Great Lakes Beach Resiliency Guide

Samuel Myers Park, Racine, Wisconsin
Photo by Julie Kinzelman

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Introduction

Coastal beaches in Wisconsin are vulnerable to numerous stressors including land use and human use impacts as well as intense storms, erosion, wave energy, flooding, and Great Lakes water levels hazards. These stressors can impact public and private properties, threaten the health of coastal resources and infrastructure, affect public health and safety, and impact the economic well-being of shoreline communities. Building and enhancing community and coastal resource resilience can assist in lessening the impacts of multiple stressors.

Coastal resilience, as a concept, is the ability to resist, recover, and adapt to stressors such as erosion, flooding, habitat disruptions, pollution, and climate change. Integrating coastal resilience requires assessments of likely stressors, mitigation planning, implementing projects or programs designed to reduce risks, and continual monitoring so that adjustments can be made as needed.

Beaches are a valuable resource to coastal communities. Beaches play an integral role in the health of coastal communities by providing ecosystem services and habitat, equitable public access to community resources and recreation, and contributing to the local economy. To residents and tourists alike, beaches are destinations and create a sense of place.

Recognizing the importance of beaches to coastal communities, **the objective of this document is to provide a blueprint to communities and stakeholders on how to plan, build, and maintain beaches that are resilient to coastal stressors**. This includes:

- Understanding the importance of beaches
- Identifying stressors and hazards
- Assessing beach conditions
- Planning and preparing for resilience
- Understanding the importance of community engagement
- Reviewing technical and financial resources
- Implementing resilient actions and practices
- Monitoring and adaptive management of site

This project is part of a larger initiative in Southeastern Wisconsin to improve and enhance communities' resiliency to coastal hazards by developing a community of practice, mapping shoreline recession, developing guidance documents, assessing risks and vulnerabilities, and providing technical and financial assistance for coastal resilience planning efforts. The collaborative project, between the Wisconsin Coastal Management Program, University of Wisconsin Sea Grant, University of Wisconsin-Madison Civil and Environmental Engineering, and Southeastern Wisconsin Regional Planning Commission, is funded by the Wisconsin Coastal Management Program and the National Oceanic and Atmospheric Administration, Office for Coastal Management, Regional Coastal Resilience Grants Program.

The *Great Lakes Beach Resiliency Guide* is an effort under this grant to develop resilient-specific beach guidance for coastal communities. The guidance was developed in cooperation by a diverse team of individuals from the University of Wisconsin Sea Grant, Wisconsin Coastal Management Program, University of Wisconsin-Madison Civil and Environmental Engineering, Wisconsin Department of Natural Resources, University of Wisconsin-Oshkosh, University of Wisconsin-Parkside, City of Racine Public Health Department, and Northwestern University.

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Chapter 1

Beach Resilience

Beach resilience is the ability to – by nature or design – plan for, respond to, recover from, and adapt to both natural processes and human activities without losing the desired attributes of a beach. Through the process of adaptive management, beach resilience can be enhanced. Well planned and managed beaches can adapt to the impacts of both natural processes and human activities. They are also able to recover from stressors more readily and enhance coastal habitat and access opportunities. Resilience, however, will require planning and continual assessment as challenges present themselves.

Adaptive management has been used in the Great Lakes to build resilience to changing water levels and precipitation events as well as other stressors. The Samuel Myers Park Restoration Project is an example of what can be achieved through investments in an adaptive management approach. The City of Racine Public Health Department utilized adaptive management to respond and adapt to coastal stressors that resulted in unanticipated damage during the restoration of the site. For example, coastal storms overtopping a breakwater, that was intended to mitigate the impacts of waves, resulted in the failure of the constructed wetland bounding structure adjacent to it. In response, the City of Racine Public Health Department iteratively changed their engineering design and management plan to handle higher water levels and larger storm events. In doing so, they were able to mitigate and restore Samuel Myers Park. Chapter 4 covers this case study in more detail.

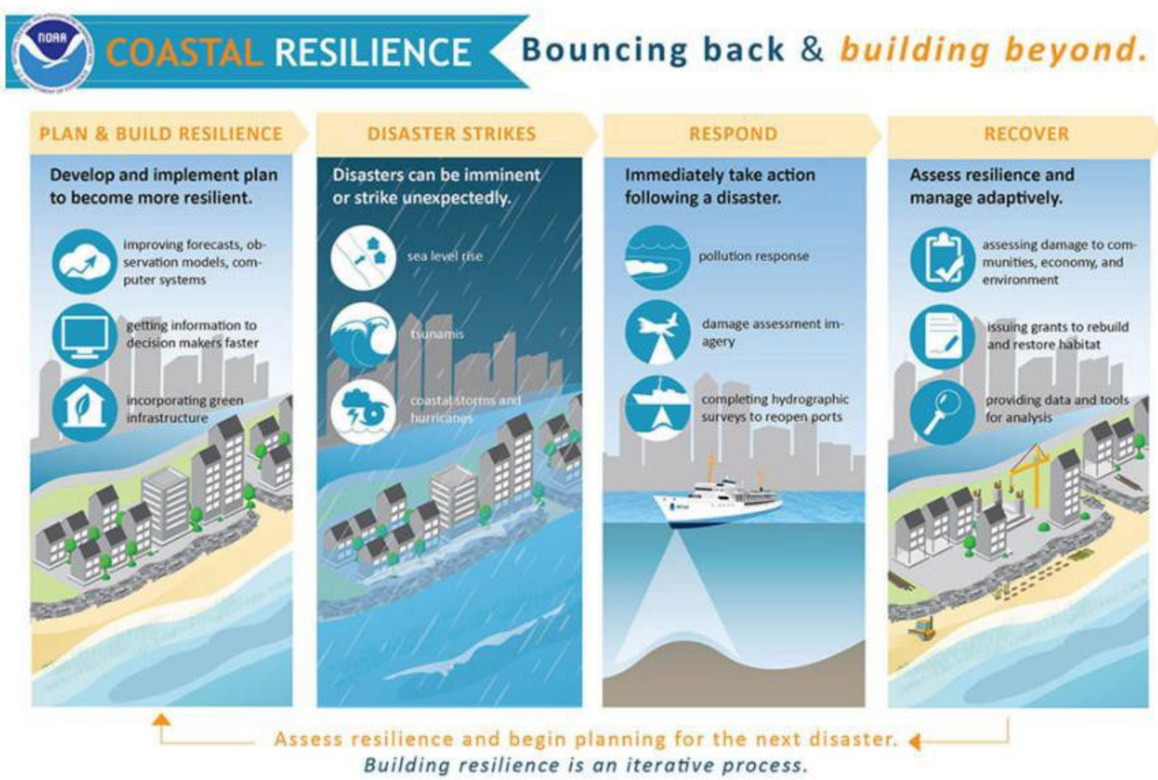


Figure 1.1. Each of the panels represent a different component of building resilience in a coastal community. (NOAA National Ocean Service: https://oceanservice.noaa.gov/ecosystems/resilience/)

Figure 1.1 describes marine specific hazards (e.g., sea level rise, tsunamis, and hurricanes) but the actions required to build resilience translate well to Great Lakes communities. An iterative planning, response (e.g., to coastal storms or lake level rise), recovery and adaptation framework will ensure that the ecosystem services provided by beaches are sustainable. The National Sea Grant College Program defines sustainability as "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. Sustainability has three equally weighted components: economic, social and environmental." Taking a stepwise approach, as described below, can assist coastal communities in achieving a sustainable, resilience beach.

> *Planning –* gathering data and information about the beach, identifying missing data that needs to be collected, assessing the coastal hazards and stressors impacting the site, and potential mitigation options to develop a plan to improve the beach's ability to withstand and bounce-back from the impacts. Plans should be developed with community engagement and support.
>
> *Response –* taking action during and after a hazard or stressor, gauging impacts to the beach by monitoring and assessing the site (physical, chemical, biological, economic, and social).
>
> *Recovery –* using data analysis and site assessments to develop projects and put plans into action to address damage from coastal hazards and stressors. Mitigation should be incorporated when/where possible.
>
> *Adaptation –* iteratively tweaking design or management plans to improve how the beach withstands and recovers from coastal hazards and stressors.

Adaptive management*,* discussed further in Chapter 3*,* is a planning process that provides a structured, iterative approach for improving resilience actions through long-term monitoring, modelling, and assessment of current and alternative strategies. The following sections of this guide will delve further into the components that need to be considered during the planning process as they will impact the development of management plans.

Throughout this guide, we look at building resilience through the lens of sustainability. To support sustainable beach management, it is important to holistically consider the ecosystem services beaches provide, the stressors that can impact them, and the management options available to build resiliency in the face of anthropogenic and environmental changes.

Why Beaches Matter

As an integral component of the natural environment, beaches provide a wealth of ecosystem services. Ecosystem services refer to a variety of benefits that humans derive from the natural environment, either directly or indirectly through their contribution to goods and services. Ecosystem services also include less tangible services like the regulation of natural processes, such as flood control, and supportive services, such as nutrient cycling, which maintain the balance of various processes necessary for life on Earth. Since much of what happens on the land can impact water resources, the results of regulatory beach monitoring can act as a sentinel of how well we are safeguarding our water resources and assist with identifying watershed issues (Table 1.1).

Economics

Historically, development has occurred along water bodies and shorelines to utilize the resources provided by aquatic environments including food, water, hydropower, and transportation. While these resources continue to generate revenue in the present day, beaches and water recreation are foundational to the development and economic support of many coastal communities. Sources of direct economic benefit also include tourism, which can support a large hospitality industry. For example, beachfront property is highly desirable to both private homeowners and developers. Indirect economic benefits contribute to quality of life and create a sense of place; attributes which improve economic welfare by contributing to a higher level of prosperity and standard of living for affected individuals or groups of individuals. Healthy and well-maintained beaches can prevent costs associated with avoided damages, or damages that would have occurred in a degraded environment. For example, the ecosystem services provided by a well-managed beach can help reduce waterborne illnesses or increase a beach's resistance to erosion. Beaches also possess non-use value such as the preservation of critical habitat due to their existence as natural spaces.

Recreation

Beaches provide a variety of active and passive recreational opportunities that can contribute to both the economic and social well-being of the communities in which they are located. Well maintained beaches are sought after sites for hosting revenue generating events, such as triathlons, professional beach volleyball tournaments, and boating festivals. They are also seen as destinations, creating a tourism economy. For community members lacking the financial resources to travel, pay for health club memberships or even air conditioning, beaches can provide a welcome respite from the heat of the summer and a low or no cost option for recreation. Active recreation can have numerous public health benefits, such as combatting obesity and reducing stress.

Habitat

Beaches are natural components of inland and coastal shorelines formed by the deposition of sediments. They possess characteristic plant communities, which serve as home to a variety of fauna, a stopover for migratory birds and spawning grounds for fish. Naturalized shorelines can contribute to genetic diversity of species that establish and live there as well as enhance stormwater infiltration, reduce carbon footprints, and provide protection from extreme weather events and cyclical lake level elevation changes.

Culture

The cultural and spiritual benefits derived from water resources are important aspects of both identity and economic prosperity. Water and culture are linked in that culture defines a person's way of life. Most cultures have deeply rooted spiritual beliefs, some of which are directly tied to water. Thus, access to and the quality of shorelines takes on a meaning over and above the direct ecosystem services beaches may provide such as recreation.

Ecosystem Services / Important Beach Attributes

Holistically managing a beach can increase its resilience to coastal stressors and anthropogenic influences as well as the value it provides to the community. Table 1.1 shows the physical, chemical, biological, and landscape attributes that are important for a beach to be able to provide the diverse municipal, environmental, recreational, educational, and cultural services listed in each use category. This table is a checklist for communities and stakeholders to indicate the attributes that should be measured, monitored, or managed to support the provision of ecosystem services at a beach. The table can be read by looking vertically down the "human use" categories to find a category of interest or concern and then horizontally across the “attribute” categories to determine which attributes are relevant to that particular use category. The presence of a check mark indicates that the attribute is relevant. For example, recreational uses such as sunbathing are impacted by physical attributes like beach width and the viewshed. The table can also be read in reverse, starting with an attribute to find the uses for which it is relevant. For example, beach width can impact several recreation opportunities. Different ecosystem services may be desired depending on beach type and purpose; however, building beach resiliency by improving certain beach attributes can increase the number of ecosystem services a beach is able to provide. Table 1.1 can be used as a visioning and planning tool to determine the current state of beach management and what gaps may need to be filled as well as a communication tool to a stakeholder base about the benefits of addressing certain attributes at the beach.

The ecosystem services produced by beaches are impacted by environmental and anthropological stressors that can degrade the health and resilience of a beach. These stressors include changes in the physical, biological, and chemical composition of the terrestrial and aquatic environments that comprise the beach (Chapter 2). Incremental or dramatic alterations at the beach and in surrounding area can compromise a beach’s economic potential as well as the social and cultural value placed on these spaces. Thus, identifying and assessing contamination sources and drivers of physical degradation are necessary components of beach management.

Beach Stressors

As previously stated, stressors include changes in the physical, biological, and chemical composition of the terrestrial and aquatic environments that comprise the beach because of natural environmental processes and anthropological influences. The stressors that can impact the resilience of a beach include surrounding land use, watershed and tributary inputs, nearby infrastructure, wave climate, water level fluctuations, and neighboring shore protection structures.

The importance of these stressors to an individual beach are dependent upon factors like the beach’s surrounding community, geographic setting, and watershed characteristics. These factors can dictate beach usage as well as nearby land use and infrastructure. For example, beaches in an urban setting may have greater usage pressures compared to beaches in a more rural or semi-urban setting. However, larger community size surrounding a beach can also provide more resources to build resilience to these stressors. In Southeastern Wisconsin, the shoreline is largely residential development, ranging from high density urban areas as seen in Milwaukee, to low density rural areas as seen in Ozaukee County. Beach geographic environments vary from the open coast, estuary/bay, deltaic, and riverine settings, all of which see differences in wave energy, water level variations, and watershed inputs. Recognizing the stressors affecting a beach is an important step in enhancing resilience.

Water Levels

Description

In the Great Lakes, water levels naturally fluctuate seasonally, from year-to-year, and over decades. Fluctuations in water levels are primarily driven by climactic influences such as precipitation, runoff, and evaporation. In an average year, Lake Michigan water levels vary seasonally by approximately one foot, from a peak in the summer to a nadir in the winter, though every year is different. Water levels also vary from year-to-year. Lake Michigan water levels have a historic range of 6.4 feet from the record high (1986) to the record low (2013). Water level fluctuations are important for the health of Great Lakes natural ecosystems and can help control invasive species.

Table 1.1. Beach Attributes Important for the Provision of Ecosystem Services

To read the table, look vertically down the "human use" categories to find a category of interest or concern. Then look horizontally across the "attribute" axis to determine which attributes are relevant to that use category. The presence of a check mark indicates that the attribute is relevant.

