

MEMORANDUM – COASTAL ENGINEERING REVIEW MWR REVIEW AND EVALUATE COASTAL SHORELINE MONITORING OPTIONS FOR NATIONAL PARK UNITS IN THE GREAT LAKES AREA TAR 17624

October 29, 2021

Project Background

Over the past two decades, the Great Lakes have undergone rapid changes in water levels, reaching historic low levels in the mid-2000s before rebounding to historic high levels more recently. Due to climate change, these water level fluctuations are expected to become more frequent and extreme. The current high-water levels, coupled with increased storm intensity and wave energy, have resulted in rapid shoreline changes in Great Lakes parks, with consequences for natural and cultural resources, facilities, and infrastructure. Unique shoreline habitats, threatened and endangered species, historical structures, archeological resources, docks, and other features have been damaged or are at imminent risk of damage or loss due to coastal erosion in these parks.

In October 2020, Great Lakes park staff (including representatives from APIS, GRPO, INDU, ISRO, PIRO, SLBE, and PEVI) and supporting staff from the Midwest Region, Great Lakes Inventory & Monitoring (I&M) Network, and WASO NRSS offices convened virtually to share coastal resource concerns and identify related needs for monitoring and management. As part of this process, many Great Lakes parks expressed a need to better document the position and condition of existing shorelines and to monitor shoreline change over the short and long term. Shoreline monitoring protocols currently implemented by other coastal I&M networks and states were reviewed briefly during the October meeting. These protocols vary substantially in terms of technical approach, intensity of effort, and cost. Considerations for monitoring goals, park size, staffing, and expertise are needed as well as a more in-depth exploration of shoreline monitoring options, with specific emphasis on their suitability and feasibility for implementation in park units in the Great Lakes area.

NPS has requested assistance in reviewing shoreline monitoring options for Great Lakes parks and facilitating related discussions about the objectives, pros, cons, and costs associated with each option. As the first step in response to this TAR, a literature review was conducted of existing monitoring guidance protocols, both within and outside of NPS, to serve as example programs. Additionally, a set of goals and objectives that the monitoring framework might eventually address has been proposed. This document is an initial step to consider shoreline monitoring options and will be supplemented with additional information through discussions and in subsequent memoranda.

Review

Before considering the potential monitoring options, which might be implemented at Great Lakes units, it is important to understand why this monitoring is needed. This should be documented before determining the appropriate monitoring options. We propose the following as a starting point for defining goals for coastal monitoring plans.

The monitoring plan will provide NPS with data relevant to:

1. Processes impacting erosion and flood potential to better assess vulnerability and risk to NPS resources, assets, and activities; and
2. Informing potential response actions necessary to reduce or eliminate vulnerability and risk associated with erosion and flooding.

Once the goals for the monitoring plan are agreed on, NPS can then define objectives to satisfy the goals. These objectives may include the collection of data to better understand the shoreline position, dune morphology, topographic and bathymetric elevations, etc. Once these program objectives are defined, the next step in the process would be to define data quality objectives and then methods, times scales, budgets, monitoring platforms/options, etc. needed to achieve the data quality objectives. Finally, it is recommended that action thresholds be defined to ensure that monitoring triggers the appropriate response activity. While these action thresholds likely cannot be defined until after baseline data are collected, considering what they might be is useful for determining what data to collect. If a response action cannot be identified, then data to be collected should be re-assessed as to whether it informs the proposed goals of the monitoring plan.

Proposed Objectives for Coastal Monitoring:

There is a wide range of possible natural and/or anthropogenic processes which can increase vulnerability and risk to NPS resources and assets in the Great Lakes coastal environment. To better identify likely objectives for the monitoring plan, it is best to first explore the parameters that can cause changes, and which are likely to increase vulnerability and risk. These potential parameters and impact examples are provided in tables 1 and 2, which are modified from *Monitoring Coastal Geologic Features and Processes* (NPS 2009).

