Historical Marsh Analysis Report

Beneficial Use of Dredged Material
Site Scoping Support Services

Naval Submarine Base Kings Bay

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On the cover: NSB Kings Bay and the Cumberland Sound; credit to Google Earth aerial imagery 2019

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Acronyms and Abbreviations

ac	Acres
AMBUR	Analyzing Moving Boundaries Using R
BUDM	Beneficial use of dredged material
C-CAP	Coastal Change Analysis Program
CUDEM	Continuously updated digital elevation model
CUSP	Continually Updated Shoreline Project
CY	Cubic yards
DEM	Digital elevation model
DMMA	Dredged material management area
DNR	Department of Natural Resources
EPA	Environmental Protection Agency
EROS	Earth Resources Observation and Science Center
GIS	Geographic Information System
HWL	High water line
ICWWG	Interagency Coastal Wetlands Workgroup
LiDAR	Light detection and ranging
m	Meter
MHW	Mean high water
MHHW	Mean higher high water
MLW	Mean low water
MLLW	Mean lower low water
NAD	North American Datum
NAVD88	North American Vertical Datum of 1988
NSB	Naval Submarine Base
US Navy	United States Navy
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWI	National Wetlands Inventory
ODMDS	Offshore dredged material disposal sites
PR&G	Principles, requirements, and guidelines
SAD	South Atlantic Division
SLR	Sea level rise
TLP	Thin layer placement
T-Sheet	Topographic sheet
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
WRDA	Water Resources Development Act

1. Introduction

Background and Study Purpose

Naval Submarine Base (NSB) Kings Bay is a United States Navy (Navy) installation located on the Cumberland Sound on the southern coast of Camden County, Georgia. NSB Kings Bay's mission supports the service and retrofit of Ohio-class ballistic missile submarines and is the Navy's only Atlantic Coast strategic submarine base. NSB Kings Bay is also proposed to homeport the future Columbia-class ballistic missile submarines, which requires continued navigability of the Kings Bay subbase channel through at least the year 2080. From 2010 to 2019, an average of roughly 0.97 million cubic yards (CY) of sediment were added annually to the base's dredged material management areas (DMMAs), shown in Figure 1. Additional dredged material has also been placed at offshore dredged material disposal sites (ODMDS), shown in Figure 2, and has been repurposed for beneficial use applications at Amelia Island, Florida. Based on current estimates and surveys, the four existing DMMAs are expected to reach capacity within the next 10 to 12 years. These estimates are refined on an annual basis, as DMMA conditions, dredge operations, and other variables change. As a result, the Navy is seeking a solution to cost-effectively manage large volumes of dredged material over the next six decades to ensure the sustainment of NSB Kings Bay's mission.

A 2021 assessment of the NSB Kings Bay DMMAs found that alternative dredged material management strategies would be necessary in order to dispose of the large volumes of dredge material cost-effectively, given the diminishing capacity of the DMMAs and the high cost associated with offshore disposal.[1] Alternative strategies, such as projects involving the beneficial use of dredged material (BUDM), present a potential solution to managing the sediments removed from the Kings Bay subbase channel. BUDM includes beach nourishment, thin layer placement (TLP), habitat creation, and other methods that provide both environmental and economic benefits when implemented.[2]

The placement of dredged material for the creation or restoration of marshes near NSB Kings Bay presents an opportunity to improve the surrounding environment while managing dredged sediment. Improving existing marsh or creating new marsh can increase resilience against sea level rise (SLR), which can drown marsh grasses and lead to erosion. Marshlands also reduce the impact of coastal storms, which are projected to increase in frequency as a result of climate change.[3] As a potential management strategy, BUDM offers a solution that can address concerns of cost, volume, and environmental benefits for NSB Kings Bay and the surrounding context.

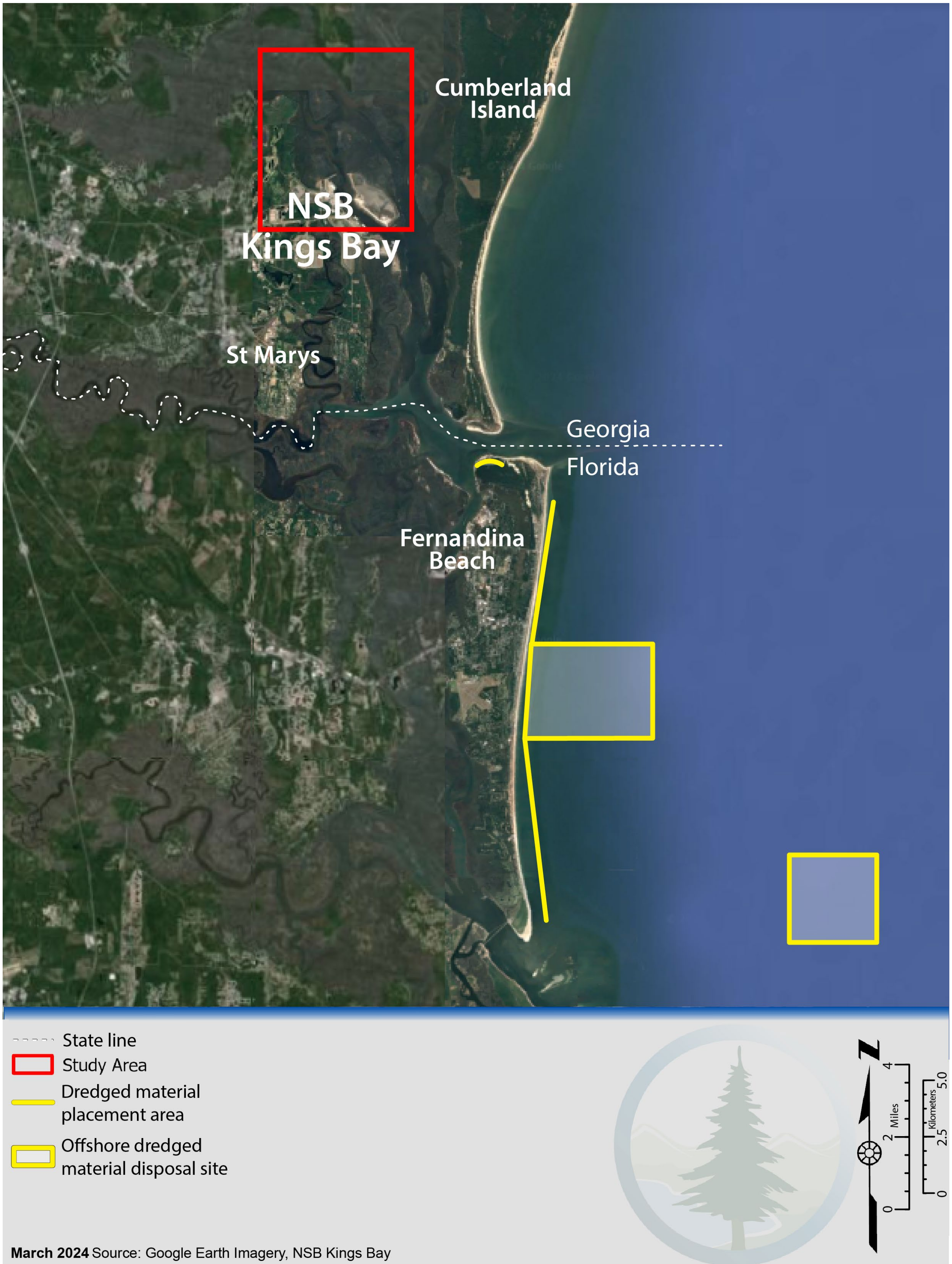
BUDM at NSB Kings Bay aligns with resilience plans and strategies being implemented by the Navy and in Camden County. The Navy's Climate Action 2030 Plan calls for the department to build climate resilience and reduce climate threat through several strategies, including the use of nature-based solutions such as wetland and salt marsh restoration and living shoreline construction. By 2027, the Navy aims to sequester five million metric tons of carbon dioxide annually using nature-based solutions on its land or through strategic partnerships.[4] Similarly, the Camden County Resiliency Implementation Workplan identifies a need for projects to bolster climate resilience across the county and in specific locations, including the City of St. Marys and NSB Kings Bay. Of the four projects identified for NSB Kings Bay in the Resiliency Implementation Workplan, the evaluation of alternative dredged material management strategies and assessing stormwater management infrastructure were identified as high-priority projects.[5]

Additionally, the Beneficial Use Site Scoping Support Services project is being conducted concurrently with Taylor Engineering's analysis of sediment transport and shoaling near NSB Kings Bay, as well as cost-benefit and trade-off analyses for BUDM sites. Through detailed hydrodynamic modeling, the shoaling and sediment transport analysis will illustrate the current trends of sediment erosion and deposition and will inform potential alternatives to decrease the frequency or amount of dredging required at the base. The cost-benefit analysis will quantify the lifecycle costs associated with potential dredged material management recommendations. The insights gathered through these concurrent studies will complement the results of the Beneficial Use Site Scoping Support Services Project. The Beneficial Use Site Scoping Support Services Project and the concurrent studies and initiatives underscore the local and regional commitments to climate resiliency and adaptation.

The Beneficial Use Site Scoping Project will identify potential BUDM sites near NSB Kings Bay through a series of three studies: the Historical Marsh Analysis, the Current Marsh Analysis, and the Future Marsh Analysis. The Historical Marsh Analysis is the first phase of this project and seeks to quantify the area and volume of marsh loss near NSB Kings Bay over a span of 90 years. The Historical Marsh Analysis results identify high-priority locations for further assessments in the Current and Future Marsh Analyses. During the Current Marsh Analysis, fieldwork will be conducted at the high-priority locations to document current conditions and verify trends observed in the Historical Marsh Analysis. The Future Marsh Analysis will assess potential conditions resulting from climate change and SLR. The Beneficial Use Site Scoping Project will culminate in the delineation of potential BUDM sites to support future dredged material management planning efforts at NSB Kings Bay.

Figure 1: Vicinity Map

Figure 2: Context Map



Study Area and Timeframes

NSB Kings Bay is managed by the U.S. Army Corps of Engineers (USACE) South Atlantic Division (SAD) Jacksonville District and is located in Camden County, Georgia, roughly five miles north of the Georgia-Florida state line. The base borders the City of St. Marys to the west and the Cumberland Sound to the east. Crooked River State Park, under management of the Georgia Department of Natural Resources (DNR), is adjacent to the northwest corner of the study area. The Cumberland Island National Seashore, managed by the National Park Service (NPS) is located across the Sound from the subbase but lies outside of the study area.

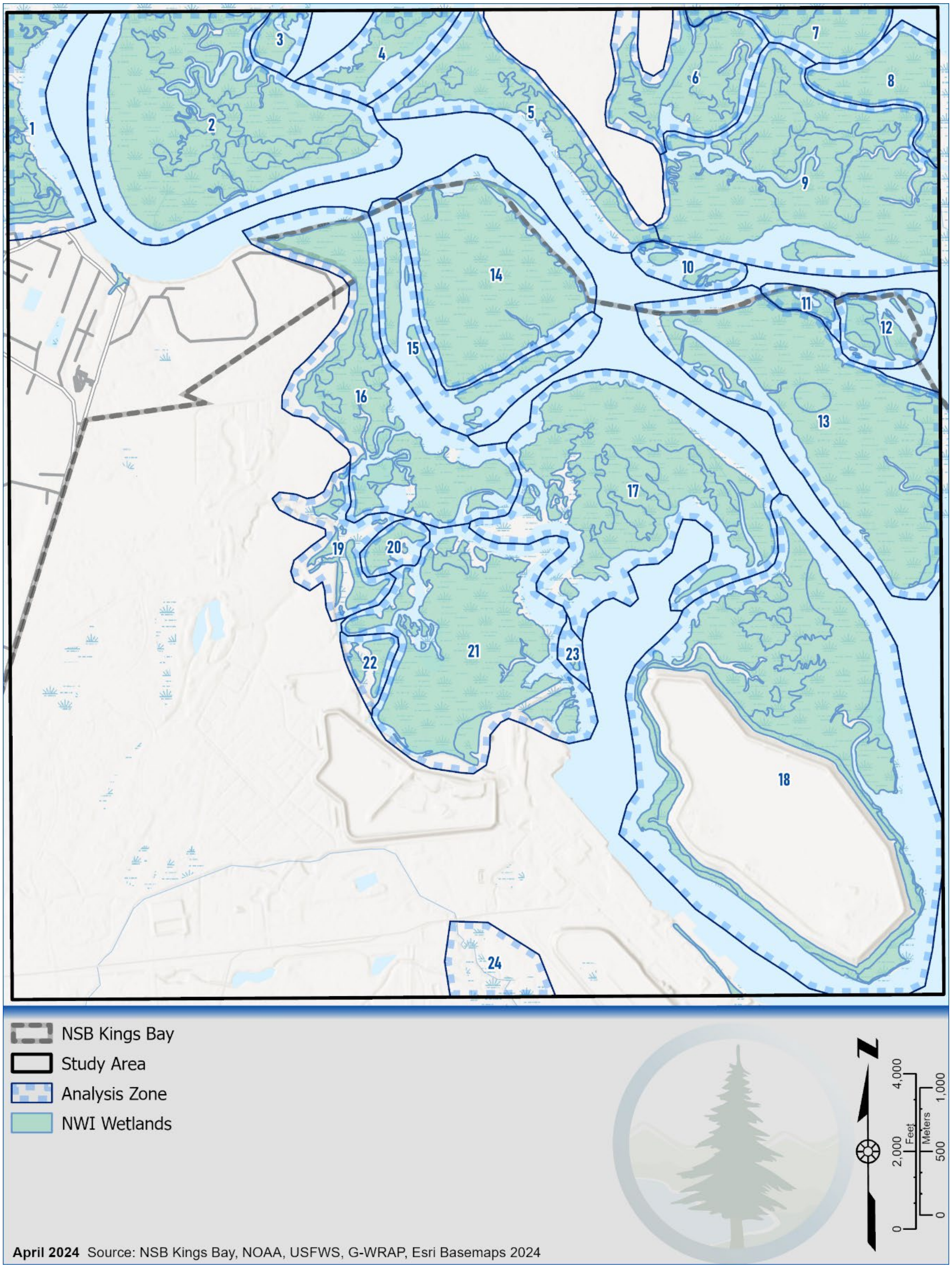
The study area for the Historical Marsh Analysis encompasses 14,020 acres delineated by the red rectangle to the northwest of the base in Figure 3. The extents of the study area were determined using the aerial map and materials provided by USACE at the start of the project. The area northwest of the base is the subject of this study because the marsh loss in this area is expected to contribute significantly to the amount of sediment that shoals into the navigation channel. The Historical Marsh Analysis aims to provide insight into these shoaling and sedimentation issues. Because the results of the Historical Marsh Analysis will lead to further on-site assessments of the marsh conditions, the study area has been divided into 24 analysis zones along the boundaries of contiguous marsh areas. The analysis zone boundaries, shown in Figure 4, were adjusted to include areas of marsh loss revealed during the analysis. See Section 4 for more information about the analysis zone delineation process.

The land at NSB Kings Bay was acquired by the Army in 1954 for the development of a military ocean terminal for shipping ammunition during emergencies. The development included a wharf, railroad tracks, and temporary storage areas. Construction of the base was completed in 1958, and the base was placed in active ready status but never activated for its intended purpose. However, the base was used for other operations until the start of Navy facility construction in 1975. The Army used DMMAs during their period of ownership. Navy operations at Kings Bay began in 1978 and continue to present day. The Navy currently occupies the original Army terminal and three major commands distributed over several thousand acres at the base.[6] In 2014, a land-water interface was constructed at the northern end of the navigation channel. After the construction of the land-water interface, maintenance dredging at the base increased in frequency and quantity. Dredged material from these operations is placed at the ODMDSs and DMMAs discussed above. The Navy has used DMMAs for dredged material management since taking ownership of the base in 1978. The primary study timeframe for this assessment (Timeframe A) spans from 1932 to 2022, which covers marsh change from before base development through full buildout for current operations, including recent developments and increases in dredging.

Six additional analyses, including 1932 to 2014 (Timeframe B), 1932 to 2002 (Timeframe C), and 1932 to 1972 (Timeframe D),1972 to 2014 (Timeframe E), 1972 to 2022 (Timeframe F), and 2014 to 2022 (Timeframe G) were conducted to determine if any significant changes to marsh loss rates had occurred and to better understand the influence of the selected datasets on the study results. More information about the analysis zones and study timeframes is provided in Section 4.