	Physical Attributes			Chemical Attributes			Biological Attributes					Landscape Attributes		
Human "Use" Categories	*Temperature*	*Conductivity*	*Clarity*	*Dissolved Oxygen*	*Chemicals*	*Odor*	*Pathogens*	*Ecosystem Health/ Biotic Integrity*	*Fish*	*Wildlife*	*Plants*	*Human "Experience Shed" Aesthetics*	*Beach Width*	*Erosion*
Recreation*														
Viewing			✓			✓		✓	✓	✓	✓	✓	✓	✓
Passive Recreation[1]			✓			✓	✓					✓	✓	
Swimming/Water Sports	✓		✓		✓	✓	✓		✓	✓	✓	✓		
Terrestrial Sports[2]			✓			✓	✓					✓	✓	✓
Fishing	✓		✓	✓	✓	✓		✓	✓			✓		✓
Boating/Paddle Boarding	✓		✓			✓	✓		✓	✓	✓	✓		
Local Units of Government														
Drinking Water Source		✓	✓		✓	✓	✓		✓	✓	✓	✓		✓
Coastal Erosion Control			✓					✓	✓	✓	✓	✓	✓	✓
Economic Development			✓			✓	✓		✓	✓	✓	✓	✓	✓
Habitat														
Avoided Damages[3]			✓		✓	✓	✓					✓		✓
Existence (Non-use Value)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education and Research														
Outdoor Classroom/Public Information	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Functional Ecosystem Analysis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Culture														
Spiritual			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Ceremonial			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Environmental Justice	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

* – tied to economic benefits
1 – e.g. sunbathing
2 – e.g. volleyball, walking
3 – e.g. waterborne illness

Impacts

High water levels can result in inundation of portions of the beach while also allowing waves to erode higher up on the beach. Low water levels, however, can increase beach width. During low water level periods, development may encroach closer to the water line on this temporarily exposed beach, leading to issues when water levels naturally rise again. Exposed beaches may also be susceptible to increases in growth of vegetation, like invasive Phragmites.

Where to Learn More

- **NOAA Lake Level Viewer** (https://coast.noaa.gov/llv/)
  Interactive map that visualizes the extent of rising and falling water levels along the shores of the Great Lakes from six feet above average lake levels to six feet below average lake levels.
- **USACE Great Lakes Water Level Information** (https://rb.gy/xyk7co)
  Webpage with official water level conditions, data, and forecasts for the Great Lakes.
- **NOAA Great Lakes Coastal Forecasting System** (https://www.glerl.noaa.gov/res/glcfs/)
  Nowcasts and forecasts about a variety of Great Lakes conditions
- **Water levels and buoys** (https://iiseagrant.org/buoys/how-buoys-help/)
  Information on buoys and how they can help measure a variety of water and sand conditions.

Wave Climate

Description

Waves are a natural force that can erode beach sand and move sediment in the nearshore. Wave height and direction are determined by factors like the fetch distance, or the length of water surface exposed to the wind; the wind speed; and the duration of the wind blowing from roughly the same direction. As waves approach the shore, they change direction due to refraction off the lake bottom and release energy by breaking before the strike the shore. The wave climate, which is dependent on the site geography and the storms experienced, describes the seasonal and annual distribution of wave heights, periods, and directions.

Impacts

Large storm waves can erode beach sand, causing a beach to narrow. These erosive storm waves typically occur in the fall and winter. Gentler waves in the summer can redeposit sand onto the beach. The wave climate also dictates how sediment is transported along the coast, with the dominant direction of sediment transport typically following the dominant wave direction.

Where to Learn More

- **USACE Wave Information Study** (http://wis.usace.army.mil/)
  Wave climatology data (height and direction) available for the entire U.S. coastline, including the Great Lakes.
- **NOAA Great Lakes Coastal Forecasting System** (https://rb.gy/tmftsz)
  Current wave forecast for the Great Lakes.

Sediment Transport

Description

Beaches are built and maintained by the transport of sediments like sand and gravel in the nearshore area by waves and currents. Waves can move sediment both on and off a beach. Erosive storm event waves move sediment off beaches and out to nearshore bars while calmer waves can deposit sediment onto beaches. Sediment is also moved along the shore by currents. Littoral cells are geographic units along the coast where sediment transport along the coast is contained. The boundaries of littoral cells are often physical barriers to sediment transport along the coast, like harbors and headlands. Within these cells, the complete cycle of sedimentation happens including sediment sources, transport paths, and sinks.

Impacts

Sediment transport dynamics will naturally remove and add sediment to beaches over time. A typical annual cycle of sediment transport will see sediment removed by erosive winter storms and replaced by gentler summer waves. Deficits in sediment transport along the coast will lead to long term erosion. Erosion can be worsened in downdrift areas by interruptions to the sediment transport system caused by natural headlands, dredging, and coastal structures. Beach nourishment can add sediment back into the nearshore transport system, though this added sediment should be expected to erode over time if sediment transport imbalances remain.

Where to Learn More

- **USGS Sediment Transport in Coastal Environments** (https://rb.gy/4adzgj)
  Ongoing sediment transport project at the USGS to help beach managers.
- **Great Lakes Regional Sediment Team** (https://greatlakesrsm.net/)
- **NPS Coastal Processes Series** (https://rb.gy/suvthl)
  Background on sediment transport and deposition.
- **Coastal Hydrodynamics and Transport Processes Wiki** (https://rb.gy/0narfj)
  Background on sediment transport.

Shore Protection Structures

Description

Shore protection structures are typically constructed to slow erosion of the shoreline but can also negatively affect neighboring stretches of shoreline like beaches. Different types of shore protection structures include (i) shore parallel structures that run along the coast such as revetments and sea walls (ii) shore perpendicular structures that intersect the beach such as groins and jetties and (iii) offshore structures located in the open water that block or trip waves such as breakwaters.

Impacts

Shore protection structures can accelerate beach erosion at neighboring properties by interrupting the transport of beach-building sediment along the coast, preventing natural erosion from protected lands, and modifying nearshore wave dynamics. While any coastal structure can have these types of impacts, the primary impacts of shore protection structure types are (1) shore parallel structures reflect waves and redirect the wave energy to neighboring shorelines which can increase erosion, (2) shore perpendicular structures trap sediment that flows along the shore which starves adjacent beaches of sediment, and (3) offshore structures primarily reflect and redirect wave energy and may eventually end up trapping sediment behind the structure.

Where to Learn More

- **Great Lakes Shore Protection Structures and Their Effects on Coastal Processes** (https://rb.gy/cw5zwn)
  Detailed fact sheet describing different types of shore protection structures and their potential impacts, both positive and negative, on the shoreline.
- **Wisconsin Shoreline and Oblique Viewer** (http://floodatlas.org/asfpm/oblique_viewer/)

Inventory of coastline photos of Wisconsin's Great Lakes coast. Can be used to view impacts of lake levels and shoreline structures on erosion.

- **NOAA Digital Coast 'U.S. Great Lakes Hardened Shorelines Classification 2019'** (https://rb.gy/qt2xsj)
  Vector data containing information on hardened shorelines in the Great Lakes. Shoreline segments are classified as either natural or artificial.

Watersheds and Tributary Loading

Description

Tributaries are one, but not the only, way that pollutants, nutrients, sediment, bacteria, and debris are conveyed from relatively distant sources within a watershed to a beach. The types of contaminants that may be conveyed through a watershed to a beach depend on land use within the watershed. Tributaries and other conduits may also carry sediment and debris from far away areas to the beach. In some instances, dangerous currents may also develop near tributary mouths.

Impacts

Tributaries and other conduits can convey sediment, nutrients, contaminants, and debris from within the watershed to the beach, resulting in water quality impairment and public safety concerns. Sediment and debris may need to be to be cleared to improve water quality or preserve recreational uses and public access.

Where to Learn More

- **NOAA C-CAP Regional Land Cover and Change** (https://coast.noaa.gov/digitalcoast/data/ccapregional.html)
  Provides information on types of land cover in coastal areas of the U.S.

Runoff and Discharge

Description

Point and non-point stormwater runoff or discharge to a beach or lake can be conveyed through upland infrastructure like roads, culverts, and storm sewer pipes and outlets. Direct runoff from impervious surfaces can reach the lake and beach area with little filtration.

Impacts

Infrastructure can convey sediment, nutrients, and contaminants through point and non-point sources to the beach to cause water quality issues and lead to beach closures for exceedances. The localized impact caused by runoff and discharge reaching the beach depends on land use, condition of stormwater infrastructure, and human activity. See the next stressor for more information.

Where to Learn More

- **The EPA Beach Technical Resources** (https://www.epa.gov/beach-tech/sources-beach-pollution)
  See section on wet weather discharges.
- **NDRC 'Beach Pollution 101'** (https://www.nrdc.org/stories/beach-pollution-101)
  See information on wet weather discharges for more details about beach pollution.
- **Wisconsin Beach Health** (https://dnr.wisconsin.gov/topic/Beaches)
  A webpage that provides information on beach health as related to *E. coli*, bacteria that can force the closure of beaches due to health concerns.

Adjacent Land Use

Description

The type of land use on contiguous, adjacent, or nearby properties can have local effects at a beach. Residential, industrial, commercial/business, agricultural, or natural land uses can all impact a beach differently because of impervious surface density, land management practices, and habitat quality.

Impacts

Nearby properties may be localized sources of pollutants, nutrients, and bacterial contaminants as substances are carried by runoff or are dumped into the water. Land use on nearby properties can also impact traffic to and across a beach. Manicured lawns can attract geese, which introduce fecal contaminants to the beach area. Beach processes such as dune building may also be constrained, especially if nearby land use conflicts with beach processes. Changes in nearby land use can result in encroachment on the beach area or, conversely, present an opportunity to expand a beach and its services. Installation of practices that buffer the impacts of adjacent land uses may mitigate competing interests.

Where to Learn More

- **NOAA C-CAP Regional Land Cover and Change** (https://coast.noaa.gov/digitalcoast/data/ccapregional.html)
  Provides information on types of land cover in coastal areas of the U.S.
- **WCMP Library of Plans** (https://rb.gy/jlegkv)
  Provides a list of adopted comprehensive plans, which might include information on how the land in coastal counties will be used.
- **Local Comprehensive Plans**
  Check with the local county planning department for local comprehensive plans.

Animal Usage (Pets and Wildlife)

Description

Wildlife that congregates at beaches, such as seagulls and geese, have been traced to fecal bacteria contamination. Pet waste from dogs can also present contamination issues. Besides water quality and public health concerns, the presence of animals at a beach may also conflict with recreational uses.

Impacts

Animals can introduce fecal contaminants to the beach, negatively impacting water quality and causing beach closures. Animals can also present a nuisance to beach visitors and create user conflicts.

Where to Learn More

- **Massachusetts Department of Public Health 'Pet Waste and Bathing Beaches'** (https://rb.gy/rhvkgd)
  A fact sheet on the impact of pet waste on beach and water health.

Human Usage

Description

The impacts of visitors on a beach can vary by type, location, and volume. For example, beaches used for swimming may have direct visitor impacts to groomed sections, especially during peak season when beach traffic is heavier. Diverse conflicts can arise with other uses such as fishing, boating,dog walking and bicycle riding. Beach usage impacts typically escalate with increased visitor volume that may result in an activity extending beyond its intended usage area or into secondary beach habitat.

Impacts

Human usage and planned development can impact the natural functions of the beach. Increased volume of users can lead to the expansion of use to unintended areas such as preserved habitat or ungroomed sections of beach to escape crowds. Users can bring contaminants to the beach or attract wildlife through the improper disposal of food-related waste. How sensitive a beach is to human use depends on the characteristics of the beach.

Where to Learn More

- **New Hampshire Wildlife Action Plan Profile** (https://www.wildlife.state.nh.us/wildlife/documents/dunes.pdf) Impact of people on dunes and beaches. Note: Jump to page B-53 for threat assessment, followed by conservation actions.
- **Alliance for the Great Lakes "Adopt-a-Beach" program** (https://greatlakes.org/get-involved/adopt-a-beach/)

Visitor Access and Foot Traffic

Description

The type, location, and number of access points to a beach can affect which areas are impacted by human usage. Directing access at thoughtfully planned points can enhance the visitor experience and limit unintended user impacts to the beach.

Impacts

Foot traffic over beaches and dunes can erode beach sediments and trample vegetation, further promoting erosion. The creation of "social" trails by visitors straying from designated paths can damage more natural or environmentally sensitive sections of beach.

Where to Learn More

- NOAA Office of Coastal Management **"Managing Visitor Use Impact Training"** (https://rb.gy/aahhfl) A two-day classroom training on how to balance visitor usage and site preservation.

Building Resilience

Impacts of coastal stressors can be anticipated by evaluating site infrastructure and condition, current erosion and flooding, future projections, habitat disruptions, water quality and potential sources of pollution. Employing an adaptive management approach (planning, implementing, monitoring, evaluating, and adjusting) will create a framework where progress can be made, even with the inherent uncertainty that exists within this dynamic environment.

Preferred solutions consider site specific stressors, solution feasibility, sustainability, and resilience. In general, solutions which consider the natural function of the landscape (hydrology, hydrodynamics, and the biome) and human interactions are more resilient, sustainable, and adaptable. Multiple techniques can be used to achieve management priorities. With the advent of historic high-water levels and more frequent/intense precipitation events, coastal resilience should be incorporated into site management plans. Achieving coastal resilience at recreational beaches will be dependent on a balance between the desire to maximize utility (direct economic benefits) and the need for environmental preservation (avoided damages). The following chapters in this guide discuss the elements of assessing the resiliency of a beach and how to develop a management plan that incorporates resilience.

The assessments included in Chapter 2 are used to determine a beach's vulnerability to specific stressors and help inform the management plan created for a site. Chapter 3 describes an adaptive management planning process and considerations for planning a beach mitigation project with a contractor or consultant. Finally, the case study presented in Chapter 4 illustrates the adaptive management cycle and how it was successfully utilized at a Great Lakes beach.

Chapter 2

Assessments

An important first step in assessing whether a beach is meeting resiliency goals is to consider existing information or determine if related assessments already exist. Information sources include:

- Beach sanitary survey data and reports
- Water quality monitoring data
- Historic aerial photographs or other imagery
- Sanitary sewer, stormwater drainage areas, county septic system inspections
- Community development plans or master plans
- Watershed plans
- Hazard mitigation plans
- Land use maps (GIS)
- Impaired Waters Listings: https://dnr.wi.gov/topic/impairedwaters/

In Wisconsin, about half of the identified coastal recreational beaches are monitored at least weekly during the beach season (www.wibeaches.us). Both the beach monitoring data and any associated sanitary survey information can be useful for assessing stressors and beach resilience. The information collected in sanitary surveys provides clues and symptoms of potential problem areas and a mechanism to connect-the-dots. The following topics are included in this guide as universal concepts that should be addressed. The concepts in the economic and social/community assessments are discussed at a higher level than the physical, biological, and chemical assessments, because how those assessments are developed will depend on data needs, the needs of the community, and the questions that need to be answered to work towards the management goals of the beach.

1. Physical Beach Assessment

Background

Beaches are dynamic and constantly changing systems due to natural coastal processes. Beaches may not be a permanent fixture on the coast but are dynamic coastline features that grow, shrink, and migrate under the forces of nature. A beach being resilient to physical forces means being able to *recover* from beach loss, *not* being able to fully *resist* beach loss.

Beach Profile Terminology

Beach Berm	The nearly horizontal portion of the beach, landward of the berm crest
Berm Crest	Slope break between the beach berm and the beach face
Beach Face	Sloping section of the beach profile lakeward of the berm
Bar	Underwater ridge of sand running roughly parallel to the shore
Dune	Ridge of wind-blown sand
Foreshore	Sloping portion of the beach between the berm and lower extent of waves
Backshore	Zone from the berm crest to the point of vegetation or upland slope change
Nearshore	Area where waves begin breaking landward to the beach berm crest
Swash Zone	Area where the beach face is covered by wave runup
Surf Zone	Portion of nearshore from where waves break to swash zone
Offshore	Area lakeward of the nearshore and the point of wave breaking.

