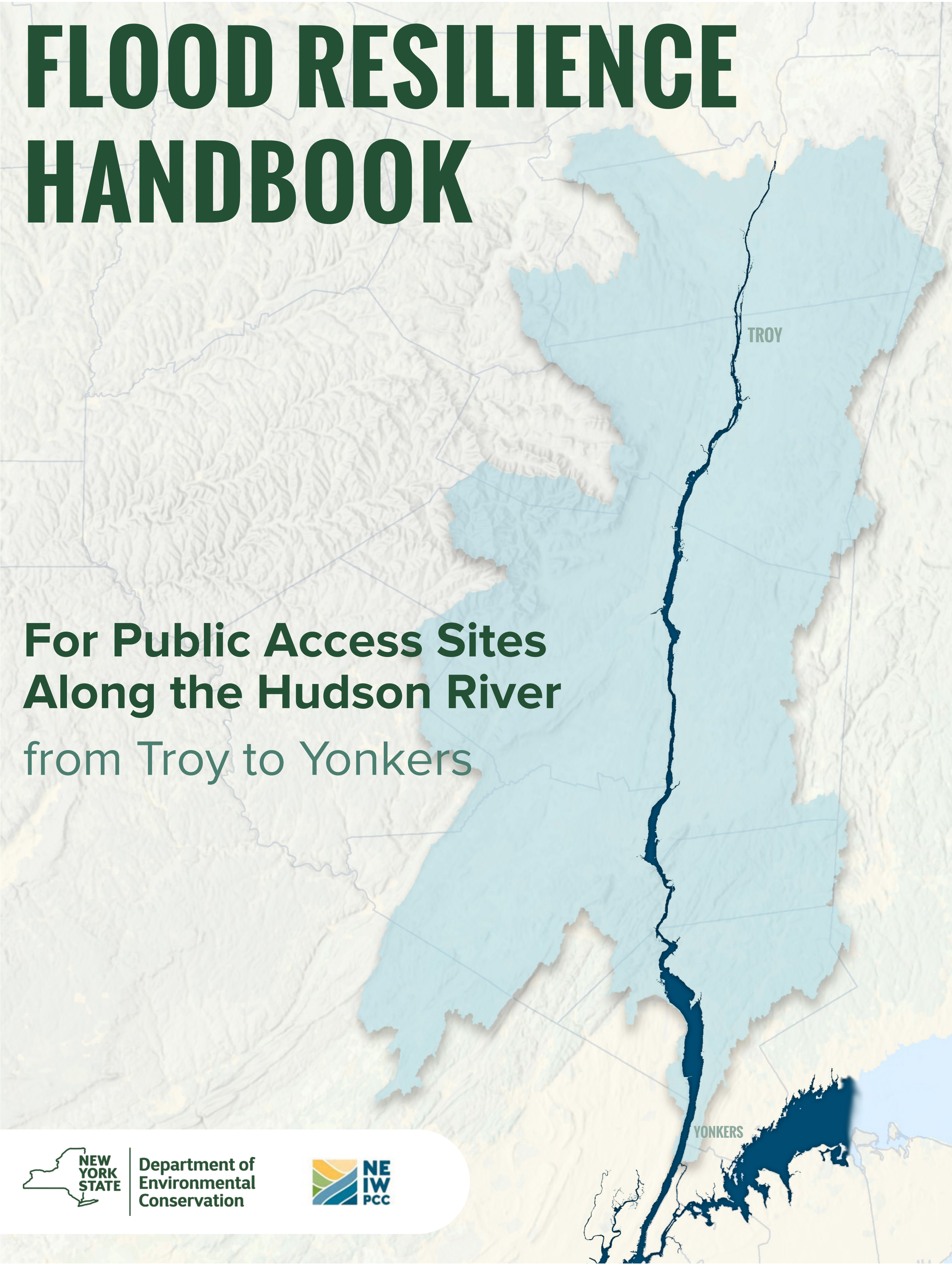
FLOOD RESILIENCE HANDBOOK

For Public Access Sites Along the Hudson River

from Troy to Yonkers



NEW YORK STATE | Department of Environmental Conservation

NEIWPCC

FLOOD RESILIENCE HANDBOOK FOR PUBLIC ACCESS SITES ALONG THE HUDSON RIVER

FROM TROY TO YONKERS

New York State Department of Environmental Conservation &

NEIWPCC

DATE: APRIL 2021

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ACKNOWLEDGEMENTS

This document was prepared for the Hudson River Estuary Program, New York State Department of Environmental Conservation (DEC), with support from the New York State Environmental Protection Fund, in cooperation with New England Interstate Water Pollution Control Commission (NEIWPCC). DEC and NEIWPCC gratefully acknowledge the leadership and assistance of NYC Parks in the development of this document and its contents. Large portions of text and graphics originally appeared in a document entitled *Design and Planning for Flood Resiliency: Guidelines for NYC Parks* (released in November 2017), adapted here with NYC Parks' permission. We greatly appreciate the NYC Parks' collaboration throughout the course of the development of this handbook.

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We would like to thank the members, as well as their agencies, who contributed significantly to the content of this handbook and helped guide and inform the whole project with their diverse perspectives, knowledge, and breadth of experience:

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Together, the team adapted the NYC Parks handbook to meet the needs of Hudson River stakeholders. This year-long effort included a project workshop early in the process to solicit ideas and feedback on the development of the handbook, site visits and interviews with case study site managers, monthly Steering Committee meetings, research, writing, and expert review.

SUGGESTED CITATION: WSP USA. 2020. *Flood Resilience Handbook for Public Access Sites Along the Hudson River from Troy to Yonkers*. Prepared for the New York State Department of Environmental Conservation and NEIWPCC. July.

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Executive Summary

The Hudson River estuary's river access sites offer an incredible network of public amenities for the many towns, cities, and villages that have long lined its banks. Today, more than 100 public access sites provide residents and visitors opportunities for active recreation, educational programming, and quiet appreciation for one of the State's great natural wonders. Over the past 50 years, public investments have resulted in a cleaner river and public access to it in nearly every community along the Hudson estuary from New York City to the Federal Dam at Troy. These parks, preserves, and other river access sites along the shores of the Hudson River estuary provide outstanding recreational, ecological, scenic, and economic value.

Climate models project the estuary's water levels may rise several feet by the end of this century, threatening the condition and viability of many shoreline access sites, along with the communities they serve, including low income, historically disadvantaged and overburdened communities.[1] **Sea level has already risen 6 inches in the last fifty years, and many river access sites along the tidal Hudson are already experiencing flooding, even on sunny days.**[2] Sites have been severely impacted by storms such as Hurricane Irene, Tropical Storm Lee, Superstorm Sandy, and seasonal nor'easters, all of which destroyed infrastructure, caused erosion, and damaged recreational resources. Low-lying sites regularly experience flooding during exceptionally high tides or periods of intense rainfall.

This handbook was developed to assist river access site owners and managers in adapting to existing and predicted flooding. **The term "river access site" is meant to act as a reference for all parks, preserves, boat launches, marinas, fishing access, trails and other public open spaces that are directly adjacent to the shoreline of the tidal Hudson.** By planning and implementing resilience strategies and public outreach plans, managers of such sites can reduce their vulnerability and thrive under changing conditions. The [Hudson River Estuary Program](https://www.dec.ny.gov/lands/4920.html)[3] has been actively promoting resilience planning to ensure the long-term health of the Estuary's resources and communities, including convening community-based "Flood Resilience Task Forces" to study climate and flood projections and propose solutions in pilot municipalities. This handbook serves that effort by providing site owners and managers with guidelines to reduce damage, costs, and other consequences associated with the effects of climate change being planning for resilience.

While many aspects of this handbook are relevant to river access sites elsewhere, the geographic focus is on the Hudson River estuary and the tidal portions of its tributaries in the 10 counties of the Hudson Valley: Albany, Columbia, Dutchess, Greene, Orange, Putnam, Rensselaer, Rockland, Ulster, and Westchester. **In this document, specific risks and projections for the Hudson River are outlined and strategies to plan, design, and build resilient river access sites directly abutting the shoreline and within the geographic floodplain are discussed.** The Hudson's recreational community is also served by numerous marinas and area boat clubs that are likewise facing resiliency challenges and hopefully will benefit from the information provided here as well. Case studies on flood resilience strategies that Hudson river access sites have implemented showcase local challenges and local solutions related to improving resiliency across the estuary.

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[1] New York State Department of Environmental Conservation (NYS DEC) Regulations, NYCRR, Chapter IV Quality Services, Subchapter I Climate Change, 490.4 Projections, https://www.dec.ny.gov/regulations/103877.html.
[2] Impacts of Climate Change in New York, NYS DEC, https://www.dec.ny.gov/energy/94702.html.
[3] NYS DEC Hudson River Estuary Program, https://www.dec.ny.gov/lands/4920.html.

1. Overview: Purpose and Principles

Throughout this handbook, the terms "river access site," "riverfront access," and "waterfront park" refer to all public parks, preserves, boat launches, fishing access sites, greenway trails and other open spaces that are directly adjacent to the shoreline as well as parts of those parks upland from the water's edge.

To adapt riverfront sites to changing climate conditions, action must be taken today and over the coming years. Managers of river access sites along the Hudson face an array of decision-making challenges and new learning curves associated with understanding resilience in the context of river access planning. This handbook is directly inspired by and borrows from *NYC Parks Design and Planning for Flood Resiliency: Guidelines for NYC Parks*,[4] which provides such assistance for managers of access sites within the Hudson River estuary and on coastal waters within New York City boundaries. That document is adapted here with the permission of NYC Parks, picking up where NYC Parks leaves off geographically to focus on the Hudson River upstream of New York City to the head of tide at the Federal Dam in Troy, NY.

This handbook focuses on the unique risks, planning and design processes, site types, resilience strategies, permitting constraints, and fundraising options specific to waterfront parks and access sites along the Hudson River and the tidal portions of its tributaries. It is intended for the diverse municipal, county, state, and non-profit entities that own, operate, plan for, and advocate for public river access sites along the Hudson. The Hudson is also host to numerous marinas and local boat clubs that are also facing challenges during these changing times. We hope those with an interest in recreation, park planning, and designing for flood resiliency will use this handbook to navigate decisions and improve park resilience in their communities.

THE PURPOSE OF THIS HANDBOOK IS TO:

- Bring awareness to the unique risks public Hudson River access sites face as recreational and community resources;
- Describe how the Hudson is and will experience flooding as the climate changes;
- Outline a process for planning, selecting, permitting, and funding resilience strategies at river access sites;
- Provide guidelines and additional resources for flood resiliency; and
- Share the experiences and lessons learned of sites that have already acted to address flooding and climate resiliency on the Hudson River.

[4] New York City Department of Parks & Recreation, Design and Planning for Flood Resiliency: Guidelines for NYC Parks, www.nycgovparks.org/pagefiles/128/NYCP-Design-and-Planning-Flood-Zone_5b0f0f5da8144.pdf, 2017.

1.1. **What is 'Resilient Riverfront Access'?**

The Hudson riverfront is not simply the outer bound of towns and villages; it is a dynamic space that supports and sustains healthy ecosystems and human enjoyment. New York State is committed to ensuring Hudson River access sites are resilient and accessible, provide recreational amenities now and into the future, and manage the risk of flooding and associated damage from sea level rise, coastal storms, and ice dynamics.

Resilience means preparing for risks and specific events, adapting as new information emerges, and recovering quickly from disruptive events when they do occur. Adapting riverfront access sites to be more resilient means designing and maintaining sites with climate risks in mind. Resilient river access sites facilitate everyday public use while incorporating components and practices that reduce the impacts felt from climate change.

Figure 1.1 Kingston Point Beach Access Site: Free Kayak Day, June 2019. (Source: Nancy Beard/DEC)

1.2. Guiding Principles

Every site is unique in its history, current conditions, surrounding upland context, recreational, ecological, and community needs, and risk factors. This handbook provides a framework through which site owners and other stakeholders can create site-specific climate resilience and adaptation plans and projects. The following principles can be applied to all river access planning:

Maintain Access

Recreational access to the river is the result of significant public investment over a period of decades and is important to maintain as climate conditions change. Boat launches, greenway trails, parks, and nature preserves enable the communities they serve to thrive.

Recover Quickly from Both Small and Large Storms

Riverfront sites should be designed and improved to recover quickly from storms with minimal pre- and post-storm intervention and maintenance once the resilience strategy is in place.

Design with Risks in Mind

Accommodate, elevate, or protect. By using durable materials and hardy plants to accommodate flooding, siting facilities and critical assets out of harm's way, and protecting what can't be moved, river access sites will be able to withstand harsh conditions and evolving climate patterns on the estuary. Waterfront parks can adapt shore edges to account for projected sea level rise by adopting structural and non-structural approaches.

Serve a Diverse Population

Users with different capabilities, resources, and interests experience the river in different ways. Design decisions should seek to be inclusive, including input from neighboring environmental justice (EJ) communities, or low-income, tribal, or indigenous populations disproportionately impacted by environmental hazards, lack of opportunity for public participation, and health risks, as well as utilizing the principles of universal design, while protecting the features unique to each site.

Where appropriate and feasible, riverfront parks can also seek to:

Bolster Ecosystems

Riverfront parks can strive to incorporate elements that promote functional ecosystems and employ natural systems-based coastal resiliency strategies.

Aid Community-Scale Coastal Resiliency

If sites are well suited, riverfront access sites can play a role in addressing community-scale coastal resiliency by employing interventions that aid in upland protection and broader neighborhood resilience. In urban areas, the water's edge at a river access site is also the edge of the community. As such, a resiliency strategy may serve to aid the resilience of a whole community.

Figure 1.2 Hudson River Access Sites are where the public comes to enjoy and learn about the River. (Source: DEC)

1.3. How to Use This Guide

This handbook may be read sequentially or referenced by section as relevant to the reader.

Chapter 1: Handbook Overview: Purpose and Principles
Purpose and Principles Provides an overview of the nature and use of this handbook.

Chapter 2: Estuary Conditions
Provides an overview of tides, water level, salinity, ice, wakes, waves, flooding and sea-level rise.

Chapter 3: Planning and Design for Resilience
Describes the steps for thinking about and implementing resilience strategies for a site, including assessment of site-specific risks, to evaluating the relative effectiveness of different resilience strategies and how to take strategies through to implementation.

Chapter 4: Land Use and Permitting
Describes permitting issues specific to the Hudson River Estuary and strategies for integrating permitting into the planning process effectively.

Chapter 5: River Access Site Types
Describes different types of access sites and specific resilience considerations for each.

Chapter 6: Resilience Strategies
Focuses on resilient design strategies, including temporary, operational, structural and non-structural solutions to reduce flood risk and protect a site, including impacts from flooding and ice dynamics.

Chapter 7: Case Studies
Provides examples for learning about the experiences and challenges of Hudson River access sites that have successfully undertaken different types of resilience strategies.

Glossary
Collects and provides meaning for key terms related to resilience in the context of the Hudson River Estuary and its public access sites.

Appendices
Provide information on topics that may require more detail and understanding:

- Additional resources
- Funding
- Permit considerations
- Ice Dynamics

2. Estuary Conditions: Understanding Tides, Salinity, Waves, Wakes, Ice, and Sea Level Rise

2.1. Introduction

Chapter 2 is organized into the following sections describing the current and future flood-related conditions to which Hudson River access sites are exposed.

- Tides and Salinity
- Waves, Wakes and Ice
- Climate Change
- Flooding

Riverfront access sites along the Hudson are vulnerable to flooding. The projected rise in sea levels, the probability of increased frequency and intensity of coastal storms, and of increased intensity of non-coastal storms will likely increase flooding, posing significant risks to access site owners and managers. The tidal Hudson also has waves, wakes, and ice that jeopardize shorelines by erosive action. This chapter explains these phenomena and how they influence planning and design decisions for river access sites.

The Hudson River estuary is a tidal waterbody. It extends more than 150 miles from the Atlantic Ocean through New York-New Jersey Harbor, to the Federal Dam in Troy, NY where tidewater ends. Because of this, water levels along the entire estuary are inherently connected to fluctuations in sea level in the Atlantic Ocean. As sea level rises globally, it also rises locally on the tidal Hudson and tidal portions of its tributaries. When a storm blows in from the ocean, it can cause the water levels in the river to surge. In addition, freshwater flows incoming from the upper Hudson and the Mohawk River above the Troy dam interact with this tidal environment, as do stream flows from the estuary's many tributaries. Rainfall or snowmelt in the watershed causes more freshwater to mix with saltwater, which can also lead to flooding. Local storms, snow melt, coastal storms, incremental changes in sea level, and ice jams all combine to make river access sites highly susceptible to seasonal and extreme flooding.

Throughout the northeast, storm intensities have increased, leading to larger amounts of rainfall. During Hurricane Irene and Tropical Storm Lee, this region experienced significant flooding due to heavy rainfall. Damage from Superstorm Sandy also caused severe damage and flooding from coastal storm surge coupled with heavy rainfall. These three storms led to significant damage to riverfront access sites. Their timing, a little more than a year apart, in 2011 and 2012 is unprecedented in the written history of the Estuary.

2.2. Tides and Salinity

Tides are caused by the gravitational pull of the moon and sun. The difference between low and high tide is about 4 feet on the Hudson River estuary, though it varies at each location. There are two low and two high tides each day. Basic definitions such as ebb tide, neap tide, and spring high tide can be found in the **"Key Terminology"** box below. However, it is important to know that local and coastal weather conditions, as well as phases of the moon can cause unusually high or low tides to occur. Planning for such tides can be a factor to consider for making river access sites resilient, for example in designing fixed and floating docks and edge stabilization.

Predicting the Tide

Information on daily predicted high and low tides can be found in local newspapers and at the tides and currents website of the National Oceanic and Atmospheric Administration (NOAA) https://tidesandcurrents.noaa.gov/map/index.html.[5] In addition, the Hudson River Environmental Conditions Observing System provides real-time data across a number of parameters (e.g., wind direction, gage height, air temperature, relative humidity, barometric pressure) and a search function for viewing data of a specific time period: https://ny.water.usgs.gov/maps/hrecos/.[6]

Figures 2.1 and 2.2 The 4th Street kayak launch in Athens at high tide, left (Source: DEC) and low tide, right, from opposite vantage points (Source: fig. 2.1, DEC, fig. 2.2, Scott Keller, Hudson River Valley Greenway)

[5] National Oceanic and Atmospheric Administration (NOAA), Tides & Currents: High and Low Water Conditions, accessed via https://tidesandcurrents.noaa.gov/.
[6] NYS DEC and USGS, Hudson River Environmental Conditions Observing System, accessed via: https://ny.water.usgs.gov/maps/hrecos/.