Table 1. Common Causes of Coastal Land Loss from Natural Processes

Parameter	Impact Examples
Erosion	Waves and Currents
	Wind
	Precipitation
	Storms
	Landslides
	Ice scour
Sediment Reduction	Climate change
	Stream avulsion
	Source depletion
Submergence	Land subsidence
	Isostatic rebound
	Rising water levels
Wetland Deterioration	Herbivory
	Freezes
	Fires
	Sediment source depletion

Table 2. Common Causes of Coastal Land Loss from Anthropogenic Causes

Parameter	Impact Examples
Transportation	Boat wakes, altered water circulation
Coastal Construction	Sediment deprivation (bluff retention)
	Coastal structures (jetties, groins, seawalls, docks)
River Modification	Control and diversion (dams, levees)
Fluid Extraction	Water, oil, gas, sulfur
Climate Alteration	Global warming
	Human response to climate impacts
	Increased frequency and intensity of storms
Excavation	Dredging (canal, pipelines, drainage)
	Mineral extraction (sand, shell, heavy minerals)
Wetland Destruction	Pollutant discharge
	Traffic
	Failed reclamation
	Burning

Each NPS unit will have unique objectives for shoreline monitoring. As such, each unit should determine which parameters described in tables 1 and 2 are appropriate for their needs and develop a site-specific monitoring plan to assess those parameters. Table 3 provides possible data objectives associated with coastal land loss parameters, along with potential monitoring methods. When examining possible monitoring methods, it is important to consider the required technical level of expertise, effort, and the relative cost associated with accomplishing each task. Selection of monitoring methods should also consider if actions taken to address an issue at one location may result in unintended consequences at another.

Table 3. Methods of Monitoring Coastal Changes

Data Objective	Monitoring Methods	Expertise	Examples of Equipment	Relative Cost	Labor Intensity
Meteorology and Climate	Rainfall monitoring	Medium	Rain gauge	Low	Low
	Wind speed, direction monitoring	Medium	Anemometer, wind vane	Low	Low
	Water level monitoring	Medium	Meter, water level gauge	Medium	Moderate
Sediment (Beach) Volume	Photo stations	Medium	Camera, location maps	Low	Low
	Profiles	Medium	GPS	Medium	Moderate
	Aerial photography	High	Drone/airplane	Medium	Moderate
Shoreline Change	Photo monitoring	Low	Camera, location maps	Low	Low
	Profiles	Medium	GPS	Medium	Moderate
	Aerial photography	High	Drone/airplane	Medium	Moderate
Dune Geomorphology	Photo monitoring	Low	Camera, location maps	Low	Low
	Site inspection	Medium	GPS	Medium	Low
	LIDAR	High	LIDAR equipment, drone/airplane	High	Moderate

Data Objective	Monitoring Methods	Expertise	Examples of Equipment	Relative Cost	Labor Intensity
Vegetation Cover	Site inspection	Medium	GPS	Medium	Moderate
	Aerial photography	High	Drone/airplane	High	High
	Satellite images	Medium	Viewing software	Medium	Moderate
Biological Monitoring	Flora and fauna surveys and community monitoring	Medium	GPS	Medium	Moderate
Topography/ Elevation	Photography	Low	Camera, location maps	Low	Moderate
	GPS or traditional survey	Medium	GPS/hand surveying tools	Medium	Moderate
	LIDAR	High	LIDAR equipment, drone/airplane	High	High
Bathymetry	Subsurface LIDAR	High	LIDAR equipment, drone/airplane	High	High
	Hydrographic survey	High	Sonar equipment, vessel	High	High
Composition of Beach Material	Photography	Low	Camera, location maps	Low	Moderate
	Sediment sampling	Medium	Sampling devices, sample storage containers	Medium	Moderate
	Sedimentological description	High	Sampling devices, sample storage containers, sediment analysis equipment	High	High
Wetland Position/ Acreage	Wetland surveys	Medium	Species identification tools	Low	Low
	Aerial photography	Medium	Drone/airplane	Medium	Moderate
	Satellite interpretation	High	A source for satellite photos	Medium	Moderate
Wetland Vertical Accretion	Sediment traps	Medium	Sediment traps, sample storage containers, sediment elevation tables (SETs)	Medium	Moderate
	Sediment coring	Medium	Sampling devices, sample storage containers	High	Moderate
Current and Wave Impacts	Current and wave monitoring	High	Acoustic Doppler Current Profiler; Wave recording buoys	High	Moderate
Stream Avulsion	Streamflow monitoring	Medium	Stream gage; current meter	Medium	Moderate

Source – This table is modified from Monitoring Coastal Geologic Features and Processes (NPS 2009).