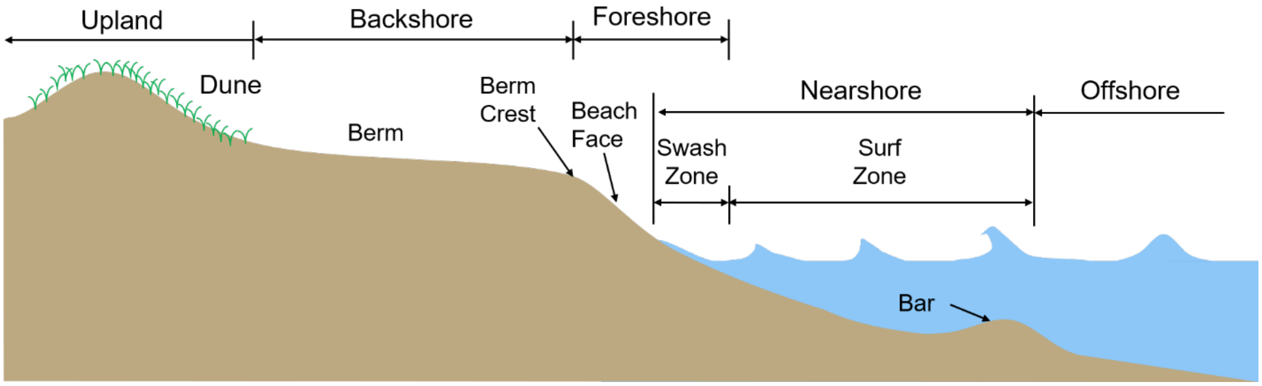


Figure 2.1. Terminology used to describe beach profile features

Coastal Processes

Water Levels

In the Great Lakes, water levels naturally fluctuate over several feet from year-to-year, primarily driven by climactic influences like precipitation, runoff, and evaporation. Water levels also vary seasonally, with a low in winter and a peak in summer. Water level fluctuations can inundate or expose portions of the beach while also allowing waves to erode higher up on the beach.

Waves

Waves are a natural force that can erode beach sand and move sediment in the nearshore. As waves approach the shore, they begin to "feel" the lake bottom and can change direction due to refraction and release energy through breaking before striking the shore. The wave climate at a particular location describes the seasonal and annual distribution of wave heights, periods, and directions, which is dependent upon the site geography and the storms experienced.

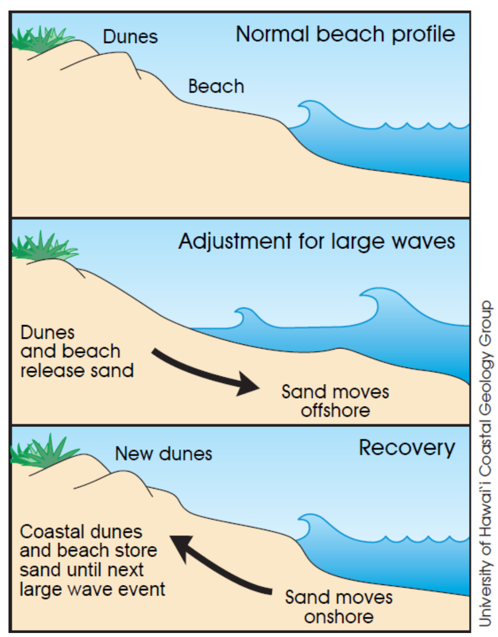


Figure 2.2. Cross-shore sediment transport process (University of Hawaii Coastal Geology Group)

Sediment Transport

Beaches are built and maintained by the transport of sediments like sand and gravel in the nearshore area by waves and currents. Waves can move sediment both onto and off a beach in a process known as cross-shore transport as well as along the shore in a process known as alongshore sediment transport while wind drives aeolian sediment transport on the land.

Cross-Shore Sediment Transport

Erosive storm waves remove sediment off beaches and out to nearshore bars while calmer waves can deposit sediment onto beaches. In the Great Lakes, erosive storm waves typically occur in the fall and winter and gentler waves in the summer can redeposit sand onto the beach. Water levels can greatly affect cross-shore sediment transport. At high water levels, waves are more able to erode the beach berm, transporting this sediment to nearshore bars. At low water levels, sediment stored in offshore bars is more readily suspended in shallower water depths and can be transported back to the beach.

Longshore Sediment Transport

Sediment is also moved along the shore by waves and currents. The wave climate dictates how sediment is transported along the coast, with the dominant direction of sediment transport typically following the dominant wave direction. When more sediment moves out of an area (in the "downdrift" direction) than moves into an area (from the "updrift" direction), erosion occurs to balance this deficit. Erosion can be worsened in downdrift areas by interruptions to the sediment transport system caused by natural headlands, dredging, and coastal structures. Beach nourishment can add sediment back into the nearshore transport system, though this added sediment should be expected to erode over time if sediment transport imbalances remain.

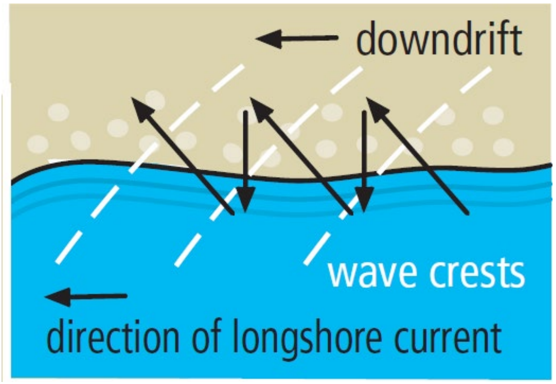


Figure 2.3. Long-shore sediment transport process (University of Wisconsin Sea Grant and U.S. Army Corps of Engineers)

Aeolian Sediment Transport

Winds can also suspend and transport beach sediments. For example, onshore winds can transport sediment to the backshore to form dunes.

Beach Changes

Changes to the beach are typically due to a combination of multiple coastal processes. Beaches naturally advance and retreat as water levels rise and fall, storms come and go, and sand supplies shrink or expand. Sandy shores tend to retreat in the face of high lake levels and storm waves as shore materials are transported offshore. Beaches can recover from loss and advance lakeward during times of low lake levels as mild winds and waves build beaches, ridges, and dunes from nearshore deposits. However, if sediment transport is significantly interrupted, such as by coastal structures, there may not be enough sand available for the beach to naturally recover from loss. In this case, beach loss may become a long-term issue as beach dynamics reach a new balance based on the amount of sediment available in the nearshore.

Assessment

The purpose of this assessment is to increase awareness of physical issues at a beach and help recognize changes so that they can be incorporated into beach management and monitoring plans. Typical observations consist of a rapid appraisal of current conditions and an in-depth assessment to examine potential long-term physical issues at a site.

Rapid Site Assessment

This rapid site assessment consists of a series of questions to help identify high, medium, low vulnerability to physical beach stressors. An assessment of current site conditions can give an indication of the physical risk a beach faces from near-term stressors in the next year or next few years. While these visual cues can be indicators of ongoing physical beach vulnerabilities, a professional evaluation is the only true way to determine the physical vulnerability of a beach. Nevertheless, routine completion of the rapid site assessment on an annual or seasonal basis can help identify obvious signs of vulnerability and track physical changes to the beach over time.

Water Level Inundation and Flooding

High water levels inundate portions of the beach while storm surges and wave runup can combine to temporarily raise water levels by several feet. Along the open coast of the Great Lakes, even moderate coastal storms commonly cause one to two-foot storm surges. Wave runup can further add two or more feet to inundation.

Higher Risk	Medium Risk	Lower Risk
Narrow or very shallow beach slope; facilities located within a few feet of the water line; signs of wave runup or other water reaching facilities	Beach is getting narrower to the point that its use is beginning to be impacted; facilities are a few feet above current water line	Wide beach with facilities located many feet above current water line
		

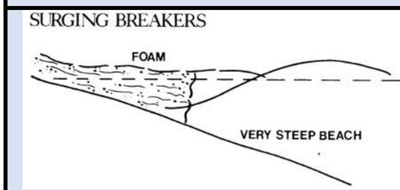
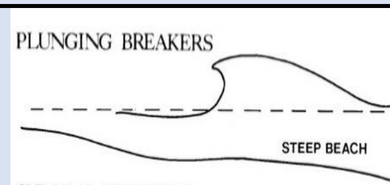
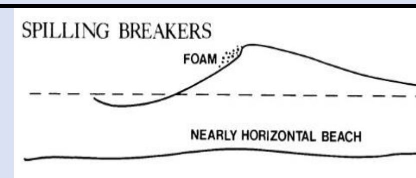
Backshore Erosion and Impacts

Evidence of erosion on backshore dunes, banks, or bluff slopes indicates that water levels and waves have combined to reach beyond the beach and potentially threaten the upland area. In the case of bluffs, this erosion is irreversible, while dunes may reform in the future if adequate sand returns to the beach.

Higher Risk	Medium Risk	Lower Risk
Recent disappearance of the backshore, noticeable erosion scarp of dunes or bluff	Some erosion of the backshore dune or bluff toe	Backshore remains in-tact with little evidence of waves or water level impact
		

Beach Morphology Type

Beach slope influences how waves interact with the beach and thereby how sensitive the beach may be to storm-induced changes. Steeper beach profiles, that reflect wave energy, can be more sensitive to these changes than wide, shallow beach profiles that tend to dissipate wave energy as waves break over them. Beach morphology type can be approximated by observing how waves break in the nearshore waters.

Higher Risk	Medium Risk	Lower Risk
Surging breakers occur at the shoreline without other breaking in the nearshore, indicating a very steep reflective beach. Reflective beaches are more likely to be sensitive to storm-induced erosion	Plunging or collapsing breakers are present in the nearshore, indicating an intermediate beach. Intermediate beaches may be sensitive to storm-induced erosion.	Spilling breakers present, with waves possibly breaking multiple times before reaching the shoreline, indicating a shallow dissipative beach with sandbars. Dissipative beaches are less likely to be sensitive to storm-induced erosion.
		

Starvation or Accretion at Bounding Structures (jetty, groin, revetment, seawall)

Shore protection structures can accelerate beach erosion at neighboring properties by interrupting the transport of beach-building sediment along the coast, preventing beach-building sediment from naturally eroding from protected lands, and modifying the nearshore wave dynamics. On the other hand, some shore protection structures can cause sediment to accumulate depending on wave dynamics.

Higher Risk	Medium Risk	Lower Risk
Visual evidence of erosion near coastal structures adjacent to the beach	Bounding coastal structures exist adjacent to the beach but no apparent impacts.	No coastal structures near beach, relatively natural shoreline – or – noticeable accumulation of sediments near coastal structures
		

Beach Profile Drainage

Low spots in the beach profile can lead to water ponding that can promote bacterial growth and make parts of the beach unusable to visitors.

Higher Risk	Medium Risk	Lower Risk
Multiple low spots in the profile with noticeable ponding after rain or wave events	Low spots in beach profile that may remain wetted but without noticeable ponding	No low spots, profile slopes down toward the lake continuously
		

Backshore and Dune Vegetation

The roots of backshore vegetation help retain sediments and resist the erosive forces of waves, runoff, and wind. Vegetation can also promote the accumulation of wind-blown sediment, assist with infiltration, and potentially absorb excess nutrients.

Higher Risk	Medium Risk	Lower Risk
Backshore and/or dunes are poorly vegetated.	Backshore and/or dunes have some vegetation, potentially invasive species.	Backshore and/or dunes are well vegetated with native vegetation.
		

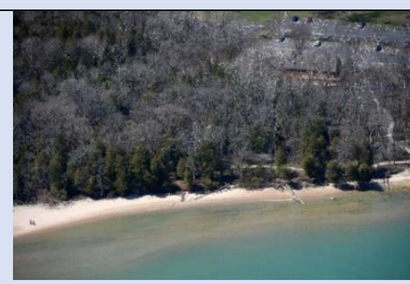
Visitor Access and Use

Foot traffic over beaches and dunes can erode beach sediments and trample vegetation, making erosion by natural processes like waves, runoff, and wind more likely.

Higher Risk	Medium Risk	Lower Risk
User access to beach has clear impacts, with trampled vegetation and incised pathways.	Most user access occurs on defined trails and access points, with some off-trail use.	User access is limited to defined trails and access points.
		

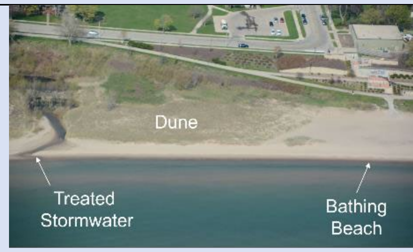
Immediately Adjacent Land Use

Impervious surfaces or turf grass areas can accelerate nutrient and pollutant conveyance to the beach during runoff events.

Higher Risk	Medium Risk	Lower Risk
Large impervious surfaces like parking lots about the beach.	Some impervious surface and non-native vegetation like areas of turfgrass about the beach.	Naturally, vegetated area surrounding beach.
		

Surrounding Infrastructure and Watersheds

Infrastructure like roads, culverts, and storm sewer pipes and outlets convey water from nearby upland areas to the beach and adjacent nearshore waters. Direct runoff from impervious surfaces can reach the lake and beach area with little filtration. Tributaries and their watersheds can convey pollutants, nutrients, sediment, bacteria, and debris from relatively distant sources to a beach.

Higher Risk	Medium Risk	Lower Risk
Potential sources of pollution are located at the beach or directly adjacent to the beach, including stormwater outfalls and tributaries from urbanized watersheds.	Potential sources of pollution are located nearby the beach on adjacent parcels or efforts have been made to treat potential sources of pollution	No sources of pollution enter the beach or are adjacent to the beach
		

In-Depth Physical Assessment

To be achieve long-term resiliency, beach management strategies should consider a range of possible conditions present at a beach, including high and low water levels and changing sediment supplies.

Beach Width Change Measurement

Beach width changes that can be expected under different water levels can be approximated by measuring past beach width changes from historic aerial photographs. This can be done using readily available mapping software (like Google Maps or Google Earth Pro), municipal or county web-based GIS mapping services, or from high-resolution orthophotos analyzed with GIS software (Figure 2.4). A brief outline of this process is given below.

1) Measure the distance from a fixed point of reference (i.e., building corner, corner of road intersection, etc.) over several years.
2) Look up water level at time of the photo. This data can be found from the NOAA Great Lakes Environmental Research Laboratory. Currently, NOAA's Great Lakes Water Level dashboard provides a user-friendly platform to find this information: https://www.glerl.noaa.gov/data/dashboard/GLD_HTML5.html
3) Fit a trendline to the measurements with water level as the dependent variable (x-axis) and distance to water line as the independent variable (y-axis). The slope of the line will give an estimate of how many feet of beach have been lost historically for every foot of water level change. In the example below, the trendline indicates that an average of 11.4 feet of beach are inundated for every foot of water level rise.
4) Consider the impacts of potential beach width changes under water levels higher than the record high should future conditions exceed past extremes. In the example below, an additional foot of water level rise past the highest water level on the graph (581.8 ft) would likely shrink the distance to the water line to less than 280 feet, resulting in almost no beach at this site.