Brackish and Fresh Water

In choosing materials and vegetation for Hudson River access sites, owners and managers must consider tolerance to salinity. Saltwater inundation can corrode electrical utilities and metal infrastructure and may harm plants or inhibit plant growth. Salty water moves up the Hudson from the ocean, where it mixes with freshwater moving downstream from the Upper Hudson and the tributaries. In Westchester and Rockland counties, the estuary is brackish. Depending on the amount of fresh water flowing south to dilute the salty water, which varies by season, brackish water is rarely detected above the Hudson Highlands near Newburgh and Beacon, and only very rarely reaches Poughkeepsie. Through increases in sea level and changes in precipitation patterns, climate change may affect the movement and amount of saltwater and brackish water within the estuary.

KEY TERMINOLOGY

Estuary

- Tidal water bodies where saltwater (tides)and freshwater meet. The Hudson River Estuary is a 150-mile estuary from the Troy dam south to New York Harbor, with average tides of 4 feet. It contains freshwater, brackish water, and saltwater, with the location and extent of salt and brackish water being influenced by the season and by rainfall in the watershed.

Tides

- Ebb tide: the period between high tide and low tide, during which water flows toward the sea.
- Flood tide: the period between low and high tide, during which water is rising, flowing away from the sea.
- Neap tide: tide just after the first or third quarters of the moon when there is least difference between high and low water.
- "Spring" high tide: tides of increased range or tidal currents of increased speed occurring semi-monthly as the result of the moon being new or full. These occur all year, not just in spring

Tidal Range

- Mean Lower Low Water: the average of the lower low water height of each tidal day.
- Mean Low Water: the average of all the low water heights;
- Mean Tide Level: the arithmetic means of mean high water and mean low water;
- Mean High Water: the average of all the high-water heights;
- Mean Higher High Water: the average of the higher high-water height of each tidal day.
- Intertidal zone: the waterfront land area between low and high tide marks that is exposed to air during low tide and is submerged during high tide. Also known as the littoral zone.

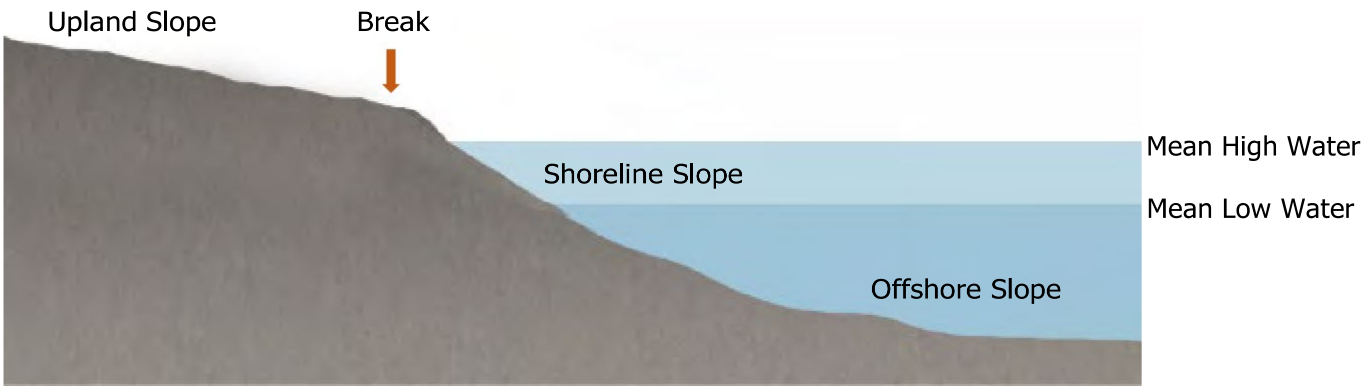

Figure 2.3 Location of Mean High and Mean Low Water and other shoreline features. (Source: WSP)

How high does the water get?

Water levels on the Hudson River estuary are determined by many factors including tides and weather conditions such as rain and wind. The National Oceanic and Atmospheric Administration (NOAA) publishes Mean Water Levels including; Mean Low Water (MLW), Mean High Water and Mean Higher High Water (MHHW) for locations throughout the estuary. These water levels can be converted to land elevations and used when designing in-water or near-water structures.

Higher High Water is the highest of the two high tides each day. Mean Higher High Water is the average of the daily higher high water during a period of observation when the mean was calculated. When designing structures in, over, or adjacent to the Hudson River, it is important to recognize that the MHHW is an average and that it is normal for the actual higher high water level to vary from that mean on a daily basis in the figure below.

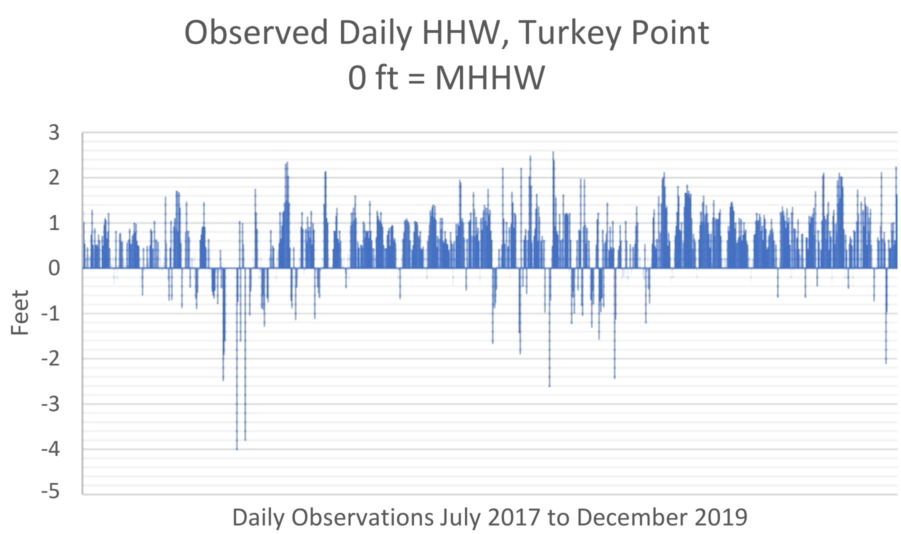

Figure 2.4 Observed Daily Higher High Water at Turkey Point. (Source: DEC using NOAA data))

To determine the “normal range” around the MHHW, three years of water-level observations at the Turkey Point National Water Level Observation Station in Ulster County and 10 years of observations from The Battery Water Level Observation Station in New York City were compared to the published MHHW for each location. Using an outlier analysis, it was determined that the actual water level during a statistically ‘normal’ event can exceed the published MHHW by approximately 2.3 feet at Turkey Point and the Battery. In addition, outlier, or extreme events, usually driven by strong storms also occur on occasion causing water levels to exceed the normal range (5 times in three years at Turkey Point, 33 times in 10 years at the Battery) (see figure below).

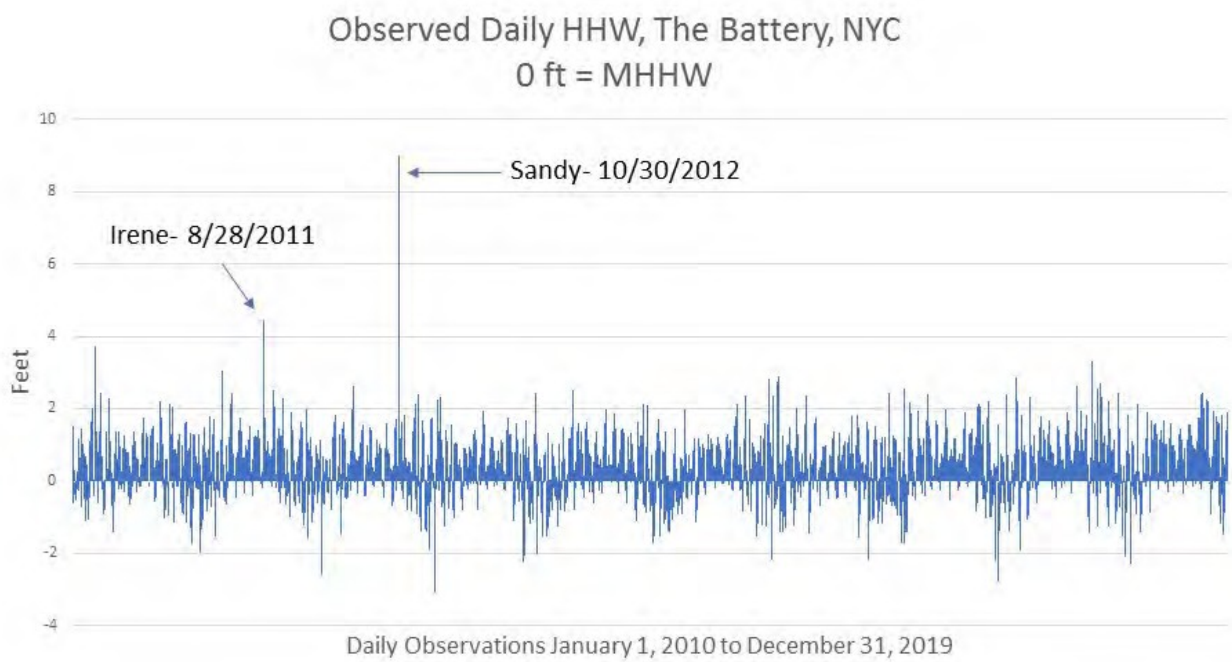

Figure 2.5 Observed Daily Higher High Water at The Battery, NYC. (Source: DEC using NOAA data)

Therefore, if constructing or planning for structures to be “dry” or out of water during the full range of “normal” daily higher high water, they should be placed at least 2.5 feet above the local MHHW elevation. This does not account for future sea-level rise, which will result in a need to increase elevation even more.

2.3. **Waves, Wakes, and Ice**

The shorelines of the Hudson and its tributaries are subject to a variety of complex and interacting physical stresses, including wakes, wind-driven waves, and ice. It is important to consider the level of stresses occurring at any location, as described more in Chapter 3: Planning and Design for Resilience.

Waves and Wakes

The size of wind-driven waves depends on the amount of open water that the access site faces. This is called the *fetch* – the distance that wind travels across open water in one direction, which can affect wave formation and storm surge. With several open-water bays and straight reaches of the river, the shorelines are subject to long fetch in some locations.

Fetch is just part of the conditions that determine waves. The following information draws on DEC's Tidal Wetlands Guidance Document: Living Shoreline Techniques in the Marine District of New York State,[7] which describes these conditions and their effects in more detail.

Shorelines are shaped and modified by wave processes. Waves are dependent on shore slope, bottom friction, angle, tides, and ultimately on meteorological conditions that control wave formation and interaction. The size of the waves is the result of energy transfer from wind (i.e. the fetch), and the duration of the blowing wind. Waves are also affected by water depth.

The following are general characteristics associated with differing wave energy environments:

- **Low energy:** Limited fetch in a sheltered, shallow, or small waterbody (estuary, river, bay); i.e., wave height is less than 2 feet.
- **Medium energy:** A range that combines elements of low and high energy (shallow water with a large fetch or partially sheltered); i.e., wave height ranges from 2 to 5 feet.
- **High energy:** Large fetch, deep water (open ocean, open reaches of the Hudson, and large bays); i.e., wave height exceeds 5 feet.[8]

Wakes of any motorized boat can cause waves to break on the shore and on docks. As a major shipping route and recreational boating destination, riverfront sites along the Hudson are subject to significant wakes. A study of wakes on the Hudson River can be found on the Hudson River Sustainable Shorelines Project website.[9]

Wind-driven waves and wakes can cause damage to boats tied up to docks due to bumping and scraping. They can also cause shoreline erosion. Knowing the location of the navigational channel for ocean-going vessels, barges, and tugs can help inform the design and maintenance of the edges of river access sites. Higher winds in more intense storms will result in increased wave height. Sea level rise will cause waves to break higher up on the shore. Thus, setting shorelines back further, designing spaces that are meant to flood, and planting hardy species along the edge can help lessen the consequences associated with wakes.

[7] NYS DEC, Tidal Wetlands Guidance Document: Living Shoreline Techniques in the Marine District of New York State. November 22, 2017, accessed via https://www.dec.ny.gov/docs/fish_marine_pdf/dmrlivingshoreguide.pdf.

[8] Ibid. Note, although the Marine District is the coastal area south of the Governor Mario M. Cuomo Bridge, the section on conditions is applicable for the entire reach of the Hudson Estuary.

[9] NYS DEC and NOAA, Hudson River Sustainable Shorelines and Stevens Institute of Technology, Hudson River Wake Study, accessed via www.hrnerr.org/hudson-river-wake-study.

Figure 2.6 Ice at Kingston Point Beach (Source: Nancy Beard/DEC)

Ice Flows and Dynamics

The Hudson River's ice is dynamic and can impede navigation, impact the stability of the shoreline and in-water structures, and exacerbate flooding.[10] The winter ice season on the Hudson River is typically from mid-December to late March. During a very cold winter, the upper portion (from Troy to West Point, a 100-mile-long reach) can freeze from bank to bank. In such conditions, the US Coast Guard opens a navigation channel in the ice cover to maintain commercial traffic.[11]

During milder winters, the River does not entirely freeze over, but ice still forms in protected coves, shorelines, and bays. The water level fluctuation created by tides and changes in river flow promotes cracking and breaking of the ice into smaller pieces. These pieces float near the water surface, and their movement is driven by the current and wind. In some areas, the fractured ice can accumulate and stack on the shoreline.

Downstream of West Point, the river does not typically completely freeze, even during very cold winters, because of its width, higher velocity currents, and salinity there (e.g., in the narrow passage between West Point and Jones Point). Several locations are prone to broken ice accumulation along the River, including West Point and Esopus Meadows (Georgas et al. 2015). In these areas, the ice transport capacity of the River is reduced because of narrowing or curves. The ice also tends to accumulate in large bays and anchorages areas.

The ice thickness tends to increase upstream in the River, under the influence of several factors including salinity, tidal effect, temperature and hydraulic conditions. For instance, the 95th percentile ice thickness calculated by Georgas et al. (2015) over the period 2004-2015 was 6 inches at George Washington Bridge, about 8 inches near West Point, and 12 inches at Esopus

[10] The following information is taken primarily from (Georgas et al, 2015). In addition, geo-spatial ice data from 2006-2012 can be found on the NYS Clearinghouse Website, http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1136

[11] John Sperr, on his Hudson River Ice Yacht Club website, www.hriyc.org, maintains an annotated archive of aerial photographs published by the Coast Guard that show winter ice conditions from Shrewsbury, New Jersey north to Troy, New York. Records go back to 2007. Weather and Coast Guard budgetary constraints limit the frequency and range of this coverage in most years.

Meadows. Georges et al. (2015) found that in 2014-2015, ice thickness records were broken for the months of February and March for most regions of the tidal Hudson.

The ice starts breaking up naturally without any intervention typically in February. During breakup, the ice sheets fracture and start moving under the influence of currents and wind. The size of the ice floes on the Hudson River is highly variable, from a dozen feet to more than 1,500 feet (Georgas et al. 2015). The Coast Guard will also break up ice if warranted to prevent ice jams. The accumulation of fractured river ice then causes an increase of the upstream water level. The sudden movement of river ice, typically during break-up, is called an ice run because of its speed.

Figure 2.7 Accumulation of fractured ice sheets, Norrie Point. (Source: DEC)

2.4. **Climate Change**

New York State has experienced measurable changes in regional climate over the past century, and trends are expected to continue through the 21st century. Site owners, managers, planners, and designers of riverfront parks are facing the need and the opportunity to reduce vulnerability to the risks associated with climate change and severe storms. By reducing these risks, river access sites are increasingly able to adapt the shoreline and increase local resilience while maintaining public benefits. There are many sources of information on the effects of climate change (see Additional Resources). The following is a summary of climate change tools and expected impacts for the estuary:

Climate Projections

The following climate projections are drawn from a "downscaled" global model used for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The process of downscaling includes inputting local information and re-running global climate models on a regional level to produce more robust projections. ***Models are inherently uncertain and***

simply present a range of possible scenarios to help people and communities plan. Future climate changes in New York could exceed or fall short of these projections.

Sea Level Rise

Global sea level is rising due to factors including thermal expansion from warmer water temperatures and melting of land-based ice. The Hudson River is connected to and influenced by the sea – it experiences tides, contains saltwater in its lower reaches, and rises with local sea levels. Sea level has already risen 6 inches in the last fifty years on the Hudson River, and over a foot since 1900. Today, we are witnessing the rate at which water is rising increase. As a result, many river access sites along the tidal Hudson are already experiencing regular flooding, even on sunny days. Sea level on the tidal Hudson is projected to rise anywhere from a low of 5 inches to a high of 30 inches by the 2050s, compared to a 2000-2004 baseline (see Tables below).

Policy

The State institutionalized its commitment to climate resiliency through the signing of the Community Risk and Resiliency Act (CRRA) in 2014[12]. Newly adopted Part 490 of the New York Codes, Rules and Regulations (6 NYCRR) ensures that the projections in the tables below apply to applicants for relevant permits, approvals, and funding in the context of programs specified in the CRRA. Due to different geologic conditions and processes, the rate of predicted sea level rise varies slightly for sites north and south of the Kingston / Rhinecliff area. New York State projects that the Hudson River south of Kingston and Rhinecliff could see a water level rise of 15-75 inches by the end of the century. North of Kingston, New York state predicts a water level rise of 11-71 inches by the end of the century, compared to a 2000-2004 baseline.

Time Interval	Low	Low-Medium	Medium	High-Medium	High
2020s	1	3	5	7	9
2050s	5	9	14	19	27
2080s	10	14	25	36	54
2100	11	18	32	46	71

Table 2-1 NYS sea-level rise projections in inches, based on 2000-2004 baseline, for the "Mid-Hudson" region[13], by

(6 NYCRR Part 490)Time Interval	Low	Low-Medium	Medium	High-Medium	High
2020s	2	4	6	8	10
2050s	8	11	16	21	30
2080s	13	18	29	39	58
2100	15	22	36	50	75

Table 2-2. NYS sea-level rise projections in inches, based on 2000-2004 baseline, for the "Lower Hudson" region,[14] by time horizon (6 NYCRR Part 490)

[12] NYS Bar Association, New York State Community Risk and Resiliency Act Summary, accessed via http://nysbar.com/blogs/environmental/CRRA_Summary.pdf. River Access Site

[13] The main stem of the Hudson River, from the federal dam at Troy to the mouth of Rondout Creek at Kingston.

