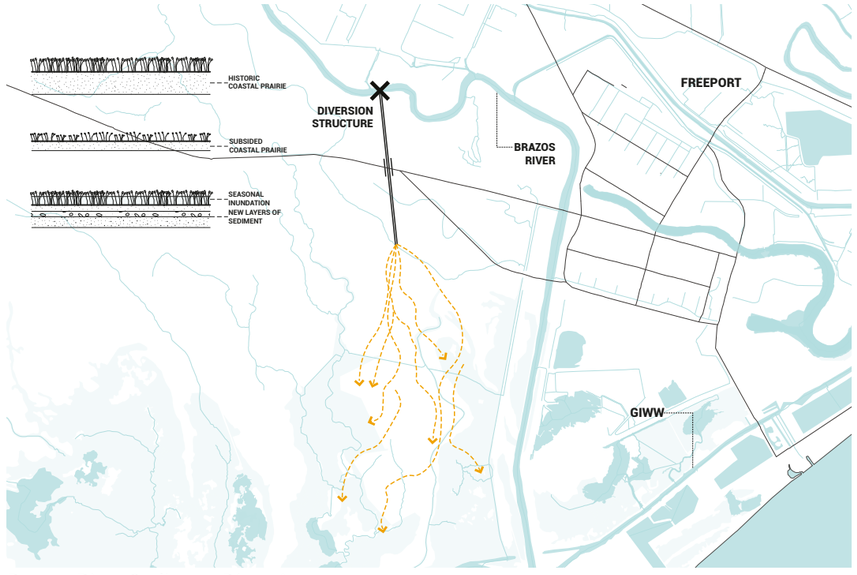
A setback levee on Oyster Creek could provide expanded floodplain capacity, reducing downstream flood impacts and providing valuable habitat.

3 FREEPORT: BRAZOS RIVER DIVERSION



Brazos River Hydrological Diversion

A diversion structure on the Brazos River could reduce water levels on the river during high flow events, potentially reducing the river's volume at the intersection of drainage canals from Freeport and the river, alleviating pressure on pump systems.



Brazos River Sediment Diversion

This diversion could be designed so that it not only connects the river with its floodplain, but also brings sediment to coastal prairie and marshes, which are currently suffering from significant subsidence, exacerbating RSLR. Sediment supply could help these ecosystems adapt.

Lower Neches WMA (Sean Burkholder)

Next Steps

The ideas in this document, and the drawings that document them, are only a first step in exploring the implementation of NNBF as a part of the S2G project. The next stages of work will require additional expertise, collaboration, and design. Key next steps that have been identified during these five months of work are:

1 Site-specific design and engineering of proposed NNBF, including modeling of storm interactions, habitat creation assessment (including quantification of benefit), predictive geomorphic evolution assessments, and design of recreational features

2 Quantification of the risk-reduction value of proposed NNBF For instance, with the Orange levee variations, vegetated foreshores have been shown to significantly reduce overtopping on traditional levee systems (Vuik, Jonkman, Borsje, and Suzuki, "Nature-based flood protection: the efficiency of vegetated foreshores for reducing wave loads on coastal dikes", Coastal Engineering 116 (2016) 42-56); quantifying this benefit could permit reducing planned levee elevations. Similarly, the value of inland storage basins can and should be quantified.

3 Real estate group evaluation of proposed sites that are not already part of the project footprint

4 Review of proposed features with local stakeholders and potential non-Federal sponsors

5 Identification of accreting/eroding wetlands and local sediment surpluses/deficits through scientific study in order to facilitate long-term sediment budgeting

6 Consideration of opportunities to reduce dependence on intensive maintenance to maintain NNBF and **enhance natural system function that can maintain NNBF**, such as natural sediment transport processes that can facilitate marsh feature accretion

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This report has been prepared by the investigators at **Auburn University**, the **University of Toronto**, and the **University of Pennsyvlania**; it also incorporates research and insights from ERDC's **Engineering With Nature®** project team.

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