Figure 3: Study Area

Figure 4: Analysis Zones



2. Literature Review

Significance of Georgia's Marshes

Georgia's coastal marshes comprise one-third of the salt marshlands on the East Coast of the United States.[7] As per Georgia DNR, approximately 368,000 acres of estuarine tidal marsh provide habitat for aquatic organisms, including fish, shellfish, waterfowl, and other wildlife; function as feeding grounds for terrestrial vertebrates; protect against coastal storm surge; improve water quality; transform nutrients; and retain sediment.[8] Georgia's marshlands also provide significant benefit by sequestering carbon. The ecological and economic value of Georgia's coastal marshes was recognized in the 1970 Georgia Coastal Marshlands Protection Act, which states:

> *"The coastal marshlands of Georgia comprise a vital natural resource system. The estuarine area…is the habitat of many species of marine life and wildlife and, without the food supplied by the marshlands, such marine life and wildlife cannot survive. The estuarine marshlands of coastal Georgia are among the richest providers of nutrients in the world. Such marshlands provide a nursery for commercially and recreationally important species of shellfish and other wildlife, provide a great buffer against flooding and erosion, and help control and disseminate pollutants. The coastal marshlands provide a natural recreation resource which has become vitally linked to the economy of Georgia's coastal zone and to that of the entire state."*[9]

In addition to storm surge protection, researchers, planners, regulatory authorities, and coastal communities have increasingly come to understand that marshes provide significant protection to shoreline areas by reducing the impacts of coastal flooding events and coastal erosion. One regional study conducted following 2012's Hurricane Sandy estimated that, in the four states with the largest wetland cover (Maryland, Delaware, New Jersey, and Virginia), wetlands reduced flood damages by 20 to 30 percent.[3]

NSB Kings Bay is located in Camden County, GA. Wetlands, which compose approximately 50 percent of Camden County's land area, are critical to the county's resiliency implementation efforts.[5] Per the Camden Resiliency Workplan, all areas in the County with concentrated development, including St. Mary's, Kingsland, and Woodbine, are at risk of flooding from the coastal storm surge caused by major storms. Marshlands in Camden County also provide significant habitat value and support recreation opportunities. Cumberland Island National Seashore includes 9,800 acres of federal wilderness area, and Ceylon Wildlife Management Area, established in 2019, provides 16,000 acres of protected habitat.[5]

Vulnerability to SLR

Although marshes can provide protection from the more frequent and severe storm events attributed to climate change, SLR can drown the vegetation that maintains and builds salt marsh, leading to decline and loss of these areas. The impact of SLR is exacerbated by subsidence of coastal areas due to decreased sediment deposition, channel widening, and marsh erosion from severe storms.[10]

Optimal growth of marsh species, such as saltmarsh cordgrass (*Spartina alternifolia*), occurs within a narrow range of the intertidal zone, which is generally between mean low water (MLW) and mean higher high water (MHHW). The plant species found in marshes can adapt to slow SLR; however, many models project rates of SLR that will drown marsh grasses. According to the University of Cambridge, 80 percent of the world's wetlands could be gone by the end of the century due to continued SLR.[11] There is significant variance between model projections regarding adaptability of marshlands to SLR rates, likely due to the different impacts of contributing factors. Localized SLR can vary due to prevailing winds and land subsidence. Static marsh resilience models do not incorporate biological factors such as the biomass contribution, erosion control benefits, and accelerated sediment accretion from marsh vegetation.[12] Recent studies in the United States and abroad have indicated that salt marshes may be better able to adapt to more rapid SLR rates in locations with a high concentration of suspended sediments and/or locations with additional sediment deposited by frequent storm events and inundation. This adaptation requires sufficient suspended sediment and healthy marsh grass populations to best ensure that sediment accrual can keep pace with SLR. Healthy grass populations have greater biomass and more effectively slow water that carries suspended sediments, increasing deposition. Studies on marsh grass adaptability show that high suspended sediment concentrations may allow marshes to adapt to SLR rates of several centimeters per year, compared to adaptation to SLR rates of only millimeters when low suspended sediment concentrations are present.[12]

Ongoing research and modeling efforts have indicated a continued reduction in sediment available to maintain coastal marshes in the Georgia Bight, the curved, westernmost portion of the South Atlantic coastline between North Carolina and Florida. Reduction of water flows due to diversion for irrigation and drinking water use, decreased rainfall, and flood control measures such as armored streambanks, riverbanks, dams, and levees can all reduce the amount of sediment available to sustain downstream marshes. A recent analysis of sediment in rivers discharging into the coastal salt marshes of the Georgia Bight estimated a 2 percent total reduction in sediment discharge per decade as the remaining riparian floodplain deposits from 17th and 18th century soil erosion caused by widespread land clearing are exhausted.[13] While such a reduction may seem small, researchers have also predicted rapid marsh losses beyond 2100 as salt marshes exhaust 'surplus' sediments deposited prior to construction of reservoirs and flood control structures that trap new sediment discharge.[14]

Although more frequent storms can provide sediment deposits, high-intensity storm events such as hurricanes can damage or even destroy marshes and leave remaining portions more prone to erosion. For example, Hurricane Sandy damaged coastal wetlands from North Carolina to Maine, and significant wetland losses were observed.[3] Hurricanes in rapid succession are also likely to cause significantly more damage as uprooted wetland vegetation cannot be replaced between storm events.[15] In addition, dredging operations and increased wave action in widened or straightened navigation channels expedite erosion at marsh edges where sediment deposition is most likely to occur.[16]

Where sediment deposition cannot build up marsh elevations to match SLR rates, marshes can also adapt by retreating inland. Salt marshes located adjacent to steep topography, hard armoring, or developed areas are typically lost to SLR as retreat is not possible. This problem is exacerbated by land use patterns that allow development in areas of potential marsh retreat. Where marshes cannot retreat inland, SLR will likely result in continued loss of Georgia's coastal marshes. In coastal areas like Camden County, adapting to continued SLR may mean identifying appropriate areas where marsh migration can occur to offset loss of existing marsh.

Loss of intracoastal marshes increases the risk of flooding and storm impacts to low-lying coastal communities in Camden County and at NSB Kings Bay. Mission sustainment at NSB Kings Bay requires access to navigable waterways which severely limits opportunities to relocate operations. Allowing marshes to retreat onto other areas of the facility would reduce available areas for mission-critical operations. In addition, many developed areas of NSB Kings Bay would be unsuitable for marsh retreat due to impervious surfaces and existing structures. Consequently, maintaining or even enhancing marsh areas in the Cumberland Sound that provide protection against flooding and storm events should be prioritized at NSB Kings Bay.

Opportunities for Beneficial Use and Restoration Projects

USACE defines BUDM as “the productive and positive use of dredged material, which cover broad use categories ranging from fish and wildlife habitat development to human recreation and industrial/commercial uses.”[17] Material dredged from the NSB Kings Bay subbase channel provides a substantial volume supply for BUDM. Especially as existing DMMAs approach capacity, increased BUDM has been prioritized by the Navy and USACE as a key dredged material management strategy. In addition, increased BUDM for marsh restoration could support the Interagency Coastal Wetlands Workgroup (ICWWG) recommendation to increase the acreage of wetlands restored in coastal watersheds.[18] The 2020 Regional Sediment Management Optimization Update prepared by USACE SAD includes BUDM strategies such as beach nourishment, open water dispersal, filling dredge holes, nearshore placement, TLP, and habitat creation.[2]

Beach nourishment uses beach-grade sand from dredging operations to restore beach areas. It is a common practice, and many beachfront communities plan for periodic beach replenishment to sustain the economic benefits of tourism and recreation. Beach replenishment is also used to protect beachfront properties from ongoing erosion and to repair damage from storms. Dredged material from NSB Kings Bay has been used for beach replenishment projects on the Florida coast. In 2020, a detailed analysis of existing demands for dredged sand for beach nourishment projects in the USACE SAD indicated that available dredged sand resources could satisfy the needs of permitted and almost-permitted projects for the next 50 years; however, sand shortages in all SAD states and future sand needs for projects in planning stages suggest that demand may outpace supply.[19]

With dredged sand in high demand for beach replenishment projects, BUDM strategies that use finer sediments, such as mud, muck, and silt, will become more essential. For example, open water dispersal typically occurs just offshore but within the littoral zone (an indefinite zone extending seaward from the shoreline to just beyond the breaker zone) and involves the addition of dredged sediment fine enough to be suspended and carried by currents.[20] Open water dispersal can be used as a method of strategic placement, allowing natural sorting of dredged materials and deposition in desirable locations by currents, while reducing impacts from earthmoving equipment. Dredged sediment can also be used to fill dredge holes in deep water areas that have reduced habitat value and are not needed for navigation. This practice may also allow for the (re)establishment of adjacent marshlands or tidal flats. Dredged material is used in nearshore placement to restore barrier islands and the protection they provide to intertidal marshes and coastal properties. TLP uses the incremental application of dredged material to raise the elevation of existing marsh. BUDM for habitat creation includes varied approaches to create or restore habitat lost to erosion, SLR, or other factors.[2]

BUDM projects along the Georgia coastline and elsewhere within the USACE SAD include numerous beach nourishment, nearshore placement, and habitat creation efforts. It is not uncommon for multiple BUDM strategies to be combined in adjacent areas to address complementary goals. For example, beach nourishment and nearshore placement projects may also create or improve wildlife habitat. In 2008, 530,000 CY of dredged sand were used to create habitat at Brunswick Bird Island in Georgia, and opportunities exist for future transitional nearshore placement.[2]

In 2020, USACE estimated that 1.3 million CY of material dredged for Kings Bay Entrance Channel Maintenance was not suitable for beach or nearshore placement. Beneficial use of finer sediment may be feasible through other strategies. Filling legacy dredge holes in areas not required for navigation can accommodate dredged material of varying particle sizes. The Jacksonville Harbor Mile Point Navigation Project, completed in 2021, used 900,000 CY of finer dredged material to restore 52 acres of salt marsh habitat. The USACE Mobile District uses TLP to place approximately 3 million CY of finer mud, silt, and clay in depths up to 12 inches outside of navigational channel areas in Mobile Bay as part of Mobile Harbor Maintenance Dredging.[2] USACE considers open-water dispersal a BUDM strategy when dredged materials are placed strategically, or when transitional placement is used. Transitional placement is another BUDM method involving strategic placement of dredged material in locations where natural forces will sort and deposit sediments in other locations where they are beneficial. Transitional placement locations are easier to determine for dredged sand. Effective placement locations for finer sediments, such as mud, silt, and clay, are difficult to determine because finer dredged material particles are suspended for longer periods, which can complicate sediment transport modeling and result in deposition outside of preferred locations.

Gradually raising marsh elevations with TLP to protect them from SLR and subsidence while maintaining existing vegetation was listed as a potential wetland restoration strategy in the Recommendations for Saving Louisiana's Coastal Wetlands in 1989. However, this practice has been implemented less frequently in Georgia by USACE SAD.[21] The Georgia DNR Coastal Resources Division commissioned the Georgia Coastal Research Council to develop a report on TLP, including case studies of projects primarily in Louisiana and Alabama.[22] The first TLP project in Georgia performed by USACE SAD began in 2019 on a 5-acre area of Jekyll Island, using dredged material consisting of mud, muck, and silt from Jekyll Creek in the Atlantic Intracoastal Waterway.[2] The Jekyll Island TLP pilot was limited to only 5,000 CY, while the remaining 97 percent of dredged material from Jekyll Creek was used to fill a deep area in St. Simons Sound.[23] Jekyll Island TLP depth varied as the sediments were hydraulically pumped onto the site.[24] Subsequent monitoring efforts observed that marsh vegetation was still recovering from the sediment placement 30 months after the work was completed, although monitoring efforts are ongoing. Researchers recommended adjusting the timing of hydraulic piping to coincide more closely with flood tides, increasing sand composition of the placed material, reducing TLP depths, and using other sediment placement methods, such as rainbowing, which involves spraying sediment-laden water onto the site.[24]

Placement of dredged material in thicker levels uses larger volumes of sediment while impacting smaller areas, and it is typically a more cost-effective way to use dredged material than TLP. The increased difficulty of creating new DMMAs, the continued need to protect Georgia's coastal marshes from SLR, and more aggressive BUDM goals may necessitate increased use of TLP and other BUDM strategies that are not necessarily the least costly to construct. As the value of dredged material for salt marsh restoration and SLR resilience is more adequately considered in calculating funding eligibility, it may become easier to fund BUDM strategies that provide for greater environmental benefits. Understanding the limits of marsh vegetation's ability to adapt to SLR and recover from the placement of dredged material will make it easier to determine the practical limits for dredged material application thicknesses. Because salt marsh grasses are foundational to the survival of the marsh, this increased understanding will help project managers more accurately estimate the potential for placement of dredged material in salt marshes and allow regulatory agencies to better weigh the benefits and risks.

Regulatory Changes Allowing Increased BUDM

Like many states, Georgia relies primarily on Federal regulatory oversight of dredging operations, with State regulatory statues limited to the required reuse of dredged sand to reduce sand loss on nearby beaches.[25] Increased BUDM in Georgia has been made possible primarily by changes in Federal regulatory requirements. The 1972 Clean Water Act classified 'dredge spoils' as a pollutant, regulated like other harmful materials including solid waste, sewage, and garbage, which typically resulted in the disposal of dredged materials.[26] The regulation of most dredged materials as waste is no longer appropriate, given that an estimated 90 to 95 percent of the material dredged by USACE does not contain harmful contaminants and can be used for aquatic and nearshore BUDM applications.[27] Even though increased environmental regulations have reduced levels of pollution and contaminants present in dredged material, significant updates to regulatory requirements were required to expand BUDM implementation. As regulatory agencies, wetland ecologists, and coastal planners' understanding of the necessity of sediment to sustain coastal marshes continues to grow, regulatory guidance has adapted to enable increased BUDM.

As DMMAs reach capacity, the cost associated with managing dredged materials in these areas or in similar types of new management areas is likely to grow. BUDM projects may become comparably cheaper relative to the cost of constructing new dredged material management sites. Additional BUDM will also help USACE achieve the goal of repurposing 70 percent of dredged material for BUDM by 2030.[17] Combining multiple BUDM strategies in adjacent areas may increase the cost-effectiveness of BUDM projects and enable increased benefits for marsh restoration. TLP is more cost-effective when the placement location is nearby to the dredging location.[22] In part due to the higher cost and relatively thin layers applied during TLP, the combination of this BUDM method with less expensive methods such as filling dredge holes can allow effective use of larger dredged material quantities while reducing the total project cost. For example, the Jekyll Island Pilot project used only a small portion of available material for TLP, while the balance was used to fill a large hole, meeting the dredging project's BUDM needs.[24] Additionally, filling erosion gaps in existing marshes, reconstructing barrier islands, or replacing lost habitat could allow for the placement of larger quantities of dredged material in tandem with smaller, more experimental placements. Alongside the more frequent use of less common placement methods such as TLP, robust monitoring efforts will be required to inform ongoing BUDM planning efforts.

3. Data

Selected Datasets

To conduct the Historical Marsh Analysis, the project team evaluated several datasets for current and historical shoreline edges, wetland boundaries, and land cover types in the study area. The project team reviewed past studies and coordinated with USACE to determine if there were any relevant datasets consistently used in past USACE reports, but none were identified. Considerations for data selection included the level of detail each dataset provided, data collection or publication in years consistent with other preferred datasets, and for the present-day dataset, ensuring that the information was the most up-to-date available for the NSB Kings Bay area. In discussions with USACE, the 1930s and 2010 were noted as milestone dates for the start and endpoints of the analysis. The 1930s are significant because data from this period is the most complete documentation of the conditions prior to the development of the area as an Army base in the 1950s.[6] Data gaps exist in the 1940s and 1960s. A 1972 dataset was selected to provide a midpoint for the study period.

A digital elevation model (DEM) for the area was published in 2022. Through a series of transformations and calculations using the DEM, described in more detail below, the project team created a dataset representative of the present-day conditions. Thus, 2022 was selected as the present-day endpoint for the primary analysis timeframe. An analysis from 1932 to 2014 was also conducted, because NWI wetland data for the area was published in 2014. The NWI wetland map is an authoritative dataset created using a standardized, well-documented, and widely accepted wetland delineation methodology that combines tide-coordinated satellite and aerial imagery and supporting datasets to identify conditions indicative of wetlands. The NWI delineation is performed using imagery that complies with federal standards and supplemental datasets that include topography and existing NWI data, if available. The delineation also references soil data, hydrological data, navigational charts, and DEMs when available and appropriate.[28, 29] Table 1 lists the datasets selected for this analysis. To update the data to the maximum extent practicable, the loss analysis will be re-run using data collected during the Current Marsh Analysis and updated aerial imagery, if possible.