Acronyms – GPS: Global Positioning System; LIDAR: Light Detection and Ranging

Expertise – Low: Needs modest background; Medium: Needs technical background in the field/related field; High: Must be specifically trained in-field use of specialized equipment, and in data processing and analysis

Cost (US\$) – Low: <\$1,000; Medium: \$1,000 to \$10,000; High: >\$10,000

Labor Intensity – Low: <few hours; Moderate: <full day; High: >full day

The data objectives outlined in table 2 are each critical in their own way for providing sound scientific basis for coastal management decisions and anticipating future conditions. The objectives are described below in more detail, including examples of how the data can be used to support management needs.

- **Meteorology and Climate** – Coastal meteorological phenomena include land and sea breezes, sea-breeze-related thunderstorms, coastal fronts, fog, haze, marine stratus clouds, and strong winds associated with coastal changes. Climatic forces affecting coasts include changes in temperature, sea and water levels, precipitation, storminess, ocean acidity, and ocean circulation. Meteorological and climatic factors influence and aid in understanding the physical, chemical, and biological oceanography of the coastal ocean. For example, meteorological data such as wind data related to speed and direction are important for understanding the typical direction and magnitude of waves that could impact coastal areas and provide insight into coastal management and are also important for numerical modeling.
- **Sediment (Beach) Volume** – Knowledge of sediment volumes (budgets) can be used as a coastal management tool to analyze and describe the different sediment inputs (sources) and outputs (sinks) in coastal areas. This information, for example, can be used to predict morphological change in a particular coastline over time and guide management actions such as where to place sediment and relocating structures.
- **Shoreline Change** – Shoreline change refers to the change in position of the shoreline or shoreline markers such as beaches, dune lines, bluffs, etc. Monitoring changes in the position of the shoreline or other shoreline markers indicate the dynamics between sea-level change, sediment supply, hydrography, and meteorology. Shoreline change data can be used in coastal planning and hazard and risk assessments. For example, long and short-term erosion rates can be calculated, and the impacts of engineering structures on erosion can be assessed.
- **Dune Geomorphology** – Dunes provide a measure of protection for coastlines against hydrodynamic forces such as storm surges and waves. Dune characteristics, such as volume, elevation, position, and if stabilizing vegetation is present dictate the level of protection dunes provide. Geomorphology data is useful, for example, for coastal resilience modeling and guiding dune restoration efforts.
- **Vegetation Cover** – Coastal zone vegetation cover provides an indication of the relative stability of coastal landforms and aids in evaluating the hydrologic system of an area. For example, taller and thicker vegetative growth provides more stability. Vegetation cover changes can occur as a result of storm impacts, long-term erosion, etc. Vegetation data are useful, for example, for coastal resilience modeling and guiding dune restoration efforts and in spatially distributed models related to habitat quality and distribution, water quality, soil loss, and nutrient export.
- **Biological Monitoring** – Measured components in biological monitoring could include plant and/or animal community composition, species abundance and richness, tracking species recovery or decline, searching for non-native species, etc. Knowledge of trends can aid in discerning the best ways to define and detect biological impacts from coastal changes and coastal management strategies including anthropogenic activities.
- **Topography/Elevation** – Air, water, and land processes result in topographic and hydrographic coastal changes. Elevation data can aid in the assessment of coastal geomorphology and sediment volumes and can be used to support modeling. Generally, larger features respond more slowly to

processes compared to smaller landform features and so the type and the frequency of monitoring will be feature specific.