[14] From the mouth of Rondout Creek at Kingston south.

Flood Risk Related to Future Impacts from Climate Change

Based on the CRRA, permitting for major projects, facility-siting, and funding programs must now all **demonstrate that future physical climate risks due to sea-level rise, storm surge and flooding have been considered** in planning and design processes. Under the CRRA, DEC, in consultation with the Department of State (DOS) is required to develop guidance for implementation of the CRRA, including on the use of natural resources and nature-based features to increase resilience. The DOS is required, in consultation with DEC, to develop model local laws to increase community resilience. There are several tools that help evaluate how sea level rise will change flood depths at a site. These tools are usually based on simple models that cannot capture the full details of site-specific hydraulics. Performing a site-specific analysis will provide more accurate future flood risk data and a point of comparison to more generalized data tools.

Resources for Analyzing and Understanding Sea-Level and Flood Risk

Scenic Hudson's Sea Level Rise Mapper

An online interactive mapping tool. Demonstrates the extent of area that could be inundated based on how many inches of sea level rise the Hudson experiences. https://scenichudson.maps.arcgis.com/apps/MapJournal/index.html?appid=3a3d0dc3884c4637ad0a51f4aa912189

Hudson River Flooding Decision Support System

An online interactive mapping tool that shows both storm surge and tributary freshwater inputs to the Hudson River and sea-level rise scenarios. http://www.ciesin.columbia.edu/hudson-river-flood-map

Climate Central's Surging Seas Tools

The Coastal Risk Screening Tool and other *'Surging Seas'* tools enable users to explore sea level rise and coastal flood risk over time and under multiple greenhouse gas emissions scenarios. https://sealevel.climatecentral.org/maps

Hudson River Resilience Network

The peer-to-peer network provides a platform for exchanging ideas, sharing lessons, and asking questions about short- and long-term adaptation, sea level rise, and flood preparedness. https://wri.cals.cornell.edu/hudson-river-estuary/climate-change-hudson-river-estuary/helping-communities-become-climate-resilient/

Temperatures

Annual average temperatures in New York State are projected to rise 2.2° Centigrade (C) to 5° C (5.4° Fahrenheit (F) to 9.7° F) by the 2080s.[15] Increasing annual temperatures will lead to more frequent, intense, and long-lasting heat waves during the summer. By mid-century, the number of days above 95 degrees F is expected to more than triple, and heat waves will occur 2.5 to nine times as often and last 25% to 75% longer.

[15] Horton, R., D. Bader, C. Rosenzweig, A. DeGaetano, and W. Solecki. 2014. Climate Change in New York State: Updating the 2011 ClimAID Climate Risk Information. New York State Energy Research and Development Authority (NYSERDA), Albany, New York.

Increasing annual temperatures and heat waves will change recreation seasons, patterns of use, and the needs of park users. Temperature changes will also influence snow and rainfall patterns and rates of evaporation. In the Hudson Valley, precipitation is more likely to come as rain than as snow as temperatures rise. High temperatures, heat waves, and drought should be considered when designing natural and artificial shade amenities and choosing vegetation.

The full climate projections for the Hudson Valley through year 2100 can be viewed online at https://wri.cals.cornell.edu/hudson-river-estuary/climate-change-hudson-river-estuary/helping-communities-become-climate-resilient/climate-projections-nys/.

Rain and Snowstorms

Storms are big weather challenges for the Hudson River Valley, even under current climate conditions. The US EPA writes:

> *Average annual precipitation in the Northeast has increased 10 percent since 1895, and precipitation from extremely heavy storms has increased 70 percent since 1958. During the next century, annual precipitation and the frequency of heavy downpours are likely to keep rising. Precipitation is likely to increase during winter and spring, but not change significantly during summer and fall. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during summer and fall. As a result, [changing climate conditions are] likely to intensify flooding during winter and spring, and drought during summer and fall.*[16]

For the Hudson Valley, the New York State Energy Research and Development Authority (NYSERDA) projects an increase in annual precipitation ranging from 1% to 21% by the end of the century above the 1971-2000 baseline.[17,18] The number of days with over 1" of rain will likely increase from an average of 10-12 days to as many as 14-15 days annually.[19] These increases in rain volume and variability may be coupled with increases in the number and severity of severe storms, following observed trends.[20]

[16] What Climate Change Means for New York, US Environmental Protection Agency. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-ny.pdf

[17] Horton, R., D. Bader, C. Rosenzweig, A. DeGaetano, and W.Solecki. 2014(a). Climate Change in New York State: Updating the 2011 ClimAID Climate Risk Information. New York State Energy Research and Development Authority (NYSERDA), Albany, New York. p. 8, Table 3. Mean Annual Changes, www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/ClimAID/2014-ClimAid-Report.pdf

[18] Hudson Valley values are computed as the lowest and highest value from the lower and upper bounds, respectively, of the middle-range of projections from across Region 2 (Port Jervis) and Region 5 (Saratoga). The middle-range of projections in 2014 are bounded at top and bottom by the 25th and 75th percentiles of data from all modeled projections. This methodology follows the computation of statewide values as described on page 3 of the brochure, Climate Change in New York State: Refined and Updated, New York State Energy Research and Development Authority (NYSERDA) www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/ClimAID/ClimAid-Brochure.pdf

[19] Hudson Valley values are computed as the lowest and highest value from the lower and upper bounds, respectively, of the central range of projections from across Region 2 (Port Jervis) and Region 5 (Saratoga) from Climate Change in New York State: Refined and Updated, www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/EMEP/climaid/ClimAID-Report.pdf, p. 34, Table 1.9 Extreme Event Projections. This methodology follows the computation of *statewide values* as described on page 3 of the brochure, Climate Change in New York State: Refined and Updated, www.nyserda.ny.gov/-/media/Files/Publications/Research/Environmental/ClimAID/ClimAid-Brochure.pdf

[20] Observed and Projected Climate Change in New York State: An Overview for the Community Risk and Resiliency Act (CRRA) Drafting Teams Final, New York state Department of Environmental Conservation (DEC) www.dec.ny.gov/docs/administration_pdf/climbkgncrra.pdf

Storm Surge

Storm surge is an abnormal rise of water generated mostly by the winds of a storm, over and above the predicted tides. Any storm can cause a surge, but Nor'easters, tropical storms, and hurricanes (defined by winds at or above 75 miles per hour) can cause water to overtop shoreline structures and flood low-lying areas with force, pushing water and debris inland. Storm surge can carry anything in its path including cars, boats, docks, and picnic tables and can damage standing structures. Climate change is predicted to cause more intense and more frequent storms and therefore more storm surges.

Figure 2.8 Bear Mountain Park Fishing Pier flooded from storm surge. Note the floating green dumpster.

(Source: DEC)

Ice Regime

Climate change will modify the ice regime on the Hudson River and the risk associated with ice in contrasting ways. For instance, the expected rise of sea level will increase the elevation of the zone where the ice and shoreline/in-water structures interact. In future climate scenarios, winter thaw and mid-winter breakup events are expected to be more frequent.

These events could cause additional stress to the shoreline by generating more ice movement on the River and more 'freeze-thaw' cycles in the shore material. An increase in the frequency of breakup events increases the risks of ice jams and winter flooding.

On the other hand, climate change and sea level rise may dampen ice risks. Greater salt intrusion higher upstream in the Hudson River would modify the structure of the ice that does form. So-called marine ice is typically less resistant than river ice. Higher temperatures due to climate change, particularly the expected increase in low temperatures, could shorten the duration of the winter season and the occurrence and thickness of the ice.

2.5. Flooding

Flooding can be caused by storm surge, rainfall, high tides, and ice jams. Average precipitation is projected to increase in the coming decades, with most of the increase occurring in winter. Extreme precipitation events are likely to increase. Flooding can damage upland infrastructure, pollute water, impact the use of a site afterwards, and cause damage to the edge of access sites.

Please note that the federally designated “100-year” or 1% floodplain is the area that statistically has a 1% chance of flooding each year, based on historical data. Compounded over a 30-year period, this storm has over a 25% chance, or one in four chances of happening. Understanding flood risk is discussed more in Chapter 3: Planning and Design for Resilience.

Key Terminology

Base Flood Elevation (BFE)
The computed elevation to which floodwater is anticipated to rise during a 100-year storm. BFEs are shown on FEMA Flood Insurance Rate Maps (FIRMs) and on the flood profiles. The BFE is the regulatory requirement for elevating or flood-proofing structures.

Flood Zone
Defined geographic areas with varying levels of flood risk that encompass different parts of the floodplain, determined with an analysis resulting in projections of varying levels of flood risk.

Floodplain
Any land area susceptible to being inundated by floodwaters from any source.

Storm Surge
The temporary increase, at a locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and / or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place

Sunny Day Flooding
Flooding that occurs without the presence of a storm, often from high tide events that exceed the norm, such as during the full or new moon. This is also known as tidal flooding, nuisance flooding, or blue-sky flooding.

Sediment and Debris

Tides and floods can wash away or bring to a site sediment and debris. Wrack, made of floatable organic material and trash, is deposited by high tides along a shore and is a specific link between the water and the land. Larger floods can deposit – or carry away – larger materials such as light poles, picnic tables, and dumpsters.

Sunny-Day Flooding

Not all floods occur because of storms. Another impact of climate change is an increase in the frequency of sunny day flooding, which occurs in low-lying areas due to low pressure or seasonal high tides during the full or new moon. This flooding is not as visible as overtopping the shoreline with large waves, but rather manifests as an unexpected submerged pier, saturated soils, or catch basins far from the shore overflowing into a dry parking lot. Sunny day flooding causes public inconvenience, which is why the term “nuisance flooding” is sometimes used to describe this phenomenon. Some Hudson River access sites are already experiencing increased frequency of sunny day floods. The frequency will increase as sea levels rises.

Figure 2.9 Flooding at Norrie Point Marina. November 2015 (Source: DEC)

Ice Jams

Ice jams can increase water levels in Hudson River tributaries. With warming temperatures and water movement, ice floes can break apart and collect against a structure, obstructing flow. Flooding can occur either upstream of the ice jam and/or downstream when the ice jam breaks and releases a burst of water. This flooding can cause higher than expected ice-free flood levels.

Compounding Factors

Although separated above, weather phenomena can and often do occur simultaneously or sequentially. Storms can produce elevated water levels, strong winds, and heavy rain or snow melt all at once. As sea level rises, minor storms that formerly produced no flooding or only minor flooding could have impacts as catastrophic as large storms due to the compounding influence of multiple factors.

Recent Extreme Weather Events

The Hudson River has been impacted by damaging storm events including the devastating storm events of the early 2010s: Hurricane Irene (2011), Tropical Storm Lee (2011), and Superstorm Sandy (2012). Storms of this capacity may become more frequent in the region due to climate change. Following Superstorm Sandy, Governor Cuomo announced the NYS2100 Commission to develop recommendations for resilient infrastructure in New York State to help protect from future storms.[22] The Commission released a preliminary report on *Improving the Strength and Resilience of New York State Infrastructure*, which includes short- and long-term recommendations in the areas of energy, transportation, land use, insurance, and infrastructure financing, as well as cross-cutting recommendations that are common to these sectors.

To see the full NYS2100 Commission report, visit:
http://www.governor.ny.gov/assets/documents/NYS2100.pdf

Figures 2.10 and 2.11 Coeymans Landing Gazebo in the Town of Coeymans, which flooded after Hurricane Irene, left. (Source: DEC) Flooding at Town of Bethlehem Fishing Access Site after Tropical Storm Lee, right. (Source: Town of Bethlehem)

Predicting a flood:

The New York Harbor Observing and Prediction System (NYHOPS), developed by the Davidson Laboratory at Stevens Institute, provides flood forecasts and hindcasts for the Hudson and can be accessed from http://hudson.dl.stevens-tech.edu/maritimeforecast/.

The standard for anticipating flooding is provided by the National Weather Service (NWS), with local forecast offices out of Albany and Upton, NY. They issue three levels of flood-related notifications: advisory, alert, and warning. A *"flood advisory"* is issued when a weather event is forecasted to cause nuisance-level and inconvenient flooding. A *"flood watch"* is issued when conditions are favorable for more significant flooding. *"Flood warnings"* are issued when flooding is imminent or occurring.

NWS' Advanced Hydrologic Prediction Service for the Hudson River reports stream gages and issues predictions for flood levels at Troy, Albany, below Poughkeepsie and above Poughkeepsie, as well as upstream locations for large tributaries. Additional sources of emergency management include local county offices as well as the New York State Division of Homeland Security and Emergency Services. It may be that your site experiences additional or alternative warning signs for flooding that are not captured by these sources.

[21] NYS 2100 Commission www.governor.ny.gov/sites/governor.ny.gov/files/archive/assets/documents/NYS2100.pdf. Other resources include ClimAID, CRRA and the Climate Leadership and Community Protection Act, https://climate.ny.gov/

[22] NYS Office of Governor Andrew M. Cuomo, News, November 2012; accessed via: https://www.governor.ny.gov/news/governor-cuomo-announces-commissions-improve-new-york-states-emergency-preparedness-and.

2.6. How River Access Sites are Affected

Damaged or Downed Trees and Electrical Lines

High winds and hurricane conditions can cause extensive damage and lead to downed trees and fallen electrical lines by the water's edge as well as inland. These downed trees and electrical lines can create hazardous situations for communities and infrastructure.

Debris Displacement

High winds and hurricane conditions can detach objects and materials from their fixed locations, causing damage when they collide with other objects, surfaces, or structures. Debris can include anything that is not tied down that can become air or waterborne, such as litter barrels, picnic tables, floating docks, trees, and boats. Debris can collect in drainage structures and exacerbate flooding. Strong storms with wind and flooding can inundate areas and shift land.

Figure 2.12 Woody Debris at Ingalls Ave. Boat Launch, Troy in May 2019 (Source: DEC)

Erosion

Wind and wake-driven waves can cause erosion of the shoreline edge. If water levels are high, damage to infrastructure can also occur. Erosion occurs over time when constant wave action causes water to remove soil and rock, transporting these materials to another location where they are deposited.

Note that while erosion is an ongoing natural process, major storms can cause more rapid erosion, with significant impact to shoreline areas. River ice can also cause erosion of the shoreline and protection structures.

Scour

Scour is a specific type of erosion during which hydrological forces and ice shift sediment and other bed material around shoreline structures, such as piles. Scour is exacerbated during major storm events. Negative effects are seen, for example, when soil or rock around the periphery of an abutment or pier erode, causing structures or pavement to become unstable. Scour may also contribute to the reduction or destruction of some estuarine habitats by disrupting ecosystems around the marine structures affected by scour. Conversely heavy deposition of sediments can bury submerged aquatic vegetation.

Figure 2.13 Scour along Kingston Trolley Path, April 2017 (Source: Nancy Beard/DEC)

Stormwater Run-off

Heavy rain and resulting stormwater runoff can overwhelm stormwater management systems. Many engineered drainage systems are “undersized” – that is, designed based on out-of-date historical averages that don’t reflect the reality of a changing climate or the extent of urban development. Overflowing storm sewers within parks and throughout the floodplain can lead to pooling and standing water, damaging assets and limiting access. The addition of constructed stormwater green infrastructure techniques can manage stormwater runoff by promoting or mimicking natural rainwater infiltration into soils and groundwater.

Inundation by Fresh, Salt, and Polluted Waters

While plants in the floodplain have evolved to withstand periodic inundation, sea level rise is causing more frequent flooding of vegetation that is not accustomed to having wet roots or higher salt concentrations. Access sites near combined sewer overflows or other sources of pollution may be impacted similarly by polluted water during storms.

Figure 2.14 Flooding / inundation of Rondout Landing, one of the main access roads to Kingston Point. The City of Kingston Wastewater Treatment Plant is behind the trees at right. (Source: Jessica Kuonen/ NYS Sea Grant)

3. Planning and Design for Resilience

Figure 3.1 Workshop participants gather at Scenic Hudson's Long Dock Park to learn about resiliency strategies incorporated in the site's design and transformation. (Source: WSP)

3.1. Introduction

Chapter 3 outlines some of the steps and processes to consider when planning and designing sites along the riverfront and in the floodplain. These projects may have greater complexity for site analysis and decision-making due to the uncertain nature of climate projections. In addition, any construction work in or along the estuary has significant regulatory oversight, which needs to be factored into the timeline and the design process.

As described throughout the chapter, the steps of the planning phase for any access site project include:

1. Developing a problem statement and initial concept
2. Gathering baseline information about the site
3. Assessing site-specific hazards, vulnerabilities, risks, and opportunities
4. Engaging community stakeholders
5. Developing the design and reviewing regulations and meeting with permitting agencies[23]
6. Evaluating the costs and benefits of alternatives

The guidelines presented here go above and beyond the standard process. **For riverfront projects, it is especially recommended to have pre-application consultation with the regulatory agencies that may be involved.** Incorporating regulatory feedback during the planning stage can help to develop feasible alternatives, streamline the design and permitting process, and assist in developing creative solutions, with the goal of an implementable design.

[23] Permitting and regulations are discussed in detail in Chapter 4.

Resilient riverfront design should account for present conditions as well as future conditions. In other words, river access sites should facilitate everyday public use during typical weather conditions while still including elements meant to address the risks associated with climate change. Though every site has unique site-specific conditions, uses, risk factors, and community context, site designers should, at a minimum, aim to meet the guiding principles described in Chapter 1. This approach maximizes both the site utility and the public investment.

> The DEC's Hudson River Estuary Program has been instrumental in providing climate resilience and adaptation planning and design support for communities along the Hudson River. Many resources are available through this program.

3.2. Step 1: Develop a Problem Statement and Initial Concept

The first step in the planning process is to clarify the resiliency problem and understand how it affects the desired public uses. At this initial stage, getting a sense of the scale of the problem and the potential costs is helpful. There are several grant programs that can support a resiliency project (see Appendices).

Because there are a variety of existing site conditions, project objectives, and risks associated with each river access site project, defining the problem clearly from the beginning is crucial. Examples might include:

- prevention of erosion at the edge;
- moving equipment out of projected floodable areas;
- designing a site so that it can easily flood and quickly recover; or
- elevating portions of a site to avoid flooding.

Determine Public Uses

Information about the desired uses of a site will help planners and designers identify and adapt best practices for resilient design. For river access projects, this process should be particularly well-considered and well-communicated with the public, as there may be limitations based on site condition and flood risk. In the floodplain, certain amenities may become unfeasible due to environmental conditions, safety concerns, or high cost. However, it is still important for planners and designers to keep the recreational, ecological, and open space needs of the local community and other stakeholders in mind and try to plan for these needs when possible.