Table 1: Historical Marsh Analysis Datasets

Year[a]	Title	Publisher	Description	Link
1932	T-sheet[b]	NOAA[c]	Historical shoreline survey	https://nsde.ngs.noaa.gov/
1972	Historic Shorelines	G-WRAP[d]	Shoreline boundaries	https://geospatial.gatech.edu/G-WRAP/
2002	T-sheet	NOAA	Historical shoreline survey	https://nsde.ngs.noaa.gov/

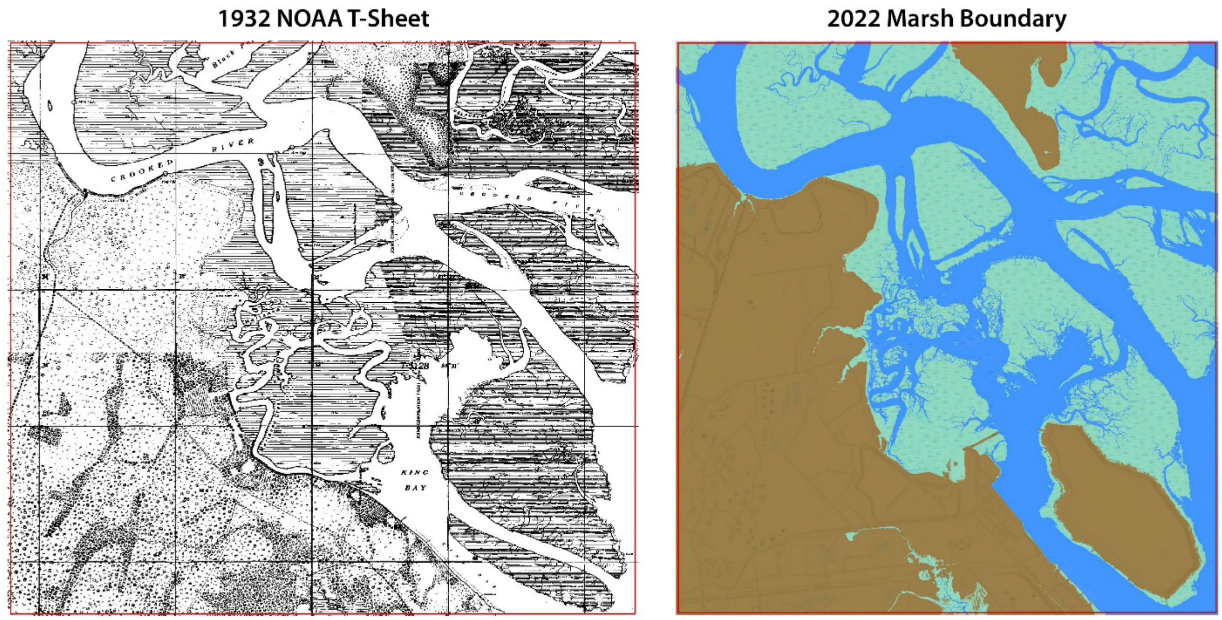
2014	National Wetlands Inventory (NWI)	USFWS[e]	U.S. standardized wetland map data	https://www.fws.gov/program/national-wetlands-inventory/data-download
2022	Georgia Statewide DEM[f]	USGS National Map	1 meter (m) DEM produced with data from 2018 and 2019	https://www.sciencebase.gov/catalog/item/629aecc4d34ec53d276f5437
2022	Topobathymetric Model of Coastal Georgia, 1851 to 2020	EROS[g]	1 m topographic and bathymetric raster	https://www.sciencebase.gov/catalog/item/627aa0d1d34e8d45aa6e4e72
2022-2023	Datums for 8679598, Kings Bay MSF Pier	NOAA	Tidal datums based on mean sea level and 2001 tidal epoch	https://tidesandcurrents.noaa.gov/datums.html?datum=MSL&units=0&epoch=0&id=8679598

a. *Year of dataset publication*
b. *Topographic sheet*
c. *National Oceanic and Atmospheric Administration*
d. *Georgia Wetlands Restoration Access Portal*
e. *U.S. Fish and Wildlife Service*
f. *Digital elevation model*
g. *Earth Resources Observation and Science Center*

Given the wide range of years and datasets used for this study, there were several points to consider when analyzing the selected datasets. The National Oceanic and Atmospheric Administration (NOAA) topographic sheets (T-sheets) are historical shoreline surveys, and the 1932 version was selected as the historical endpoint data source for this study. However, there were no standard methods of delineating shorelines when the 1932 T-sheet was created. Through the 1930s, the T-sheets documented shorelines based on the interpreted high-water line (HWL), with standard methods for shoreline delineation adopted by NOAA after the 1930s.[30] Additionally, the Georgia Wetland Restoration Access Portal (G-WRAP) Historic Shorelines dataset contained methodology metadata for other years of its publication, but not specifically for the 1972 dataset used as the midpoint in this study. The 2022 Earth Resources Observations and Science Center (EROS) topobathymetric model was compiled using NOAA's 2010 light detection and ranging (LiDAR) digital elevation data for coastal Georgia and NOAA's Continuously Updated Digital Elevation Model (CUDEM), which contains data collected between 1851 and 2020.

The project team delineated the present-day marsh boundary using the 2022 Georgia Statewide DEM and tidal data from the Kings Bay MSF Pier tide station to calculate the current mean high water (MHW) line. The data transformation methods and processes for the delineation of the present-day marsh boundary is described under Software and Data Processing.

Figure 5: 1932 T-Sheet and 2022 Marsh Boundary Comparison



Because this analysis spans a relatively long time frame and there are several data collection methods and publishers, each dataset's delineation criteria and type of delineation varies, as identified in Table 2. The NOAA and G-WRAP datasets show shorelines, which generally indicates a boundary between land and water, although the exact line of delineation along a shoreline can vary. There is no standardized definition or methodology for shoreline delineation,[30] so the process used to develop each dataset is likely to differ. The NWI data shows approximate wetland boundaries, delineated in accordance with the Federal Geographic Data Committee Standard.[28] Wetlands are mapped as an ecological community, whereas shorelines typically represent a boundary, resulting in differences between the types and intended uses of these datasets. While unavoidable, the differences between the selected datasets may result in apparent marsh change in the analyses, even if the apparent change is merely the result of mapping differences.

Table 2: Boundary Definitions for Selected Datasets

Year	Dataset	Boundary	Definition
1932	NOAA T-sheet	Shoreline	Shoreline delineated using interpreted HWL
1972	G-WRAP Historic Shorelines	Shoreline	Shoreline based on historical shoreline change as analyzed using AMBUR[h]
2002	NOAA T-sheet	Shoreline	Shoreline delineated using MHW line based on tide-coordinated aerial imagery[30]
2014	USFWS NWI Wetlands Map	Wetland	Approximate wetland delineation that analyzes the spectral signatures of high-altitude tide-coordinated aerial imagery to identify water bodies, vegetation, and soil characteristics indicative of wetlands[28]
2022	Georgia Statewide DEM	Shoreline	Shoreline delineated using bathtub model and calculated MHW line

h. *Analyzing Moving Boundaries Using R project*

In addition to the selected data, several other datasets were considered but ultimately dismissed, as described ahead. Some potential datasets were derived from one another. For example, data from the Continually Updated Shoreline Project (CUSP) was derived from the 2002 NOAA T-sheet, but more recent data is available and thus preferred. The Coastal Change Analysis Program (C-CAP) Regional Land Cover Dataset has a 30-meter resolution while the selected EROS topobathymetric model has a 1-meter resolution. Because the 30-meter resolution is much less detailed, the C-CAP data was not selected for further analysis. Other datasets, such as the 1978 National Shoreline Survey and the 1979 NOAA T-sheet, were explored as potential midpoint options but were excluded because the extents of the datasets did not cover the full study area for the Historical Marsh Analysis.

Parcel information was retrieved from the Camden County Board of Tax Assessors website using the online tax parcel map. Ownership information for the parcels identified in this analysis was retrieved from the website in March 2024. Given the dynamic nature of tidal shorelines, there are several key points to consider regarding property ownership and boundaries. NOAA's guidance identifies the State of Georgia's ownership between the MHW and mean lower low water (MLLW) lines in navigable waterways.[31] Navigable tidewater is defined by the Official Code of Georgia as tidal waterways that, at mean low tide, support navigation and transportation of boats loaded with freight in the regular course of trade. Timber rafting and maneuvering of small boats are not considered "navigation" in this instance. NOAA's delineation of ownership is consistent with section 44-8-7 of the Official Code of Georgia, which states that Georgia holds the land in the foreshore.[32] Georgia's 1981 Protection of Tidewaters Act declares Georgia as "the owner of the beds of all tidewaters within the jurisdiction".[33] Additionally, although the state owns the land within the foreshore of navigable waterways, USACE regulates projects and activities (including dredging and dredged material disposal) occurring within navigable waterways under the Rivers and Harbors Act of 1899 and the Clean Water Act.[34]

According to the US Department of Transportation, the channel between the NSB Kings Bay installation and the Crab Island DMMA is considered a navigable waterway. The Atlantic Intracoastal

Waterway is also classified as a navigable waterway and is immediately adjacent to the eastern side of the study area. The other waterways within the area are nonnavigable.[35] 'Navigable waterways' and 'waters of the United States' are terms used to determine USACE regulatory oversight under the Clean Water Act, as administered by the US Environmental Protection Agency (EPA). Recent changes to the definition of 'waters of the United States' have resulted in litigation that impacts the way the regulations are applied. Currently, Georgia follows the pre-2015 regulatory regime interpretation of 'waters of the United States', but conditions may change as the litigation continues.[36] Although these definitions do not directly affect the results of the Historical Marsh Analysis, they may influence the identification of potential BUDM sites and regulatory requirements in the future phases of this project and are important to consider, particularly given the changing conditions.

Software and Data Processing

The Historical Marsh Analysis was performed in ArcGIS Pro 3.2.1 using the datasets listed in Table 1. The input dataset shapefiles (.shp), which include the NOAA T-Sheets, G-WRAP Historic Shorelines, and the NWI wetlands map, were provided in North American Datum (NAD) 1983 or NAD 1989 (2011) geographic coordinate systems. Because the selected datasets used consistent coordinate systems, the built-in, on-the-fly data transformation function in ArcGIS Pro was used during data processing. The units for the area and volume calculations are provided in acres and CY respectively. Unit conversions were built into the data processing functions associated with calculating the area and volume of marsh loss.

The 1932 NOAA T-sheet and the 1972 G-WRAP Historic Shorelines datasets required additional data processing actions to be used in this analysis. The 1932 T-sheet data contained a scanned survey and a digitized shoreline edge, but a boundary between upland and marshland was not digitized. The project team used the scanned survey in this dataset to digitize the inland boundary of the marshland.

The original 1972 G-WRAP Historic Shorelines dataset contained a series of discontinuous line segments. However, the analysis requires closed polygons in order to calculate the area of marsh loss or gain. Straight-line extensions were made from the endpoints of the line segments to form closed shapes using an AI extension. The original 1972 dataset was uploaded to the platform with a command to connect each endpoint to the next nearest endpoint (while avoiding self-connections and limiting the search radius) and to export a shapefile once complete. The project team then manually reviewed and adjusted the closed shapes to correct misconnections. The closed lines were converted to polygons using ArcGIS Pro 3.2.1. Although the straight-line extensions do not follow the exact shoreline boundary, they comprise only a small portion of the overall boundary. Creating closed polygons enables dataset to be analyzed as a midpoint to validate the general trends of marsh loss that are revealed during the other timeframes in this study.

The delineation of present-day marsh boundary also required several data transformations and calculations. To be able to accurately incorporate tidal information into the 2022 Georgia Statewide DEM, the elevations of the DEM required conversion into the tidal data's vertical datum. Using the NOAA VDatum software tool, the project team downloaded the *Florida-Georgia East Bays 31* datum transformation grid file (.gtx) and created a point grid using the adjusted elevations from the transformation grid file. Because the extents of transformation file did not cover the entire study area, the ArcGIS Pro IDW Interpolation Tool generated additional points from the transformation grid to fill the entire study area. Using the point grid, the 2022 DEM was then transformed from North American Vertical Datum of 1988 (NAVD88) into the Florida-Georgia East Bays 31 tidal datum and from meters into feet to be congruent with the tidal data for the area.

The current MHW elevation is needed to determine the boundary between water and land on the 2022 DEM. The project team calculated the MWH line, rather than using the current projected MHW elevation, because the projected MWH elevation is based on the 2001 epoch and tends to be lower than the actual measured values. Tidal epochs are 19-year periods used to determine tidal elevations, and the current epoch spans from 1983 to 2001.[37] Although the tidal epochs are typically updated every 20 to 25 years, the 2001 epoch has not yet been updated.

To account for increasing sea levels, the project team downloaded tidal data from NOAA for Station 8679598, Kings Bay MSF Pier, collected between December 2022 and April 2023, which was the best available data for the study period. Any values that were not a high water or predicted high water elevation value were then removed from the dataset. The change and standard deviation between the measured and projected MHW elevations were calculated, and a normal distribution of these results produced a bell curve. The high point of the bell curve, which represents the most common value for the difference between the projected and measured MHW elevations, was selected as the anticipated present day MHW elevation for the analysis of the DEM. Selecting the high point of the bell curve helps to minimize the influence of exceptionally high tides. Using this methodology, the anticipated present-day MHW elevation is 0.659 feet above the projected MWH line.

The bathtub model was reclassified in ArcGIS Pro using the 0.659-foot adjustment to determine the boundary between water and marsh. Current ESRI data was used to determine the inland boundary between marsh and land. The resulting marsh boundaries were then processed using the same methods as the other datasets to determine the area and volume of marsh loss for the applicable study periods.

4. Methodology

Analysis

The Historical Marsh Analysis began with a review, selection, and preparation of the preferred datasets that would cover the desired time range, encompass the study area, and provide sufficient detail for marsh and shoreline boundaries, as discussed in Section 3. The selected 2D datasets were used to determine the current and historical extents of marshland in the study area.

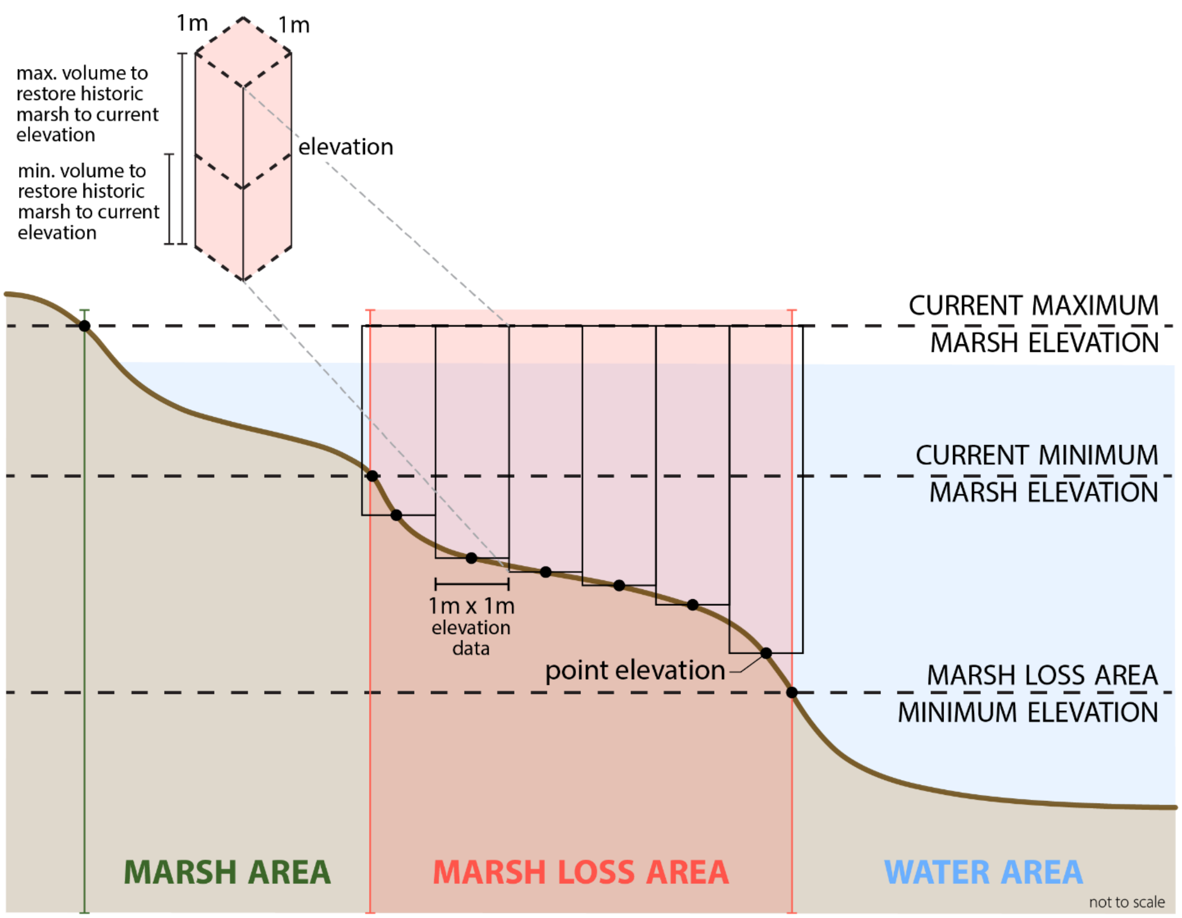
After determining historical and current marshland extents, a comparative analysis was performed to identify locations where the extents had changed. The ArcGIS Pro Union tool was used to compare the marsh area boundaries and identify and delineate locations where marsh had been lost, gained, or remained the same. The results provided polygons that show the acreage of marsh loss and gain within the study area.

Figure 6 illustrates the process used to calculate the volume of marsh loss, described in more detail below. The 2022 EROS topobathymetric model provided the elevation information used in this analysis, which was run using the Zonal Statistics as Table tool in ArcGIS Pro. The results of the analysis were then joined to the marsh loss area dataset to associate the volumes with each corresponding loss area.

To calculate the minimum volume of marsh loss in each loss area, the current elevation of the marsh loss area was subtracted from the minimum elevation of existing marsh to determine the vertical difference between these two values. The minimum elevation of existing marsh varies between analysis zones and study timeframes because it is based on the highest elevation of the loss areas within each zone. This information was derived from the 2022 EROS topobathymetric model. The minimum elevation of existing marsh in each analysis zone is provided in Appendix A.

Because the topobathymetric model provides elevation data in a 1 m x 1 m raster grid, the difference (in meters) between the current elevation of the marsh loss area and the minimum elevation of existing marsh was multiplied by 1 m^2 to calculate the volume difference. The volume of each grid square was counted if the grid square's centroid was within the boundary of the marsh loss area. The volumes for all of the grid squares within the loss area were then summed and converted to CY to get the total minimum volume of marsh loss for the area.

Figure 6: Volume Calculation Methodology



Similarly, the maximum marsh loss volume was determined by subtracting the current elevation of the marsh loss area from the maximum elevation of existing marsh. The maximum elevation of existing marsh was determined using the 2014 NWI data and the 2022 EROS topobathymetric model. The elevation used for the analysis was the maximum elevation within the NWI wetland boundary in each analysis zone. The maximum marsh elevation in each analysis zone is provided in Appendix A.