- **Bathymetry** – An important factor for coastal monitoring is bathymetry (underwater topography) as nearshore slopes are vital in determining the behavior of waves and currents immediately offshore of the site. Absorption and dissipation of wave energy can be more effective with a milder slope, whereas deflection of wave energy can be more effective with a steeper slope. Offshore water depth is also a useful dataset as it aids in determining wave response. Bathymetric data can also be used to create models that can calculate currents, tides, water temperature, and salinity in an area which can also be used to predict tides and currents, as well as hazards like coastal flooding and rip tides. Bathymetric data can be used to study the effects of climate change and to monitor beach erosion, water level rise, and subsidence.
- **Composition of Beach Material** – Beach material composition refers to characteristics of the sediment or other material making up the beach, dunes, bluff, or intertidal zone, such as particle grain size, source, and mineral composition. The beach material composition provides information about the geologic history and anthropogenic impacts if any. This information is important when pursuing management actions (e.g., sediment placement, habitat restoration) and can be included in modeling.
- **Wetland Position/Acreage and Wetland Vertical Accretion** – Coastal marshes play a critical role in sustaining the health of coastal ecosystems. They contribute to shoreline protection by absorbing wave energy and can decrease the severity of flooding by absorbing large amounts of water during heavy rain. Therefore, landward, or seaward movement of a wetland margin and the total acreage of a coastal wetland is key in informing coastal management. For example, this knowledge can help guide locations of proposed restoration and identify areas where restoration should be avoided. It can also provide an understanding of wetland losses and growth and the resulting impacts to the ecosystem which can in turn help guide the planning of hard infrastructure coastal resiliency strategies such that installation promotes wetland growth in the most beneficial locations. Wetland vertical accretion is the rate of sediment accumulation in a coastal wetland and is critical information for assessing if a marsh has been/will be able to keep up with sea-level rise or if it will be inundated.

Analyzing data associated with shoreline position within the Great Lakes provides very different information from that of shoreline position associated with tidal environments. Within the Great Lakes, shoreline position is historically interpreted by the elevation of the water level at the time of observation. In other words, in 2014, when water levels were low, at most locations it appears that the position of the shoreline is far away from upland areas (though this is not always the case). Similarly, in 2019, during high water levels, it appears that the shoreline is very close to the upland areas (though, again, this is not always the case). It is important to distinguish true shoreline change due to geomorphic processes, from visually deceptive shoreline change, from water level variations. Therefore, selecting data objectives and monitoring methods that measure both geomorphic change and water level are recommended. This is just one of the significant differences that must be considered when using guidance or example monitoring efforts that have been produced in tidal environments where shoreline position is typically normalized to MHHW (or similar), and shoreline position is typically dictated by changes in geomorphic features. Within the Great Lakes, shoreline position can be dictated by a change in water level and/or changes in geomorphic features or a combination of these factors.

Additional considerations related to impacts from seiche effects and ice are considerations that while not

unique to the Great Lakes, may not be considered by all guidance/example documents. As such, table 2 should be used as a starting point in developing the data objectives related to shoreline observations within the Great Lakes.

NPS Coastal Monitoring Protocols:

Coastal Inventory and Monitoring (I&M) networks within NPS as well as U.S. states and other entities have a wide range of established protocols for coastal monitoring in a variety of locations targeting a wide range of categories. Once a targeted monitoring option is identified for an area, these protocols can be used as templates or reused in their entirety in some cases if found to be applicable. In most cases, modifications will be necessary based upon scope, duration, and cost, to be used elsewhere. A list of NPS examples of existing protocols is presented in table 4 below.

Table 4. NPS Coastal Monitoring Protocol Examples

Protocol	Location	Description
Gulf Coast Network Monitoring Shoreline Position at Gulf Coast Network Parks – Protocol Implementation Plan (2017)	Gulf Coast	The Gulf Coast Inventory & Monitoring Network (GULN) Protocol Implementation Plan describes the implementation of the Northeast Coastal and Barrier Network (NCBN) Ocean Shoreline Position Protocol in the Gulf Coast Network.
Southeast Coast Network Standard Operating Procedure – Conducting the GPS Shoreline Survey (2021)	Southeast Coast	The Standard Operating Procedure - Conducting the GPS Shoreline Survey describes the process for conducting GPS shoreline survey monitoring based on the NCBN Geomorphological Monitoring Protocol.
Southeast Coast Network (SECN) Monitoring Coastal Shoreline Change in Southeast Coast Network Parks – Protocol Implementation Plan (2018)	Southeast Coast	The Southeast Coast Inventory & Monitoring Network (SECN) Protocol Implementation Plan describes the implementation of the NCBN Ocean Shoreline Position Protocol in the Southeast Coast Network.
Golden Gate National Recreation Area Shoreline Change Shoreline Monitoring Protocol (2020)	Golden Gate National Recreation Area	This network will monitor shoreline change by determining changes in shoreline position across years, as well the type of shoreline change. Staff will also identify areas of highly dynamic shorelines and areas of accretion and erosion. Global Positioning System (GPS) and Geographic Information System (GIS) equipment is used to measure changes in shoreline positions.