Explore Community Context

Since many Hudson River access sites are the edge of the community, there may be opportunities to integrate river access sites with community flood protection strategies. Floodable parks and other open space access sites are often the best use of the floodplain. River access sites may also include protective barriers or significant structures which protect adjacent community assets. The planning process should prioritize accessibility of the river access site and quality of user experience, as well as examine impacts on the adjoining community, such as traffic and increased economic activity.

Reach out to Stakeholders

Local stakeholders and managers that know the site can provide important insight. They come to riverfront resilience planning with an existing, deep, and nuanced understanding of the dynamic conditions, uses, and historic events that are specific to their site. Community stakeholders can help inform the visioning and design process and help ensure any alternatives proposed are feasible for implementation. In this context, a unique problem statement can be crafted for each individual river access site. At the end of Step 1, there should be an initial concept that will be further refined and adapted.

3.3. Step 2: Gather Baseline Information About the Site

As discussed in Chapter 2, sea level rise is projected to result in increased depth of coastal flooding, and is projected be a permanent condition. A detailed understanding of a site's topography and flood risk, with specific focus on sea level rise is recommended when planning riverfront projects.

Conduct a Shoreline Inventory

Identify the existing conditions and establish a baseline of site flooding and damage from storms. Information on the condition of the shoreline should be used to tailor plans and design approaches for the edge. A thorough understanding of the site includes documenting the site topography and bathymetry, as well as the tides, water level, erosion, stormwater drainage and history of storm damage and ice scour.

Understanding the physical condition of the shoreline at a given project site is a critical part of the planning process if edge management is needed. Is it natural? Is it armored? Is it eroding? Is the armored structure failing? What is the slope? Is the substrate natural soil and sediment or is it fill brought from elsewhere? Some access sites on the Hudson were built on former brownfield or Superfund sites, or on fill that was contaminated. Will this material need to be removed or encapsulated or limit what strategies can be applied?

Results from inspections can help shape large-scale project phasing, determine whether interim or emergency repairs are necessary, and, ultimately, influence design approaches. Inspections are also essential in generating accurate cost estimates. All too often "invisible" capital needs are associated with the shoreline portion of an access site.

Conduct a Resource Inventory and Determine Critical Assets

An inventory of site assets will help prioritize which assets to protect or relocate. For developed sites, the inventory might include lighting, electrical equipment, restrooms, buildings, pathways, playgrounds, parking lots, dog park, sports fields, etc. For natural areas, the inventory would document the natural components of the site, including habitats, vegetation, and unique features. Any proposed resiliency measures for natural areas should complement the existing plant and animal life to ensure minimal impact to the existing habitat.

The Hudson Valley Natural Resource Mapper[24] is a free, web-based tool that provides a plethora of information on tidal wetlands, submerged aquatic vegetation (SAV), bathymetry, and more to help decision-makers better understand their natural context and plan for resilience accordingly.

[24] NYS DEC, Hudson Valley Natural Resource Mapper: A Tool for Viewing Natural Features in the Hudson River Estuary Watershed, accessed via: www.dec.ny.gov/lands/112137.html.

Once a comprehensive asset inventory has been established, the assets can then be grouped by importance and asset type. The process to define importance is subjective but aims to determine how critical each asset is to the functioning of the park.

First, think through the varying impacts of flooding. How will the river access site be affected if the parking lot is flooded or if the comfort stations are flooded? Can the park operate without a parking lot or restrooms?

Second, separate what is a temporary inconvenience and what will prevent the river access site from opening to the public for days or months.

Third, begin to prioritize what is most expensive to protect. If certain assets can be flooded and require only minimal cost to be restored, it may be more cost effective to let them flood. Similarly, there may be assets whose flooding and failure would require extensive cost and time to be restored, but if one is critical to the whole site and one isn't, efforts should be focused on the critical asset.

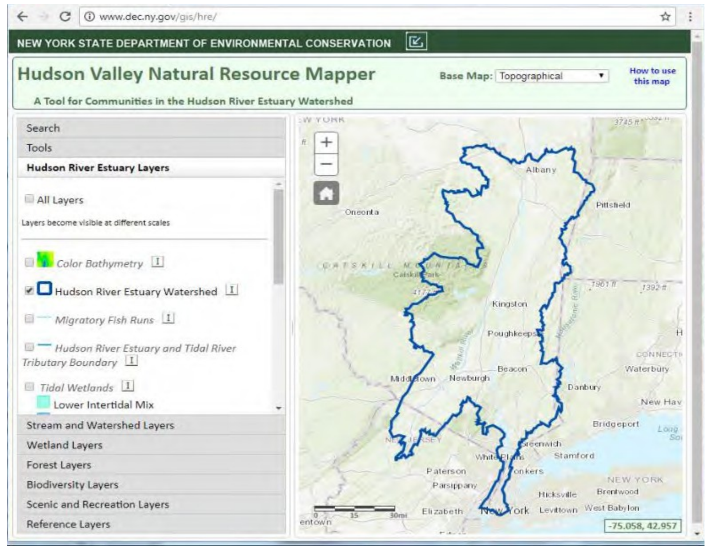

Figure 3.2 The Hudson Valley Natural Resource Mapper is an online, interactive tool that provides information on tidal wetlands, submerged aquatic vegetation (SAV), bathymetry, and more to help decision-makers in planning for resilience. The mapper also highlights Hudson River recreation sites and other areas where residents and visitors can enjoy the region's natural beauty. (Source: DEC)

Criticality designation can also assist in developing operational plans to employ before, during, and after severe storms. The criticality of some assets may need discussion with stakeholders.

Learn About Natural Edge Habitats

Some river access sites maintain vegetated shorelines – a specific type of natural resource. Managing the edge, particularly of a nature preserve or wetland, requires knowing something about the habitat type and the type of plant succession that may occur with sea level rise. On the Hudson the following are common shallow water edge habitats.[25] Each one is vulnerable to sea level rise. The best resiliency strategy for protecting the edge of such sites is to conserve the land on the upland side and keep it in a natural state, so that vegetation may migrate inland or form in new places.

- **Subtidal**: Submerged aquatic vegetation (SAV) grows sub tidally in pools and slow runs of the river securing the bed sediment and preventing erosion and scour. The most common species of submerged vegetation in the Hudson River is water celery *(Vallisneria americana).* Due to turbidity, SAV is limited to shallow water depths (<10 feet). As the water level rises, this habitat will disappear or move inland if the river edge has a shallow slope and muddy bottom.
- **Estuarine habitats consist of the following four communities:**

  Intertidal Shore These nearshore communities are dominated by plants tolerant of tidal inundation. Characteristic plants include knotweeds (*Polygonum sp.*), spatterdock (*Nuphar advena*) and pickerel weed (*Pontederia cordata*)

[25] NOAA, Ecological Profile of the Hudson River National Estuarine Research Reserve, https://coast.noaa.gov/data/docs/nerrs/Reserves_HUD_SiteProfile.pdf

Mudflats: This community occurs in tributary mouths where energy is low. Mudflats are characterized by low-growing aquatic plants that can be exposed during low tide and completely submerged during high tide.

Marshes: This community type occurs at the mouth of tributaries in large river systems where the water is usually fresh. While invasive Phragmites has become common, other characteristic vegetative species include tall reeds and cordgrass (*Spartina alterniflora*), rushes, sedges, and cattails (*Typhus angustifolia*).

Tidal Swamp: This community is globally rare but can be found in locations within the mid to upper regions of the Hudson River Estuary. This community is characterized by gentle slope gradients with tidal influence. The community has a high abundance of woody and herbaceous plants.

Upland forest: This community thrives in wet locations and easily recovers from flood disturbances and exists in a floodplain or wetland areas where a gentle slope exists. These forests are typically very diverse and composition changes in relation to flood frequency.

Figure 3.3 Natural wetland edge on Hudson River. (Source: Hudson River National Estuarine Research Reserve)

Figure 3.4 Natural bedrock edge on Hudson River (Source: Hudson River National Estuarine Research Reserve)

Refine the Initial Concept

At the end of Step 2, the initial concept should be further refined and adapted. It is strongly encouraged that at this point, a request be made for a DEC pre-application jurisdictional review from the applicable regional permit administrator[26] to confirm what permits may apply and to rule out any strategies that may not be appropriate to the site's conditions.

See Chapter 4: Land Use Regulations and Permitting for more information regarding permits.

3.4. Step 3. Assess Site-Specific Hazards, Vulnerability, Risks, Opportunities

It is important to understand what is meant by risk. Deciding what level of risk is acceptable can depend on the criticality of assets and cost benefit analysis (note, this may be a preliminary or "rough" analysis weighing costs and benefits). Using an understanding of tides, waves, ice, flooding, sea level rise and other factors, as described in Chapter 2: Estuary Conditions, provides a strong foundation upon which to build.

Risk, Hazard, Exposure and Vulnerability

It is important that site managers develop an understanding of how regional weather and climate may impact an individual site. This entails evaluating the hazards, exposures vulnerabilities and risks which are the consequences of ice, floods, increasingly intense rainfall, and sea- level rise. It is important to consider what level of risk the site managers and stakeholders deem acceptable. Flooding of a picnic area or ball field may be more acceptable than flooding of restrooms, for example.

[26] NYS DEC, Contact Us: Regional Permit Administrators, accessed via www.dec.ny.gov/about/39381.html.

STORM RISK = HAZARD x EXPOSURE x VULNERABILITY

- HAZARD the likelihood and magnitude of storm events.
- EXPOSURE the moderating effect of topography and landscape features.
- VULNERABILITY the level of impairment an asset would experience from a storm event.

Erosion Risks

Understanding the rate of erosion is essential for planning and designing edge approaches. Hudson River shorelines are dynamic in nature, and erosion is to be expected. Not all eroding shores need to be protected or stabilized. In some cases, natural landscapes may be able to withstand and recover from the forces causing erosion. Erosion control is most important where the shoreline experiences intense erosion and where valuable natural or physical assets are at risk. Understanding the cause of erosion, the rate of erosion and the dynamics of sediment movement is essential.

Erosion of the shoreline is caused by overland flow, groundwater seep and the energy impacts of ice, waves, wakes and currents. Erosion can also be caused by foot traffic or adjacent shoreline structures. Increased precipitation, stronger storms and storm surge related to climate change will affect the rate of erosion, and sea-level rise will cause waves to break higher up on the edge.

One site may be at a higher risk of erosion than another, based on where it is located along the river and the geographic context in which it sits. Sites located at an inlet, across from an island, near a marsh, or on deep open water will each have different erosion factors. The energy of wind-driven waves is related to the fetch at the site, as described in Chapter 2. The amount of boat traffic and wake-generating wave characteristics in a project will also have an effect.

The rate of erosion (amount of sediment lost over time, measured in inches or feet per year), can be most readily estimated through photographic evidence. Sources of photography include historical aerial or satellite imagery (www.historicaerials.com and Google Earth) as well as dated site photos showing gradual root exposure or loss of land based on the distance to a fixed object.[27] Understanding the shoreline condition of neighboring properties is necessary as well, because that will affect the success of any project proposal and vice versa.

Soil and sediment types are important for understanding sediment mobilization potential and choosing vegetation. Soil / sediment type will influence stability, rate of growth, and root penetration. Matching appropriate soil and sediment grain size with proposed measures is important for nature-based shoreline protection. Soil bearing capacity, or the ability of soils to hold up to the weight of overlying structural elements such as stone or concrete without settling, is important to understand particularly for designing pavilions, restrooms, or other structural amenities.

Flood Risk

There are many factors to consider in assessing flood risk at a site, including the location of the floodplain, evidence of historic flooding, projections of future flooding, and regulatory maps designating flood zones.

The Floodplain

The floodplain is a low-lying land area adjacent to a water body that is susceptible to inundation by floodwaters. “Floodplain” is a geological term, referring to the form and elevation of the land itself. The floodplain is a scientific definition of a natural feature of a river or estuary.

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[27] Hudson River National Estuarine Research Reserve, Hudson River Sustainable Shorelines, *Is Your Shoreline Eroding?,* accessed via: www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/shoreline-eroding

Flood Zones

Flood zones are mapped geographic areas resulting from projections of flood risk. Flood zones in the United States are established and mapped by the Federal Emergency Management Agency (FEMA). Flood risk is projected based on the probability that a flood of a certain severity or greater will occur during a certain time frame – also known as the "annual exceedance probability" (AEP). Typical flood zones are categorized as follows:

- 10-year (1 in 10-year chance – 10% AEP)
- 50-year (1 in 50-year chance – 2% AEP)
- 100-year (1 in 100-year chance – 1% AEP)
- 500-year (1 in 500-year chance – 0.2% AEP)

Local development trends and changes in land use that alter the amount of impervious area in the floodplain can also affect how flood events and flood zones are designated.[28]

The geographic extent of the 10-year flood zone is smaller than that of the 100-year flood zone, and it is anticipated that a smaller area will flood with greater frequency.

The mapped 100-year flood zone, also sometimes known as the 100-year floodplain, is the most important one for planning and design purposes. It is the geographic area projected to be at risk of flooding during a "100-year flood" (also called 1 percent annual flood, or base flood), which means it has a projected one percent chance of occurring during any given year. The 100-year flood is the standard used by FEMA for mapping flood-prone areas. Flood insurance requirements, development regulations, and building codes for new construction are determined in part by the 100-year flood zone.

However, this terminology can be misleading, and the likelihood of a 1 in 100-year storm can be too easily dismissed. Over a 30-year period, a 1 in 100-year storm has over a 25% probability, or one in four chances, of happening. In addition, due to natural variation in the climate record and the rapidly increasing impacts of climate change, the "100-year flood" of yesterday is not the "100-year flood" of today and will not be the "100-year flood" of tomorrow as the frequency of storms at this level of intensity is increasing over time.

The 500-year flood zone, also known as the 500-year floodplain, is projected to have a 1 in 500 (0.2%) chance of being met or exceeded in any given year. In other words, there is a 0.2 percent chance of that level of flood occurring in any given year. When planning for sea level rise, the 500-year flood zone may be a useful baseline for future impact.

[28] Dr. Robert Holmes, Jr., USGS, "Floods and Recurrence Intervals," accessed January 2020 www.usgs.gov/special-topic/water-science-school/science/floods-and-recurrence-intervals?qt-science_center_objects=0#qt-science_center_objects

FEMA Flood Insurance Rate Maps (FIRMs) as a Planning Tool

FEMA produces Flood Insurance Rate Maps (FIRMs),[29] which can be useful for project planning purposes, in addition to knowing where flood insurance is required. FIRMS are generated for each county from detailed coastal engineering, and hydrologic and hydraulic analyses. FIRMs identify an elevation to which the floodwaters are projected to rise during a 100-year flood, known as the Base Flood Elevation (BFE).

> The assessment of flood risk has several components. First, check to see where the access site is located relative to current flood risk as defined by FEMA flood zones on FIRMs or other FEMA online tools. FEMA maps define the baseline for regulatory floodplain development standards. The location of a site relative to these zones is directly related to the site's probability of flooding. If the site is covered by or assessed in other municipal, state, or federal initiatives or plans, that may also help with finding topographic data.
>
> Next, gather and review future sea level rise projections for the site using one of the flooding tools discussed in Chapter 2 and listed in Additional Resources. This will influence location choices for various site features and amenities. If sites are determined to be subject to high-tide flooding at the time of a project's inception or in the future during the project's useful lifecycle, it may be necessary to consider alternative siting options for critical and/or high-cost features.
>
> Once this information is in hand, resiliency solutions can be considered, as described in Chapter 6: Resilience Strategies. Such decisions need to also factor in the permitting and regulatory constraints, as described in the next chapter.

FIRMs are based on existing and historical data and are not designed to include future risks from sea level rise and changing precipitation patterns due to climate change. For several counties along the Hudson, FIRMs have not been updated since before Superstorm Sandy in 2012 and therefore may not reflect recent development that has impacted the floodplain. Due to these limitations, FIRMs should be considered alongside other available data, including the sea level rise mappers described in Chapter 2.

The land area covered by floodwaters at the BFE is delineated on FIRMs as Special Flood Hazard Areas (SFHAs). Flooding can occur outside of mapped SFHAs. SFHAs are assigned different zone designations based on their specific risk, which are labeled with letter / number codes. These zones and codes vary for coastal and riverine areas, both of which are represented along the Hudson. Several of the zone designations used along the Hudson are explained in the call out box below and illustrated by example in a sample map.

[29] FEMA, Flood Map Service Center: Flood Mapping Products, accessed via: https://www.fema.gov/flood-mapping-products.

SPECIAL FLOOD HAZARD AREAS (SFHAs)

BFE is Base Flood Elevation, where the Base Flood is the 100-year (1% AEP) flood

COASTAL ZONES

- **Zone VE:** 100-year flood zone subject to wave heights of 3 ft. or more with BFEs determined
- **Zone V:** 100-year flood zone subject to wave heights of 3 ft. or more without BFEs determined
- **Zone AE:** 100-year flood zone subject to wave heights of less than 3 ft. with BFEs determined
- **Zone A:** 100-year flood zone subject to wave heights of less than 3 ft. without BFEs determined

RIVERINE ZONES

- **Zone AE:** 100-year flood zone with BFEs determined
- **Zone A:** 100-year flood zone without BFEs determined
- **Zone AH:** Portion of the 100-year flood zone susceptible to shallow flooding (usually ponding) where flood depths are 1 to 3 feet; BFEs are determined
- **Zone AO:** Portion of the 100-year flood zone susceptible to shallow flooding (usually sheet flow on sloping terrain) where flood depths are 1 to 3 feet; average depths are determined

OTHER FEMA FLOOD RISK TERMS

- **Zone X:** 500-year flood zone – an area with a 0.2% or greater chance of flooding in any given year.
- **Limit of Moderate Wave Action (LiMWA):** the inland limit of the area expected to receive 1.5-foot or greater breaking waves during the 1-percent-annual-chance flood event

All V zones and A zones are in SFHAs and are therefore likely to be inundated by a 100-year flood. As discussed above, that means these zones have over a 25% probability of being flooded every 30 years. **From a planning perspective, existing and planned structures in these zones are subject to flood insurance requirements and may also be subject to certain development regulations and building codes for new construction.**

Flood zone labels also indicate whether or not BFEs or flood depths have been determined for the flood zone. Flood zones without BFEs or flood depths have been determined without detailed hydraulic analyses and are therefore more approximate. For these approximate zones, site-specific hydraulic modeling may be required to achieve a more accurate flood risk analysis. FEMA requires use of standard hydrologic and hydraulic engineering techniques to determine a BFE when a proposed project exceeds five (5) acres and encroaches upon an A zone without a BFE, whereas New York State recommends this for projects of two (2) acres or more.