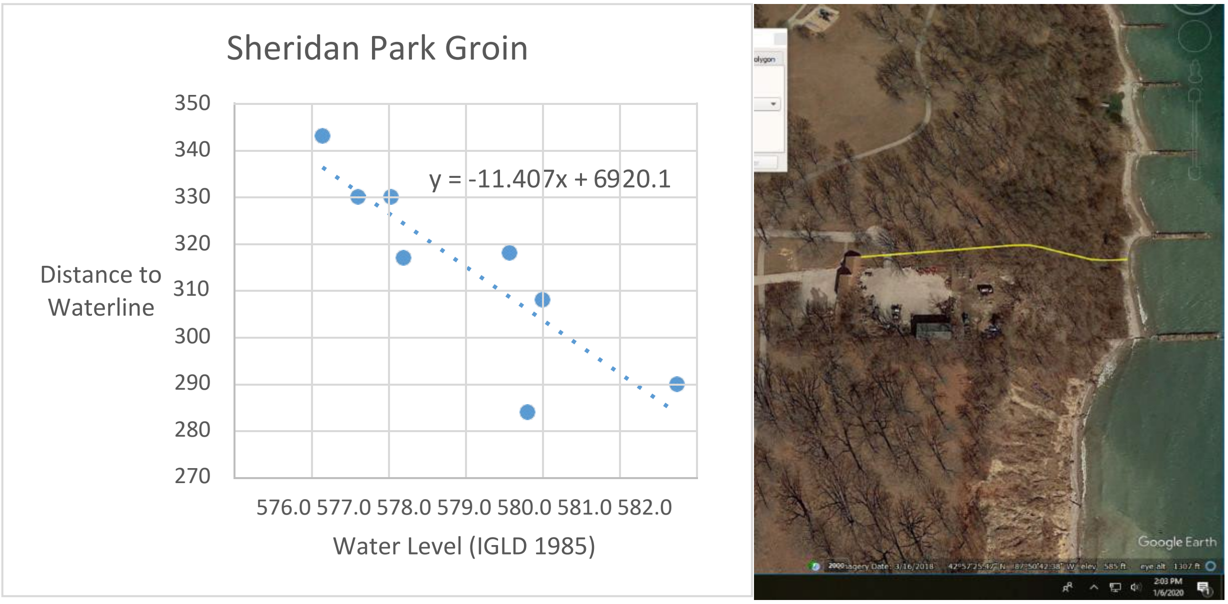


Figure 2.4. Beach width measured from aerial photographs compared with water levels at the time of the photos provides an understanding of how beach width may respond to different water levels.

Flooding Potential

Flood Insurance Rating Maps (FIRM), issued by FEMA, can provide information to estimate the long-term coastal flooding hazard at a site. Official and preliminary FIRMs can be found and downloaded here: https://msc.fema.gov/portal/home. FIRMs on the Great Lakes coast depict the anticipated inundation elevations during a 1% annual chance event (also known as the 100-year event) due to the combined effect of water levels, storm surge, and waves. It is widely accepted that locations within the 1% annual chance event inundation zones have an obvious long-term vulnerability to flooding. Locations outside of the mapped coastal floodplain still have some long-term vulnerability to flooding. For example, property just above the 1% annual chance inundation zone can still be impacted by individual wave runups during the 1% annual chance event and are likely to be flooded during even larger events (Figure 2.5).

- The Coastal Processes Manual is a resource that provides step-by step instructions on how toestimate risk to Great Lakes coastal property from extreme lake levels, storms, and erosion: https://publications.aqua.wisc.edu/product/coastal-processes-manual/
- FEMA has also created a story map using ArcGIS that demonstrates how coastal risk is shown on FEMA FRIMs. The story map can be accessed using this address: https://fema.maps.arcgis.com/apps/MapSeries/index.html?appid=89d2e393f2c64d7cae07264f4d00c19d

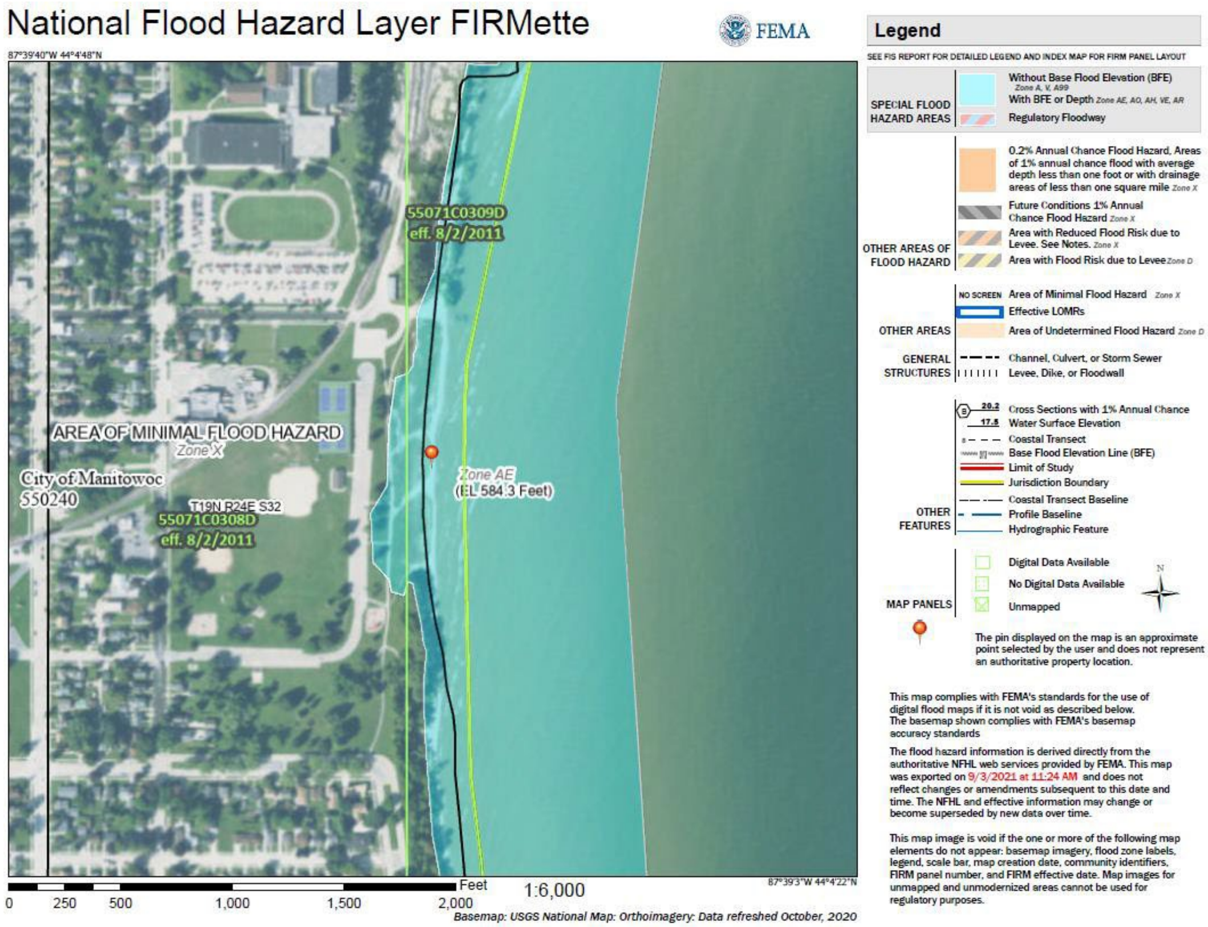


Figure 2.5. National Flood Hazard Layer show the inundation extent of a 1% chance flood in blue. At this beach, the beach would be fully inundated and some pathways partially inundated. The map indicates that no accessory buildings or roadways would be expected to be inundated at this level of flooding (FEMA, 2020).

Aerial Photo Physical Change Analysis

Current and historic aerial photos can be referenced to get a sense of nearby changes on the coast that may physically impact the beach, such as beach nourishments or construction of new coastal structures or storm sewer outfalls (Figure2.6). This can be done using readily available online mapping services (like Google Maps or Google Earth Pro) or from high-resolution orthophotos available from local, regional, state or federal governments agencies. Some potential sources of imagery include:

- Wisconsin Shoreline and Oblique Photo Viewer – viewer for low elevation geolocated aerial photos from 1976, 2007, 2012, 2016, 2017, 2018, 2019, 2020, and beyond: http://floodatlas.org/asfpm/oblique_viewer/
- Wisconsin Aerial Photo Catalog – UW Madison Robinson Map Library directory of available historic Wisconsin aerial photography dating back to the late 1920's. Note this catalog does not have imagery available for download but directs users to their sources: https://maps.sco.wisc.edu/apcat/
- USGS Earth Explorer – Federal government repository of historic and modern aerial photography: https://earthexplorer.usgs.gov/
- Local GIS mapping services – municipal and county GIS web platforms may have up-to-date high resolution aerial photography for viewing.

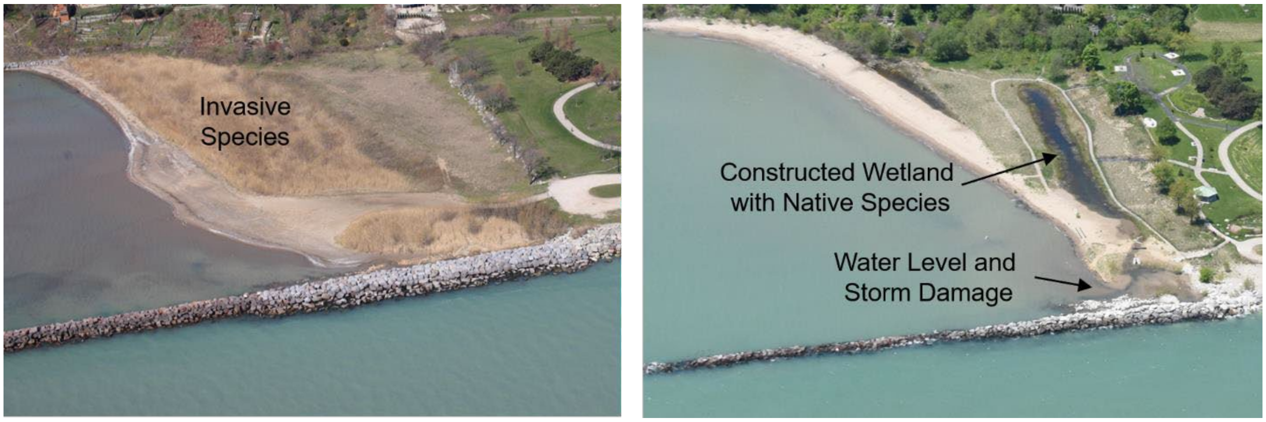


Figure 2.6. Historic photos from the Wisconsin Shoreline and Oblique Photo Viewer of Samuel Myers Park from 2012 (left) to 2020 (right) show the positive effects of a restoration effort as well as the damaging effects of high-water levels and coastal storms. (2012 – USACE; 2020 – Capt. Dennis Carr, Wisconsin Wing Civil Air Patrol)

Beach Profile

A topographic survey of the beach profile is valuable for identifying low or flat slopes on the beach that may be difficult to see from a visual assessment. Hiring a surveyor or using in-house staff to establish topographic surveys of the beach profile of the backshore and foreshore may be helpful to monitor significant changes in the beach profile that may warrant further investigation in the future.

The EPA's Great Lakes Beach Sanitary Survey also has a simplified method for measuring beach slope (Figure 2.7) (from Annual BSS Section 4, Page 3; See Great Lakes Beach Sanitary Survey User Manual page 6-7 for instructions).

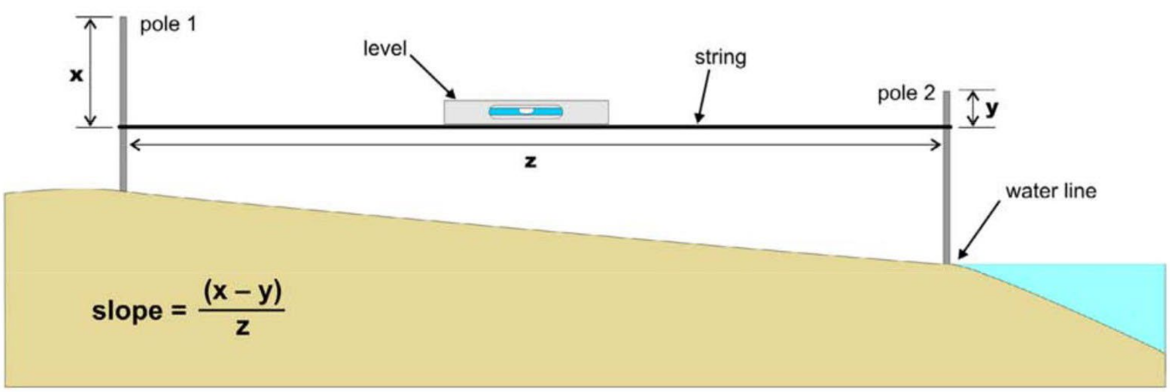


Figure 2.7. Calculating a beach's slope using method a simplified method with two poles, string, and a level. This method is described in EPA's Beach Sanitary Survey User Manual (EPA).

2. Biological and Chemical Assessment

Beach health is an important indicator of overall watershed and nearshore health. Pollutants originating from direct and indirect stormwater discharge, industrial outflow, permitted and unintentional sewage releases, boaters, beach visitors, and wildlife can impact surface water quality. Whether end-of-pipe discharge, runoff or watershed influences, pollutants can present a public health risk, degrade habitat, and impact the local economy.

Table 2.1. Indicator, method or application and common uses.

Indicator, Method, or Application	Common Use(s)
Fecal Indicator Bacteria (FIB) e.g., *E. coli* and enterococci	Recreational Water Quality Monitoring (Regulatory) Investigative & Post-implementation Monitoring
Cyanobacteria/Cyanotoxins	Indicator of harmful algal blooms
Routine Beach Sanitary Survey	Associate ambient conditions at time of sampling to FIB concentrations (at the shoreline)
Annual Beach Sanitary Surveys	Associate FIB concentrations to surrounding watershed and examine trends over time
Microbial Source Tracking (MST)/eDNA	Species level FIB source attribution or source identification (e.g., human, gull, canine, bovine)
Bacterial Community Profiling	Regional and localized variation in microbial communities (e.g., river vs. nearshore waters)
Quantitative Polymerase Chain Reaction (qPCR)	Molecular (DNA) tests used to rapidly quantify FIB; also used in MST and community profiling
Environmental Modeling	Predicting FIB levels from ambient conditions Fate and transport of environmental pollutants
Quantitative Microbial Risk Assessment (QMRA)	Estimate exposure risk based on pollution sources
Nutrients (Phosphorus & Nitrogen)	Determination of productivity (e.g., algal blooms)
Chlorophyll a	Measure of productivity (e.g., trophic state or amount of algae)
Detergents/Surfactants	Detection of sanitary infiltration into stormwater infrastructure
Chlorine	Detection of sanitary infiltration into stormwater infrastructure (in proximity to source)
Turbidity/Total Suspended Solids	Quantifies suspended particles in water (point of attachment for bacteria and nutrients)
Other Constituents	Debris and vegetation can serve as points of attachment for FIB

The purpose of biological and chemical assessments is to identify locations and/or conditions that facilitate the delivery of pollutants to the nearshore environment. An increased awareness of physical beach attributes will aid in identifying potential pollutant hot spots or mechanisms of transport. Walking site assessments, a review of upstream land use, and infrastructure inspections, as well as conducting routine and annual beach sanitary surveys provide strength and context to biological and chemical data generated through regulatory or investigative monitoring.