Protocol	Location	Description
Arctic Network of Parks Coastal Change Protocol Shoreline Monitoring Protocol (2012)	Arctic	This protocol provides background, a summary of historic coastal change, methodological rationale, data and operational guidelines, and stepwise procedures for geospatial analysis of coastal change (specifically, erosion and accretion of the shoreline). Future research should obtain new imagery, make sure it is properly orthorectified for required accuracy, and then: build a spatial database; digitize new shorelines; assess errors; analyze the shorelines using the USGS Digital Shoreline Analysis System (DSAS); and then synthesize and present the results as tables, graphs, and maps in reports.
NCBN Geomorphological Monitoring Protocol: Part I – Ocean Shoreline Position (2010); NCBN Geomorphological Monitoring Protocol Part II – Coastal Topography (2012); Geomorphological Monitoring Protocol (Part III) - Coastal Landform Elevation Models Standard Operating Procedures	Northeast Coast	The Geomorphological Monitoring Protocol (Part I) provides the methodology to track the spatial position of the neap tide, high tide swash line under conditions of temporal sampling to monitor the direction and magnitude of shoreline change. The Coastal Topography Monitoring Protocol (Part II) is an established local, long-term monitoring program that provides metrics (SI, meters) to help understand the processes that are driving coastal change of beaches, dunes, and bluffs within the parks. The Geomorphological Monitoring Protocol (Part III) - Coastal Landform Elevation Models Standard Operating Procedures provides the 10 SOPs within the NCBN Geomorphological Monitoring Protocol.

Note – This table references the Northeast Coastal and Barrier Network (NCBN).

Existing and Past Monitoring Resources and Examples

In addition to NPS coastal monitoring protocols, a cursory review was performed of existing and past monitoring guidance, programs, and resources based within and outside of the Great Lakes Region. Table 5 provides a snapshot of information in a wide variety of categories which include, but are not limited to, ongoing monitoring programs at specific sites, online clearinghouse sites for geographic areas, applications completed or under development, and past historical resource compilations.

Table 5. Coastal Monitoring Tools, Data, and Programs

Tools, Data, and Programs	Owner/Operator	Location	Relevant to NPS Great Lakes Monitoring?	Description
Foundations for Future Restoration Actions: Apostle Island Monitoring	USGS	Chequamegon Bay, Lake Superior	Yes	A time-lapse camera provides images every 15 minutes to the public and researchers. Winds and seiche affect currents and stratification in the bay. Data are being used by NOAA, USFWS, NPS, Northland College, WDNR, and other agencies in the Chequamegon Bay Partnership to provide temporal continuity to discrete samples, surveys, and modeling.
Science in the Great Lakes	USGS	Great Lakes Region	Yes	Clearinghouse website: USGS has developed the Science in the Great Lakes (SiGL) Mapper, a data-discovery tool that captures information about a wide range of scientific activities and provides details on how to access associated data and products. A centralized location where researchers and managers can identify relevant scientific activities and access fundamental information.
Technical Memorandum 2010 National Coastal Condition Assessment Great Lakes	The Great Lake States, USEPA	Great Lakes Region	Partially	Water quality and sediment study.
US Great Lakes Shoreline Mapping Plan Developed by the National Oceanic and Atmospheric Administration and US Geological Survey	NOAA, USGS JOMAR	Great Lakes Region	Yes	Plan from 1990 to produce up-to-date large-scale maps of the impacted coastal and nearshore regions essential to establish setback limits, guide planning, and safe development, and protect the environment. The plan contains a schedule to update existing maps and develop new ones, where needed, that depict the geographic and geologic framework of the Great Lakes shorelines, the areas of change, and some of the processes responsible for those changes.
Lake Level Viewer	NOAA	Great Lakes region	Yes	The data and maps in this tool illustrate the scale of potential flooding or land exposure at a given water level, not the exact location. They do not account for erosion, subsidence, or future construction. Water levels are shown as they would appear during calm conditions (excludes wind-driven changes in water levels). The data, maps, and information provided should be used only as a screening-level tool for management decisions.
The Great Lakes Shoreviewer	Michigan Office of Great Lakes, NOAA	Great Lakes coastline in Michigan	Yes	The Great Lakes Shoreviewer is a risk assessment and climate adaptation planning tool. It provides stunning, oblique-angle color photography plus multiple layers of additional analysis for prioritized sections of the Great Lakes coastline in Michigan (Lake Superior, Lake Michigan, Lake Huron).
Lakes Michigan-Huron Shoreline Throughout Time	NOAA, Michigan Department of Environment, Great Lakes and Energy	Great Lakes region in MI	Yes	Aerial photos for several years. Documents Michigan Great Lakes shorelines throughout time.
Monthly Bulletin of Great Lakes Water Levels	USACE	Great Lakes region	Yes	Monthly Hydrology graphs for Great Lakes. Water levels for the previous year and the current year to date are shown as a solid line on the hydrographs. A projection for the next six months is given as a dashed line. This projection is based on the present condition of the lake basin and anticipated future weather.
High-Risk Erosion Areas and Critical Dune Areas	Michigan Department of Environment, Great Lakes and Energy	MI figures by county	Yes	EGLE staff conducted the initial recession rate research of coastal counties between 1980 and 1986; during that time, they identified high-risk erosion areas in 36 of 41 coastal counties. Recession rates change over time as water levels fluctuate and coastal conditions change. The recession rate research is ongoing and often results in changes to the locations of high-risk erosion areas along the shoreline.