The same steps were then followed to convert the elevation difference into the maximum volume for the marsh loss area. The minimum marsh loss volume represents a conservative estimate of the volume of sediment required to support marsh in the loss areas, while the maximum marsh loss volume estimates the largest volume of sediment that could be present in these areas while still supporting marsh growth.

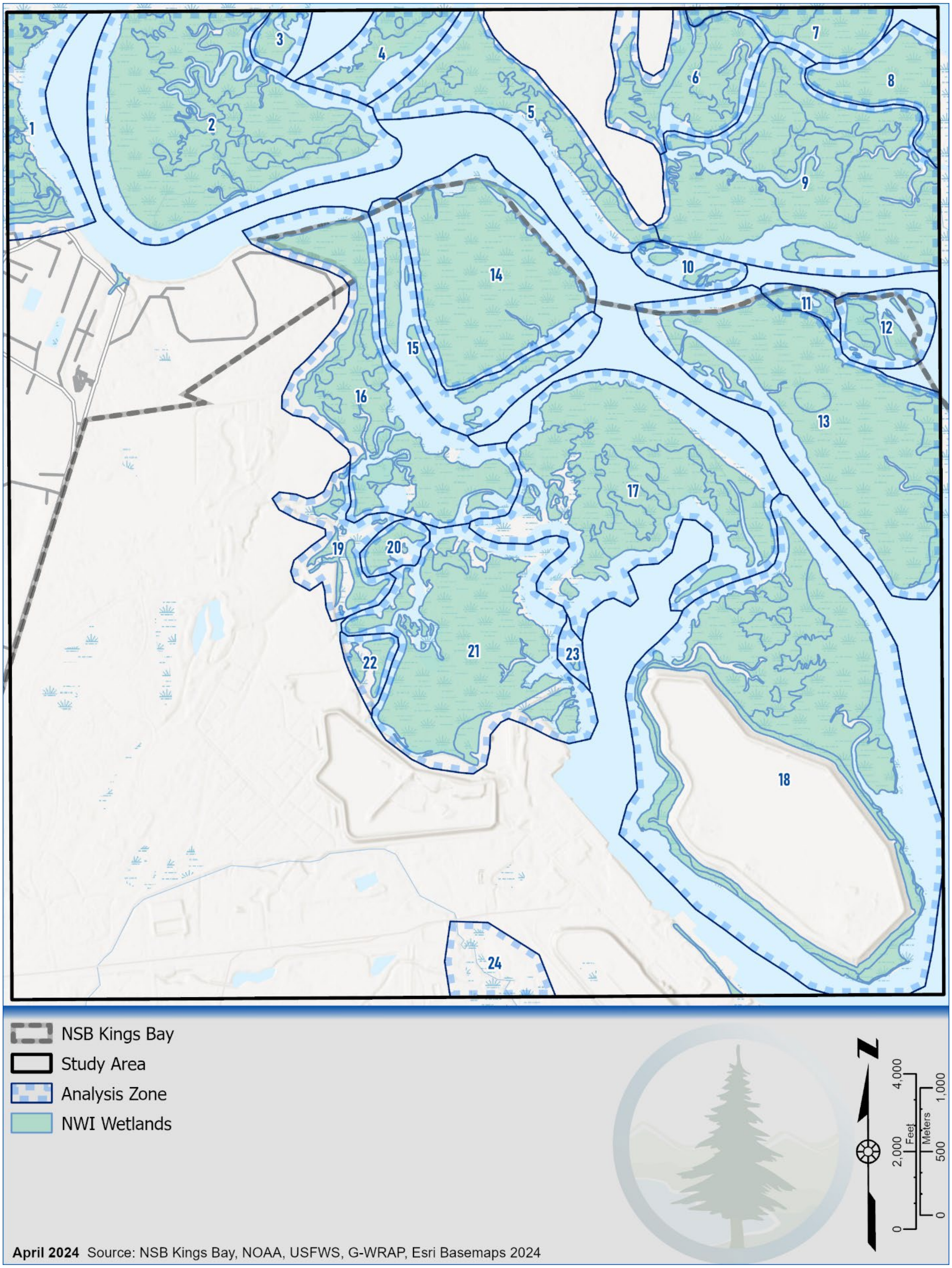
After identifying areas of marsh loss, the project team coordinated with Taylor Engineering's team to establish a uniform method of delineating Analysis Zones where marsh loss has been identified, to ensure consistency between the two teams' efforts. Although a gridded layout would enable comparisons of marsh loss across Analysis Zones that are all the same size, using this method does not address the way that marshland functions as an ecological system.

BUDM projects sometimes involve several different sediment placement methods in adjacent areas. While the Historical Marsh Analysis primarily identified loss areas along the edges of existing marshland, BUDM strategies such as TLP are likely to be applied across a larger marsh area. To capture this, the Analysis Zones were delineated manually by grouping the identified marsh loss areas within contiguous marshland as mapped by NWI. The 24 Analysis Zones are shown in Figure 7.

Delineating the Analysis Zones in this way accommodates the potential use of multiple BUDM strategies in a single zone and better reflects marshlands as ecological systems. Given the scale of some of the Analysis Zones, a phased approach would likely be necessary to implement several, separate projects within a single zone. The Analysis Zones cover 7,831 acres of marsh to the northeast of NSB Kings Bay.

During the analysis, areas of marsh gain were identified in the same way as loss areas. While the locations of marsh gain are not currently considered a priority in this study, these locations have been documented if needed for future reference. Marsh gain was not deducted from the total when calculating the area and volume of marsh loss.

Figure 7: Analysis Zones



Analysis Timeframes

Based on the available data and coordination with USACE, the primary study period (Timeframe A) for the Historical Marsh Analysis spans 1932 to 2022, using the 1932 NOAA T-sheet and the marsh boundary delineated using the 2022 Georgia Statewide DEM. The results from the analysis during Timeframe A will be used in future phases of this project.

Because the project team created the marsh boundary for the 2022 analysis, a second analysis (Timeframe B) was conducted using the 1932 NOAA T-Sheet and the 2014 NWI wetland map, given the rigorous and standardized delineation method used to create the NWI wetland maps.

Since NOAA T-sheets are available for both 1932 and 2002, a third analysis (Timeframe C) was conducted to determine if any notable differences resulted from using congruent datasets. Although the 2002 T-sheet is over 20 years old at the time of this study, comparing two like datasets improves consistency between the years being compared and can validate marsh loss trends observed in the analysis of Timeframe A. Timeframes A, B, and C cover the time period before NSB Kings Bay was developed, through development of the base in the 1950s, initiation of dredging operations after the base was developed, and up to roughly present day, as discussed in Section 1.

The midpoint between 1932 and 2022 is in the 1970s. Timeframe D, 1932 to 1972, is used to understand marsh change trends during the earlier portion of the primary study timeframe. Timeframe E assesses the trends of marsh change during the later portion of the primary timeframe, from 1972 to 2014. Timeframe F also covers the later portion of the primary timeframe, but it assesses the loss from 1972 to 2022. Finally, Timeframe G covers the most recent developments at NSB Kings Bay between 2014 and 2022. The seven analysis timeframes are summarized in Table 3.

Table 3: Study Timeframes

Study Timeframe	Years	Datasets	Notes
A	1932 2022	NOAA T-Sheet Marsh boundary from Georgia Statewide DEM	Primary analysis timeframe; includes the most complete dataset prior to the establishment of the base and the most up-to-date conditions
B	1932 2014	NOAA T-Sheet NWI Wetlands Map	Assesses marsh change using two published and authoritative datasets
C	1932 2002	NOAA T-Sheet NOAA T-Sheet	Compares two like datasets for consistent data collection and mapping methodology
D	1932 1972	NOAA T-Sheet G-WRAP Historic Shorelines	Midpoint: Assesses marsh change for the earlier portion of the primary analysis timeframe

E	1972 2014	G-WRAP Historic Shorelines NWI Wetlands Map	Midpoint: Assesses marsh change for the later portion of the primary analysis timeframe, using the published NWI wetland data
F	1972 2022	G-WRAP Historic Shorelines Marsh boundary from Georgia Statewide DEM	Midpoint: Assesses marsh change for the later portion of the primary analysis timeframe, using the marsh boundary created by the project team
G	2014 2022	NWI Wetlands Map Marsh boundary from Georgia Statewide DEM	Assesses the marsh change following the most recent developments at NSB Kings Bay

Although Timeframe A is the primary study period for the Historical Marsh Analysis, the evaluation of the other periods helps to identify patterns, such as consistent loss areas, or anomalies in the datasets resulting from different mapping standards and methodologies across years and data publishers.

While the 2D marsh data differed between the study timeframes, the 3D data from the 2022 EROS topobathymetric model was used for volume calculations in all timeframes, because detailed elevation data is limited in the study area. The area and volume calculation methodologies described in the section above were applied to all seven study timeframes for the Historical Marsh Analysis.

Prioritization

After the marsh loss areas and volumes were calculated, the Analysis Zones were prioritized for future analysis using two key factors. Prioritization was based on the scale of marsh loss and the ownership status of the parcels on which the Analysis Zones were located. Compatible land use was also considered and is discussed more in Section 5.

The maximum marsh loss volume calculated during Timeframe A was used to identify high-priority loss areas. Larger volumes of loss suggest that these areas are historically vulnerable and may continue to lose marsh in the future. The five Analysis Zones with the greatest volume loss are each estimated to have lost over 900,000 CY of marsh since 1932. It must be noted that the volume of marsh loss does not necessarily represent the volume of sediment that could be placed in the loss areas as part of BUDM projects. Most of the marsh loss identified in this analysis is located along shorelines, but shoreline restoration projects using dredged sediment pose some implementation challenges. The volume of dredged material that could be used for TLP or other BUDM strategies outside of the marsh loss areas has not been considered as part of the prioritization effort under this task, but it will be assessed in more depth in future phases of this project.

Ownership status is a consideration given the high cost associated with land acquisition and the additional time required to establish easements or other agreements to perform work on land not held by the Federal government. Most parcels within the study area are owned by the State of Georgia or by the US Navy, which holds the parcels occupied by NSB Kings Bay. While both of these ownership types are advantageous, parcels held by the US Navy have been prioritized because projects at these sites would require fewer land management agreements with external agencies, thus simplifying the planning and implementation process.

Most of the land within the study area is undeveloped marshland, which is compatible with BUDM strategies. However, some areas at NSB Kings Bay have been developed for mission-sustaining activities and are not suitable for BUDM projects. See Section 5 for further discussion on the land use compatibility considerations.

Although several high-priority marsh loss areas have been identified, the prioritization exercise was not used to reduce the number Analysis Zones. It is anticipated that the site assessments and desktop analyses in the next phases of this project will provide valuable information that can be used to refine potential project areas within the Analysis Zones. No areas of identified marsh loss have been excluded from further consideration at this point in the assessment, aside from the areas with incompatible land use, discussed in Section 5 below.

5. Land Use Compatibility Analysis

While performing the Historical Marsh Analysis, two areas of marsh loss were identified on the base, but further investigation and coordination with USACE revealed that these areas are incompatible with potential BUDM due to their current land use. The Historical Marsh Analysis process was used to identify and quantify marsh loss over time, but the analysis process does not differentiate between loss due to erosion, SLR, or development at NSB Kings Bay. Although areas lost due to erosion and SLR may present opportunities for BUDM, historical marsh areas that have since been developed by the Navy are not suitable despite being revealed in the preliminary analysis. Discussions with USACE clarified that two marsh loss areas identified on the base are the result of constructing a land-water interface and developing the Crab Island DMMA, as shown in Figure 8. Although these areas were considered in the preliminary analysis, they were excluded from further evaluation and are not reflected in the final results. Given the land use and important functions of infrastructure at NSB Kings Bay, developed areas on the base are incompatible with marsh restoration and BUDM projects, regardless of whether or not they were highlighted by the Historical Marsh Analysis.

Following the construction of the land-water interface, maintenance dredging of the navigation channel increased in both frequency and volume, and visible marsh loss occurred in nearby areas. While the land-water interface itself has been removed from the analysis, the surrounding areas that are impacted by altered flows and velocities remain within the Historical Marsh Analysis results. Please see Section 6, Timeframe G, for additional discussion about the effects of the land-water interface.

Although marsh loss was identified at the land-water interface and the Crab Island DMMA during the preliminary analysis, marsh loss within in the footprints of these developments at the base were removed from further analysis because they are not suitable for placement of dredged material as part of a beneficial use strategy. The assessment has been adjusted to exclude these two areas. The removed areas only account for approximately 600 acres of land, or less than 5 percent of the study area. By removing these portions of the NSB Kings Bay installation from the study, the Historical Marsh Analysis provides more targeted insight into potential BUDM areas to be studied during on-site assessments in the next set of analyses.

Figure 8: Marsh Loss Areas Removed from Further Analysis

6. Results

The results of Timeframe A (1932 to 2022) are the primary results for the Historical Marsh Analysis. Additional timeframes have been analyzed to better understand marsh change over time and the influences of the selected datasets. Areas of marsh gain were not deducted from these totals, as described in Section 4. The marsh loss identified at the land-water interface and Crab Island DMMA in the preliminary analysis has been removed and is not included in any of the results below, as discussed in Section 5. The midpoint analyses provide insight into areas consistently experiencing loss, or where there may be inconsistencies in the datasets that could impact the results. The results across all seven timeframes are summarized in Table 4 and discussed in more detail in the following sections. In each of the following sections, the top five areas of marsh loss by the maximum volume lost have been provided for consistency and comparison.

Table 4: Total Historical Marsh Loss Results, Timeframes A-G

Timeframe	Years	Marsh Loss (ac)	Minimum Marsh Loss (CY)	Maximum Marsh Loss (CY)
A	1932 - 2022	772	11,086,508	18,835,732
B	1932 - 2014	764	10,287,463	15,184,116
C	1932 - 2002	820	9,862,775	17,605,350
D*	1932 - 1972	318	4,410,738	6,715,934
E*	1972 - 2014	729	9,531,503	14,553,125
F*	1972 - 2022	740	9,771,672	17,044,370
G*	2014 – 2022	245	3,474,065	4,471,972

**Midpoint/partial timeframe analysis*

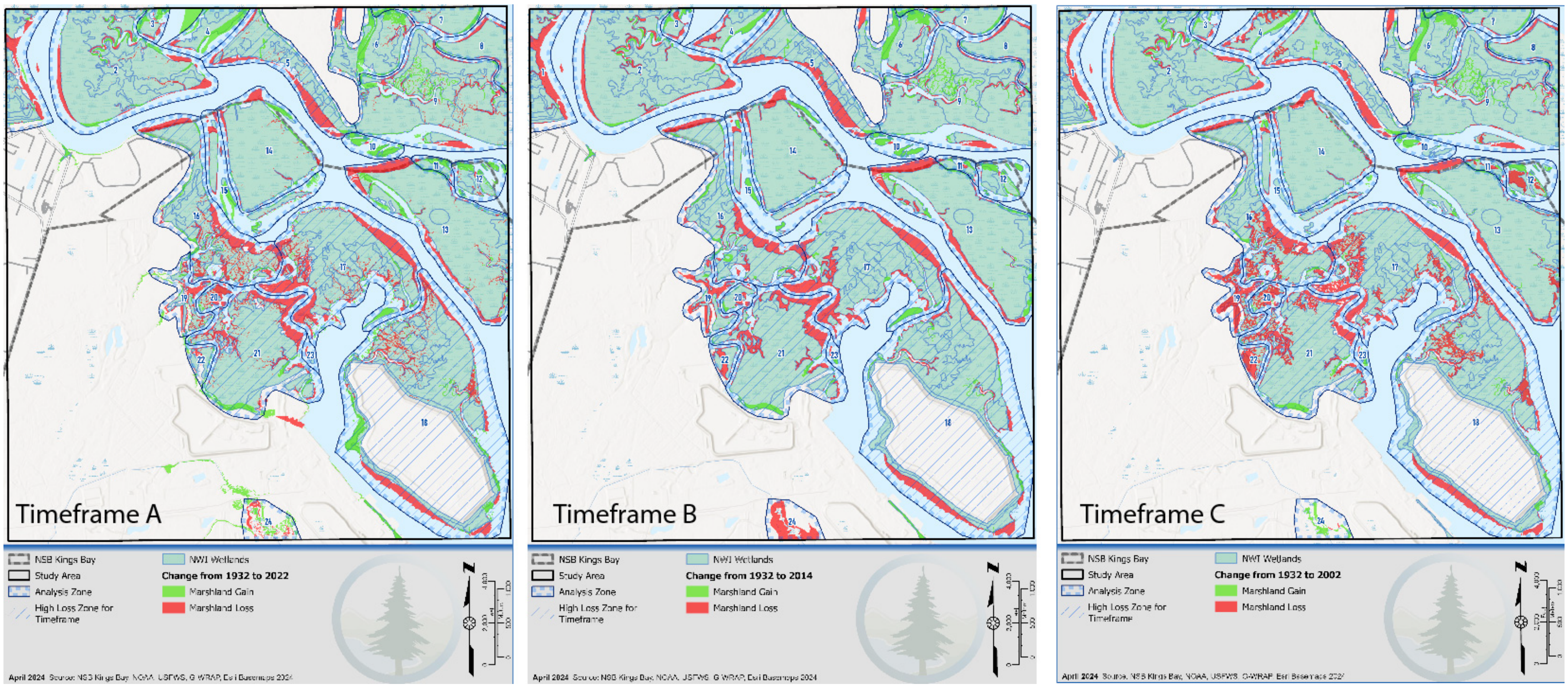
Although Timeframe A is the primary focus of the Historical Marsh Analysis, the additional timeframes provide useful comparisons between different time periods and datasets. Because the 2022 marsh boundary in Timeframe A was developed by the project team, Timeframe B was assessed to compare two published and authoritative datasets. The fact that the results of Timeframe A were similar but slightly higher than Timeframe B helps to validate the results of Timeframe A.