The aim of regulatory monitoring is to inform the public of heightened health risk when established standards are exceeded, for example, bacteria (e.g., BEACH Act, U.S. Legislature 2000) or blue green algae (HABs; harmful algal blooms). Investigative monitoring expands upon regulatory monitoring, allowing beach managers to target potential pollution sources (e.g., stormwater outfalls, wildlife, domesticated animals, tributaries, and beach sands) or conditions (e.g., precipitation, high waves, elevated air/water temperatures, increased turbidity) that may result in water quality degradation.

Many biological and chemical assessment methods are useful for the determination of pollutant loading and source attribution (Table 2.1). While each site is unique, the US EPA routine and annual beach sanitary surveys provide a broad general condition assessment, leveraging regulatory monitoring data to look at the strength of association to ambient water quality conditions. Beach sanitary survey data can be used in the development of environmental models, which forecast water quality conditions in advance of, or as a substitution for, lab-based analytical methods and provide information on the fate and transport of pollutants.

Fecal Indicator Bacteria (FIB)

Fecal material from humans and wildlife often contains a wide variety of bacteria, viruses, and other pathogens that can increase the risk of disease. While FIB are not pathogens (disease causing agents), they have been shown through epidemiological studies to have a strong association to waterborne illness resulting from these organisms, especially bacteria. Measuring FIB, such as *E. coli or* enterococci, are useful when evaluating exposure risk at beaches as well as the initial step in the investigative process. The EPA's recreational water quality criteria provide benchmarks, including procedures for determining whether sustained bacteria concentrations throughout the recreational season rise to the level of water quality impairment.

Cyanobacteria/Cyanotoxins

Poor circulation, warm water, an influx of nutrients (phosphorus and nitrogen) and favorable wind and wave conditions can result in HABs. Cyanobacteria, the causative agent of HABs, can produce toxins (cyanotoxins) harmful to both humans and animals. Airborne HAB toxins may also cause breathing problems and, in some cases, trigger asthma attacks in susceptible individuals. HABs can also have direct economic impacts, closing beaches and shellfish beds (https://oceanservice.noaa.gov/facts/why_habs.html). The US EPA has developed criteria for microcystin and cylindrospermopsin, two of the toxins associated with HABs.

The Wisconsin Department of Health Services has developed a HAB toolkit (https://www.dhs.wisconsin.gov/publications/p0/p00853.pdf), as well as educational signage available for purchase (Figure 2.8, https://www.dhs.wisconsin.gov/water/bg-algae/health-pros.htm).

For more information on HABs:

- https://www.epa.gov/wqc/recommended-human-health-recreational-ambient-water-quality-criteria-or-swimming-advisories
- https://www.dhs.wisconsin.gov/water/bg-algae/index.htm
- https://dnr.wi.gov/topic/GreatLakes/Cladophora.html
- https://dnr.wi.gov/lakes/bluegreenalgae/
- https://www.dhs.wisconsin.gov/water/bg-algae/health-pros.htm

Figure 2.8. Harmful Algal Blooms (HAB) sign developed by the Wisconsin Department of Health Services, Division of Public Health.

Beach Sanitary Surveys (Routine and Annual)

The physical and structural information provided through sanitary surveys begins the process of site evaluation by assessing the magnitude and frequency of pollution (particularly FIB) as well as identifying priority locations and times for water quality testing. Sanitary surveys are often used at beaches and other recreational waters, at shellfish harvesting areas, and in watershed protection programs. Routine sanitary survey data provides a snapshot of ambient conditions at the time of sample collection. Annual sanitary surveys cast a wider net, looking at trends over time and at a watershed scale. Beach managers can use the sanitary survey results to help improve recreational water quality. In addition, sanitary survey data (e.g., bacteria levels, source flow, turbidity, rainfall) can be used to develop environmental or predictive models. Technical support/training material, beach sanitary survey forms and links to the new beach sanitary survey app can be found on the US EPA website: https://www.epa.gov/beach-tech/sanitary-surveys-recreational-waters#great.

Molecular Methods (MST, eDNA, Bacterial Community Profiles, qPCR)

Fecal matter from large numbers of loafing gulls and geese frequently contributes significant amounts of *E. coli* or enterococci to the beach environment. While quantification of these common FIB occurs through regulatory monitoring, such as employing traditional culture of qPCR methods, it provides no information regarding the source. Additional testing, such as employing MST methods, is necessary to attribute to FIB to their host. Other MST methods look for species specific markers, for example, human, gull, canine, and bovine. These techniques require specialized equipment and highly trained staff but are useful when pollution hotspots have been identified but the source cannot be identified through other biological or chemical assessments. Environmental DNA (eDNA), shed through urine, saliva, blood, or skin, may be indicative of fecal contamination. Source tracking may provide a more in-depth understanding about the relative contribution of various hosts (human, bird, or other animal) to total FIB bacteria levels and the associated health risks.

Microbial community profiling (e.g., 16s rRNA gene sequencing), rather than looking for a specific host marker, assesses the relationship between microbial communities in potential sources (river and wetland) and receiving waters. The expansion of MST markers and microbial community profiling may also contribute to a better understanding of the microbial profile making up these unique environments, leading to more effective and complete mitigation of pollution sources (Figure 2.9, Kinzelman et al. 2020).

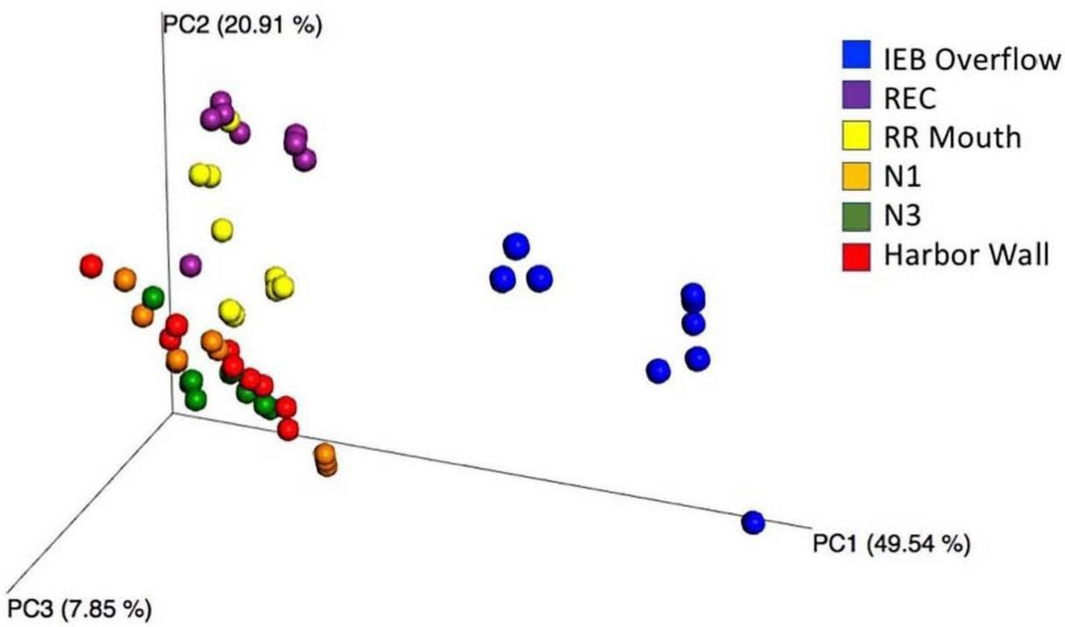


Figure 2.9. 16s rRNA gene sequencing demonstrated the similarity of bacterial communities in nearshore and offshore Lake Michigan surface water samples (N1, N3 and Harbor Wall) to the Root River mouth (RR Mouth) but not the adjacent engineered wetland (IEB Overflow) (Kinzelman et al. 2020).

Environmental Modelling/QMRA

Software packages, such as US EPA Virtual Beach (https://www.epa.gov/ceam/virtual-beach-vb), allow beach managers to develop site-specific statistical models for the prediction of FIB levels at recreational beaches. These models use locally collected data (beach sanitary surveys), web captured hydrometeorological data, or a combination of both. Other environmental models can be used to estimate the fate and transport of pollutants in the aquatic environment (Benham et al. 2014).

Quantitative microbial risk assessments (QMRA) estimate the degree of health risk associated with exposure to fecal contaminants in water. Multiple factors determine infection rates from exposure to fecal pathogens, including degradation rates, dispersal dynamics, and whether the contamination is human sewage versus non-human fecal matter (see Southern California Coastal Water Research Project; https://www.sccwrp.org/about/research-areas/microbial-water-quality/microbial-risk-assessment/.

Chemical Tracers (Nutrients, Detergents, Chlorine, Temperature, Turbidity/TSS)

Measurements of nutrients (phosphorus, nitrogen), detergents (surfactants), chlorine (total residual), turbidity (clarity) and total suspended solids (TSS) are common chemical assessment methods. Elevated phosphorus and nitrogen levels are indicators of agricultural or landscape runoff, and can contribute to high productivity (e.g., algal blooms). Detergents and chlorine are useful for detecting illicit discharges, misconnections, cross connections, and sanitary infiltration into stormwater infrastructure due to their prevalence in treated (chlorine) and spent (detergents) water supplies. Changes in temperature can indicate an influx of water from an external, non-environmental source (Figure 2.10). Highly turbid waters have been frequently associated with elevated FIB, nutrients, and other contaminants due to the ability of these pollutants to adsorb onto particulate matter. Once transported, particle bound pollutants can be redistributed in onshore/offshore sediments and the water column due to precipitation and wave action.

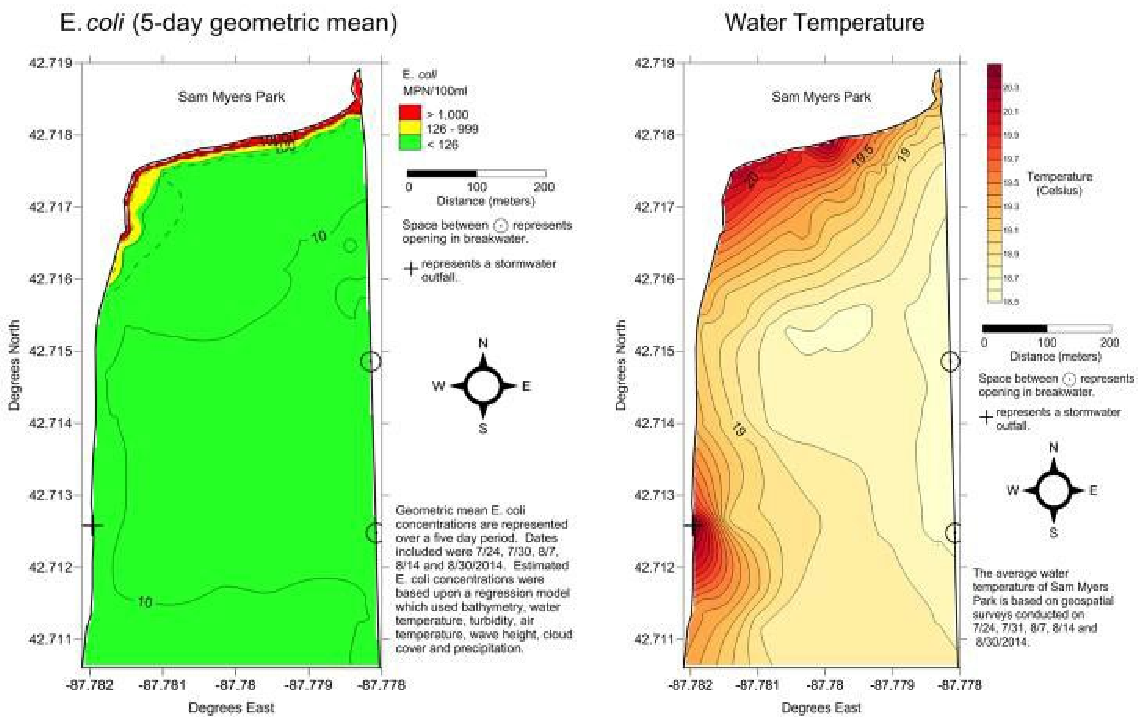


Figure 2.10. Mapping of chemical tracers (e.g., temperature) can assist in identifying source of fecal contamination (City of Racine Public Health Department, 2014).

Other Constituents (Debris, Vegetation)

Debris on the beach, whether it be trash or natural materials, such as decaying vegetation or woody debris, can become media for growing pathogens, impacting water quality. Accumulation of debris can also impact tourism, degrade habitat, harm wildlife, and create health and safety hazards.

Algae is naturally occurring and an important part of the food web. However, the presence of excessive amounts of algae in the water or on the beach is an indication of nutrient loading. Beaches may be placed on the impaired waters list when elevated nutrients or excess algae is present. Identification is key to assessing whether a beach is affected by filamentous or other green algae, impacting aesthetics, and potentially contributing to elevated FIB levels versus HABs.

Land-based vegetation can serve as a deterrent to shorebirds as well as enhancing resilience. Stands of vegetation act as a natural deterrent for loafing geese and gulls, reducing their line of sight with respect to potential predators. Vegetation with deep, fibrous root systems improves resiliency by anchoring beach sands, thereby buffering the effects of wind and waves, reducing erosion. Native species, like American Dune Grass (*Ammophila breviligulata*), are ideally suited to beach ecosystems, not only anchoring but capturing wind-blown sand and promoting dune formation through their flexible grass stems. Root systems of some species of trees and shrubs can also provide an anchoring function as well as promote stormwater infiltration. Native vegetation can also be beneficial in absorbing excess nutrients and some contaminants.

Conversely, turf grass can reduce overall resilience because it does little to slow runoff and it tends to attract geese. Invasive species (e.g., *Phragmites australus*) that form tall, dense stands with aggressive growth can take over an entire beach area. While their presence may provide some shoreline stabilization, overall, it reduces both the social and ecological value of the beach by limiting access, reducing visibility to the water, and disrupting beach habitat. Invasive species may also have reduced nutrient uptake capacity.

For more information on dune building and Phragmites:

- https://archive.lib.msu.edu/DMC/Ag.%20Ext.%202007-Chelsie/PDF/e1529-1981.pdf
- https://www.mass.gov/service-details/cz-tip-dune-building-with-beachgrass
- https://www.greatlakesphragmites.net/phragbasics/
- https://www.greatlakesphragmites.net/management/techniques/

For more information marine debris:

- https://marinedebris.noaa.gov/great-lakes
- https://marinedebris.noaa.gov/great-lakes-land-based-marine-debris-action-plan

3. Economic Assessment

Successful beach mitigation has been shown to not only improve water quality but also increase usage of the beach, attracting large numbers of visitors to local communities. It is clear from the apparent success of design and mitigation projects in Wisconsin that not only have pollution sources been abated, but also the aesthetic improvements have (or will) enhance the beach user experience. Better beach user experience has led to increased usage of these beach resources by local community members and visitors alike. The increase of beach usage poses opportunities for local communities to capitalize on this 'blue investment' – investments in water quality which then has indirect impacts due to the increased beach usage – in their communities in ways that were not obvious or traditional methods of economic development.