In coastal areas, flood damage caused by the depth and extent of flood waters can be compounded by wave action. Wave heights as low as 1.5 feet can cause significant damage to structures, so the LiMWA is used to assess wave damage to a structure that might occur during a 30-year mortgage. The figure on the following page shows the different FEMA coastal zones and how wave heights vary across those zones. It also shows where the LiMWA, defined above, is located within these zones. Zone X has a much smaller probability of flooding under current conditions. When planning for sea level rise, though, this zone may be a useful baseline for future impact.

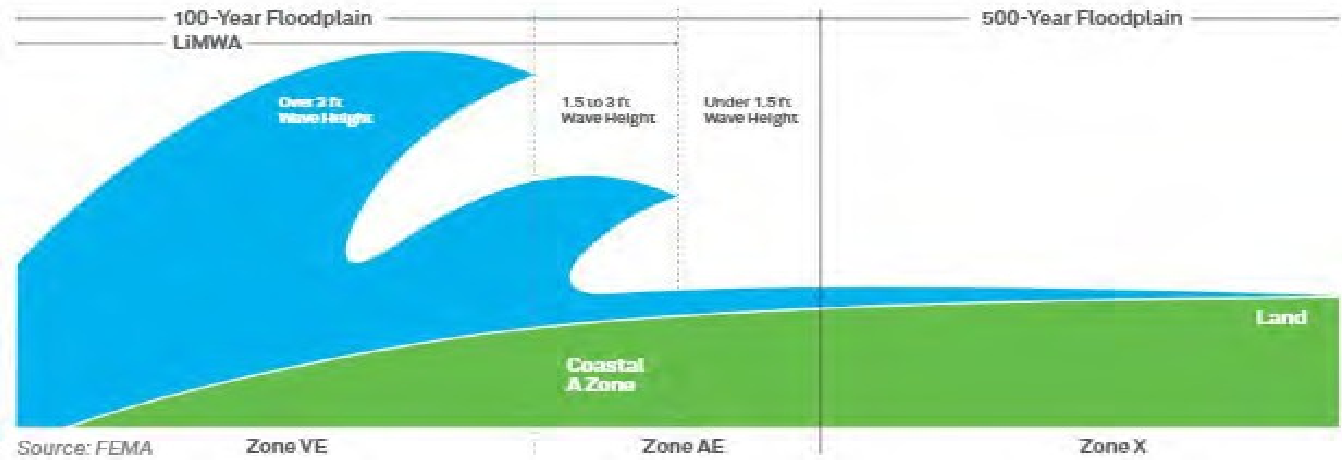


Figure 3.5 Schematic of Coastal Flood Zones. (Source: FEMA)

The figures below show the flood zones as defined above. Figure 3.6 shows coastal flood zones for Croton Point Park, and Figure 3.7 shows riverine flood zones for Sleightsburgh Park.

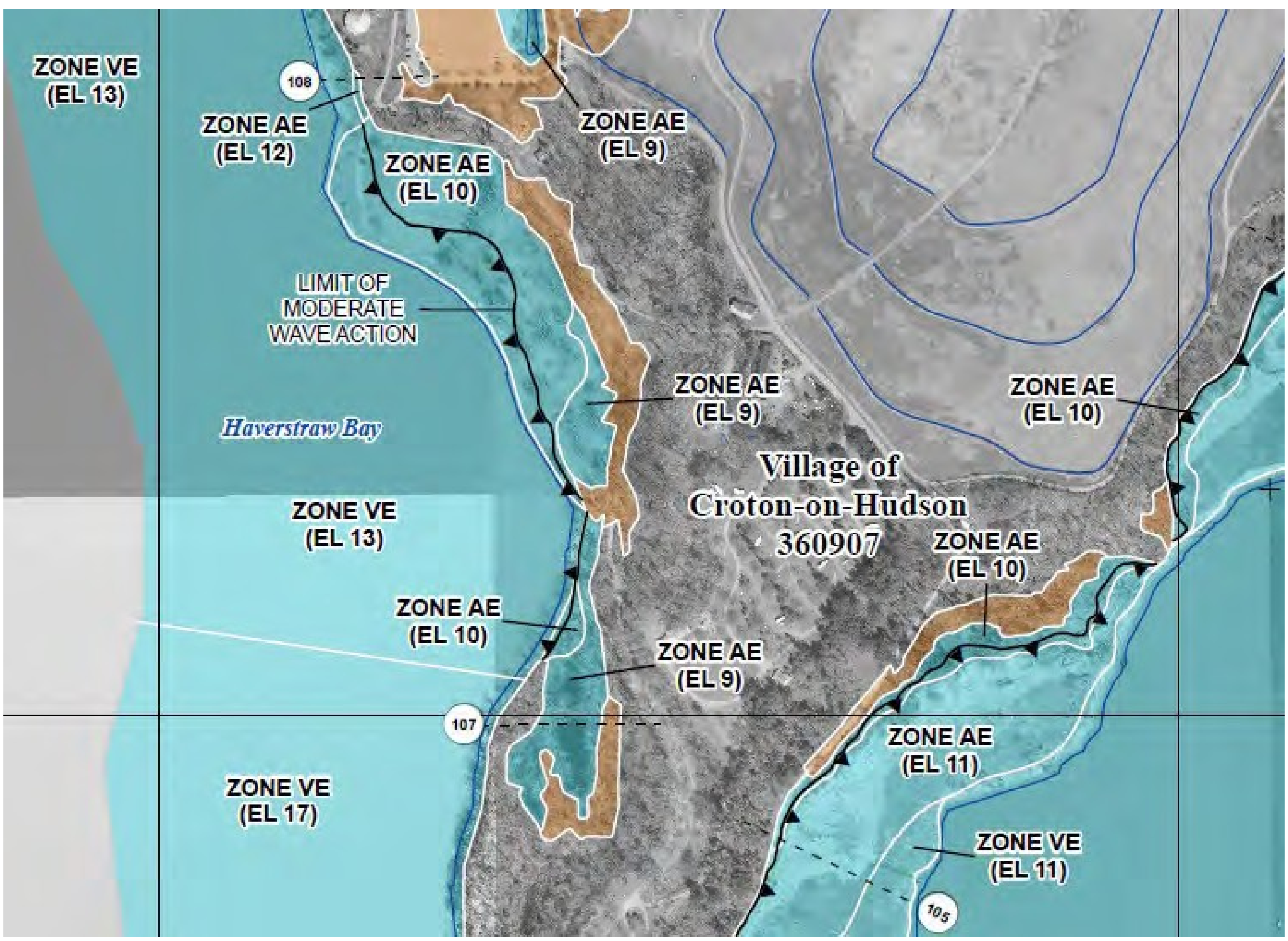


Figure 3.6 Preliminary FIRM (P-FIRM) for Croton Point Park in Croton-on-Hudson, NY. (Source: FEMA)

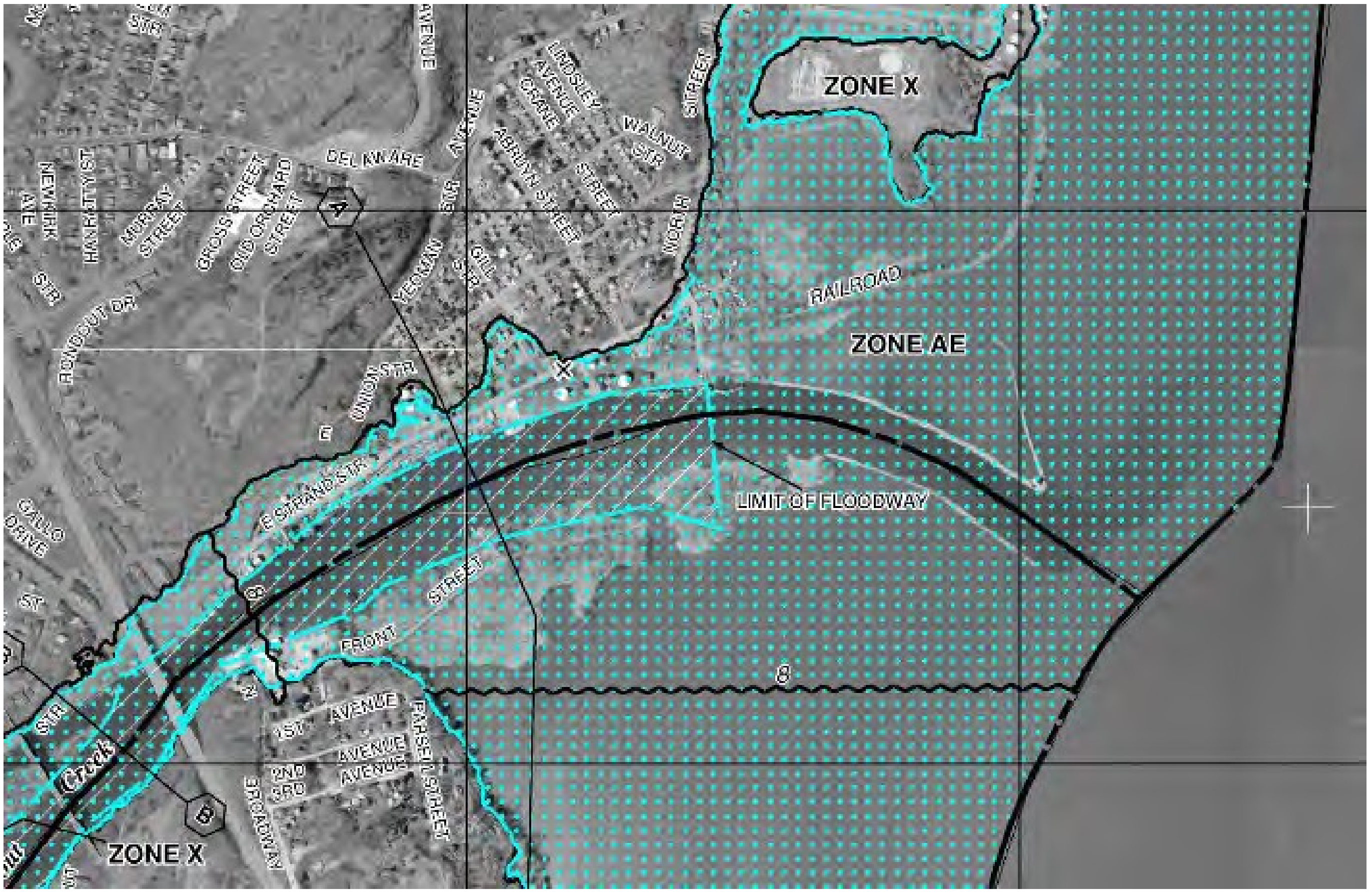


Figure 3.7 FIRM for mouth of Rondout with access sites, Sleightsburgh Park in Port Ewen, NY., T.R. Gallo Park and Kingston Point in Kingston. (Source: FEMA)

NOAA Flood Data

The National Oceanic and Atmospheric Administration (NOAA) also has information on existing flood risk. NOAA's products include a range of coastal data along with tools, training, and information about how to use and understand these data (see NOAA in Additional Resources).

Draft New York State Flood Risk Management Guidance

As part of the Community Risk and Resiliency Act, (CRRA) applicants for permits for major projects, as defined by the State Uniform Procedures Act (ECL Article 70) must demonstrate consideration of future risk due to sea level rise.

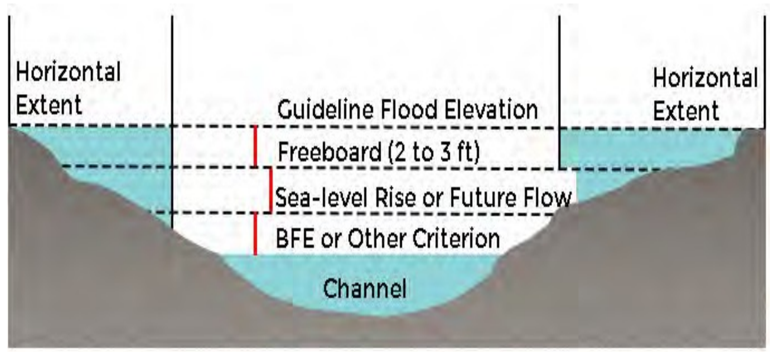


Figure 3.8 Extent and Elevation of Flood Hazard Area by Adding Sea Level Rise and Freeboard above BFE. (Source: DEC)

The Draft State Flood Risk Management Guidance recommends that projects should not be sited in coastal areas that result from adding the medium sea level rise projection applicable for the full, expected service life of the facility, plus two feet of freeboard, to the BFE and extending this level to its intersection with the ground. Where avoidance of this area is not feasible, facilities for which flooding is a concern should be designed for resilience to this level.

Ice Risk

For every project along the Hudson River, the challenges associated with ice dynamics should be addressed based on a site-specific analysis. Structures intended specifically for shoreline protection are civil structures that must be designed by a qualified engineer. Many shorelines not intended exclusively for protection are designed by a landscape architect or restoration biologist familiar with Hudson River vegetation. Piers must be designed by structural engineers. Ice will impact all of the above and should be assessed as part of the planning and design process.

Planning and design steps for managing ice risk include the following:

- Understand the use of the site and what infrastructure or assets should be protected.
- Collect and review ice and winter hydrology data. This step provides background for understanding ice behavior at project sites. Additional data to be reviewed include ice thickness, air temperature, and ground, aerial, and satellite photos.
- Describe the site-specific ice regime. This step provides a description of how the ice is forming and moving at the project site. Where existing, results of hydraulic modeling in ice-free conditions (even though it does not integrate river ice) can be used to describe the expected ice movements and ice floe velocity in the area. The static and dynamic loads are defined at this step.
- For structures, calculate ice loads using standard equations and include conservative safety factors in the stability analysis to account for extreme ice load scenarios.
- Assess ice-related risk. This step defines the level of risk for the area based on the hazard, exposure and vulnerability, as described in Step 3 above.
- Determine the high-water level, the maximum water level that can be reached during winter when ice is present, and maximum ice height. This is done preferably through a combination of historical hydrological data and on-site observational data. The definition of a high-water level should be based on winter water level measurements and observations – not only ice-free hydrology. At some locations, winter water levels could be higher than ice-free flood levels, due to ice roughness and ice jam conditions.

The above steps should result in proper selection of vegetation, sizing of structures, and other construction details.

For shorelines, taking no action followed by utilizing nature-based protection strategies should always be considered before hard armoring alternatives (bulkhead, sheet piles, wood or stone revetments). The Hudson River Sustainable Shorelines Project has several case studies of nature-based edge protection that have survived many winters successfully.[31] Species of vegetation must be carefully selected based on their adaptive abilities, including developing a robust root network. Also, the time required for the vegetation to grow must be considered. In other words, a protection method that includes vegetation may not be fully resistant during the first years of establishment or following an extreme event (i.e. drought, freeze-thaw, erosive event).

[30] New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act (June 2018 Draft), www1.dec.state.ny.us/docs/administration_pdf/frmgpublic.pdf.

[31] NYS DEC, Hudson River National Estuarine Research Reserve, Hudson River Sustainable Shorelines, https://www.hrnerr.org/currentprojects.

LEARNING FROM SLEEPY HOLLOW'S EAST PARCEL

Village of Sleepy Hollow, Westchester County

The Village of Sleepy Hollow, New York is implementing a suite of green infrastructure and resiliency projects on the former site of the General Motors assembly plant, which has been vacant since the 1990s. To support the public and private sector investment, the Village of Sleepy Hollow developed a clear vision for the future of the downtown, set goals and strategies to implement the catalytic project, formed a local stakeholder committee, and demonstrated united leadership to leverage the Downtown Revitalization Initiative plan.

Flood modeling, bathymetric survey, and hydraulic and coastal analyses were performed to understand existing site conditions and sea level rise projections on the site's East Parcel out to 2080, to evaluate current and future risks and impacts. As part of re-imagining the flood-prone area, a collection of green infrastructure improvements were designed to serve multiple purposes, including stormwater management, educational programming, recreational opportunities, and cultural preservation.

The plan raises the existing Village Department of Public Works facilities out of the floodplain; incorporates pervious pavement in the parking lot and proposes a great lawn area designed to be flooded, as well as a multi-purpose athletic field and large bioswale designed to retain stormwater; and includes a terraced community center with civic plaza that also serves as an emergency response center. The plan ensured that the site's development would meet National Flood Insurance Program requirements.

Figure 3.9 Sleepy Hollow Waterfront Redevelopment Project. (Source: WSP)

3.5. Step 4: Engage Community Stakeholders

Community members who live near or visit the river access site are key partners in developing and stewarding resilience strategies along the riverfront. A particular focus for developing these strategies will be targeted outreach to stakeholders from disadvantaged or underrepresented communities. Community stakeholders can help inform the visioning and design process and reality-check ideas to ensure any alternatives proposed are feasible for implementation. Information about the desired uses of a site will help planners and designers identify and adapt best practices for resilient design. There may be limitations based on waterfront site condition and flood risk. Certain desired amenities may be rendered impractical due to environmental conditions, safety concerns, or high cost.

Refine Public Use Goals and Engage Community Stakeholders

It is important for planners and designers to keep the recreational, ecological, and open space needs of the local community and other stakeholders at the forefront and try to plan for these needs when possible. Engaging stakeholders early on is critical in the design process and may involve design charrettes and site visits. This is particularly important for disadvantaged or environmental justice communities, as well as people with disabilities who are often under-represented in the planning and design stages. Continue engagement throughout the process to get feedback and report on progress. Be clear about how stakeholder input will be used in decision making, which may range from simply informing to full collaboration. See Additional Resources on engaging stakeholders.

3.6. Step 5: Develop the Design

All design projects should build on the planning process described in Steps 1 through 4. Design details and other design considerations are included in chapters on River Access Site Types and on Resiliency Strategies. Overriding design considerations are discussed here.

Build Ecosystem Functionality into the Approach

Whether designing shoreline treatments or determining how to address constant inland flooding of low-lying areas, a functional ecosystem-based approach can be a highly beneficial practice. For example, along the estuary's shoreline, which is subject to erosion, a vegetated sloped bank may be a more resilient approach than installing a bulkhead edge. Sloped banks and vegetation have the added benefit of creating and/or restoring habitats and supporting ecological functions while also attenuating wave action and buffering against storm surge.

Even when a full-scale natural ecosystems approach is not possible, design solutions should integrate wetland and riparian species that are tolerant of flooding, salt intrusion (along brackish waters), and disturbance regimes into the river access site design. No matter the approach, the potential effects on surrounding ecosystems, including sedimentation and scour, should be considered when designing built structures or natural systems at any site.