While Timeframe B compared two datasets produced by different agencies, Timeframe C was assessed to provide a comparison for a comparable period of time while using datasets produced by the same agency through similar data collection and mapping methods. The marsh loss area in Timeframe C is slightly higher than Timeframes A and B due to the high level of detail achieved when comparing the two like datasets. However, the minimum and maximum marsh loss quantities in Timeframe C are relatively similar to the results from Timeframes A and B. Although Timeframe A is the primary timeframe, the results of Timeframes B and C strengthen the findings because similar scales of marsh loss are documented across multiple datasets and sources.

Figure 9 shows marsh loss over each of the full timeframes. The maps emphasize the vulnerability of these zones and validate the results of Timeframe A. Marsh loss is shown consistently across timeframes in several Analysis Zones, including Zones 5, 13, 16, 17, and 19 through 22. The loss identified in Zone 24 is inconsistent across timeframes, with significant marsh loss shown in Timeframes B. This appears to be caused by a lack of data for Zone 24 in the 2014 NWI dataset, and Timeframe B was the only full timeframe that used this dataset. The results for Zone 24 during

Timeframe C are likely more representative of the conditions in this area because both the 1932 and 2002 NOAA T-Sheets provide data for this area. The results highlight the influence of the selected datasets and underscore the importance of and need for consistent data and mapping for this type of historical analysis. While there are differences between each timeframe's results, the relative consistency of the large marsh loss areas supports the results of Timeframe A because there is documented loss across several decades and datasets.

Figure 9: Marsh Loss Comparison Across Full Analysis Timeframes



Midpoint Analysis Discussion

Timeframes D, E, and F, and G break down the full span of this study into smaller portions. Timeframe D assesses the earlier portion of the study period and found the marsh loss area to be about 41 percent of the acreage lost during Timeframe A. Similarly, the minimum volume loss during Timeframe D was 40 percent of the loss during Timeframe A, and the maximum volume loss was 36 percent of Timeframe A. During Timeframe D, the land at NSB Kings Bay had been acquired and developed by the Army with associated dredging operations, but the site had not yet been transferred to the Navy. Given the onsite and climatic conditions during Timeframe D, these results align with the expected outcomes.

Timeframe E covers the second half of the study period, using two published datasets. The marsh loss area was over 90 percent of the acreage calculated during Timeframe A. The minimum volume lost during Timeframe E was 86 percent of Timeframe A, and the maximum volume lost was 77 percent of Timeframe A. While the results of Timeframe D appear to be representative of the conditions during this period, the losses calculated for Timeframe E are much higher than anticipated. During Timeframe E, Kings Bay became a Navy base and was expanded to support their operations, and dredging continued. Notably, a study of saltmarsh cordgrass biomass in Georgia marshes found significant decline between 1984 and 2011, driven by climate change.[38] During this period, continued development, climate change, and SLR impacts put further strain on waterways and potentially lead to higher losses than those in Timeframe D.

Similar to Timeframe E, Timeframe F assesses the marsh loss during the second half of the study period, but the 2022 marsh boundary delineated by the project team was used instead of the 2014 NWI wetland map used in Timeframe E. The area of marsh loss during Timeframe F was 96 percent of the total area of loss in Timeframe A, and the minimum and maximum volumes of loss were 88 and 91 percent of Timeframe A respectively. The area loss and minimum volume loss in Timeframe F are similar to Timeframe E, while the maximum volume loss is higher in Timeframe F.

In addition to the marsh impacts driven by climate and activities at the base, the 1972 G-WRAP Historic Shorelines dataset, which was used in Timeframes D, E, and F, has several noted gaps and deficiencies. Discontinuous line segments had to be closed and some of the linework in the dataset did not clearly align with apparent waterway boundaries. This dataset also has a low level of detail in the smaller upstream portions of the waterways. Where the 1972 survey did not document a waterway that was delineated in other datasets, the analysis highlighted an area of marsh loss, even if a loss had not truly occurred there. In addition to the other influences noted above, the lack of detail in the dataset likely contributed to the higher-than-anticipated losses that were particularly pronounced in Timeframe E, given the comparison between the limited detail of the G-WRAP Historic Shorelines dataset with the more detailed 2014 NWI wetland map. See Section 3 for a discussion of the differences between the methodology and intent of these datasets.

Since Timeframes D, E, and F are midpoint analyses, as a result, it is expected that the results of these timeframes could be added together to calculate the total loss across the study period. For example, the combined losses in Timeframe D (1932 to 1972) and Timeframe F (1972 to 2022) should equal the loss in Timeframe A (1932 to 2022). However, when added together, the loss acreage in Timeframes D and F exceeds Timeframe A by nearly 300 acres, and the combined minimum and maximum volume losses from Timeframes D and F both exceed Timeframe A by over 3 million CY.

The discrepancies between the totals of the midpoint timeframes are caused by overlapping areas of gain and loss that cancel each other out. This overlap means that the gains in one timeframe are directly negated by the losses in another timeframe for the same areas.

Due to the low level of detail in the 1972 G-WRAP dataset, some areas appeared as marsh loss during Timeframe D and then appeared as gain during Timeframes E and F. In other areas, gain was shown during Timeframe D and then became loss during Timeframes E and F. Because areas of marsh gain are not deducted from the results of each timeframe, the changes from gain to loss or loss to gain essentially become double-counted. Without adjusting the calculations, adding two midpoint analyses result in loss totals that are much higher than the overall results of Timeframe A. When the calculations are adjusted for the areas that changed from gain to loss or loss to gain, the results of adding the midpoints are within one acre of the results of Timeframe A. The acreage of areas that converted from loss or gain during the midpoint timeframes is outlined in Table 5. The conversion to loss and gain in each Analysis Zone is provided in Appendix B.

Although the calculations when adding multiple timeframes can be adjusted to verify the results compared to Timeframe A, the results for the individual midpoint analyses cannot be modified to account for these differences. The individual timeframes cannot be adjusted because this would require removing the areas of gain or loss that are being double counted across timeframes, which would misrepresent the gain or loss areas shown during the individual midpoints. Despite this unique condition in the analyses that use the 1972 dataset, the individual midpoint timeframes show that several locations within the study area have historically been vulnerable and support the results of Timeframe A.

Table 5: Conversion to Loss and Gain During Midpoint Analyses

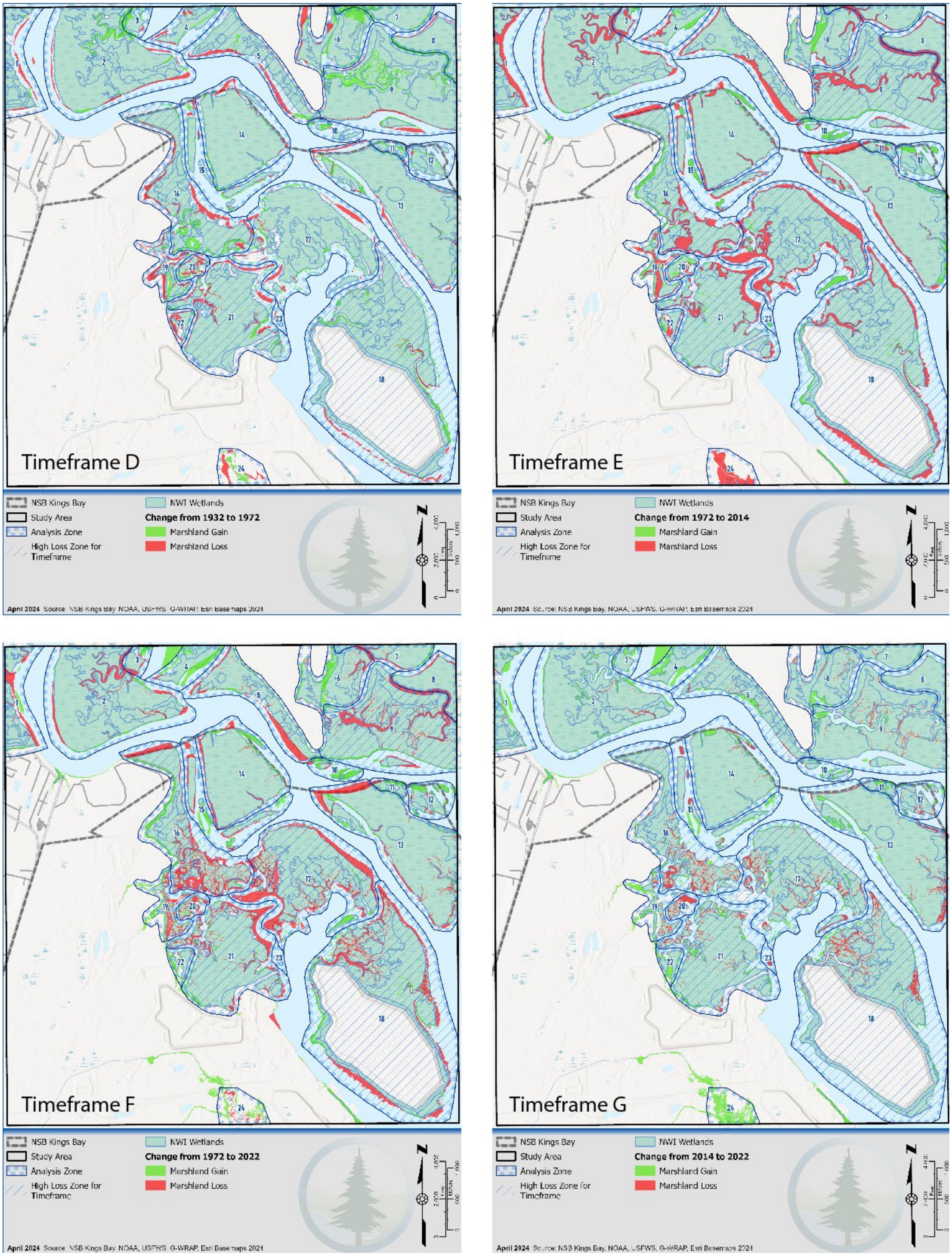
Years	Timeframes	Gain to Loss (ac)	Loss to Gain (ac)	Total (ac)
1932 to 1972 1972 to 2014	D E	211.09	70.76	281.86
1932 to 1972 1972 to 2022	D F	185.45	97.01	282.46

Note: When adding midpoint analysis results to compare them to overall timeframes, the above values should be doubled to account for overlap of these areas on each side of the analysis.

Timeframe G is a partial timeframe that covers 2014 through 2022. The 2014 NWI wetland map is the most recently published dataset for the study area, and the 2022 marsh boundary was prepared by the project team. In 2014, the land-water interface was constructed at NSB Kings Bay, and a notable increase in dredging occurred following its completion. Timeframe G assesses marsh changes following this development at the base and represents the conditions closest to the present day. The acreage of marsh loss during Timeframe G is 32 percent of that during Timeframe A. The lower volume of marsh loss is 31 percent, and the higher volume of marsh loss is 24 percent of that during Timeframe A. While Timeframe G covers about 9 percent of the primary study period, the acreage and volume of marsh loss during Timeframe G is greater than 9 percent of the overall losses during Timeframe A. While part of this may result from the finely detailed 2022 data, the significant increase in maintenance dredging at NSB Kings Bay since 2014 illustrates that sediment erosion is accelerating compared to pre-2014 conditions.

Figure 10 shows a comparison of the marsh loss areas across the four midpoint timeframes. The high level of detail in the 2022 DEM marsh boundaries are apparent in Timeframes F and G, with marsh loss appearing along small stream segments within the larger marsh areas. As described previously, the changes in Zone 24 are likely attributed to limited data availability, because Zone 24 is located within NSB Kings Bay. The comparisons below demonstrate the distribution of marsh loss and gain across the midpoint analyses. Similar to the overall results in Timeframes A, B, and C, the maps for Timeframes D through G continue to highlight losses that are concentrated near NSB Kings Bay in Zones 16 through 23, and along Crooked River in Zones 5, 13, and 14.

Figure 10: Marsh Loss Comparison across Midpoint Analysis Timeframes



Timeframe A: 1932-2022

Timeframe A is the primary study period for the Historical Marsh Analysis, spanning from before the development of the Kings Bay area as an Army base in the 1950s through nearly present day, including the construction of the land-water interface and the subsequent increase in dredging operations. Timeframe A compares the 1932 NOAA T-sheet and the marsh boundary created by the project team using the 2022 Georgia Statewide DEM and the adjusted MWH elevation. See Section 3 for more information about the creation of this dataset.

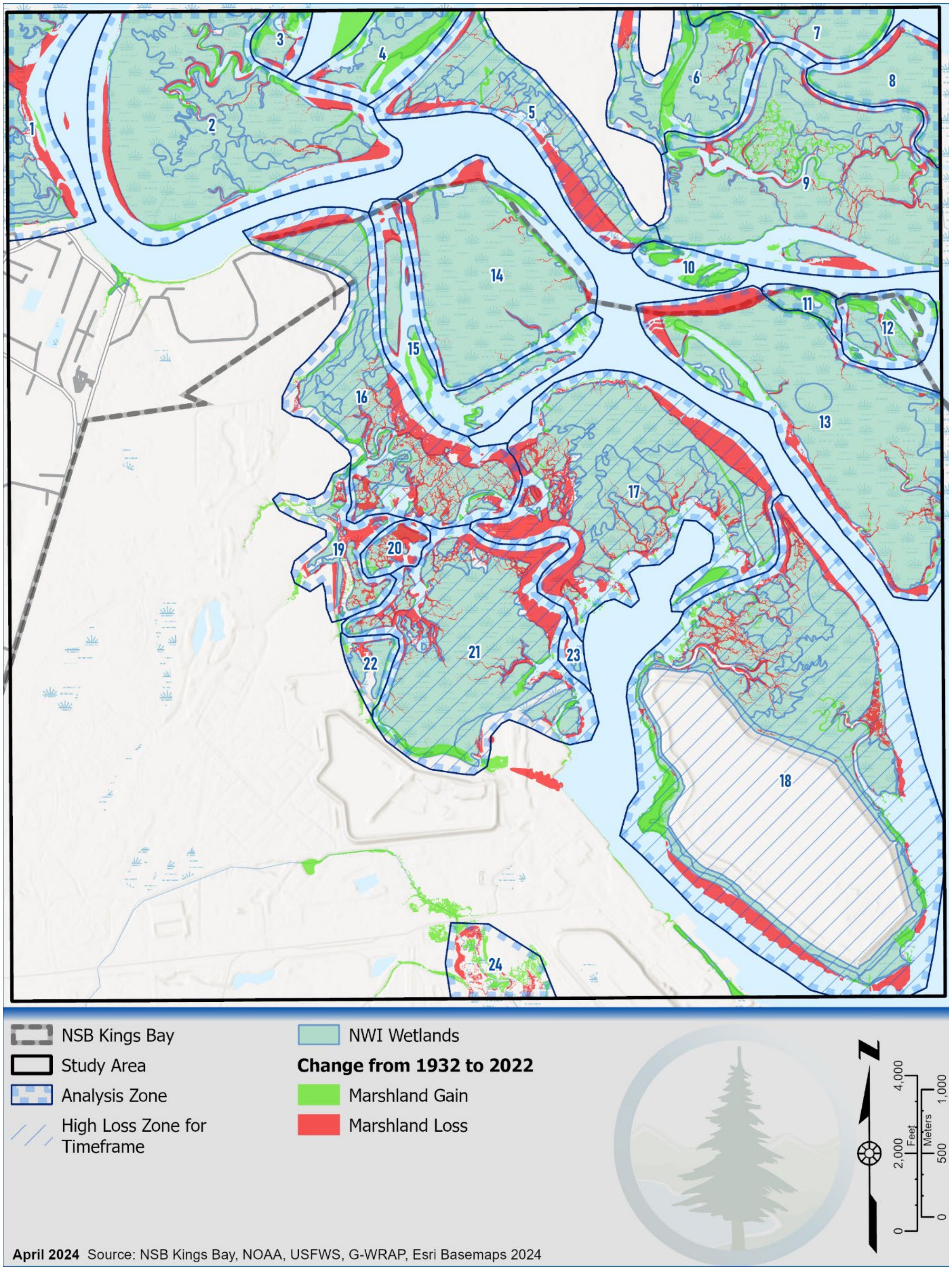
A total of 772 acres of marsh were lost during Timeframe A. The lower estimate of marsh loss is 11,086,508 CY and the upper estimate is 18,835,732 CY. Table 4 summarizes these values. Figure 11 illustrates the marsh loss areas during Timeframe A.

During Timeframe A, the five Analysis Zones with the greatest maximum volume loss during are Zones 5, 16, 17, 18, and 21. Together, these areas lost 467 acres and between 7,110,191 CY and 14,318,506 CY of marsh, as shown in Table 6. Zones 16, 17, 18, and 21 are adjacent to NSB Kings Bay, indicating that marshes near the base could be particularly vulnerable.