Tools, Data, and Programs	Owner/Operator	Location	Relevant to NPS Great Lakes Monitoring?	Description
California Coastal Records Project	Private	California Pacific Coast	Yes, as an example effort	Over 96,000 photographs (totaling over 509GB) of the California coast are now online, covering from the Oregon Border (42N latitude) to the Mexican Border (32.5N latitude), except for the Vandenberg AFB restricted area. An additional 5833 images from 1972, 8000 images from 1979, 2890 images from 1986, 4173 images from 1987, 1074 images from 1989, and 2407 images from 1993 are now online.
Regional Coastal Monitoring Data	Florida Department of Environmental Protection	Florida	Yes, as an example effort	Collection of data sampled from 2015-2017 to examine the relationships among soils, vegetation, and composition of the microbial communities along a dunal chronosequence- a series of coastal dunes that formed at different times, where the younger dunes are near the lake or seashore and the older ones are inland.
Hawaii Beach Monitoring Program	USGS	Hawaii	Yes, as an example effort	The overall objectives of the Hawaii Coastal Erosion Study are to document the recent history of shoreline change in Hawaii and to determine the primary factor(s) responsible for coastal erosion in low-latitude environments.
IRMA NPS Data Store	NPS	Canaveral National Seashore, Cape Hatteras National Seashore, Cape Lookout National Seashore, Cumberland National Seashore, Fort Matanzas National Monument, Timucuan Ecological and Historic Preserve	Yes, as an example effort	Measure the position of the ocean and sound side shorelines. Identify coastal erosion hotspots in ocean and sound side shorelines within network units
Digital Shoreline Analysis System (DSAS)	USGS	Florida	Yes, as an example effort	The Digital Shoreline Analysis System (DSAS) v5.0 software is an add-in to Esri ArcGIS desktop 10.4-10.6 that enables a user to calculate rate-of-change statistics from multiple historical shoreline positions. It provides an automated method for establishing measurement locations, performs rate calculations, provides the statistical data necessary to assess the robustness of the rates, and includes a beta model of shoreline forecasting with the option to generate 10 and/or 20-year shoreline horizons and uncertainty bands. A user-friendly interface guides the user through the major steps of shoreline change analysis. An in-depth user guide and video tutorials are available that provide detailed instruction on the DSAS workflow including how to define a reference baseline for measurements, the steps needed to generate automated measurement transects and metadata based on user-specified parameters, guidelines on how to manually add or edit existing transects, and an explanation of the visualization options to display calculated rates of shoreline change and other statistical information.
SurfRCaT	St. Petersburg Coastal and Marine Science Center	Software	Yes	The Surf-camera Remote Calibration Tool (SurfRCaT) is a Python-based software application to calibrate and rectify images from pre-existing video cameras that are operating at coastal sites in the United States.
Cliff Feature Delineation Tool and Baseline Builder Tool, Version 1.0 User Guide	USGS	California coast	Yes	The Cliff Feature Delineation Tool (CFDT) and the Baseline Builder Tool are designed to increase the efficiency of deriving seacliff features from remote sensing datasets by utilizing an automated, quantitative approach that eliminates traditional interpretive methods and ensures reproducibility.
Louisiana Coastal Zone Sediment Characterization	USGS	From the Western Chenier Plain to the Chandeleur Island in Louisiana	Yes, as an example effort	Physical properties of the samples (sediment grain size and sorting) were measured and provided in data reports to CPRA. Additional samples collected by the USGS from around Breton Island in 2014 and 2015 supplemented the 2015–2016 BICM data to complete the coastwide dataset. This report compares the results of the 2008 and 2015–2016 sedimentologic analyses and documents changes in composition (percent sand) and mean sediment grain size between the two time periods. At most sample sites, differences in mean grain size varied by less than $\pm 0.25 \phi$. The largest changes occurred at sites located near tidal inlets or along rapidly eroding shorelines.