In some locations, introducing or maintaining hard structures can impact shorelines by altering water flow and natural sediment transport. As such, estuarine shoreline designs should take care not to exacerbate or deflect erosion down-shore from the project site. Any installation of hard shore structures should include considering the consequential impacts they might inflict on nearby ecosystems. As an alternative to the use of hard structures, vegetated shorelines can provide wave attenuation benefits and reduce impacts from storms. In low-lying areas, which constantly flood and experience great and frequent damage, returning the shoreline to a natural area might be the better approach to take if possible.

Adapt River Access Site Edges for Sea Level Rise and Storm Surge Risks

Whether a river access site is undergoing a partial renovation or full reconstruction, adaptation to future sea level rise should be included in relevant coastal and estuarine projects when appropriate and feasible. Guidance on design flood elevations for estuarine edge designs should be acquired during the planning phase and should be based on the best available data at the time of the project.

FEMA provides technical fact sheets on how to determine design flood elevations (DFEs), such as Technical Fact Sheet No. 1.6: Designing for Flood Levels Above the BFE: www.fema.gov/media-library-data/20130726-1537-20490-8057/fema499_1_6_rev.pdf

There are a range of approaches to adapting estuarine river access site edges to future sea level rise. For sites with hard structures such as bulkheads or riprap, approaches may include raising the edge itself, raising the adjacent esplanade if present, and / or shifting pathways near the river's edge to higher ground. For sites with soft edges such as wetlands, allowing for the landward expansion of marsh through the regrading of slopes and plantings may be appropriate.

Manage Water on All Sides of the Site

Any intervention to help increase resiliency in river access sites should consider management of water as integral to its solution. In the floodplain, where the water table is high, the absorptive properties of river access sites are diminished during extreme storms. Therefore, the use of green infrastructure for storm water management within river access sites in the floodplain is recommended only for management and detention of water from average rainstorms, not for larger floods. See Chapter 6: Resilience Strategies for more information on constructed stormwater green infrastructure. If a site is adjacent to a stream, the impact of flooding and sea level rise on the stream should be factored into the assessment of problems and the selection of solutions.

Determine Regulatory Requirements

In coordination with regulatory agencies, the entity advancing the project, i.e. the project sponsor, will have to determine which regulations apply to the project. Permitting is discussed in more detail in the next chapter, but it is worth noting that it is an integral part of the planning and design process. New York's State Environmental Quality Review Act (SEQR) requires all state and local government agencies to consider environmental impacts equally with social and economic factors during discretionary decision-making. For many park projects, the size and impact of the project may not be significant or are otherwise precluded from environmental review under SEQR. Incorporating regulatory feedback during the planning stage can help to develop feasible alternatives, streamline the design and permitting process, and assist in developing creative solutions, with the goal of an implementable design. For instance, understanding the available construction window based on endangered and threatened species permits will help determine how many seasons a project may take.

Employ Principles of Universal Design

Universal design goes beyond the legal requirements of the Americans with Disabilities Act[32] and considers the needs and potential for enjoyment of a diverse cross-section of users. Universal design is particularly important when resilient strategies entail changes in elevation, facility siting, emergency communications, and methods for the public to access the Hudson. The types of amenities and the design of those amenities for the river access site should follow the seven principles shown in Table 3.1 below.

[32] U.S. Department of justice, Civil Rights Division, *A Guide to Disability Rights Laws* (February 2020), accessed via https://www.ada.gov/cguide.htm#anchor62335.

Table 1.1 Universal Design Principles (Source: Center for Universal Design, North Carolina State University)

Principle	Description
1. Equitable Use	The design is useful and marketable to people with diverse abilities.
2. Flexibility in Use	The design accommodates a wide range of individual preferences and abilities.
3. Simple and Intuitive Use	Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or existing concentration level.
4. Perceptible Information	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities
5. Tolerance for Error	The design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. Low Physical Effort	The design can be used efficiently and comfortably and with a minimum of fatigue.
7. Size and Space for Approach and Use	Appropriate size and space are provided for approach, reach, manipulation, and use, regardless of user's body size, posture, or mobility.

Specify Resilient Materials and Plantings, and Utilize Durable Design Details

Selecting resilient materials, choosing appropriate native wetland and riparian plants, and using durable and appropriate construction methods will help enable parks and open spaces to withstand the major risks associated with climate change. Understand that delicate design elements may not be appropriate in a floodplain. Additionally, river access sites that incorporate natural areas with plants adapted for estuarine environments will be better able to withstand and rebound from flooding. See Appendix B in Design and Planning for Flood Resiliency: Guidelines for NYC Parks Guidelines[33] for Materials and Components for details of resilient materials and components for use in waterfront access areas within the floodplain.

3.7. Step 6: Evaluate Costs and Benefits of Alternatives

Once the site and permitting constraints are known, alternative resilience strategies can be refined, and cost estimates can be developed. There are several funding sources available for Hudson River access sites to design and / or implement resiliency upgrades. Although the cost of making a site resilient may seem high, upfront costs are typically paid back over the lifespan of the resilience strategy. In addition, there may be funding options available specifically for investing in resilience. These should be explored before ruling out a good option based solely on cost. Funding sources are described in the Appendices.

Alternative Strategies

The resilience strategies discussed in Chapter 6 offer many alternatives to consider; choosing the best one for a site depends on the many factors described throughout this handbook, including feedback from stakeholders. Refining the selection of alternatives includes evaluating priorities, which may be accomplished through using tools such as a matrix with project criteria or cost benefit analysis.

[33] NYC Parks, Design and Planning for Flood Resiliency: Guidelines for NYC Parks (2017), https://www.nycgovparks.org/pagefiles/128/NYCP-Design-and-Planning-Flood-Zone 5b0f0f5da8144.pdf.

Table 3.2 Example Multi-Criteria Matrix for Evaluating Project Alternatives. The criteria and priority levels shown here are just examples and will be different for each site and site manager.

Criteria	Priority	Alternative A	Alternative B	Alternative C
Minimize maintenance costs	1 (Highest importance)	*- description*	*- description*	*- description*
Protect the long term viability of the site	1 (Highest importance)			
Continue all current uses	**2** (Medium importance)			
Avoid future capital costs	**3** (Medium importance)			
Implementable within three years	**4** (Lower importance)			

Costs and Benefits

A cost-benefit analysis (CBA) provides the rationale for taking a specific planning and design action because it compares project benefits with project costs over the lifespan of the project, thereby providing perspective on effectiveness of investments.

Assessing costs and benefits is an essential component of the planning process and may be a useful approach to making investment decisions and evaluating alternatives. It can also help justify a project for a potential funding source, influence whether certain elements are included in a design or even determine whether it is feasible to pursue project implementation at all. A key element of cost-benefit analysis is determining the projected lifespan of the structures and amenities. Are the investments meant to last 10 years or 50 years? This will affect the evaluation of alternatives and choices.

For large or high-expense projects, a formalized CBA may be advantageous and should be built into a project's scope of work. CBAs are typically necessary for federally funded mitigation projects. Examples of project benefits that might go into a CBA include:

- Protecting parkland, infrastructure, or other upland assets;
- Protecting or improving the functioning of ecosystems; or
- Protecting vulnerable riverfront community shorelines.

Conduct a Life Cycle Assessment

A lifecycle assessment (LCA) is a method to measure the holistic impact that a project or process has on the environment. The methodology looks at the full lifespan and the full inventory of the project's components. LCA can be a powerful decision-making and reporting tool for planning and design teams to understand the impacts of the energy use, materials, on-site processes, repairs and maintenance.

Resiliency features within the floodplain may have a shorter lifespan than outside the floodplain. As a result, it is valuable to understand the life cycle costs of materials and components to make informed design choices and specifications. For example, when evaluating how to repair a damaged element or structure, it is important to know the repair versus replacement costs, along with their associated frequency and degree of maintenance. Understanding service life, associated costs, and maintenance frequencies can all factor into decision making on materials selection and construction techniques.

4. Land Use Regulations & Permitting

4.1. Introduction

This chapter explains land use regulations and the types of permits that might be required depending on the resiliency solution to be implemented and based on the particular conditions of river access sites. It does not explain the environmental review process under New York State's Environmental Quality Review Act (SEQR) or how the Community Risk and Resiliency Act (CRRA)'s Flood Risk Management Guidance is changing DEC permitting programs in the Permit Issuance Standards section below. CRRA requires applicants for permits or funding in a number of specified programs to demonstrate that future physical climate risk due to sea-level rise, storm surge and flooding have been considered, and that DEC consider incorporating these factors into certain facility-siting regulations. Especially considering that permitting regulations may change, **engaging relevant agencies early will identify constraints and determine the key components of permitting in the planning and design process**. This will save time and money later. Sometimes a minor adjustment in the design can turn a problematic alternative into a permittable one.

4.2. Local Land Use Regulations

Typically, river access sites will be zoned as park, open space, marina, or a special use district. These designations are defined in a municipal code, with specific purpose and use outlined in the general legislation. For example, the City of Kingston zoning states the purpose of the RF-H Hudson Riverfront District is to:

> *"Afford priority to water dependent uses, achieve public access to the coastal area, control development, create distinct Hudson River and Rondout Creek waterfront districts and to implement the policies and purposes of the City of Kingston Local Waterfront Revitalization Program. Further, it is the purpose of the districts to provide opportunities for permanent public views and access to the Hudson River and Rondout Creek and to encourage the phase out of certain uses which are incompatible with and detract from the Hudson River and Rondout Creek waterfront areas."*

The zoning code may also list the types of uses permitted by right or uses that require access to coastal waters. These could include charter boat operation, municipal parks, and beaches. Land use regulations also define the types of zoning use incentives, special permit uses, requirements such as building heights and setbacks. Some municipalities have local wetland protection laws. Municipal staff, such as a code enforcement official, planner, or building inspector, should be able to help with interpreting municipal codes and point out the constraints and opportunities within which the project must be designed. **Contact municipal staff early in the planning process.**

All communities that participate in the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) have a local law or ordinance that regulates development within mapped floodplains (visit www.floodsmart.gov for additional information on the NFIP). All development, including buildings and other structures, paving, excavation, drilling, or storage of equipment or materials is subject to construction regulations if it occurs within a Special Flood Hazard Area (SFHA). The **municipality is the local floodplain administrator** and is the entity that should be sought for approvals for this type of permitting. Please see the DEC website Flood Plain Construction Requirements[34] for more information.

[34] NYS DEC, Floodplain Management, *Floodplain Construction Requirements for NYS,* www.dec.ny.gov/lands/40576.html.

4.3. State and Federal Permitting

Depending on both the type of access site and the proposed alterations to the site, implementation may involve local, state, and federal approvals. The following discussion is focused only on permits needed for in-water work or work along the shores of the Hudson River. Information about the regulatory permitting processes that apply to riverfront access sites are provided below and in greater detail in the Appendices.

Consult with Agencies Early, Especially DEC

There are many regulatory agencies involved in the review of actions affecting the Hudson River estuary, and there are a variety of related jurisdictional boundaries. **Meeting early with DEC Regional Permit Programs for a pre-application meeting will clarify project objectives, confirm jurisdictional boundaries, determine which environmental permits will be required to complete the project, and engage relevant DEC program staff.** Feedback can improve the applicant's project planning and permitting application process. For example, if a project proposal includes work that will require a time of year restriction due to the presence of endangered or threatened species, the applicant will know in advance and can plan the project timeline accordingly. On occasion, minor changes to a project can avoid disagreements and delays and, in some cases, eliminate the need for a permit.

The permitting process requires a site owner or project partner to complete one or more applications, which typically require the following documents:

- Application form
- Location map
- Project plans
- SEQR Forms
- Supplemental information (e.g., that are required by 6 NYCRR Part 621, Uniform Procedures Regulations, and any specific program implementing regulations pertaining the specific permit(s) sought for the project).

Applicants should keep their plans flexible until DEC staff reviews the proposal and comments on its potential to conform with permit issuance standards. It is important to remain willing to adjust the project at this stage in the planning and design process. More complex projects, particularly those with significant technical requirements specified in the regulations, may benefit from the expertise of an environmental consultant or similar expert to help guide the process. Depending on the permit type, technical details may be required that warrant the use of an engineer or architect. DEC staff can advise applicants with regard to the technical requirements of the applicable permits. It should be noted that consultants are not required for all permit applications or project plan sketches, as long as the application shows the necessary information. In fact, applications submitted by individual landowners may go just as smoothly or even more smoothly than those submitted by consultants.

Permit Issuance Standards

The decision to issue an environmental permit for a shoreline or in-water project is based on the permit issuance standards outlined in each set of regulations. Because the permit issuance standards differ depending on permit type and the varying agencies involved, it is best to discuss the issuance standards directly with each regulatory agency.

Resiliency strategies are discussed in Chapter 7 and offer many choices and alternatives to consider and discuss with DEC and other agencies. As a rule, projects should be designed to minimize impacts to ecological functions, critical habitat areas, recreational activities, and to protect human health and welfare. If it is not possible to avoid impacts entirely, projects must seek to first minimize their impacts to the greatest extent practical.

State Agencies Involved in the Permitting Process

The following state agencies may have jurisdiction in resiliency projects common in the Hudson River estuary:

- **NYS Department of Environmental Conservation (DEC)**
  - The entire Hudson River and its tributaries are subject to the Protection of Waters Act, Article 15, Title 5 and the implementing regulations, 6 NYC-RR Part 608.[35] Relevant regulated activities include disturbances to the bed or banks of a protected waterbody – such as the Hudson River – and/or excavation or fill below mean high water in navigable waters of the State. A permit may be required for projects within the regulated river area, up to the mean high-water line or to the top of the bank depending on the project location, which can be confirmed by the DEC Regional office. Determinations on jurisdiction are made by the Division of Environmental Permits in conjunction with the Bureau of Ecosystem Health or Division of Marine Resources. Historically, hard structures have provided protection from erosion and minor flooding and regulations have evolved to manage their construction. However, DEC is developing guidance on natural and nature-based solutions as well.[36] When available, the guidance will pertain to these permits.
  - The shorelines of the Hudson River, as well as some of its tributaries, which lie approximately south of the Governor Mario M. Cuomo Bridge are subject to the Tidal Wetlands Act, Article 25, and the implementing regulations, 6 NYC-RR Part 661.[37] A permit is required for almost any activity that can alter a state-regulated tidal wetland and the regulated adjacent area up to 300 feet from the shoreline. The DEC Info-Locator mapping tool[38] shows the mapped location of the state-regulated tidal wetlands. Regulated actions and current wetland boundaries and adjacent area boundaries can be confirmed by the DEC Regional office.
  - Tidally influenced wetland areas on the Hudson River north of the Governor Mario M. Cuomo Bridge may be mapped pursuant to the Freshwater Wetlands Act, Article 24, and the implementing regulations, 6 NYC-RR Part 663.[39] The approximate location of State-regulated freshwater wetlands can be found by using the DEC Info-Locator mapping tool. This includes a "check zone" around the mapped wetlands in which the actual wetland may occur. The area surrounding the actual wetland boundary for 100 feet is the regulated adjacent area. Regulated

[35] NYS DEC, Permits, Licenses, and Registrations: Protection of Waters Program, www.dec.ny.gov/permits/6042.html.
[36] Using Natural Resilience Measures to Reduce Risk of Flooding and Erosion in New York State (expected publication 2020) NYSDEC.
[37] NYS DEC, Permits, Licenses, and Registrations: Freshwater Wetlands Permits, http://www.dec.ny.gov/permits/6058.html.
[38] NYS DEC, DECinfo Locator Mapping Tool, accessed via: https://gisservices.dec.ny.gov/gis/dil/.
[39] NYS DEC, Permits, Licenses, and Registrations: Tidal Wetlands Permit Program, http://www.dec.ny.gov/permits/6039.html.

actions and exact state-regulated freshwater wetland boundaries can be confirmed by the DEC Regional office.

- The entire Hudson River is considered potential habitat for the State listed endangered shortnose sturgeon. Large portions of the shoreline are also habitat for the state listed endangered peregrine falcon and Indiana bat as well as the threatened bald eagle and northern long-eared bat. These species are all regulated pursuant to the Endangered and Threatened Species Act, Article 11, Title 5[40] and the implementing regulations 6 NYCRR Part 182.[41] Time of year restrictions may be required to avoid impacting these species. If impacts cannot be avoided, a Part 182 permit for Incidental Taking of an Endangered or Threatened Species may be required. A determination on the presence of endangered/threatened species and necessary avoidance measures can be obtained from the DEC Regional office.
- Additional regulations may apply on a site by site basis. For example, plantings, grassing and mulching, landscaping, and other such activities must comply with DEC invasive species regulations 6 NYCRR Part 575 and 576[42] to ensure no invasive species are introduced or released into the project area or the other parts of the site. Many other additional regulations like Part 575 and 576 are largely compliance requirements, not actual permits, such as policies issued for environmental remediation sites – which is a substantial portion of the shoreline.
- The Environmental Resource Mapper[43] is an interactive tool to identify natural resources and environmental features that are state or federally protected, or of conservation concern. Examples of additional regulations that might be required include permits related to the State Pollutant Discharge Elimination System (SPDES) program, Clean Water Act certifications (see federal section below), and approvals related to the handling and transport of hazardous materials and soils. DEC can identify any applicable permits or compliance requirements through a jurisdictional determination request or during pre-application meeting.

[40] The New York State Senate, Environmental Conservation: Section 11-0535, *Endangered and Threatened Species, Species of Special Concern*, https://www.nysenate.gov/legislation/laws/ENV/11-0535.
[41] NYS DEC, Animals, Plants, Aquatic Life: New York's Endangered Species Regulations, https://www.dec.ny.gov/animals/68645.html.
[42] NYS DEC, Animals, Plants, Aquatic Life: Invasive Species Regulations, https://www.dec.ny.gov/animals/99141.html.
[43] NYS DEC, Animals, Plants, Aquatic Life: Environmental Resource Mapper, www.dec.ny.gov/animals/38801.html.