Table 6: Top Five Marsh Loss Zones, Timeframe A

Analysis Zone	Marsh Loss Area (ac)	Minimum Marsh Loss Volume (CY)	Maximum Marsh Loss Volume (CY)
5	50	950,554	1,261,239
16	94	1,442,383	3,275,552
17	134	1,438,571	1,577,762
18	112	1,945,031	4,362,641
21	77	1,333,652	3,841,313
Total	**467**	**7,110,191**	**14,318,506**

Figure 11: Marsh Loss during Timeframe A



Timeframe B: 1932 to 2014

Timeframe B, from 1932 to 2014, covers most of the study period and uses two published datasets. The data for these years includes the 1932 NOAA T-sheet and the 2014 NWI wetland map. Although the T-sheet and the wetland map are not congruent datasets, the wetland map is the most current published data for the study area, and the T-sheet is the most complete and recent dataset available prior to the development of NSB Kings Bay in the 1950s. Together, these datasets provide a comprehensive view of the marsh loss from before the area's development through nearly present day, using data with documented and standardized production methodologies.

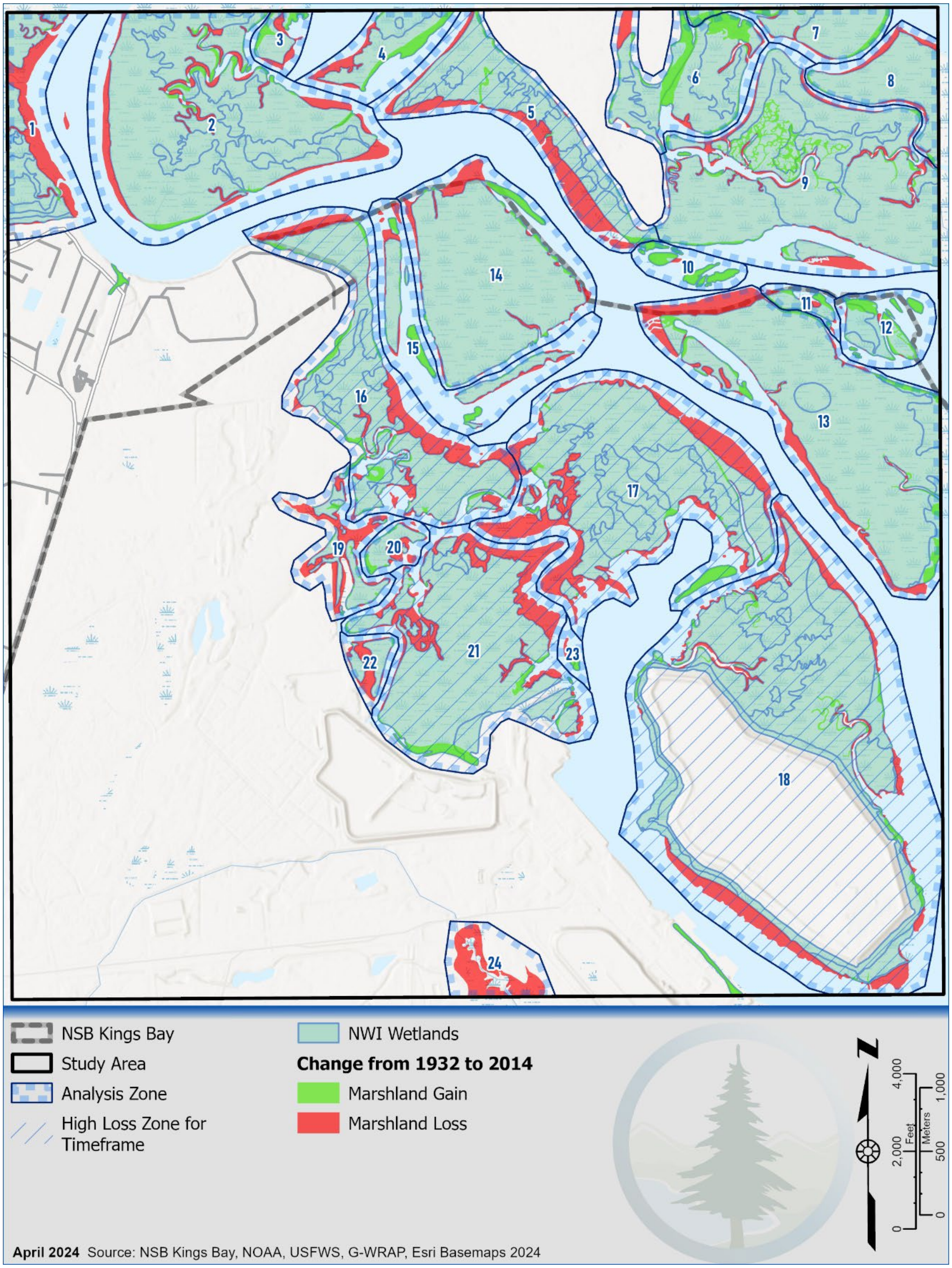
In the 24 Analysis Zones, the Historical Marsh Analysis identified a total of 764 acres of marsh loss during Timeframe B. The low estimate of marsh loss volume is 10,287,463 CY, while the high estimate is 15,184,116 CY, as summarized in Table 4. Figure 12 shows the locations of the marsh loss areas in the Analysis Zones for this timeframe. The total marsh loss area in Timeframe B is 99 percent of Timeframe A. However, the minimum marsh loss volume is 92 percent and the maximum marsh loss volume is 81 percent of Timeframe A. Given that the span of Timeframe B is about 91 percent of the length of Timeframe A, the overall results of Timeframe B are proportionate and validate the findings of Timeframe A.

The five Analysis Zones with the largest loss by maximum volume during Timeframe B are Zones 5, 16, 17, 18, and 21. These five loss areas encompass 400 acres, a minimum loss volume of 5,948,248 CY, and a maximum loss volume of 9,909,980 CY. The areas and volumes of these five Analysis Zones are summarized in Table 7. The top five Analysis Zones by maximum volume within Timeframe B are the same as Timeframe A, further supporting the results of Timeframe A.

Table 7: Top Five Marsh Loss Zones, Timeframe B

Analysis Zone	Marsh Loss Area (ac)	Minimum Marsh Loss Volume (CY)	Maximum Marsh Loss Volume (CY)
5	58	1,024,217	1,385,335
16	68	1,044,948	2,357,747
17	116	1,297,954	1,418,437
18	86	1,824,413	3,474,542
21	73	756,716	1,273,920
Total	**400**	**5,948,248**	**9,909,980**

Figure 12: Marsh Loss during Timeframe B



Timeframe C: 1932 to 2002

The analysis of marsh loss during Timeframe C, 1932 to 2002, uses NOAA T-sheets from these respective years. The comparison of two congruent datasets provides consistency between the data collection and mapping production methods, as evidenced in the much finer detail in the marsh loss areas shown in Figure 13. However, given that the 2002 T-sheet is over 20 years old at the time of this study, preference was given to the 2022 Georgia Statewide DEM (Timeframe A) for present-day conditions and the 2014 NWI wetland map (Timeframe B) as the most recently published dataset.

The total marsh loss area during Timeframe C is 820 acres. The low estimate of marsh loss volume is 9,862,775 CY and the high estimate is 17,605,350 CY, as shown in Table 4. Compared to Timeframe A, this analysis found a higher acreage of marsh loss, but a lower minimum and maximum volume loss. Because Timeframe C compares two like datasets, there is a much finer level of detail in the small upstream areas, likely resulting in the higher area of loss shown in Timeframe C. However, given that Timeframe C is 20 years shorter than Timeframe A, the lower levels of volume loss in Timeframe C align with the expected conditions.

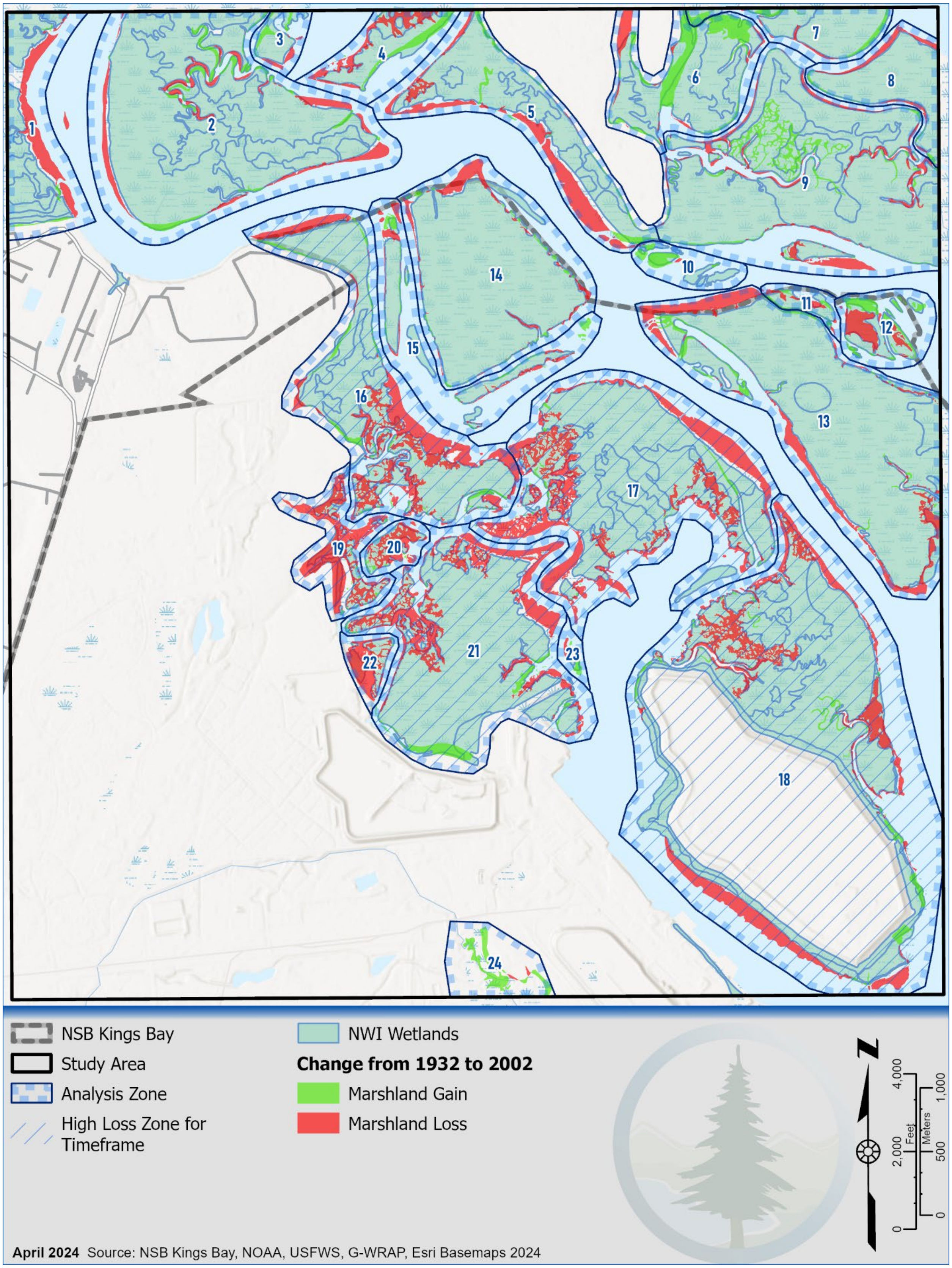
The top five marsh loss zones during Timeframe C include Zones 16, 17, 18, 19, and 21, as summarized in Table 8. These five zones lost a total of 486 acres of marsh. The minimum volume of marsh loss from these five zones is 5,906,160 CY and the maximum marsh loss volume is 12,229,427 CY.

Four of the five top Analysis Zones by maximum volume during Timeframe C are the same as those from Timeframes A and B, but Zone 5 was replaced by Zone 19. The results for Zone 5 did not change significantly between Timeframe A and Timeframe C. However, Zone 19 showed a much higher area and volume of loss during Timeframe C than during Timeframe A. The acreage and minimum and maximum volume of marsh lost in Zone 19 during Timeframe C were double the loss identified during Timeframe A. The level of detail in the NOAA T-sheets in the Zone 19 marshland captured loss during Timeframe C that was not as clearly defined in Timeframe A. Similarly, the Timeframe C analysis found a slightly higher total area loss than Timeframe A, which is likely attributed to the finer level of detail in the survey of the marsh areas shown in the T-sheets.

Table 8: Top Five Marsh Loss Zones, Timeframe C

Analysis Zone	Marsh Loss (ac)	Minimum Marsh Loss (CY)	Maximum Marsh Loss (CY)
16	95	1,428,204	3,271,168
17	136	1,320,489	1,595,334
18	121	1,494,065	4,661,149
19	50	921,758	1,254,366
21	84	741,644	1,447,410
Total	**486**	**5,906,160**	**12,229,427**

Figure 13: Marsh Loss during Timeframe C



Timeframe D: 1932 to 1972

Timeframe D, from 1932 to 1972, was used to assess the change in marshland during roughly the first half of the primary study period. Timeframe D covers 40 years of the 90-year study period, or about 44 percent of the primary timeframe. The 1932 NOAA T-sheet and the 1972 G-WRAP Historic Shorelines datasets were used for this timeframe.

The total area of marsh loss during Timeframe D is 318 acres. The lower estimate of marsh loss volume is 4,410,738 CY, while the upper estimate of marsh loss volume is 6,715,934 CY, as noted in Table 4. The area of marsh loss during Timeframe D is 41 percent of the total area of loss identified during Timeframe A. Similarly, the lower estimate of marsh loss volume is 40 percent and the higher estimate of marsh loss volume is 36 percent of that calculated for Timeframe A. As previously discussed, the results of Timeframe D are consistent with the expected results for an assessment of marsh loss that covers 44 percent of the primary timeframe.

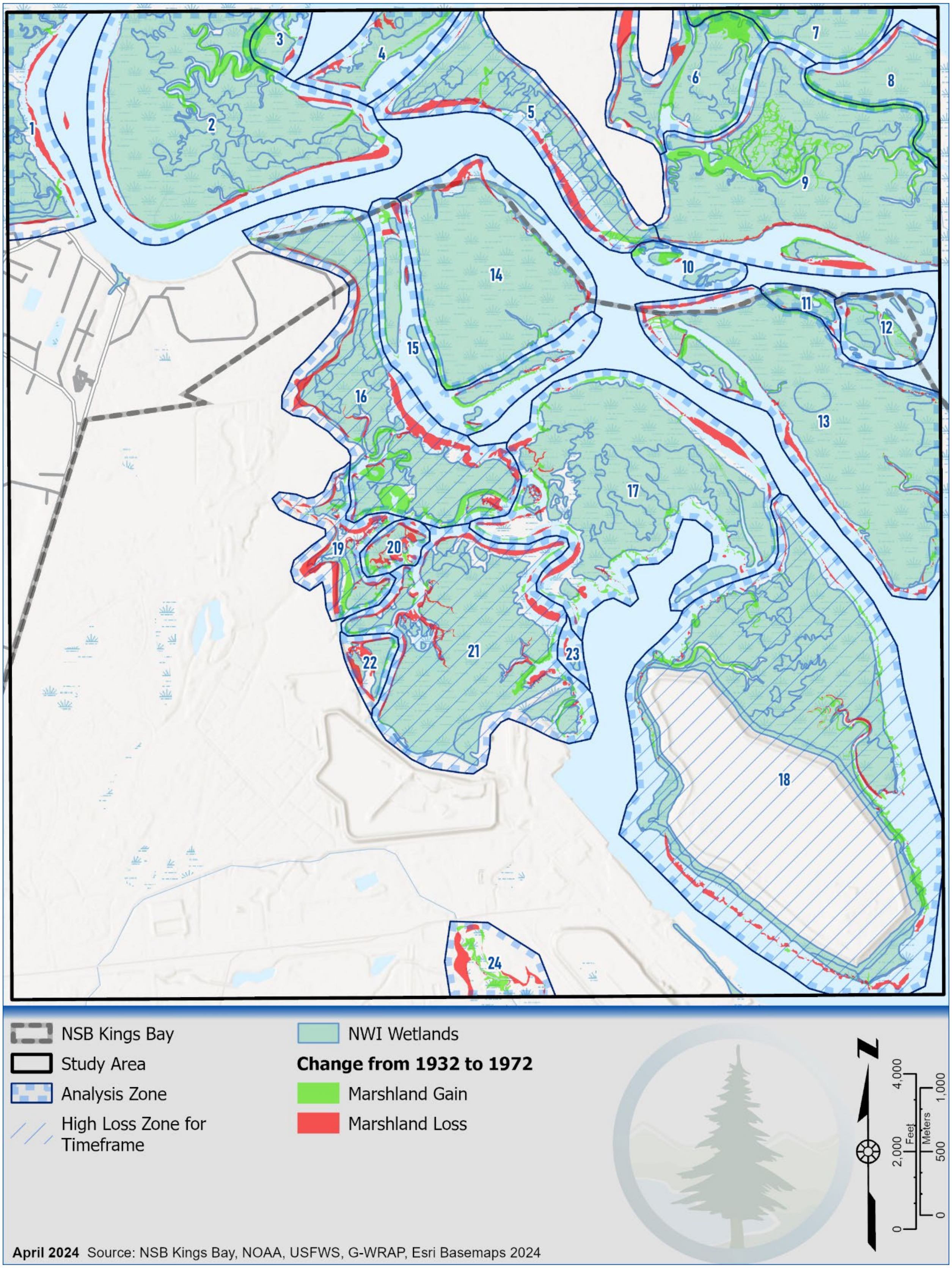
Four of the five Analysis Zones with the largest maximum volume of marsh loss during Timeframe D are consistent with the top Analysis Zones in Timeframe A. The top five marsh loss zones for Timeframe D are listed in Table 9. Analysis Zones 5, 16, 18, and 21 had the highest maximum marsh loss in both Timeframe A and Timeframe D, but Zone 19 replaced Zone 17 in Timeframe D. Zone 19 appears to have experienced significant loss during Timeframe D, resulting in higher losses than Zone 17 at this time.