Tools, Data, and Programs	Owner/Operator	Location	Relevant to NPS Great Lakes Monitoring?	Description
Bureau of Economic Geology	Texas Coastal Management Program and NOAA	Texas Gulf Coast	Yes, as an example effort	The goal of the Texas Shoreline Change Project is to develop and maintain a modern shoreline monitoring and change-analysis program that will help guide coastal-erosion and storm-hazard-mitigation projects along Texas' Gulf and bay shorelines.
Coastal Monitoring & Analysis Program (CMAP)	State of Washington Department of Ecology	Washington Marine Coast	Yes, as an example effort	Coastal Monitoring & Analysis Program (CMAP) conducts surveys to map and monitor Washington's marine coastline.
Coastal Monitoring Program	NCSU Department of Civil, Construction, and Environmental Engineering and USFWS	Pea Island National Wildlife Refuge	Yes, as an example effort	This report presents detailed monitoring data for the 2018 study year. Conditions throughout the year are compared to conditions in the prior year (2017) and baseline conditions (2010).
South Atlantic-Gulf and Mississippi-Basin Protocol Framework for Coastal Wetland Elevation Monitoring	USFWS	USFWS Wildlife Refuges of the South Atlantic-Gulf and Mississippi-Basin	Yes, as an example effort	This regional protocol provides a framework for monitoring surface elevation, accretion, and porewater salinity in wetlands on coastal USFWS Wildlife Refuges of the South Atlantic-Gulf and Mississippi-Basin.
Vegetation Plot Data of the Coastal Wetland Elevation Monitoring Sites on National Wildlife Refuges in the South Atlantic Geography.	USFWS	20 CWEM sites across 18 refuges within the SALCC	Yes, as an example effort	Historical data using a framework for monitoring surface elevation, accretion, and porewater salinity in wetlands on coastal USFWS Wildlife Refuges of the South Atlantic-Gulf and Mississippi-Basin.
Drone-Based Citizen Science for Monitoring Coastal Hazards throughout the Great Lakes of North America (In Progress)	NSF	Great Lakes Region	Yes	Utilizing citizen science to help document the impacts of coastal hazards of large spatial scales both before and after the event. The goal is to incorporate citizen drone-based monitoring into the coastal area (DEMs/orthomosaic images).
Culvul: Culvert Vulnerability Assessments with the Wisconsin Coastal Management Data Infrastructure	Wisconsin State Cartographer's Office, Department of Geography	Wisconsin	Yes	Developing hydro-enforced digital elevation models (heDEMs) for statistical flood vulnerability analyses.
The USGS Coastal National Elevation Database (CoNED): Integrated Topobathymetric Models and Applications for US Coastal Zone	USGS	Select regions around the U.S. coast (Northern Gulf of Mexico, the eastern seaboard from New England to North Carolina, California, the Pacific Northwest, the North Slope of Alaska, and select central Pacific islands and atolls)	Yes, as an example effort	Develops enhanced topographic and bathymetric datasets for coastal areas, examples were given for Lake Michigan.
Creating Seamless Topo-Bathymetry Maps to Study the Dynamic Nearshore of the Great Lakes' "White Ribbon"	Michigan State University	Illinois Beach State Park	Yes	White ribbon refers to the region nearshore that is hard to survey with LiDAR and vessel methods, it is where hydrodynamic parameters interact with the shoreline. Created topobathy for Illinois Beach State Park by collecting onshore data, and offshore data with an RTK/single beam.
Coastal Benthic Mapping: A Data Fusion Approach in Western Lake Michigan	USACE Ecosystem Management and Restoration Research Program; Michigan State University	Western Lake, Michigan	Yes	The project aims to use existing and new geospatial technologies to improve the understanding of bottom type variation in the nearshore zone as a critical habitat parameter.
Coastal Wetland Monitoring Program (CWMP)	Funding provided by the Great Lakes National Program Office under USEPA, grant number 00E01567	Great Lakes Region	Not likely	The Great Lakes Coastal Wetland Monitoring Program (CWMP) is a collaboration of federal agencies, states, and academic partners in both the United States and Canadian sides of the Great Lakes. This basin-wide, collaborative approach allowed for major coastal wetlands throughout the entire Great Lakes to be sampled on a rotating basis over 5 years (2011-2015) using a comprehensive, standardized procedure. Data collected by the CWMP can be used to determine the health of Great Lakes coastal wetlands and help managers make better-informed decisions. Five taxonomic groups (Amphibians, Birds, Fish, Macroinvertebrates, and Plants) were sampled and surveyed over the 5 years.