To evidence this phenomenon, Egg Harbor Beach in Door County had an average daily visitation rate of 15-30 beach users per hour per day (which could be many of the same people over a long period of time) prior to beach redesign efforts. After redesign, this number increased to over 400 beach users per day on some days. This change in beach visitation can translate to thousands of new visitors to this community over a summer tourism season. The Town of Egg Harbor has won multiple awards for their redesigned lake (beach) front and surrounding area. In a community that depends on tourism revenue, and only has a yearly population of 201 (2011), the influx of visitors during the summer beach season can translate into major increases in community economic development through the visitor spending at local businesses.

Previous studies such as Shaikh and Tolley (2006), suggest that each beach user spends at least $35/day when visiting a beach. This represents $14,000 in expenditures per day, or over $1.5 million in beach season (about 107 days) expenditures. More recent preliminary studies have suggested these expenditures may reach as high as $262/user/day (Harrison, 2014). This would represent over $10 million of beach goer economic impact in this single Door County community. Initial results from a University of Wisconsin-Oshkosh and University of Wisconsin-Whitewater study suggest a more conservative estimate of $78/user/day that is spent in the local community. This is a roughly $3.2 million dollar increase in local community spending because of the increased beach usage.

While biological and chemical parameters have been important in beach evaluations, another more contemporary method of success is to investigate the value-added impact these restorations have on the economics of local communities (Austin *et al.,* 2007, Balance *et al.*, 2000, Lew and Larson, 2005). While it is understood that there is an impact on the local community as a result of increased beach usage, how to assess that impact can vary widely. However, the importance of these economic evaluations can be seen. First, users have choices in beaches and with websites and smartphone apps directing them to 'healthy' beaches, each community must showcase their locations. Second, with finite resources available for large-scale projects, communities must prioritize their projects. Having projects that solve environmental and public health concerns while simultaneously providing economic benefit make for attractive projects for funding. It is unusual to find projects that can serve a multitude of benefits to a community. This type of investment is considered a 'blue investment.'

The methods researchers have used to evaluate these economic impacts have been almost as diverse as the beach locations they are studying. A study by Loomis and Santiago (2013) used the Contingent Valuation Method (CVM) to estimate the economic impact of beaches on local communities in California. A second study utilized a Choice Experiment (CE) model to evaluate the attributes that impact beach selection in Puerto Rico (Dwight *et al.,* 2012). While each project brought novel ideas, they fall short of completeness and relevance to Great Lakes beaches. Local beach managers do not need to be economists or know how to conduct such economic studies, but rather realize that there are many methods to put a return on investment to beach investments. To choose the right method a beach manager must work with a partner that can accurately account for all of the variables that are unique to their beach and community. There are limitations and benefits to each method so the assessment method chosen should make the most sense for each community.

Estimating Economic Impact

An accurate survey of Great Lakes beach users should be conducted randomly, but systematically, throughout the season so total usage can be evaluated. Most studies evaluated in the peer-reviewed literature relied on one or two days of surveys being administered during busy weekends, potentially biasing results. Sometimes the beach users are counted at the time of sampling, but this can cause problems if water sampling is done early in the morning when smaller numbers of visitors are present. Intercept surveys at selected beaches can be administered during weekdays, weekends, and holidays. This will provide a better cross-section of the actual users and prevent data being skewed to users during specialized times of visit. Previous studies were also conducted in warm climates (California and Puerto Rico), so the seasonal nature of visits and differing user groups would not have been a concern, as it is in the Great Lakes region. All types of beach users should be interviewed to assess (1) the characteristics possessed by the beach which influence the decision to visit, (2) the impact beach closures have on the visitation decision, (3) current overall usage of Great Lakes beaches, (4) the economic value of the user's most recent visit, and (5) potential changes in value and visitation from altered beach characteristics resulting from remediation. Beach usage patterns can then be compared to historical data to provide an external validity check on the results.

The survey instrument used should measure the economic impact and social well-being of users attributable to beach reengineering at the selected beaches. To demonstrate the effectiveness of this approach, a trial economic survey draft was used in the summer of 2016 by researchers from UW Oshkosh and UW Whitewater. It was deployed at a select set of beaches to obtain preliminary estimates, demonstrate proof of concept, and improve survey design for future data collection. Administration and response resulted in approximately 400 completed responses. After reviewing the literature and holding several focus groups to arrive at a reasonable set of the beach attributes most important to users. Six attributes were ultimately included in the pilot survey: presence of native grasses, water quality, temperature, density, distance, and payment. The initial results indicate that beach users' highest priority is beach water quality, with users strongly desiring better water quality over worse. Users were either indifferent to the presence of native grasses (e.g., remediation practice on or near the beach), although depending on model specification it was viewed as a positive amenity (never a negative). Users disliked more densely crowded beaches, as well as longer distances to travel to a beach and higher payments for use. These results provide important initial feedback regarding beach attributes and the impact of reengineering.

If possible, it would be best to incorporate both sites that have not experienced reengineering (control group), and those beaches where reengineering has already occurred (completed). This allows comparison between beach usage and expenditures both across sites where reengineering has and has not taken place, as well as within beaches before and after reengineering takes place.

Estimating Change in Pattern of Activity

A good survey instrument should include questions which assess the number and duration of beach visits by users. Estimating the change in the pattern of activity resulting from improvements in the beach characteristics which occur from remediation is necessary for establishing the change in economic value attributable to the beach reengineering. Questions on trip frequency and duration can be asked to provide the lead in to total expenditures. The survey instrument tool should also include questions to assess the importance of different beach attributes to users. This can include questions to determine the importance a respondent places on the beach characteristics and will allow determination of both the ranking of beach attributes' importance and how changes in these attributes affect the visitation decision, as well as user willingness-to-pay to support changes in beach attribute quality.

Estimating Change Associated with Beach Remediation

The economic survey of beach users can also be used to estimate the changes in economic impacts and values associated with beach reengineering. This is an important principle when considering a blue investment and the return on investment (ROI) of that blue investment. There are several different sets of economic values which are linked to changes in beach remediation such as:

1) Changes in direct expenditures in the area from local and non-local beach users,
2) Changes in indirect and induced expenditures in the area from local businesses and suppliers impacted by changes in beach user visitation, and
3) Changes in the overall social value local and non-local users and non-users place on the changes to beach amenities and water quality.

These estimates start by establishing changes to attendance and expenditures of beachgoers, resulting from changes in the beach amenities experienced. At times one may see that as the quality of the beach changes, users may increase their frequency and/or duration of visit both of which impact their expenditures. They also may simply increase their expenditures per visit (without changing frequency or duration) because of the increase in the quality of the experience. To assess these changes in economic impact, questions on trip expenditures should be asked of respondents. Correctly establishing this baseline value for economic activity is a necessary step in accurately estimating the change in economic value which occurs from remediation.

The direct expenditure estimates obtained through combining expenditures on the trip, as well as the distance users traveled to arrive at the beach (Freeman, 2003) provides a means of estimating not only direct economic impacts attributable to remediation, but also changes in social value. The UW Oshkosh and UW Whitewater pilot survey mentioned above showed that direct expenditure by users is approximately $78/person/day. This initial value is above that suggested by Shaikh and Tolley (2006) that a beach user spends at least $35/day, but less than more recent preliminary studies which have suggested these expenditures may reach $262/person/day (Harrison, 2014). Pilot survey users engaged in approximately four beach visits over the course of the summer. This indicates the sample alone had direct expenditures of nearly $300/person/beach season.

Table 2.2. Summary of methods used to estimate economic impacts of beach remediation, by type of impact.

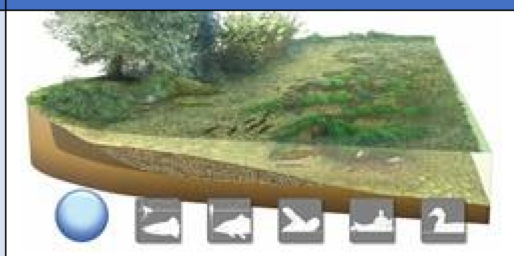
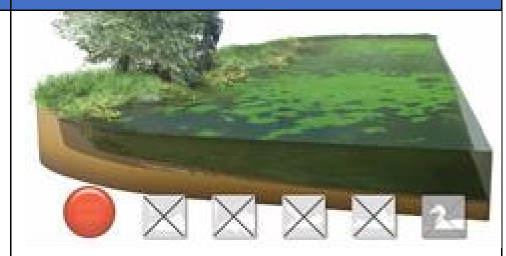
Economic Impact Type	Revealed Preference (TCM)	Stated Preference(CE)	Benefits Transfer Approach	IMPLAN	Pilot Survey Estimates
Direct Expenditure			X		$78.12 *user/day*
Local (resident)	X			X	
Non-local (tourist)	X			X	
Indirect and Induced Expenditure/Employment				X	$71.87 *user/ day*
Social Value	X	X	X		$228.75 *user/ year*

The second set of economic impacts mentioned above which must be measured are indirect and induced impacts. The direct expenditures of users result in economic value in the communities they visit through local spending at restaurants, grocery stores, hotels, etc. These direct expenditures lead to indirect and induced expenditures in the community as the business owners and their suppliers hire more individuals and spend more (Miller and Blair, 1985). Some of this spending stays local, while some "leaks" from the community and goes to other regions. Expenditures for implementation of beach remediation practices (particularly at the local level) could in fact be outweighed by potential tourism increases and enhanced regional benefits due to ecosystem restoration resulting from beach improvements (Johnson and Moore, 1993). This information is critical to overcoming any impediments to implementation – knowing costs and potential benefits for each project. The total direct expenditures of the pilot survey sample suggest an additional $414,000 in indirect and induced regional spending. With complete estimates over the studied beach and aggregated over the population of users, the economic impact of healthy beaches and water quality in promoting tourism and supporting regional economic activity can be estimated fully.

Furthermore, changes in social value occur as a result of remediation (Table 2.2). Although an individual beach user may not have to pay more per beach visit, the satisfaction and enjoyment they receive from the beach experience may increase. That is, the beach visitor may be willing-to-pay more through user fees (such as a park pass) or taxes in order to enjoy the amenities at a remediated beach, as opposed to the amenities at the non-remediated beach even if that beach did not charge a user fee. A stated preference Choice Experiment (CE) can then be performed to determine beach user preferences over relevant beach amenities and establish willingness-to-pay values for beaches with different types and levels of amenity (Dwight et al., 2012; Kanninen, 2006; Loomis & Santiago, 2013; Louviere, Hensher & Swait, 2000). The CE allows estimation of the value of changes in characteristics such as water quality, water clarity, and beach debris at different levels (even hypothetical ones which currently are not present at the beach). An example of the types of attributes that could be examined can be seen in Table 2.3. The goal of these surveys is to establish individuals' preferences for beach remediation projects which impact the quality and feel of a beach. To effectively determine an individual's and community's benefits from improving beach quality through remediation, a series of choice scenarios need to be designed to estimate trade-offs between the important attributes affected by potential remediation projects. In the initial economic survey trials, estimates of the social value users' place on the improvement in water quality is approximately $228/person/year to move from the current water quality experienced on the beaches to the highest water quality level ("Blue") presented.

A conjoint analysis choice experiment can be conducted to elicit individuals' relative preferences regarding the different beach attributes impacted by a given remediation outcome such as water clarity, number of closures, etc. Each resulting choice alternative represents a different potential type of beach after implementation of a remediation program. The outcome of the CE determines user willingness-to-pay for implementation of remediation at control beaches, as well as user's value and preferences over beach characteristics.

Table 2.3. Example choice set for choice experiment.

Beach Features	**Beach A**	**Beach B**
Level of **Water Quality**	 Highest Quality	 Lowest Quality
Aesthetics	Abundant Native Vegetation	No Native Vegetation Present
Beach **Size**	Length 100 Feet, Width 12 Feet	Length 400 Feet, Width 32 Feet
Level of **Congestion**	No People Present	Some People Present (10-20)
Distance to the Beach	0 to 2 miles	Greater than 30 miles
Payment	$35	$75
I would choose	Beach A: ☐	Beach B: ☐
I would **not** choose to visit either beach: ☐		

When the direct expenditure estimates, indirect and induced expenditure estimates, and willingness-to-pay estimates are combined, the results provide key insights into what factors are used by beach goers to attend a beach, as well as what value that visit has on the local economy. This is critical when researchers and communities want to understand what aspects of the remediation efforts influenced beachgoer decisions. These decisions translate to usage, which translate to economic impact in the local communities. After all primary and secondary data sources are compiled, a full policy analysis can be performed to estimate the benefits and costs associated with remediation. This will inform how the state and local communities can best proceed in beach remediation efforts.

In summary, assessing the economic impact of beach remediation or investments is complex. While it is possible to measure the direct spending from increased usage, the blue investment at a beach can result in many behavioral changes that can lead to further indirect willingness-to-pay (i.e., park fees, etc.). In an age of economic centricity, it is important for beach managers and those working on the behalf of beach health and water quality to find economic metrics that can sell the investment in these beach improvements to local leaders. Often the complexity of these metrics will suggest the partnership of local beach managers with those experienced in these studies.

4. Social/Community Assessment

Beaches provide important societal benefits including recreation, public access, and cultural services. Many different users come to beaches seeking recreational opportunities, including boating, fishing, swimming, walking, birdwatching, playing, and sunbathing. While water-front access may be easy for some coastal citizens, public beaches often provide the only access to recreational water opportunities for under-served groups. In the Great Lakes, beaches also have a cultural and spiritual component in their tie and access to water. Quality of and access to shorelines must be balanced among these different user groups in addition to the environmental services beaches provide. To maintain a positive user experience and balance conflicting user groups, beach managers need to consider the recreational carrying capacity of the beach (Needham et al., 2008; Zacarias et al., 2011).

Measurements/Data Collection

To assess the social and community value of the beach, a manager should consider how many people are using the beach, what user groups are represented, how those users are recreating, and how satisfied beach users are with their experience.

Beach Usage

Beach usage numbers can be gathered through the Great Lakes Beaches Routine On-Site Sanitary Survey (https://www.epa.gov/sites/production/files/documents/greatlakes_onsite.pdf), Great Lakes Beaches Annual Sanitary Survey (https://www.epa.gov/sites/production/files/documents/greatlakes_annual.pdf), or other routine survey methods such as lifeguard reports. These surveys should count the number of people at the beach, those in water and out of water, and breakdown, if possible, how users are recreating at the beach. Additional surveys (described below) can be done to gain additional information on beach usage while also assessing user experience.

Beach-User Experience

Assessing beach-user experience can be accomplished through questionnaires or surveys of users while they are recreating on-site. Beach users are interviewed to assess (a) whether they are local users or tourists; (b) what their primary and secondary reasons for visiting the beach are; and (c) overall level of satisfaction while visiting the beach. Additional questions may be added as needed to discern management information (e.g., perceived crowding, quality of public facilities, sources of conflict, impression of beach cleanliness, etc.). These simple surveys can serve to generate additional information for beach managers to consider and may be sufficient for most beach managers in assessing user-experience and conflicts. More advanced methods will incorporate the multiple satisfaction approach (Hendee, 1974), where beach users are asked to rate the level of importance and satisfaction of existing and hypothetical conditions on a point-based scale (e.g., Zacarias et al., 2011).

Community Benefits

Community benefits can be assessed or incorporated as part of a beach user survey. The beach manager can check off services that are provided to the community at the beach or survey respondents can describe or check off services that they perceive the beach as providing.