As shown in Figure 14, large areas of marsh loss started to develop during this time period and correspond closely to areas of significant loss shown in Timeframe A. While not the main focus of this study, the Timeframe D results support the findings in Timeframe A and reveal that areas prone to marsh loss in present day were already starting to show signs of vulnerability several decades ago.

Table 9: Top Five Marsh Loss Zones, Timeframe D

Analysis Zone	Marsh Loss (ac)	Minimum Marsh Loss (CY)	Maximum Marsh Loss (CY)
5	25	532,750	689,374
16	40	518,069	1,296,494
18	25	490,835	1,073,574
19	21	331,238	471,889
21	34	394,689	639,784
Total	**145**	**2,267,581**	**4,171,114**

Figure 14: Marsh Loss during Timeframe D



Timeframe E: 1972 to 2014

Timeframe E evaluates the marsh loss during the second half of the primary study period, spanning from 1972 to 2014. This analysis compares two published datasets for the study area: the 1972 G-WRAP Historic Shorelines data and the 2014 NWI wetlands map.

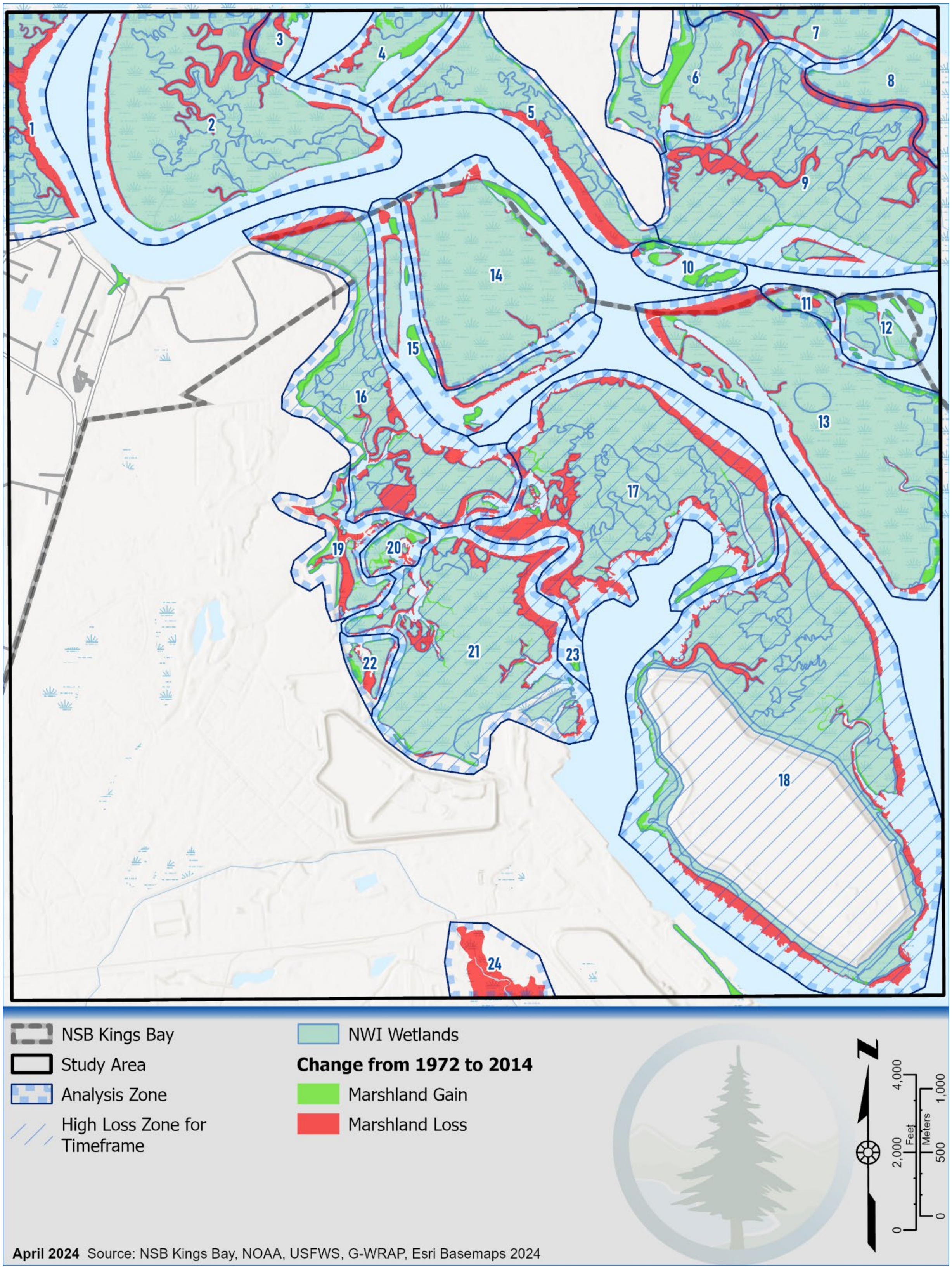
The total area of marsh loss during Timeframe E is 729 acres. The lower estimate of marsh loss volume during Timeframe E is 9,531,503 CY, and the upper estimate is 14,553,125 CY, as previously summarized in Table 4. Although Timeframe E covers 42 years (or about 47 percent) of the 90-year study period, the marsh loss area and volumes are all over 90 percent of those calculated during Timeframe A. Given that Timeframe D showed nearly half of the marsh loss during the first half of the study period, and that Timeframe E only covers roughly half of the study period, the marsh loss results between 1972 and 2014 are much higher than anticipated. As described in the Midpoint Analysis Discussion, the 1972 G-WRAP Historic Shorelines dataset has several gaps and provides a comparatively low level of detail, particularly in small upstream areas that appear to have not been surveyed in 1972 when the dataset was published. When compared with the more detailed 2014 NWI wetlands map, the unsurveyed marsh areas in the 1972 dataset were highlighted as loss areas, even if loss was not truly occurring there. In addition to the data influences, significant declines were observed in Georgia marshland during this time period.[38] For these reasons, Timeframe E shows higher amounts of marsh loss than initially expected. However, the larger marsh loss areas along Crooked River and near the base appear to be consistent with the loss areas present in Timeframe A, which helps to confirm the results of the assessment.

Four of the five Analysis Zones with the greatest maximum marsh loss volume match the top five loss zones during Timeframe A. Analysis Zones 16, 17, 18, and 21 are consistent between Timeframe A and Timeframe E, while Zone 9 replaced Zone 5. Zone 9 replaced Zone 5 because the loss areas in Zone 9 appeared as marsh gain during Timeframe D, likely due to the data differences described in the Midpoint Analysis Discussion above. Because of these data differences, it appears that all the loss in Zone 9 occurred during this timeframe (although this is not representative of the actual conditions), thus making Zone 9's loss higher than Zone 5 during Timeframe E. Aside from this area, the results of Timeframe E emphasize that the top loss areas have been vulnerable to loss over many decades.

Table 10: Top Five Marsh Loss Zones, Timeframe E

Analysis Zone	Marsh Loss (ac)	Minimum Marsh Loss (CY)	Maximum Marsh Loss (CY)
9	64	1,125,518	1,242,284
16	69	640,809	2,405,359
17	111	1,099,274	1,214,622
18	90	1,710,169	3,441,920
21	52	840,990	1,859,994
Total	**386**	**5,416,761**	**10,164,178**

Figure 15: Marsh Loss during Timeframe E



Timeframe F: 1972-2022

Similar to Timeframe E, Timeframe F evaluates the marsh loss during the later portion of the study period, but it uses the 1972 G-WRAP Historic Shorelines data and the project team's marsh boundary based on the 2022 DEM and the calculated MHW elevation. Together, these datasets cover 55 percent of the primary study period.

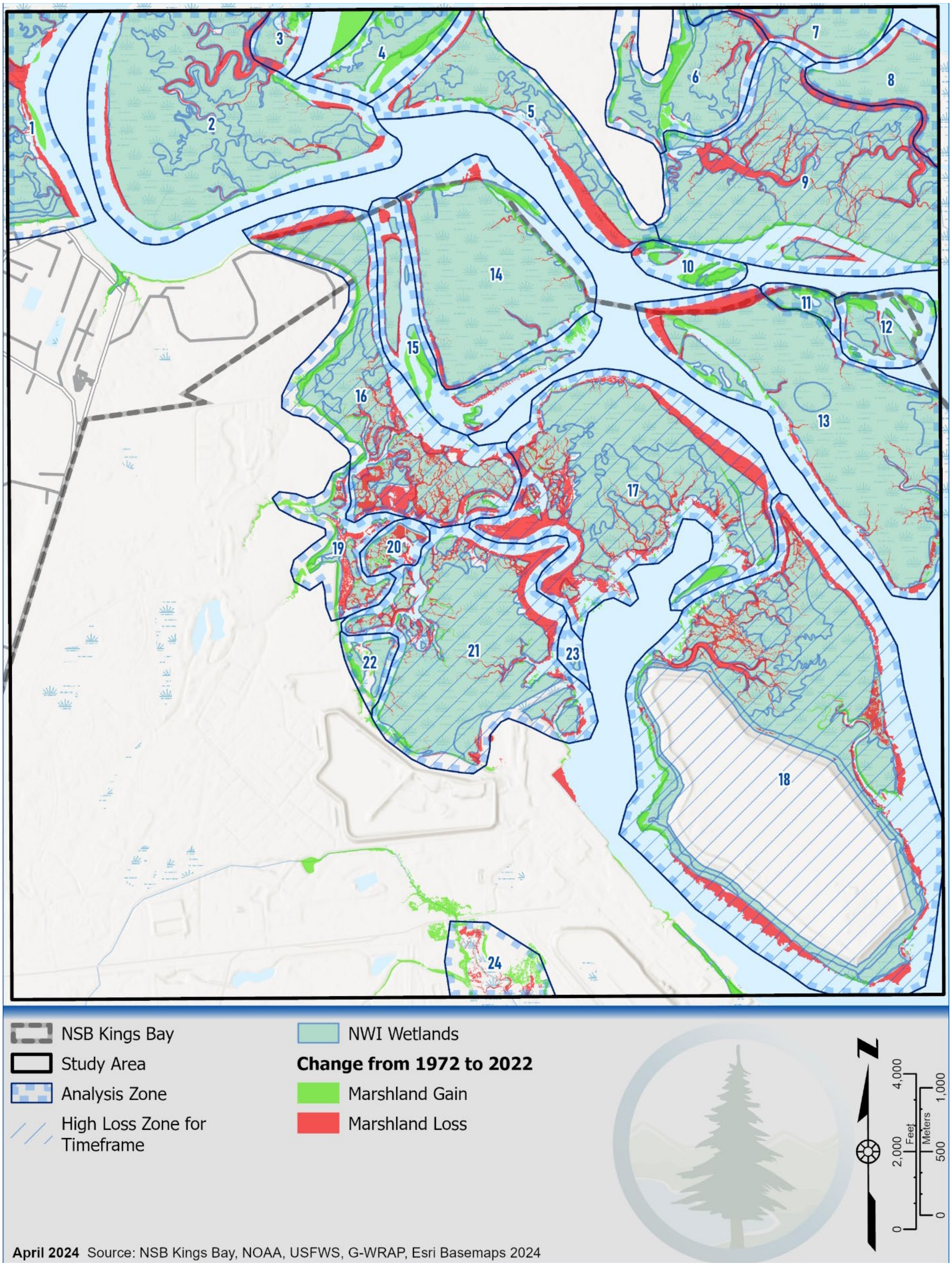
During Timeframe F, the analysis identified 740 acres of marsh loss. The minimum marsh loss volume is 9,771,672 CY, while the maximum marsh loss volume is 17,044,370, as shown in Table 4. The acreage and minimum marsh loss during Timeframe F are similar to Timeframe E, but the maximum volume loss during Timeframe F is about 2.5 million CY higher than Timeframe E. There has been a documented increase in dredging following the 2014 construction of the land-water interface at NSB Kings Bay, which would be captured in Timeframe F. Additionally, the methodology used to analyze the 2022 Georgia Statewide DEM resulted in a high level of detail along the shoreline and in small upstream areas, which could result in larger areas and volumes of loss compared to Timeframe E.

The five Analysis Zones with the highest maximum marsh loss volume during Timeframe F are Zones 9, 16, 17, 18, and 21, with a total marsh loss area of 472 acres and a volume loss between 6,379,327 CY and 13,376,590 CY. Table 11 summarizes the totals for the top five loss areas during Timeframe F. The top loss areas during Timeframe F are the same as Timeframe E. Additionally, compared to Timeframe A, four of the five top Analysis Zones are the same. In Timeframe F, Zone 9 replaces Zone 5 when compared to Timeframe A for the same reasons as described under Timeframe E and the Midpoint Analysis Discussion. However, the consistency of Zones 16, 17, 18, and 21 as top loss areas across the timeframes underscores the vulnerability of these areas and supports the validity of the assessments.

Table 11: Top Five Marsh Loss Zones, Timeframe F

Analysis Zone	Marsh Loss Area (ac)	Minimum Marsh Loss Volume (CY)	Maximum Marsh Loss Volume (CY)
9	70	1,214,762	1,343,516
16	97	1,159,749	3,379,129
17	126	1,220,741	1,352,094
18	116	1,832,257	4,354,107
21	61	951,818	2,947,744
Total	**472**	**6,379,327**	**13,376,590**

Figure 16: Marsh Loss during Timeframe F



Timeframe G: 2014-2022

Timeframe G spans only 8 years (roughly 9 percent) of the 90-year study period, but important changes occurred at NSB Kings Bay during this time. The land-water interface at the northern end of the navigation channel was constructed during the winter of 2013 and 2014. Prior to its installation, maintenance dredging at NSB Kings Bay was sporadic but averaged 800,000 CY of material dredged annually. Since the land-water interface was completed, maintenance dredging has been conducted on a much more consistent schedule with an average of approximately 1,300,000 CY of material dredged annually. Thus, after the land-water interface was installed, an average increase of 500,000 CY of material has been dredged annually. Timeframe G captures the effects of the land-water interface and subsequent dredging efforts using the 2014 NWI wetlands data and the project team's marsh boundary created using the 2022 Georgia Statewide DEM and the calculated MHW elevation.

During Timeframe G, the total area of marsh loss was 245 acres. As summarized in Table 4, a minimum volume of 3,474,065 CY and a maximum of 4,471,972 CY of marsh were lost during this timeframe. Figure 17 shows the marsh loss areas of Timeframe G. The overall area loss during Timeframe G is 32 percent of the loss during Timeframe A. The minimum and maximum loss volumes during Timeframe G were 31 and 23 percent of the loss during Timeframe A respectively. The volume of dredged material removed annually from the NSB Kings Bay navigation channel nearly doubled following the construction of the land-water interface. Additionally, the methodology used to develop the 2022 marsh boundary resulted in a high level of detail along the shorelines and waterways. When compared to the relatively smooth boundaries of the 2014 NWI dataset, some apparent loss areas may have also resulted. Considering the onsite conditions and the datasets, the marsh loss during Timeframe G aligns with the expected results.