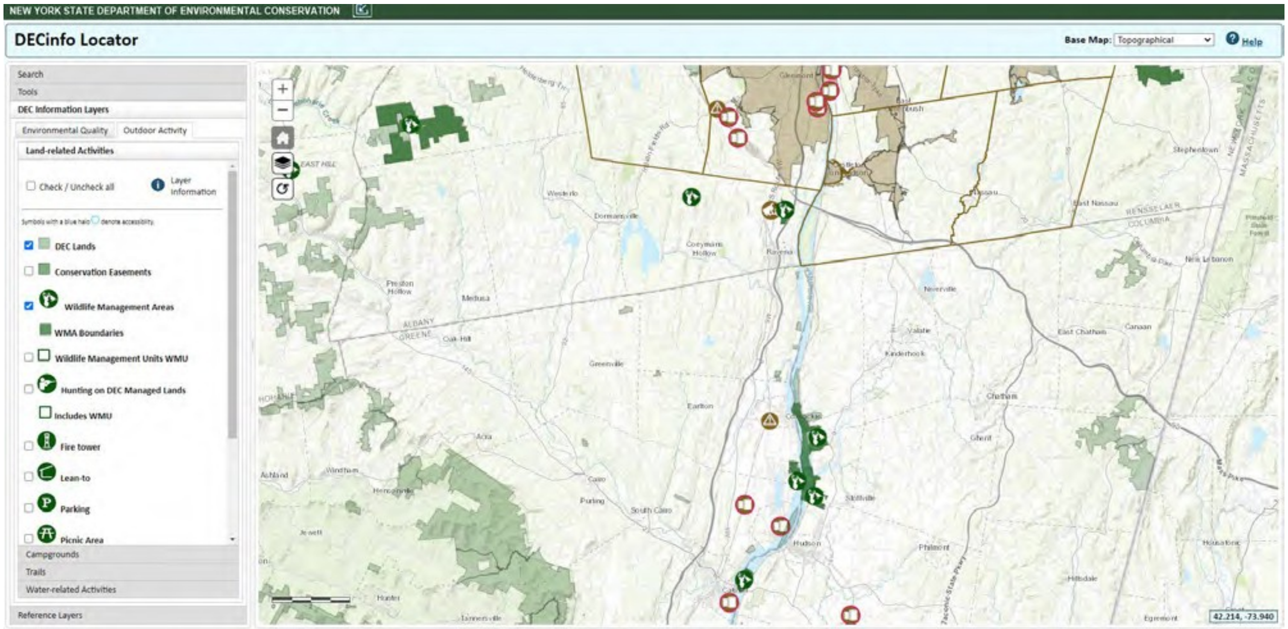


Figure 4.1 Screenshot of DEC's Environmental Resource Mapper, which includes layers such as DEC Lands, Wildlife Management Areas, and environmental quality permits and registrations (e.g., Municipal Separate Storm Sewer System (MS4)). (Source: DEC)

- **NYS Department of State (DOS)** – The NYS DOS is the State agency charged with implementing the federal Coastal Zone Management Act (CZMA), as amended, for actions proposed within the coastal area of NYS, including the Hudson River estuary. The federal consistency provisions of the CZMA are applicable to federal direct actions, funding, and permitting activities. Information on the process and requirements are available on DOS Planning & Development website,[44] including links to the applicable section of, and in accordance with, the NYS Coastal Management Program.
  The NYS DOS Coastal Boundary Map is available at:
  www.dos.ny.gov/opd/atlas/index.html.
- **New York State Coastal Management Program:** All state agency decisions must be consistent with the New York State Coastal Policies[45] established pursuant to the Waterfront Revitalization and Coastal Resources Act. This is separate from the federal coastal consistency reviews administered by NYS DOS. Each agency must make its own state coastal consistency decision.
- **Local Waterfront Revitalization Programs:** Municipalities (cities, towns, and villages) prepare Local Waterfront Revitalization Programs[46] (LWRP) pursuant to the New York State Waterfront Revitalization of Coastal Areas and Inland Waterways Act (NYS Executive Law, Article 42). LWPRs must be adopted by the municipality and approved by the NYS Secretary of State. Consistency with the adopted LWRP may be a component of local approvals for a project. Links to a complete list of LWRP communities and currently

[44] NYS DOS, Office of Planning & Development: Consistency Review, https://www.dos.ny.gov/opd/programs/consistency/federal.html.
[45] NYS DOC, Coastal Management Program, State Coastal Policies (June 2017), www.dos.ny.gov/opd/programs/pdfs/CoastalPolicies.pdf
[46] NYS DOS, Office of Planning & Development: Local Waterfront Revitalization Programs, https://www.dos.ny.gov/opd/programs/lwrp.html.

proposed Draft LWRPs is available on the NYS DOS LWRP website. The Coastal Boundary Map referenced above also shows the location of LWRPs.

- **NYS Office of Parks, Recreation and Historic Preservation (OPRHP)** – OPRHP serves as a liaison to the Federal government for purposes of administering the Land and Water Conservation Fund (LWCF) program, including monitoring compliance with LWCF requirements.
    - OPRHP is responsible for regulation and issuance of permits for "Floating Objects other than Aids to Navigation" pursuant to the Navigation Law Article 3, Section 35-a outside of the Adirondack and Catskill Parks.[47] All floating structures require a permit, including docks, platforms, and mooring structures. Links to the application form and the regulations are available on OPRHP's website at: https://parks.ny.gov/recreation/boating/navigation-law.aspx#floatingobjects
    - In practice, OPRHP issues very few permits on rivers where there is joint federal and state jurisdiction such as Hudson River, Niagara River, and the Great Lakes; however, any project manager that believes this type of permit is applicable should inquire with a local OPRHP Regional Office.
    - Note: If flood protection measures are desired, careful consideration should be given to their integration with and contribution to river access site use. The taking of parkland for non-park use in New York State is known as Parkland Alienation, which requires State legislature approval, and is then signed into law by the governor. As such, careful consideration should be given to flood protection features as they may be considered non-park use.
- **The State Historic Preservation Office (SHPO)** is charged with implementation of the federal review process pursuant to Section 106 of the National Historic Preservation Act[48] (NHPA) with respect to designated and protected properties on the State and National Registers of Historic Places and properties determined eligible for such listing. SHPO is the delegated agency to make the determinations.
- **Office of General Services (OGS)** – OGS is responsible for public lands under Article 6**.** The title to the bed of numerous bodies of water, including in many areas of the Hudson are held in trust for the people of the State of New York. Structures, including fill, located in, on, or above state-owned lands under water may require authorization from the state. A determination on state ownership of underwater lands can be requested from OGS Land Management; additional information and links are available online at: https://ogs.ny.gov/real-estate/lands-now-or-formerly-underwater.
    - Note: Where New York State is not the owner of the underwater lands, ownership of the land must be determined and, if necessary, right of use obtained from the owner for any structures or uses.

[47]Within Adirondack Park and Catskill Park these permits are issued by DEC.
[48] U.S. General Services Administration, Legislation, Policy, and Reports, Section 106: National Historic Preservation Act of 1966, https://www.gsa.gov/real-estate/historic-preservation/historic-preservation-policy-tools/legislation-policy-and-reports/section-106-national-historic-preservation-act-of-1966#:~:text=Section%20106%20of%20the%20NHPA,when%20making%20final%20project%20decisions.

Federal Agencies Involved in the Permitting Process

U.S. Army Corps of Engineers (USACE) – The federal permitting agency responsible for shore protection projects is the U.S. Army Corps of Engineers (USACE), including permits or authorizations for activities in Waters of the U.S. (Section 404 of the Clean Water Act) or structures within navigable waters (Section 10 of the Rivers and Harbors Act).

- The USACE consults the National Marine Fisheries Service (NMFS), Environmental Protection Agency (EPA), and the U.S. Fish and Wildlife Service (USFWS) during the review process.
- Permitting issues may arise when the design encroaches on designated wetland areas or impacts wildlife habitat. Resilience strategies that are located above Spring High Tide will not require federal permits.
- The USACE issues two types of permits: Nationwide Permits and Individual Permits. Nature-based shoreline approaches that require federal review may qualify for coverage under Nationwide permits for activities including stream and wetland restoration and enhancement, the creation of oyster habitats, and bank stabilization. Other activities will require an Individual Permit which includes a more detailed process and considers multiple impacts.
- Permits pursuant to Section 404 of the Clean Water Act also require a Section 401 Water Quality Certification. Issuance of these certifications in New York is delegated to DEC.

U.S. Environmental Protection Agency (USEPA), U.S. Fish and Wildlife Service (USFWS), and National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) – These are advisory agencies to the USACE environmental review process, focusing on activities that affect wetlands, water quality, protected plant and wildlife species, and essential fish habitat.

U.S. Coast Guard (USCG) – This agency coordinates and authorizes placement of construction barges and underwater work.

Federal Emergency Management Agency (FEMA) – This agency reviews flood protection design and potential changes to Flood Insurance Rate Maps (FIRMs).

National Park Service (NPS) – This agency coordinates the authorization for activities that may be necessary within parkland that was improved using federal Land and Water Conservation Funds (LWCF).

4.4. Permitting Projects that are Designed for Future Conditions and Sea Level Rise

Shoreline protection strategies that seek to enhance resilience may be designed to be permittable now with built-in adaptive capacity to accommodate future sea level rise. The chapter on case studies provides examples of sites that have or will take sea level rise into account, including Kingston Point Park and Long Dock Park.

5. River Access Site Types

5.1. Introduction

This chapter describes various river access site types and their facilities that are found on the Hudson, presented on a scale from natural to built:

- Nature Preserves and Wetlands
- Beaches
- Picnic Sites and Campgrounds
- Walkways and Greenway Trails
- Marinas, Floating Docks, and Piers
- Boat Launches
- Urban Waterfronts
- Playgrounds
- Recreation Centers, Buildings

These are not official DEC designations, but rather created for the purposes of this handbook to help site managers understand shoreline conditions and uses. There is overlap in the nine types and many access sites have multiple access types. Each access type description includes an overview and best practices for resilience, discussed in greater detail in Chapter 6: Resilience Strategies. Examples of some relevant access sites are included in Chapter 7: Case Studies.

A few notable concepts discussed in this chapter include:

- Siting high-cost / high-value amenities at higher elevations.
- Grading sites carefully and avoiding steep slopes when possible to minimize erosion.
- Using native vegetation to stabilize habitats and provide shade.
- Directing foot traffic and trails in natural areas to allow access while minimizing compaction and negative ecological impact.
- Appropriately locating marinas, floating docks, and piers and designing them for environmental exposure.
- Considering playground designs that encourage use of low maintenance landforms, plantings, and resilient materials.
- Utilizing natural turf for athletic activity.

5.2. Nature Preserves and Wetlands

Figure 5.1 Wetland complex near Iona Island at the Hudson River National Estuarine Research Reserve. (Source: HRNERR)

Overview

Natural areas provide habitat for fish and wildlife and enhance water quality. They also provide wonderful scenic value as well as recreational and educational opportunities. Wetlands and other natural shoreline habitats are critical buffers between upland areas and open water so they provide natural, resilient components to access sites, but are also threatened by sea-level rise. On the Hudson, preserves are managed by DEC, OPRHP, Audubon, Scenic Hudson and other land conservancies. Many parks have naturally preserved areas. All preserves serve important recreational, open space and resilient functions.

The gradual slope of a natural shoreline and a natural vegetated edge can act as barriers between coastal storms and upland assets by attenuating wave action and capturing debris. Differing natural edges present varied levels of storm surge protection, erosion control, and ecological biodiversity.

Natural shorelines, though generally resilient, are still vulnerable to erosion, both sudden and gradual, particularly in the face of climate change. As sea level rise accelerates, the estuary is at risk of continuing to lose large areas of tidal marsh, which converts to mudflat. Tidal marshes may be able to migrate inland where slopes are sufficiently low and land remains undeveloped. Sites like these should be protected from development whenever possible.

Floodplains and the shore zone act as buffers between water and the adjacent landscape. The floodplain is important for flood retention. Vegetated buffers allow floodplains to store flood flows associated with storm surges. Native plant species found within each of these plant communities can also be effectively used outside the floodplain as species that will tolerate harsh conditions such as salt, drought, high winds, or low nutrients.

Best Practices

- Assess projects carefully regarding the ecological context and habitat management objectives as well as vulnerability to sea level rise.
- Protect and conserve existing natural edges, including, where possible, an undeveloped buffer or no mow zone.
- Conserve all open space lands adjacent to the river edge that have a gentle slope to help wetland and other natural shoreline habitats migrate inland with sea level rise.
- Projects located adjacent to or within these natural systems should minimize negative impacts and disturbance to pre-existing features.
- If boardwalks or platforms are used to access wetlands, they should be designed with similar best practices as piers. They should be accessible, sufficiently high above MHW to minimize topping from floods, designed to reduce uplift from water, strong enough to avoid damage from floating debris.

5.3. Beaches for Swimming, Walking, and River Viewing

Figure 5.2 Free Kayak day at Kingston Point Park Beach. (Source: Nancy Beard/DEC)

Overview

The Hudson River has a limited number of public beaches created with imported sand that provide for sunbathing, wading and swimming, and kayak launching. The greatest risk to these beaches comes from large waves and storm surge that erode the beach and cause damage to its infrastructure. The guidelines presented here can minimize these risks from future storms. In addition, the river's natural beaches, which tend to be narrower, and can be sandy, rocky or cobbled, can serve as protective features for areas upland from the shore. All beaches serve as a natural buffer for incoming wave action during high tides and major storms. In some areas, erosion reduces the natural buffer between the water and developed land.

Best Practices

- Recognize that wrack and woody debris on beaches is natural and has both habitat value and resiliency benefits by decreasing wave energy. There can be a tendency to remove it because it is "ugly" or "messy", but it is best to leave it alone.
- Design and construct native-vegetated edges with relevant experts (e.g., landscape architects, ecologists, botanists, engineers, etc.) to help protect the beach and beach edge against wave action and erosion. Use native vegetation adapted to the coastal environment, as invasive species may grow out of control (see example described in Haverstraw Bay County Park case study).
- Foot traffic across vegetated beach edges should be limited to designated access routes to minimize deterioration of the vegetation.
- Limit structures on beaches to those that provide crucial riverfront uses such as bathrooms and lifeguard stations. If deemed necessary, those structures should be elevated, flood proofed, and designed for vertical and lateral loads due to floods and storm surge. If possible, design to be moved in the event of a significant storm event.
- Avoid drainage structures that can easily clog with sediment such as catch basins and drop inlets on beaches and parking lots.

5.4. Picnic Sites and Campgrounds

Figure 5.3 Picnic Site at Kingston Point Park. (Source: DEC)

Overview

Although summer is prime outdoors season in the Hudson Valley, picnic sites and campgrounds attract locals and visitors throughout the year. The campsites along the Hudson River shore, including Schodack Island State Park, are at great risk to flood related impact.

Best Practices

- As much as possible, locate infrastructure and camp sites out of the floodplain.
- If camp sites are in the floodplain, warn users about the potential for flood risk with appropriate signage and other educational materials.
- Picnic tables and other amenities that float should be secured.

5.5. Walkways and Greenway Trails with a Hard Waterfront Edge

Figure 5.4 Walkway / Promenade at Scenic Hudson River Walk Park in Tarrytown, NY. (Source: WSP)

Overview

Many Hudson River public access sites have pedestrian walkways or greenway trails usually protected by or part of a “hard” waterfront edge, such as a vertical bulkhead, or sloped revetment. In addition to providing unique recreational spaces adjacent to water bodies, these sites also serve as corridors for pedestrians and cyclists to travel along the waterfront. Protecting these facilities from flood damage is critical to maintaining quality river access.

The greatest flood risks to walkways with a hard waterfront edge involve overtopping by floodwaters and constant wave action against the shoreline structure. These forces can cause erosion or damage to the structure and destabilization of the shoreline. During Superstorm Sandy, many stretches of the waterfront were inundated due to storm surge, causing destabilization of riprap edges as well as damage to pavements, in-ground infrastructure, furnishings, and railings. To better protect these facilities, the following best practices are recommended.

Best Practices

- Where feasible, move paths to higher ground and/or elevate the walkway onto a berm. Otherwise, adapt and elevate waterfront edges to account for relevant sea level-rise projections and potential ice stacking.
- If regrading of the shoreline is necessary, where feasible, avoid steep slopes to minimize possible erosion during floods (see slope regrading in Chapter on Resilient Strategies).
- Investigate existing drainage patterns and groundwater elevation in order to best determine which storm water management strategies to employ. Use or create natural topographic features and landforms, such as berms, to direct water away from walkways and help alleviate flooding impacts.
- Raise the elevations of walkway amenities, such as lighting and park benches.
- Use permeable surfaces for walkways, where possible, to allow for better water drainage in flood prone areas.

Figure 5.5 Redesigned after Superstorm Sandy, the new Riverside Park features a deeper rip rap and deeper footing in the pedestrian pathway's curb edge. (Source: NYC Parks)

5.6. **Marinas, Floating Docks, and Piers**

Figure 5.6 Boat and kayak launch at Haverstraw Bay County park. (Source: Rockland County)

Overview

It is important that marinas, docks, and piers be properly sited, well-constructed, and maintained. These considerations will minimize damage from the daily hazards facing these sites and help to reduce potential damages from future floods and severe weather related to climate change.

The resilience of marinas and waterfront structures depends as much on the characteristics of the body of water in which they are built as it does their initial design and construction. For example, sites facing large areas of fetch on the Hudson will be subject to stronger wind driven waves, which can threaten the structural stability of docks and piers and damage boats. These areas and the waves they generate are relatively small compared to coastal areas and comparable to large lakes. Alternatively, marinas and docks located in more protected coves can provide safe harbor for vessels and recreation.

The designs must consider currents, tides, and prevailing winds and sources of waves and flotsam accumulation areas. Design heights should be set using the mean higher high water, expected wave heights at the location, and expected sea level rise over the design life of the facility. Chapter 2: Estuary Conditions provides more information about tides and waves, and Chapter 3: Resilience Design and Planning provides more information about flood risk and FEMA resources to determine wave heights.

For emergency preparedness, Comprehensive Emergency Management Plans and Hurricane Preparedness Plans should be defined in advance to protect life, property damage and to minimize business disruption. See Chapter 6: Resilience Strategies.

Figure 5.7 ADA accessible fishing pier. The bottom of the deck was constructed 3.1 feet above the mean higher high-water elevation, Ferry Landing at Nutten Hook, April 2020. (Source: DEC)

Best Practices

- Select location and siting that minimize exposure to the elements; select materials that survive prolonged exposure to high water and heavy winds.
- Conduct a comprehensive water-dependent use assessment of the site. Analysis of environmental conditions such as fetch, currents, water depth, exposure and water level, wake exposure, storm conditions, and boat traffic should determine the appropriateness and feasibility of design components for a site see Chapter 3: Planning and Design for Resilience.
- Consider winter ice conditions when siting. Freshwater and brackish bodies of water freeze more often than saltwater. If possible, incorporate ice breakers or breakwaters at sites that are leeward of the dominant wind direction to block drifting ice.
- Consider removing floating docks during winter season to avoid ice issues.
- Consider proximity to combined sewer overflows (CSOs), water depth, and upland access when siting.
- Design heights should be set using the mean higher high water, expected wave heights at the location, and expected sea level rise over the design life of the facility.
- Pier widths should accommodate accessibility for water dependent uses, but not to expand upland recreation features or amenities like food vendors.
- Design piers so that they can withstand submergence, uplift, and lateral wave forces.