Access to Waterfront

- Is there waterfront access to any member of the public?
- Is the waterfront ADA accessible?
- Is the beach on or near a public transportation route?
- Recreation
- Swimming
- Boating
- Fishing
- Sunbathing
- Walking/running
- Surfing
- Kayaking
- Bird/animal viewing

Access to the Beach

The beach manager should assess who has access to the beach and if access is the same across all populations. Do disadvantaged or mobility impaired patrons have the same access to the beach and water as others?

Conflicting User Groups

Some users (e.g., animal watchers and boaters) can regularly conflict with one another. This may place limitations on when and where recreation can occur, resulting in a need to balance the experience of all user groups. Using the Routine and Annual Great Lakes Sanitary Surveys and any additional survey mechanisms (see *beach usage* and *beach user experience* sections), the beach manager can determine what groups make up most beach users. On-site survey questions can specifically ask users what types of access they consider when recreating at the beach, or what types of access are missing from the site that are beneficial for their desired use. Beach managers can pull together focus groups of beach users to discuss key issues each group faces and identify conflict and possible solutions in a collaborative setting.

Chapter 3

Planning, Adaptation, and Mitigation

This chapter combines the topics covered in *Chapter 1 - Examining the Importance of Beaches* and *Chapter 2 - Assessing Beach Conditions* into a framework to help identify opportunities to incorporate resilience and sustainability into beach mitigation projects to help managers better plan and adapt to coastal stressors.

As defined earlier in this guide, beach resilience is the ability of a beach to, by nature or design, respond to, recover from, and prepare for forces of nature or human activities. Stressors can degrade the health and condition of a beach. Holistically managing a beach can increase its resilience to stressors and improve its ability to achieve the desired management goals.

The following steps outline an adaptive management framework for developing and implementing flexible management plans for a beach. Adaptive management is a planning process that provides a structured, iterative approach for improving actions through long-term monitoring, modelling, and assessment of current and alternative strategies (Figure 3.1). Natural events or human actions may impact, or even negate, actions taken to mitigate the beach and it may be necessary to rebuild, change, or modify the original design and/or management plan. Adaptive management is the process of accounting for the management needs of the beach over time to ensure the practices are performing as intended. The assessment processes in *Chapter 2 - Assessing Beach Conditions* can be used for adaptive management purposes – adaptive management does not require a separate set of assessment tools.

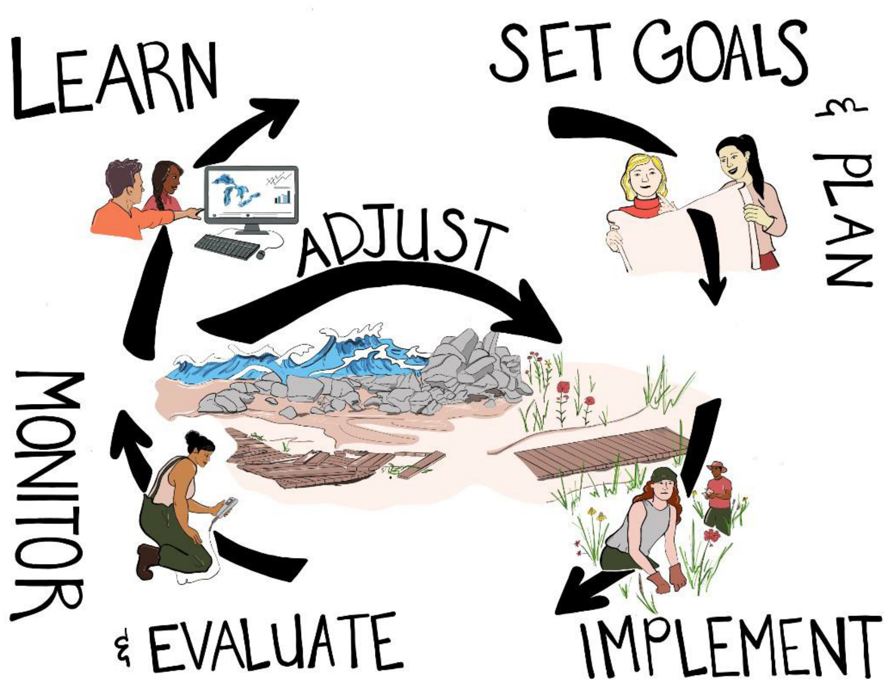


Figure 3.1. Monitoring and adaptive management framework (Brooke Bowser).

This framework walks the user through the questions that should be asked when working with consultants or contractors to holistically weigh different mitigation options to incorporate resilience and sustainability into planning. A list of potential management practices is provided in Table 3.1. Due to the large number of available practices, this is not an all-inclusive list – when necessary, utilize external consultants to develop an appropriate management plan.

In addition to considering the ecosystem services beaches provide, the stressors that can impact them, and the different management options available, socioeconomic considerations must be taken into account when crafting sustainable beach management plans and building resiliency. For example, if the chosen management plan does not incorporate the limitations of the annual budget, staff expertise, or equipment needs, long-term monitoring may not be completed, causing future degradation of the beach. Additionally, if the management plan does not consider the needs of the community, the desired uses for that beach may not be achieved because visitors may want to access a portion of the beach that was not designed for recreation. The planning process helps put together a road map for redesign planning (e.g., as part of a park master plan) or mitigating a beach that has suffered damages due to storms, high water levels, erosion, etc.

It's important to note here that incorporating beaches into larger local and regional planning efforts (open space, natural resource, hazard mitigation, etc.) is critically important to ensure public participation and engagement, increase awareness of the importance of the resource, identify possible threats, assist with building public ownership of the resource, develop a vision for the beach, identify future needs and opportunities, and build consensus on long term management. Successful long-term management often depends on community engagement. Community visioning can be an important tool in the planning process to build stakeholder engagement. Visioning is a process that allows a community to define the future of its resources. Through public involvement, communities identify a purpose, core values and vision for the future. When beaches are integrated into larger planning efforts, opportunities to access state and federal resources for site improvements or hazard mitigation are increased.

A common shortcoming of beach mitigation projects is securing funding. Funding should be a key priority when developing beach management plans. This framework will assist in putting together a competitive application for funding. It can be easier to secure funding for planning, community engagement and outreach, design, and construction than for post-construction maintenance and monitoring; however, these activities are fundamental to the sustainability of the resource. Thus, it is important to develop a strong proposal. Planning can help provide leverage for budget and policy decisions as well as demonstrate the need to invest in beach mitigation projects. The provided framework will walk users through the process of incorporating long-term maintenance and monitoring, as well as outreach and communication, into management plans to bolster the plan and help make an application for funding more competitive.

Beach redesign or hazard mitigation actions, which guides the development of a management plan or road map, is primarily undertaken to address underlying issues impacting the health and resilience of the beach. Therefore, the potential impacts from, and to, neighboring reaches of shoreline and properties should be considered for every practice and action outlined in the management plan. Additionally, this framework emphasizes sustainability and resilience. Sustainable co-benefits of various practices should also be considered. For example, use of beneficial materials such as clean, dredged sand can be used for beach nourishment or dune construction.

Framework for Resilient & Sustainable Beaches

Adaptive management is fundamentally a feedback loop. This means iteratively adjusting the management plan based on continuous monitoring and evaluation of different management strategies. This could mean starting over from scratch after finding that a solution is not appropriate for that beach. Finding the best solution for a beach is rooted in willingness to act and sound science. The following framework depicted in Figure 3.2 breaks down the components of the adaptive management cycle to help beach managers design a sustainable beach restoration project. Chapter 4 illustrates how this roadmap was applied in a case study on Wisconsin's shore of Lake Michigan.

Learn		**Set Goals & Plan**				**Implement**		**Monitor & Evaluate**	**Adjust**
Determine Key Attribute Status	Identify Underlying Issues & Characterize Risk	Identify Management Goals	Education & Outreach	Identify Funding Sources	Select Management Practices	Determine When to Act	Maintenance	Monitor and Evaluate Management Practices	Fine-tune Management Plan & Management Practices

Figure 3.2. Framework for incorporating resilience and sustainability into beach mitigation projects.

Learn

Determine Key Attribute Status

What are the key attributes that play a role in achieving the desired uses of the beach?

Use Table 1.1 to determine which physical, chemical, biological, and landscape attributes are critical to the desired uses of the beach. Desired uses cannot be achieved if the key attributes supporting them are impaired. The desired uses should incorporate municipal needs as well as community and habitat needs.

Education and Outreach

Who should be at the table when developing the management plan?

Incorporating outreach and education opportunities into the process of developing a management plan will strengthen the sustainability of the project by garnering buy-in from local elected officials and the community. Refer to *Chapter 2* to revisit the socio-cultural community component of the beach. Including stakeholders in the planning and visioning process will create ownership of these projects and generate support for using funds for beach enhancement or mitigation projects to support designated uses.

Identify Underlying Issues and Characterizing Risk

Are any of the key attributes impaired? What are the underlying problems impacting the key attributes? What is the risk associated with these issues?

Use physical, biological, chemical, economic, and social/community assessments to identify specific issues impacting beach attributes in the ecosystem services table and note the associated risk. Collect historical data needed for these assessments and look for gaps in the existing information. Resilience is achieved by managing beaches holistically. In-depth assessments of the environmental and anthropogenic stressors will help fully address the issues impacting the beach. Further, being able to demonstrate the physical, economic, and social impact can make grant applications more competitive.

Set Goals and Plan

Identify Management Goals

What are the management goals for the beach?

Determine management goals based on the desired uses and identified impairments of key attributes. Example management goals include improving nearshore water quality, creating habitat, and improving public access. These goals are site specific and will vary based on the needs of the site and the community. Management goals should include, but may not be limited to, addressing key attribute impairments.

Education and Outreach

Who is the target audience? What is the information that will be shared? How will the information be delivered? How will stakeholders be involved in the planning process?

Identify the target audience and consider when and how stakeholders should be engaged throughout the planning process to help prioritize management goals, use of the site, and mitigation measures. Additionally, consider how to inform visitors or the public about resilient beach management as well as how the site could be used as an educational asset such as a living laboratory. Educational opportunities should be age appropriate.

Identify Funding Sources

How will the project be paid for? What level of action is feasible? When should funding be secured?

It is important to identify how a beach redesign or mitigation project will be funded. After a needs assessment is performed, funding can be sought to meet those needs. One approach to this may include developing a series of management options and projected outcomes as part of the community visioning process. Funding may limit what actions can be taken and when. This is important to keep in mind as management practices are identified. Always include long-term maintenance and monitoring when determining how much funding will be needed for a project; develop benchmarks or metrics by which to gauge success.

Select Management Practices

What management practices will help address the issues affecting the beach?

Table 3.1 lists items to consider when developing a holistic beach management plan to address underlying issues and achieve desired management goals. Remember to choose options based on available funding, socioeconomic considerations, desired ecosystem services, and capacity to provide ongoing site maintenance. Include discussions about permitting early in the planning phase to ensure the management practices are allowable.

Consider the following information when choosing a management practice:

- Location of the issue or management priority area
- Relative installation and maintenance costs
- Benefits of the practice
- Impact on beach use
- Permit requirements
- Maintenance requirements
- Balance of competing interests
- Related management options

- Considerations that may impact the sustainability of this management practice or the chosen management plan
- Potential negative impacts on other identified issues

Implement

Determine When to Act

What actions can be taken?

Adaptive management is an iterative process, and it may not be feasible or appropriate to do everything outlined in the management plan all at once. While working through the steps of this framework, think about short-term goals for the site and which attributes should be prioritized for investment. Funding may be a limiting factor and might require the work to be phased. Short-term actions can maintain momentum for the project and take advantage of available funding to help iteratively work towards reaching the long-term management goals for the beach.

The process of adaptive management inherently requires adjustments to the management plan based on post-implementation monitoring and evaluation of current practices. This process may take time and not every component may be able to be implemented at once.

Maintenance

What are the short-term and long-term maintenance requirements? Who will be responsible for maintenance?

Maintenance is key to supporting the useable life of each management practice. While working through the adaptive management process, different beach management practices will be implemented and iteratively adjusted to achieve the management goals for the beach. It is important to have a plan for how each management practice will be maintained.

Consider the following when developing a maintenance plan:

- Short-term maintenance needs
- Long-term maintenance requirements
- Funding to support long term maintenance
- Who will be doing the work
- Does the maintenance require any specialized knowledge, skill, and equipment?

Monitor and Evaluate

Monitor and Evaluate Management Practices

Are the management practices performing as they should be? Have any natural or human stressors effected the environmental health of the beach or the long-term life of the practices?

Long-term monitoring and evaluation of a beach and the selected management practices is also foundational to both the adaptive management process and the sustainability and resiliency of a mitigation project. Using assessments before selecting mitigation options and after the implementation of the management plan can help determine the effectiveness of the practices, if the management goals are on track, and if any unintended consequences have occurred.

Adjust

Fine-tune Monitoring Plans and Management Practices

What needs to be changed based on monitoring and evaluation efforts? Are there data gaps in the monitoring plan?

Because site conditions change due to either environmental conditions, such as storm events, or because of construction or implementation of management practices, recurring evaluation and assessment should be included as part of every management plan. They provide the opportunity to evaluate individual management practices and the overall management plan. Evaluation will also identify data gaps, e.g., past assessments may not be collecting the correct data and new data needs to be collected. Adjustments to the overall management plan, to individual management practices, or to the assessment methods can be made based on the post-implementation monitoring and evaluation results. Iteratively adjusting the management plan based on how the management options are performing can increase the success of the project.

Adaptive Management Exemplified on the Great Lakes

The case study described in Chapter 4 demonstrates how a Wisconsin beach incorporated funding, maintenance, monitoring, and outreach/education components into the management plan. The case study exemplifies how managers identified needs, implemented actions to improve resiliency, and used an iterative assessment and modification process to achieve resiliency.