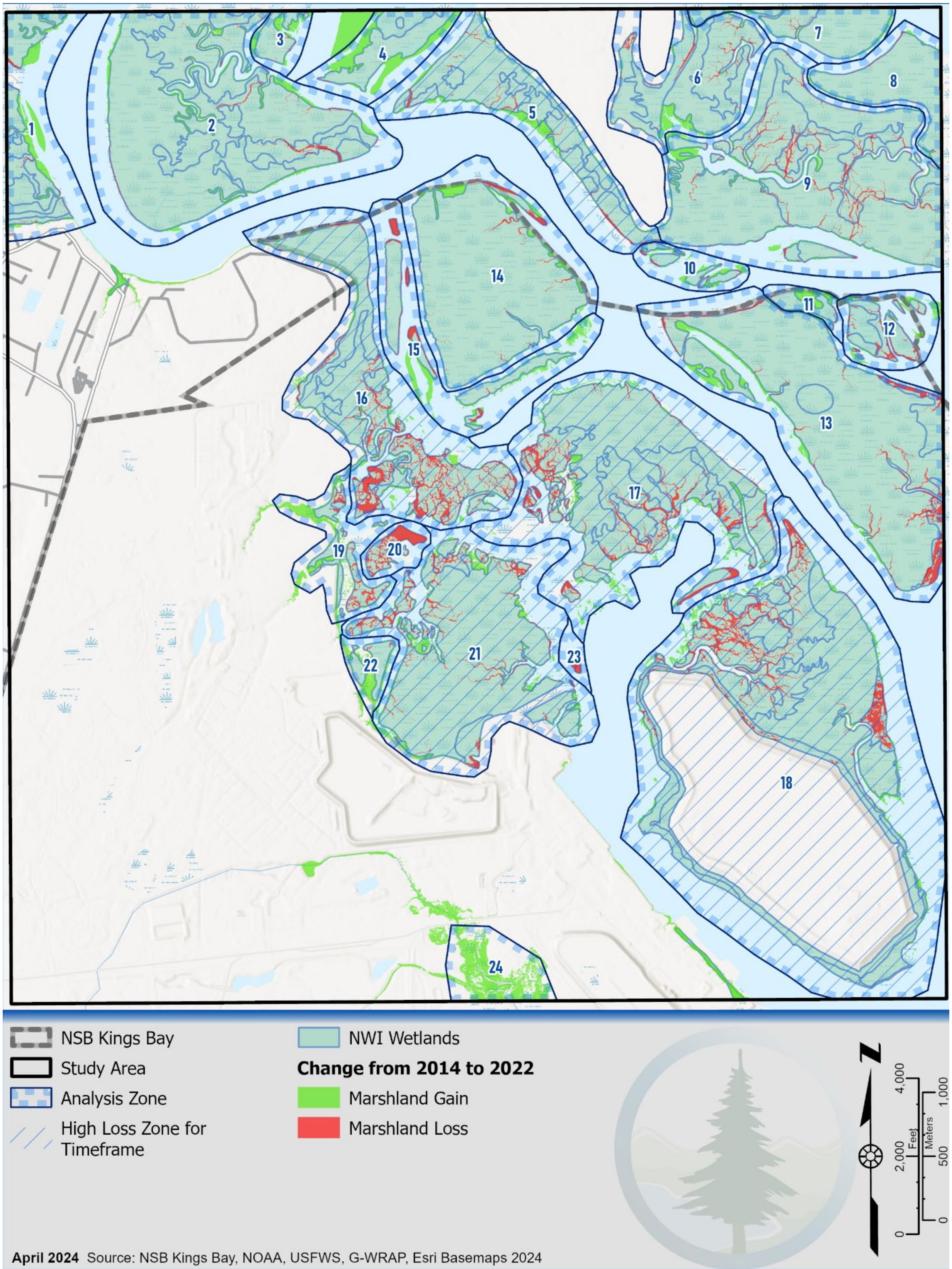
Analysis Zones 9, 16, 17, 18, and 21 had the highest maximum volume of marsh loss during Timeframe G, as noted in Table 12. Some zones in Timeframe G, including Zones 9 and 16, have minimum and maximum marsh loss volumes that are equal. This occurs when the current elevation of the marsh loss area in the Analysis Zone is the same elevation as the maximum marsh elevation, which was determined using the 2014 NWI wetland map for all of the analyses, as described in Section 4. Zones 16, 17, 18, and 21 are consistent between Timeframes A and G. In Timeframe G, Zone 9 replaces Zone 5. The majority of the loss in Zone 5 appears to occur in earlier timeframes, while Timeframe G documents many small areas of loss in the upstream reaches of Zone 9, thus placing it higher than Zone 5 in this timeframe.

Although Zone 23 was not identified as one of the top five loss zones during Timeframe G, notable losses have occurred in this zone since the construction of the land-water interface in 2014. Based on the Timeframe G results, Zone 23 has lost nearly 10 percent of its acreage in 8 years, which is the second highest percentage of loss in this timeframe. Zone 23 should be considered as a potential project location, given the losses documented in the analysis and observed by on-base stakeholders.

Table 12: Top Five Marsh Loss Zones, Timeframe G

Analysis Zone	Marsh Loss Area (ac)	Minimum Marsh Loss Volume (CY)	Maximum Marsh Loss Volume (CY)
9	21	251,516	251,516
16	41	1,364,404	1,364,404
17	37	280,646	319,844
18	45	572,511	1,471,455
21	20	263,069	273,042
Total	**165**	**2,732,146**	**3,680,262**

Figure 17: Marsh Loss during Timeframe G



Discussion

The Historical Marsh Analysis is intended to quantify the area and volume of marsh loss near NSB Kings Bay to identify key loss areas for future assessments. Over the span of the primary analysis timeframe, 1932 to 2022, the total area of marsh loss was found to be 772 acres. The lower estimate of marsh loss volume is 11,086,508 CY, and the higher estimate is 18,835,732 CY, based on the difference between the existing elevation of loss areas and the minimum and maximum elevations of existing marshland, as described in Section 4. The five areas of greatest marsh volume loss during Timeframe A are Zones 5, 16, 17, 18, and 21. Notably, four of the five areas with the largest volume of marsh loss (Analysis Zones 16, 17, 18, and 21) are immediately adjacent to NSB Kings Bay. Three of the five Analysis Zones with the largest maximum volume loss (Zones 16, 18, and 21) were consistent across all of the study timeframes. Analysis Zones 9 and 19 were the only other zones that occurred within the top five of maximum volume loss in any of the study periods, and Zone 19 is also adjacent to NSB Kings Bay. The consistency of the zones with the maximum volume loss highlights the historical and continued vulnerability of these areas.

Three high-priority loss areas (Zones 16, 17, and 21) have been identified based on the high volume of loss and their location on land held primarily by the Federal government. Although Zone 18 was initially considered in the prioritization exercise, the loss area along the navigation channel would not be suitable for BUDM projects because of the risk of sediment eroding into the channel and impeding travel. Zone 16 has been selected in place of Zone 18, although a portion of Zone 16 is located on land held by the State of Georgia. Additionally, significant losses have been observed in Zone 23 since the construction of the land-water interface in 2014. Because Zone 23 is an island, it was delineated as a separate analysis zone, and its small size compared to the other analysis zones prevented it from rising to a top priority area in the Historical Marsh Analysis. However, the noticeable losses in this area warrant special consideration as a potential project area, particularly in conjunction with projects in Zones 17 or 21, which have both been designated as priority areas.

Although the Historical Marsh Analysis identified a significant volume of marsh loss, this quantity does not directly translate into the amount of dredged sediment that could be placed in these areas. The marsh loss areas are primarily located along shorelines, and shoreline restoration projects using dredged sediment may have unique implementation challenges compared to other types of BUDM projects. Because this analysis was focused on quantifying historical marsh loss, the amount of dredged material that could be used for TLP or other BUDM strategies within or adjacent to the marsh loss sites has not been assessed as part of this study. Future phases of this project will evaluate these possibilities, particularly in the high-priority areas identified in this phase. Combining several BUDM projects in a single area can be used as a strategy to best address the current and future site conditions, increase the amount of sediment placed, and maximize the available funding for these projects. Future work to evaluate these possibilities will build upon the trends and locations of loss discovered through this analysis.

Table 13 lists the 24 Analysis Zones studied in the Historical Marsh Analysis as well as key data points including ownership, prioritization status, marsh loss quantities (during Timeframe A), and other information. Analysis Zones with a maximum volume loss over 100,000 CY have been highlighted in grey, and Analysis Zones with a maximum volume loss over 1,000,000 CY have been highlighted in blue. Three priority Analysis Zones have been identified based on a large volume of marsh loss occurring on land held primarily by the US Navy.

Table 13: Results Summary Table

Analysis Zone	Total Area (ac)	Marsh Loss Area (ac)	Minimum Marsh Loss Volume (CY)	Maximum Marsh Loss Volume (CY)	Parcel Number	Ownership Type	Owner
1	202.3	28.6	439,670	463,579	132 009 131 002	Private Private	Sovereign Holdings, LLC 2021 Granddaughters Trust
2	728.5	42.4	540,547	558,407	156 001	State government	State of Georgia (Atlanta)
3	43.1	3.9	38,185	44,376	156 001	State government	State of Georgia (Atlanta)
4	119.5	3.3	35,175	42,109	156 001	State government	State of Georgia (Atlanta)
7	98.6	2.7	31,238	40,778	156 001	State government	State of Georgia (Atlanta)
8	129.5	10.6	162,602	188,518	156 001	State government	State of Georgia (Atlanta)
9	687.1	45.7	725,010	780,531	156 001	State government	State of Georgia (Atlanta)
10	57.2	0.5	5,210	5,564	None	N/A	N/A
11	31.0	1.4	15,590	18,440	158 002	State government	State of Georgia (St. Marys)
12	102.6	3.0	21,461	25,910	158 002	State government	State of Georgia (St. Marys)
13	653.7	66.3	862,845	939,397	158 002	State government	State of Georgia (St. Marys)
14	449.9	18.2	195,398	217,709	158 001	State government	State of Georgia (St. Marys)
15	215.3	10.5	94,361	94,361	158 001	State government	State of Georgia (St. Marys)
16	505.7	94.4	1,442,383	3,275,552	158 001 147 001	State government Federal government	State of Georgia (St. Marys) US Navy
17	722.1	134.2	1,438,571	1,577,762	147 001	Federal government	US Navy
18	1630.8	112.0	1,945,031	4,362,641	147 001 158 003	Federal government Federal government	US Navy US Navy
19	132.2	23.5	446,998	602,547	147 001	Federal government	US Navy
20	40.9	14.8	125,695	131,765	147 001	Federal government	US Navy
21	590.1	76.6	1,333,652	3,841,313	147 001	Federal government	US Navy
22	43.1	4.4	54,526	142,645	147 001	Federal government	US Navy
23	17.9	1.2	11,981	13,404	147 001	Federal government	US Navy
24	97.2	12.2	92,881	92,881	147 001	Federal government	US Navy
Total	**7,831**	**772**	**11,086,508**	**18,835,732**			

Note: Table shows the calculations from Timeframe A, 1932-2022, and ownership status as of March 2024.

Analysis zones with a maximum volume loss over 100,000 CY

Analysis zones with a maximum volume loss over 1,000,000 CY

Priority Analysis Zones

7. Conclusion

Takeaways

The Historical Marsh Analysis identified a total of 772 acres of marsh loss from 1932 to 2022, as well as a minimum marsh loss volume of 11,086,508 CY and a maximum volume loss of 18,835,732 CY across the 24 Analysis Zones during Timeframe A. Five Analysis Zones (Zones 5, 16, 17, 18, and 21) each have an estimated maximum loss of over 1,000,000 CY. Three high-priority loss areas (Zones 16, 17, and 21) have been identified based upon the scale of marsh loss and the ownership conditions of the parcels on which the loss areas are located.

Most of the marsh loss areas were concentrated along shorelines. Although hundreds of acres and millions of CY of marsh are estimated to have been lost near NSB Kings Bay, the volume of marsh loss does not necessarily represent the volume of dredged material that could be placed as part of BUDM projects. The Historical Marsh Analysis identifies key locations for further evaluation, while future project phases will conduct analyses to better understand the true capacity of BUDM strategies to accommodate dredged sediment from NSB Kings Bay.

The availability and consistency of data presented a challenge for this project. While gathering data and performing the marsh loss area and volume calculations, two data needs were identified. Given the goal of calculating the volume of marsh loss, historical elevation data for the 1930s or 1970s would have been beneficial for the analysis. While topographic maps are available, they do not provide sufficient detail, elevation data, or bathymetric data for performing this type of study. Additionally, several data sources are available within the timeframes of this study, but datasets produced by a consistent agency or using the same shoreline/marsh delineation method do not appear to exist. The NOAA T-sheets are the only datasets that provide data from both 1932 and the early 2000s using comparable delineation methods, which allows for a direct comparison of marsh areas between these two data points. Timeframe C conducted an analysis of the change between 1932 and 2002 using NOAA T-sheets for both years. However, because more recent data (the 2022 Georgia Statewide DEM and tidal information) was available, preference was given to more up-to-date information as the primary data source for this analysis, rather than comparable datasets. Having consistent and detailed 2D and 3D data across the study years would be beneficial for this type of analysis.

Next Steps

Following the completion of the Historic Marsh Analysis, the project team will use the identified marsh loss areas to select locations for onsite assessments of the current marsh conditions. The Current Marsh Analysis will measure physical and biological parameters to develop a deeper understanding of the health of the existing marshland surrounding NSB Kings Bay. The results of the onsite evaluations will provide data that the project team will use to further narrow and prioritize the 24 Analysis Zones.

Following the Current Marsh Analysis, the project team will conduct a desktop analysis to study the future marsh conditions. The Future Marsh Analysis will quantify the acreage and volume of the projected transition of current vegetated marshland to unconsolidated marsh or mudflats under future SLR scenarios. Updated aerial imagery will be combined with topographic, bathymetric, and other data collected during the Current Marsh Analysis to generate more up-to-date marsh loss results during the Future Marsh Analysis, if possible. The results of the Future Marsh Analysis will identify areas of greatest restoration potential, which will be refined using the insights gained from the Current Marsh Analysis.

The Historical, Current, and Future Marsh Analyses will culminate in a charrette-style meeting with USACE and Navy stakeholders to present the identified areas of greatest restoration potential for BUDM projects. Following this event, the project team will delineate the potential BUDM sites for use in future planning efforts. The sites identified through this work will inform future strategies and projects for dredged material management at NSB Kings Bay.

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Appendix A: Minimum and Maximum Marsh Elevation Tables

Table 14: Minimum Marsh Elevation Values

Zone	Elevation (meters)						
	1932 - 2014	1932 - 2002	1932 - 1972	1972 - 2014	1932 - 2022	1972 - 2022	2014 - 2022
1	1.8081	0.35708	1.8081	1.546801	1.8081	1.351007	1.650047
2	0.787001	0.750719	0.642862	0.919847	0.838373	0.838373	0.838373
3	0.509203	0.444748	-0.187479	0.509203	0.359802	0.359802	0.319168
4	0.713539	0.332941	0.313065	0.713539	0.412722	0.412722	0.412722
5	2.725466	2.725466	2.725466	1.731667	2.725466	1.731667	1.545334
6	2.287704	2.287704	2.287704	1.726482	2.287704	1.726482	1.699547
7	0.767731	0.820065	-4.98266	0.79306	0.376539	0.376539	0.376539
8	0.837269	0.893944	1.020645	0.987198	0.936604	0.936604	0.936604
9	1.904463	1.904463	1.904463	2.020512	1.904463	2.020512	1.674845
10	0.879738	0.267086	0.267086	0.943167	0.879738	1.00448	1.00448
11	0.520355	0.49641	1.049553	0.791765	0.750546	1.082561	1.082561
12	0.654142	0.290415	0.538107	0.654142	0.527094	0.527094	0.577829
13	0.956884	0.515182	0.935112	0.956884	0.956884	0.962639	0.998415
14	0.735262	0.474014	0.779947	0.735262	0.752844	0.752844	0.752844
15	0.740431	0.424417	0.965824	0.740431	0.965824	0.74641	0.965824
16	1.921883	1.921883	1.921883	0.754606	1.921883	1.288107	5.590752
17	0.848051	0.663221	0.765245	0.848051	0.848051	0.848051	0.846558
18	2.037802	0.727108	1.309744	2.037802	1.590216	1.590216	1.900377
19	4.525467	4.525467	4.525467	3.186947	4.525467	3.275944	3.275944
20	0.559616	0.478094	0.673853	0.587227	0.608984	0.608984	0.608984
21	0.732161	0.483261	0.727318	5.751499	8.260588	8.260588	1.983309
22	5.55946	5.55946	5.55946	0.695219	5.55946	0.220938	1.072178
23	0.183787	0.183787	0.183787	0	0.183787	0	0.413742
24	2.783106	1.733934	2.783106	2.647465	2.783106	2.647465	0

Note: Values based on the maximum elevation within the loss area from the 2022 EROS topobathymetric model

Table 15: Maximum Marsh Elevation Values

Zone	Elevation (meters)
1	1.650047
2	0.917904
3	0.659327
4	0.809898
5	1.545334
6	1.699547
7	1.041456
8	1.400452
9	1.674845
10	1.00448
11	1.127964
12	0.80648
13	1.174976
14	0.984304
15	0.965824
16	5.590752
17	1.043995
18	5.667231
19	3.275944
20	0.686499
21	2.078739
22	1.740852
23	0.413742
24	0

Note:

Values based on the maximum elevation within the 2014 NWI wetland boundaries from the 2022 EROS topobathymetric model

Values used in all study timeframes

Appendix B: Marsh Gain/Loss Conversions by Zone

Table 16: Marsh Gain/Loss Conversions by Zone

Zone	1932 - 2014		1932 - 2022	
	Gain to Loss (ac)	Loss to Gain (ac)	Gain to Loss (ac)	Loss to Gain (ac)
1	1.63	0.98	1.38	4.33
2	17.04	1.80	13.58	4.55
3	5.46	0.00	3.35	0.10
4	0.23	2.03	0.00	3.87
5	4.57	2.79	4.27	4.68
6	8.23	6.50	7.08	6.46
7	6.56	0.00	5.11	0.00
8	8.05	0.21	6.70	0.29
9	36.51	6.84	34.52	7.97
10	1.75	0.08	1.61	0.06
11	1.94	0.25	0.99	0.22
12	0.53	0.76	0.89	0.56
13	5.53	3.78	4.49	3.32
14	7.27	1.14	6.27	2.71
15	8.95	1.79	7.40	1.53
16	28.00	13.41	28.92	14.21
17	18.33	2.52	16.53	1.71
18	23.14	4.85	22.29	6.80
19	8.38	6.54	7.49	10.90
20	2.20	4.54	2.65	1.93
21	7.39	6.65	8.11	8.65
22	1.14	3.28	0.47	5.80
23	0.00	0.00	0.00	0.00
24	8.25	0.00	1.36	6.36
Total	**211.09**	**70.76**	**185.45**	**97.01**

Note: When adding midpoint analysis results to compare them to overall timeframes, the above values should be doubled to account for overlap of these areas on each side of the analysis.