Tools, Data, and Programs	Owner/Operator	Location	Relevant to NPS Great Lakes Monitoring?	Description
Microbial Communities Across a Successional Gradient at Indiana Dunes National Park, 2015-2017	Great Lakes Science Center	Indiana	Not likely	Collection of data sampled from 2015-2017 to examine the relationships among soils, vegetation, and composition of the microbial communities along a dunal chronosequence- a series of coastal dunes that formed at different times, where the younger dunes are near the lake or seashore and the older ones are inland.
Great Lakes Invasive Plant Management Plan/Environmental Assessment	NPS	Great Lakes region: Apostle Islands National Lakeshore, Grand Portage National Monument, Ice Age National Scenic Trail, Indiana Dunes National Lakeshore, Isle Royale National Park, Mississippi National River and Recreation Area, Pictured Rocks National Lakeshore, Sleeping Bear Dunes National Lakeshore, St. Croix National Scenic River, and Voyageurs National Park.	Not likely	The National Park Service (NPS) is planning to prepare an Environmental Assessment (EA) for a Great Lakes Invasive Plant Management Plan (IPMP) for ten parks located in the Great Lakes region. This IPMP/EA will be intended to provide strategies for park staff to manage terrestrial and emergent wetland invasive plants on both NPS and NPS-managed lands within the designated boundaries of the 10 Great Lakes parks.
Nearshore conditions in the Great Lakes national parks: A baseline water quality and toxicological assessment	NPS	Apostle Islands National Lakeshore, Indiana Dunes National Park, Isle Royale National Park, Pictured Rocks National Lakeshore, Sleeping Bear Dunes National Lakeshore	Not likely	Water quality and sediment study from the Great Lake national parks in conjunction with the EPA National Coastal Condition Assessment program (NCCA). The results of the survey found that water quality was generally good within park boundaries, as assessed using NCCA criteria, and did not differ significantly from the larger Lakes Michigan and Superior with one exception.

Acronyms – JOMAR: Joint Office for Mapping and Research; NCSU: North Carolina State University; NOAA: National Oceanic and Atmospheric Administration; NPS: National Park Service; NSF: National Science Foundation; USACE: US Army Corps of Engineers; USEPA: US Environmental Protection Agency; USFWS: US Fish and Wildlife Service; USGS: US Geological Survey

Next Steps

Upon receipt of comments on this memo, it is recommended that a call be scheduled with NPS regional and park staff to:

- Further review and discuss the information provided in table 2.
- Further discuss and better acquaint NPS staff with existing resources noted in tables 3 and 4.
- Discuss park-specific circumstances.
- Address any outstanding questions.

In addition, a Phase 2 memorandum may be pursued to produce a general guidance document covering all Great Lake units, and/or a checklist/template that each park might use as they develop their own monitoring programs.