Table 3.1. Examples of Management Practices for Beach Mitigation

BMP	Description	Impact on Beach Use?	Issue	Potential Benefits	Maintenance	Related Options	Installation Costs	Maintenance Costs	Considerations
Beach grooming	Removal of debris and aeration of sand with tractors and rakes	Yes	• Aesthetic • Water quality	• Inhibit bacteria growth • Debris removal	Frequent	• Trash receptecles signage • Bird harrassment	2-3	2	• Trained operators & equipment • Potential habitat disturbance • Temporarily inaccessible during grooming
Beach ambassadors	Beach welcoming committee	No	Education	• Clean beach • Educated beach users	Frequent	• Signage • Traditional and online media messaging	N/A	1	• Recruitment & Retention • Training
Lifeguards	Swimmer supervision	No	• Education • Safety	• Swimmer safety • Rip current education	Frequent	• Signage • Flags	N/A	1	• Recruitment & Retention • Training • Liability
Signage	Use of signs to educate and direct users	Yes	• Education • Safety	• Litter reduction • Educated beach users	Minimal	• Beach ambassadors • Lifeguards	1	1	• Visibility and placement • Design and accessibility • Multi-lingual messaging • Static vs dynamic content
Integrated invasive plant management	Mechanical, biological, cultural, and chemical management of invasive species	Yes	• Invasive species	• Native plants • Beach aesthetics	Frequent	N/A	1-2	2	• Trained operators • Identify and select native plant species • Decrease chemical usage
Groin	Shore-perpendicular structure designed to catch sediment	Yes	• Loss of beach	• Keeps sediment in place • Erosion reduction	Periodic	• Piers • Docks	3-4	3	• Interrupts sediment transport • Formation of dangerous currents • Less effective at higher water levels • Public access & safety • Potential change to circulation and water quality
Revetment	Shore-parallel structure designed to protect against wave erosion	Yes	• Loss of beach	• Erosion reduction	Periodic	• Seawall • Breakwater	4-5	3	• Potential flanking erosion at ends of revetment • Interrupts sediment supply • Impacts beach creation lakeward of revetment • Public access & safety
Beach nourishment	Use of sand and sediment to replace material that has been washed away	Yes	• Loss of beach	• Erosion reduction • Beneficial use of dredged materials	Periodic	• Dredging • Dune construction • Dune stabilization	2-3	3-5	• Access to clean and suitable* sediment • Transportation and placement of beach sediment • Renourishment periodically needed • Potential transport of sediment off-site
Dune construction	Creation of new sand dunes with the use of native dune vegetation, fences, nourishment, and boardwalks	Yes	• Loss of beach	• Erosion reduction	Periodic	• Beach nourishment • Nature-based shoreline structures • Dune stabilization	4	2	• Identification and selection of dune vegetation • Time for vegetation to establish • Establishment of public access trails* • Requires adequate space
Dune stabilization	Use of native dune vegetation, fences, nourishment, and boardwalks to enhance existing sand dunes	Yes	• Loss of beach	• Dune preservation	Periodic	• Dune construction • Beach nourishment	1-2	2	• Identification and selection of dune vegetation • Establishment and maintenance of public access trails • Requires adequate space
Canine goose harassment	Use of dogs to scare off geese	Yes	• Water quality • Beach aesthetic	• Reduction in goose feces • Bacterial reduction	Frequent	• Hazing • Signage forbidding feeding • Relocation of molting	1	1	• Recruitment & Retention • Training • Birds may acclimate or relocate
Bioswales	Man-made, vegetated, low-lying areas that catch and drain stormwater	No	• Water quality	• Reduced stormwater runoff • Stormwater filtration • Provides habitat • Aesthetically pleasing	Frequent	• Ditch • Gutter system • Rain garden • Buffers	2-3	2	• Requires suitable soil • Identification and selection of native plants • Frequent management to ensure function • Beach sand may block drainage • Potential need for re-plantings
Storm water ordinances	Community-wide standards that manage stormwater and water quality	No	• Water quality	• Better water quality • Fewer beach contaminants	N/A	• Pipe discharge identification • Green infrastructure	N/A	N/A	• Local decision-maker support • Enforcement capacity
Rain Gardens	Depressed area planted with native, long rooted plants to collect runoff	No	• Water quality	• Reduced stormwater runoff • Stormwater filtration • Provides habitat • Aesthetically pleasing	Frequent	• Bioswales • Ditches • Permeable pavement • Engineered wetlands	3	2	• Requires suitable soil and engineered substrate • Identification and selection of native plants • Frequent management to ensure function • Beach sand may block drainage • Potential need for re-plantings

Chapter 4

Samuel Myers Park Restoration Project

Figure 4.1. Location of Samuel Myers Park (Bodus et al, 2020 and https://bit.ly/38R0oLb)

Samuel Myers Park is an embayed beach separated from the high wave energy of Lake Michigan by a rubble mound breakwater. The site was found to be impaired for fecal indicator bacteria (FIB) and a decades long swim ban existed prior to restoration. Thus, the primary goal of the project was to improve nearshore water quality, which is integral to habitat restoration and ecosystem function.

In 2014, the Racine Public Health Department initiated a project to improve nearshore water quality at Samuel Myers Park in Racine, Wisconsin, utilizing an adaptive management approach to help achieve resiliency. The following case study exemplifies how the assessments discussed in Chapter 2 and the adaptive management framework outlined in Chapter 3 can be used to plan, implement, and maintain a site mitigation initiative to improve coastal resilience.

Learn

Determine Key Attribute Status

What are the key attributes that play a role in achieving the desired uses of the beach?

Desired uses included the provision of recreational (e.g., passive recreation, swimming, and boating/paddle boarding), educational, and research opportunities, enhanced natural habitat, stormwater runoff management, and protection from coastal storms and erosion. Key attributes (Table 1.1) identified as playing a role in achieving each of the desired uses for Samuel Myers Park are listed below (Table 4.1). Some key attributes were significant to more than one desired use.

Table 4.1. Key attributes for Samuel Myers Park Restoration Project

Recreation	• Temperature • Clarity • Chemicals (Nutrients e.g., phosphorus and nitrogen) • Odor (Resulting from decaying algal mats) • Pathogens (Potentially, as indicated by elevated fecal indicator bacteria levels) • Beach width
Coastal Erosion	• Ecosystem health/biotic integrity • Fish • Wildlife • Plants • Aesthetics • Clarity • Beach width • Erosion
Education & Research	• All physical, chemical, biological, and landscape attributes
Natural Habitat (“avoided damages”)	• Clarity • Chemicals (Nutrients e.g., phosphorus and nitrogen) • Odor • Pathogens • Aesthetics • Erosion *Note: All categories in Table 1.1 apply for existence (non-use value)*

Education and Outreach

Who should be at the table when developing the management plan?

Site management was/is an internal process dictated, in part, by their engineering merit report and permits. The Racine Public Health Department sought advice on invasive species management from the Ozaukee Washington Land Trust, hired the Root Pike Watershed Initiative Network to do educational sign design and coordinate volunteer workdays, worked with stakeholders such as Friends of Myers Park on invasive species removal and naturalization, and held public meetings as part of the permitting process. They also interacted with the US Army Corps of Engineers and Wisconsin Department of Natural Resources throughout the process.

Identify Underlying Issues and Characterizing Risk

Are any of the key attributes impaired? What are the underlying problems impacting the key attributes? What is the risk associated with these issues?

Prior to the Samuel Myers Park Restoration Project, overtopping of the rubble mound breakwater structure extending from the shoreline resulted in erosion and the formation of a channel of stagnant water that was redistributed across the beach during subsequent overtopping events due to poor hydrodynamics. In addition, stormwater runoff originating from the upland area of the park brought bacteria and nutrients to the shoreline, contributing to the exceedance of recreational water quality standards, algal blooms, and the distribution of accumulated debris along the beach face. Vegetation at the site was predominantly invasive or non-native species, such as phragmites, which contributed to reduced uptake of phosphorus and nitrogen and poor-quality habitat.

Figure 4.2. Samuel Myers Park pre-construction
(Wisconsin Shoreline Inventory and Oblique Viewer)

Set Goals and Plan

Identify Management Goals

What were the management goals for the beach?

The project team, with input from stakeholders, identified four management goals based on the desired uses characterized earlier in the process. The management goals for the project were to (1) improve nearshore water quality, (2) create habitat, (3) improve public access, and (4) create opportunities for environmental education and research.

Education and Outreach

Who is the target audience? What is the information that will be shared? How will the information be delivered? How will stakeholders be involved in the planning process?

Education and outreach throughout the implementation and maintenance phases of the restoration included providing service opportunities and job training for the Great Lakes Community Conservation Corps and AmeriCorps NCCC. Additionally, college interns were employed to collect field samples, conduct laboratory analysis, and assist with site maintenance and monitoring. The Racine Public Health Department also hosted citizen volunteer planting and clean up events at the park. Education and research opportunities were provided for K-12 and university students. Finally, the water quality data collected at the park is made publicly available.

Identify Funding Sources

How was the project be paid for? What scope can be afforded? When should funding be secured?

The Racine Public Health Department utilized multiple, sequential public and private funding sources to pay for each phase of the restoration project. Funding was leveraged from grants, donations, in-kind work, revenue and tax levy. Among these funding sources were several larger grants awarded by US EPA Great Lakes Restoration Initiative, Wisconsin Coastal Management Program, Fund for Lake Michigan, US Forest Service, and US Fish and Wildlife Service.

Select Management Practices

What management practices will help address the issues affecting the beach?

The Racine Public Health Department selected a mix of gray, green, and public access infrastructure to help address impaired nearshore water quality and work towards reaching their management goals. The management practices they selected are shown in Table 4.2.

Table 4.2. Management practices utilized in Samuel Myers Park Restoration Project

Gray	• Raise height of breakwater
Green	• Constructed (engineered) wetlands and bounding structures (dunes) • Rain garden • Bioswale • Stormwater trees • Invasive species management • Establish native vegetation (multiple habitat types)
Public Access	• Cordwalk and asphalt paths • Gazebo (also acts as outdoor classroom space) • Scenic overlooks • Picnic area

Consideration of the following were made in regard to each selected management practice:

- Location of the issue or management priority area
- Relative installation and maintenance costs
- Benefits of the practice
- Impact on site use
- Permit requirements
- Maintenance requirements
- Balance competing interests
- Related management options
- Considerations that may impact the sustainability of this management practice or the chosen management plan
- Potential negative impacts on other identified issues

Implement

Determine When to Act

What actions were taken?

Ultimately, the breakwater was raised by about 3-4 feet to prevent overtopping. It also provided an area protected from high wave energy to support the installation of constructed (engineered) wetlands. The constructed wetlands were connected with a culvert and a pair of channels were built along the breakwater and in between the two wetland cells to help mitigate the impacts of large storm surges and runoff resulting from significant precipitation events. A French drain system was built under the main public access point and dissipaters (flow moderators) were installed to reduce runoff intensity to the constructed wetlands. Dunes, functioning as bounding structures for the constructed wetlands, also help capture runoff and enhance habitat.

Invasive species were removed, and the existing coastal and constructed wetlands were revegetated with native species. A rain garden, bioswale, sedge meadow, and trees were planted to help capture runoff and increase infiltration. A series of cord walk paths, a scenic overlook, and gazebo were installed as part of this project to improve public access and provide educational opportunities (via informational signage).

Maintenance

What are the short-term and long-term maintenance requirements? Who will be responsible for maintenance?

Currently the Racine Public Health Department project team is managing the short and long-term maintenance of the project, which is dictated, in part, by the US Army Corps of Engineers (i.e., annual wetland mitigation report). A municipal site maintenance plan is in development and will take effect after the permit conditions are met. Maintenance includes weekly surface and groundwater monitoring within the wetland and nearshore areas. It also includes native plant community surveys, invasive species assessments and control, estimations of plant coverage, upkeep of site amenities, and routine park and trail maintenance by parks/public health department staff and interns.

Monitor & Evaluate

Monitor and Evaluate Management Practices

Are the management practices performing as they should be? Have any natural or human stressors effected the environmental health of the beach or the long-term life of the practices?

Monitoring of the site includes seasonal weekly surface water and groundwater monitoring, invasive species assessments, and native plant community surveys. Monitoring also includes checking the site's gray and green infrastructure after storm events.

Storm events during initial construction resulted in localized damage to some facilities which provided the opportunity to amend the project site plan to enhance coastal resilience. Three years after project completion, a major storm event (January of 2020) resulted in coastal storm damage significant enough to warrant a federal disaster declaration for Racine, Milwaukee, and Kenosha counties. It is anticipated that FEMA funded restoration to pre-disaster conditions will also provide mitigation opportunities to avoid future damages.

Figure 4.3. Damage from January 2020 storm event
(Top) Cord walk
(Bottom) Bioswale

(Bodus et al, 2020 and https://bit.ly/38R0oLb)

Adjust

Fine-tune Management and Monitoring Plans and Management Practices

What needs to be changed based on monitoring and evaluation efforts? Are there data gaps in the monitoring plan?

As a result of the January 2020 storm damage, mitigation activities were proposed. These activities included:

- Increase width of return channels
- Increase diameter of culvert connecting engineered wetlands
- Provide dune toe protection
- Vegetate constructed wetland bounding structures using a geotextile grid system to enhance stability

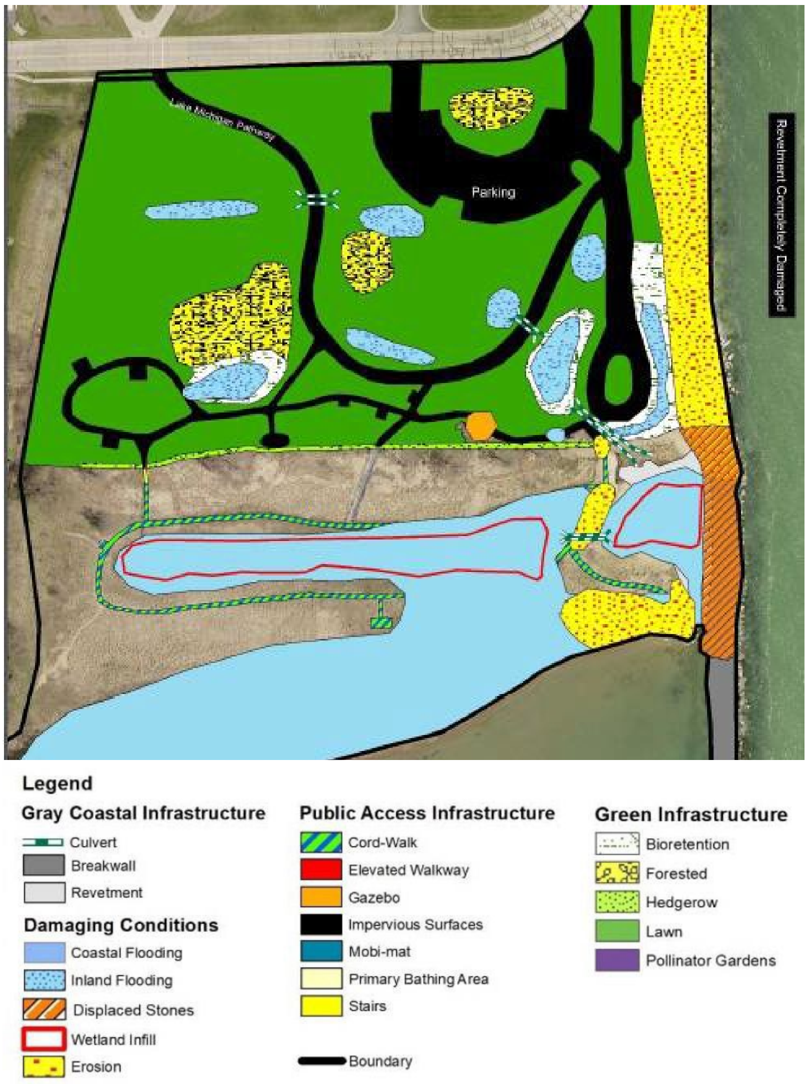


Figure 4.4. Location of flood prone areas, erosion, and other coastal storm damage.

(Bodus et al, 2020 and https://bit.ly/38R0oLb)

Outcomes

By utilizing an adaptive management approach to site restoration, the Racine Public Health Department was able to achieve all four of its management goals at Samuel Myers Park and support each of the park's desired uses. In summary:

- Recreational water quality improved – an offshore swim zone was established, and the impairment removed. The offshore swim zone has been open since 2017.
- Nutrient levels (e.g., phosphorus) have decreased.
- Algal blooms have decreased – none have been occurred since the project's completion.
- Species diversity (e.g., migratory birds, mammals, herptiles, and fish) has increased.
- Critical species habitat and monarch waystation designations received.
- Public access, including ADA access, to the park and shoreline has been improved.
- Utilization by the public has been enhanced.

Figure 4.5. Samuel Myers Park post construction.
(Images courtesy of Julie Kinzelman, City of Racine Public Health Department)

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