- Use the strongest and most durable pilings appropriate for the site conditions. Appropriate pile types will be dictated by the type and magnitude of loading, design life of the project, site soil conditions, and available project budget. A qualified design professional can assist in development of a subsurface investigation plan, and selection of appropriate pile types for the project.
  - In brackish water, steel pilings should be coated or employ cathodic protection to resist corrosion. Concrete piling should be appropriately specified to provide dense, impermeable concrete to protect the internal reinforcement from corrosion. Avoid timber pilings, which weaken over time and are highly susceptible to damage from marine borers.
  - Timbers, concrete or steel can be used for freshwater conditions. Note: NYS has a financial policy of prohibiting the procurement of tropical / exotic hardwoods for state construction projects
- Use larger than standard structural elements such as pilings, pile caps, cross member bracings, and stringers to mitigate against pile section loss over time due to corrosion and impact damage.
- Design and install gangways and ramps that can be manually raised up off, or lowered down onto, the floating dock in advance of a storm surge or heavy wave action.
- Alternative anchoring methods should be designed to manage higher tides under sea level rise conditions. For instance, floating docks anchored by pilings should use taller pilings.
- If possible, look at wave attenuation methods like wave screens or floating wave attenuators.
- For marinas, develop an emergency plan that includes temporary removal of boats and secure storage in parking lots or other upland areas. Boats left in the water can turn into debris.
- Design access features to meet the current standards for the NYS Public Buildings Law (Article 4a), the Americans with Disabilities Act (2010), and the Architectural Barriers Act Guidelines for Outdoor Recreation Areas to meet the needs of all users, including people with disabilities.
- In addition, where possible, utilize the principles of Universal Design to the greatest extent possible to provide equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort and appropriate size and space for approach and use.

5.7. **Boat Launches**

Figure 5.8 Haverstraw Bay County Park trailered boat launch (Source: Rockland County)

Overview

There are more than 30 public boat launches (trailer) on the Hudson River between Troy and Yonkers, and more than 116 designated Hudson River Greenway water trail sites, providing access for hand launching of smaller boats.

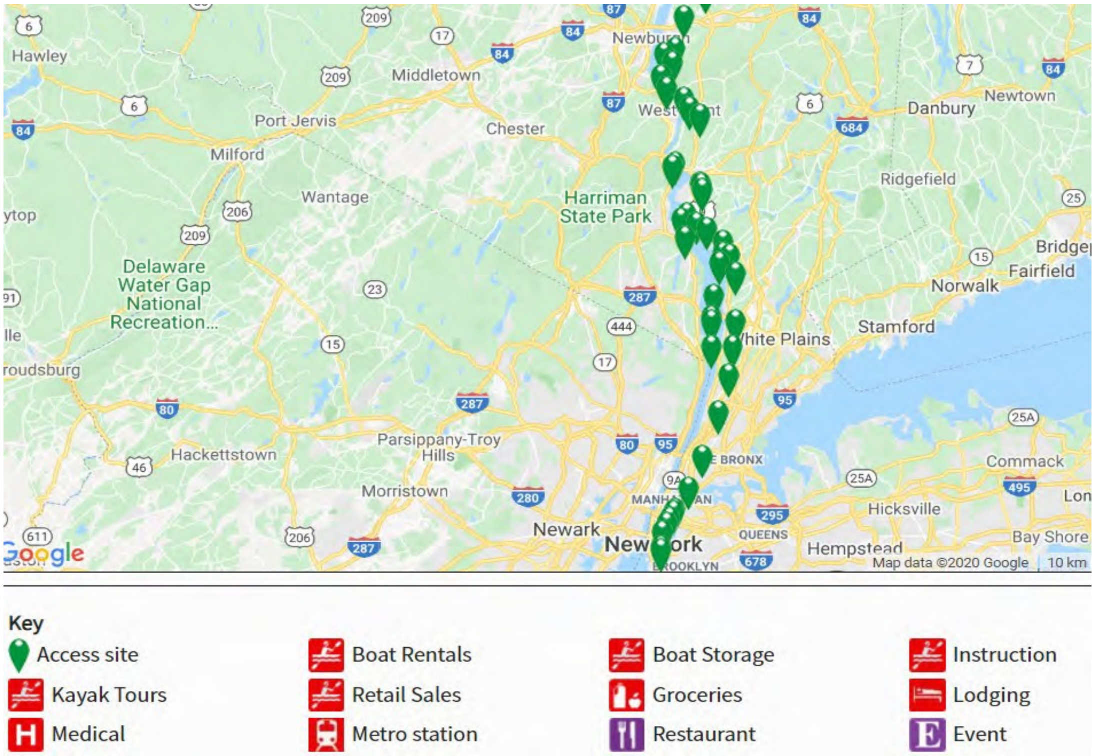
The boat launches site category covers:

- Trailer launches, hard surface/concrete ramp. Float-off and float-on launching/retrieving, structures designed for use by cars or trucks with trailered boats.
- Hand launches with no trailer capacity. Boats must be hand carried to the water. Designed for small, light boats, kayaks, canoes and paddle boards.

The Hudson River is subject to rough weather conditions, strong currents and heavy commercial and recreational boat use, which creates wakes and waves. The resilience of boat launching structures depends as much on the characteristics of the body of water they are built on as it does proper design and construction. For example, sites facing open water or near the shipping channel may be subject to strong waves or wakes, which can threaten the structural stability of docks and piers at a launch site.

Best Practices

- Analyze environmental conditions such as currents, water depth, exposure to wakes, fetch, storm conditions, and water levels.
- Follow the guidance above for resilient docks and piers.
- Consider how the length and slope of the launch and the parking associated with it will be affected by tides and sea level rise. At a minimum, parking areas should be located above predicted high tide throughout the design life of the project, considering sea level rise. Buildings and utilities, if provided, will need to be elevated above the design flood elevation or suitably flood proofed.
- Launch ramps should have a slope between 12 and 15% (1.2 to 1.5 feet of drop in 10 feet of length). Steeper ramps make retrieval of boats difficult. Flatter ramps require the user to back further into the water before the vessel floats free.
- Ramp materials should be selected based on site conditions, including wave and wake climate, current, and local soil and ice conditions. Suitable materials will be durable inorganic materials, and may include natural rock, crushed stone, steel matting, poured concrete or precast concrete depending on site conditions.
- Design for access features to meet current standards for the NYS Public Buildings Law (Article 4a), the Americans with Disabilities Act (2010), and the Architectural Barriers Act Guidelines for Outdoor Recreation Areas to meet the needs of all users, including people with disabilities.
- In addition, where possible, utilize the principles of Universal Design to the greatest extent possible to provide equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort and appropriate size and space for approach and use.
- The following recommendations apply to improve the user experience:
  - For trailered launches, the amount of boat traffic should determine the appropriateness and feasibility of design components for a site. High volume ramps should provide adequately wide channels to promote safe vessel traffic.
- Hand launches should be located at a distance from trailered launches, if possible, to avoid user conflicts.
- The site selection and design of a hand launch for non-motorized or human-powered boats must take into consideration:
  - Launching and retrieval of a variety of sizes and types of craft; and
  - Adequate space to handle multiple craft launches.
  - Adequate space to assist others who may need support getting into or out of boats
  - Parking and access routes to the launch site should be located an appropriate distance from the launch to ensure safety of boaters landing or launching vessels and meet applicable accessibility requirements.



Figures 5.9 and 5.10 Hudson River Greenway Water Trails - Access Site Map, above (Source: Hudson River Valley Greenway) Kayakers wait to disembark at the 4th Street kayak launch in Athens, below. (Source: Scott Keller, Hudson River Valley Greenway) The same site is also shown in Figures 2.1 and 2.2

5.8. **Urban Waterfronts**

Figure 5.11 Pedestrian Waterfront of Downtown Yonkers (Source: WSP)

Overview

While the waterfronts of the Hudson's many river communities are unique in their own ways, the challenges and increasing risks from climate change, sea level rise, and coastal storms are shared by many, if not all communities, throughout the region.

Urban waterfronts are critical elements for public enjoyment, cultural activities and provide economic benefits for both public and private owners. The recreational use of these access sites serves integrated functions such as fishing, boat touring, walking, and entertainment. The urban waterfront could also be a historic port, industrial, or other essential structure of mixed land use characteristics. Often, these urban sites have a hard edge of revetments or concrete or wooden bulkhead. In some cases, the hard edge is failing and needs to be replaced. In other cases, it is already over topped by flood waters during sunny weather flooding or will likely be overtopped with sea level rise.

Best Practices

- With often limited acreage, urban waterfronts are the frontlines for their municipalities. Planning and design for flood resilience in this setting is best achieved by a comprehensive framework that integrates resilience planning into the neighborhood context.

- When an edge needs to be repaired, where space allows, replace a vertical structure with a sloped shoreline engineered for enhanced stability by utilizing a flat, base layer of stone, revetment for protection, and an engineered top layer to hold these various components in place.
- Since urban waterfronts tend to be dense with hard infrastructure, elevating a portion of a site or elevating utilities within the site may be the most practical option.
- Manage water from many sources by installing backflow prevention valves to prevent tidally-influenced river flow onto low-lying areas and use green infrastructure to direct the movement of stormwater. For sunny day flooding, make sure floodwater can recede as quickly as possible.

5.9. Playgrounds

Figure 5.12 ADA accessible playground at Haverstraw Bay County Park (Source: DEC)

Overview

Playgrounds and outdoor fitness areas promote active recreation for children and adults. These facilities can either be stand-alone sites or be part of a larger park and may include steel equipment and water features such as spray showers and drinking fountains. Because playgrounds serve as important fitness and educational environments for children and provide social opportunities for families, it is important to plan for the risks that these site types face when located in a floodplain at a river access site.

Best Practices

- Locate playgrounds and outdoor fitness areas at higher elevations, if possible.
- Consider playground designs that rely less on standard play equipment structures and more on landforms, plantings, and resilient materials that are easy to maintain.
- Increase subsurface drainage around the site.
- Do not install sandboxes in the floodplain, as parents may expect sandboxes to be clean and the sanitary condition cannot be guaranteed.
- Provide shade around playgrounds and outdoor gyms. Shade trees should be wind tolerant, adapted to dry and wet conditions, salt tolerant (where applicable), and elevated wherever possible. Provide a generous root zone to increase root stability.
- Select materials with light colors to help keep the playground cooler.
- Design for access features to meet current standards for the NYS Public Buildings Law (Article 4a), the Americans with Disabilities Act (2010), and the Architectural Barriers Act Guidelines for Outdoor Recreation Areas to meet the needs of all users, including people with disabilities.
- In addition, where possible, utilize the principles of Universal Design to the greatest extent possible to provide equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort and appropriate size and space for approach and use.

5.10. Recreation Centers and Other Buildings

Figure 5.13 Kingston Point Park Beach utility shed showing elevated elements and wet floodproofing (Source: DEC)

Overview

Buildings in the floodplain range from large, complex facilities to smaller but still vulnerable comfort stations, lifeguard stations, and field houses. This category also includes historic structures for which there are special considerations. These buildings, like all buildings in the floodplain, contain utilities that can be vulnerable to flood damage if low-lying and not flood-proofed.

Best Practices

There are multiple ways of increasing resiliency of buildings, described in Chapter 6: Resilience Strategies. Buildings in floodplains are regulated by FEMA through a local floodplain administrator. Best practices include:

- Dry Floodproofing
- Wet Floodproofing
- Building Elevation
- Utility Elevation

6. Resilience Strategies

6.1. Introduction

This section describes in detail riverfront access resiliency strategies, organized as follows

- Policy, Planning, Procedural, and Operational Approaches
    - Strategic Location or Relocation
    - Emergency Planning & Communications
    - Operational Planning & Policies
    - Insurance
- Physical Strategies
    - Edge Strategies – Natural & Nature Based
    - Edge Strategies – Structural
    - Upland Strategies
    - Building Protection Strategies

Often, several resilience strategies are integrated and implemented in a holistic way to adapt the riverfront to changing climate conditions and provide long-term public benefits.

Each site is uniquely affected by changing climate and has a unique set of uses, assets, and amenities that require differing levels of protection and adaptation. Many of the strategies outlined in this section can be utilized collectively as integrated systems. Others require trade-offs.

Accommodating flooding by elevating assets or moving assets upland is ideal from a flood risk reduction perspective. However, these strategies may have other implications to everyday recreational and water access use.

It may help to use a decision-making framework to screen resilience strategies through an evaluation process to select the alternatives that best suit the specific needs and context of a river access site see Chapter 3: Planning and Design for Resilience Discussing complementary strategies with subject matter experts including engineers, ecologists, landscape architects, and designers as well as state agency officials, other site managers and stakeholders can help illuminate the ways various sets of resilience strategies can function together in a complementary way.

6.2. Policy, Planning, Procedural, and Operational Approaches

Much can be accomplished through good planning, procedural approaches, and temporary measures.

Strategic Location or Relocation

When flood-related repairs and maintenance become too resource-intensive and damaging to natural systems and infrastructure, site managers may elect to plan to relocate structures and amenities out of the way of flooding. Planning for new structures and amenities should include location out of flood prone areas and restrict any future site development in those areas. This will help site owners mitigate real and potential consequences and costs associated with flooding on the site. The strategy options are discussed in the section “Physical Strategies” but implementing them starts with a plan.

Strategic location of new facilities or relocation of existing ones, places all or parts of a river access site out of areas that experience persistent or repetitive flooding Critical facilities are typically sited or moved upland and inland out of flood-prone areas. While it is difficult to move a whole river access site, holistic site design can promote absorption and drainage in certain areas while identifying dry, elevated areas for locating vulnerable or critical site assets. See Chapter 2: Estuary Conditions and Additional Resources for information on sea-level rise, flooding and online interactive tools to help with long-term planning.

Once site-specific flood risks have been assessed, including existing and projected tidal flooding and sea-level rise, planning can begin for location or relocation of vulnerable or critical site assets especially those that require a high initial cost or those that are nearing the end of their lifecycles, including:

- Park offices, restrooms, recreational centers
- Parking areas
- Playgrounds, picnic areas and sports fields

Long term planning should assess the need to relocate the site. These sites will need to be identified and property acquired.

Emergency Planning & Communications

Planning for a flood event, should happen well in advance: the decisions about how to respond and who is responsible. Flooding should be part of your emergency plan. Emergency plans describe how risks should be assessed and what actions should be taken to minimize the impact from flooding when certain conditions or thresholds are met. They describe how far in advance of an event, during an event, and after an event, staff resources should be mobilized. Emergency plans ensure that all parties know what they're supposed to do, can be tested in non-emergency exercises/drills, and can be revised after a drill or actual event. An example of impromptu emergency actions is in the case study for Norrie Point.

Figure 6.1 Traffic Sign warning bicyclists and motorists of regular flooding (Source: DEC)

Key considerations in the plan should be:

- Ensuring the safety of visitors and staff
- Mitigating damage to property
- Development of scenarios for dealing with low, medium, and high floodwater rise
- Consideration of how time of day and season might affect the emergency plan
- Availability of staff and equipment to install protection measures or

- Availability of staff to move equipment - or assist in moving boats - in advance of a flood
- Consideration of securing buildings and vehicles
- Consideration of securing potential air borne or waterborne items and equipment suchas litter barrels, picnic tables or boats.

The emergency operational plan for flood protection systems should be comprehensive, ensuring that all protection components are functional.

Emergency plans and associated support documents should be reviewed annually and post-incident reviews within the first two weeks after an event.

Operational Planning & Policies

Operational planning & policies refers to integrating resilience into existing planning processes and daily activities – or any time where decisions are made about the future. These may include:

- purchasing
- staffing and training
- inspections and maintenance
- capital planning

Decisions about materials and services should take into consideration flooding and ways to reduce flood risk. Policies and protocols for hiring and staffing can consider skills, capabilities, and availability of staff during emergencies. Training should include flood risk. The performance of flood protection and drainage systems is not static – increasing inspections and maintenance before and after storm events is crucial. Budgeting and capital planning should include integrating and planning about resilience strategies.

The strategies below, though physical, are temporary and rely on operational capabilities and staff power, rather than expensive investments.

Equipment Mobility: Move Things Out of Harm’s Way

As little as 12” of water can float away a car. Docks, picnic tables, and equipment that is not anchored can get displaced, damaged, or completely lost in a flood. Moving such assets out of the flood zone, is a great way to protect them and to make sure that they don’t cause damage themselves. Some equipment may have to be retrofitted or replaced to allow for easy and safe disconnection. Moving them may take specialized equipment like trailers and trucks with higher load ratings and requires a suitable location to store the items that are moved. If planned in advance, with necessary staffing, temporarily moving assets can be an effective way to reduce the impacts from rare, high-impact flood events. A list of equipment and assets to move and their destination location should be included in the emergency plan, as discussed above. Assets that need to be moved frequently or are difficult or dangerous to move are better suited for long-term strategic relocation, as discussed above. Any amenity that can’t be moved, should be at least temporarily anchored during storms and floods, including floating docks, boats, picnic tables, propane tanks and playground equipment. See case study for Norrie Point.

Deployable Defenses: Moving Protection into Harm's Way

There are many types of protection which can be deployed "just-in-time" in the 24-36 hours before a major flood event. These include conventional sandbags, plastic sheeting, moveable flip up barriers, door flood shields or inflatable dams. These physical devices can be stored off-site and their storage, maintenance, deployment, and removal after an event, can even be outsourced entirely to a contractor. They can be assembled in different shapes and to varying heights quickly. However, they do require specialized equipment.

When protection from water isn't required or desired, temporary fencing can be installed to protect a site from small debris, reducing the risk of damage and clean-up maintenance costs. A list of devices to deploy should be included in the emergency plan, as discussed above.

Figure 6.2 An Aqua Dam installed along Lake Ontario's shoreline in Irondequoit, NY, where severe flooding is a problem being inspected by Governor Andrew M. Cuomo (Source: Mike Groll / Office of Governor Andrew M. Cuomo)

Flood Insurance

Land use planners and floodplain managers recognize parks and access sites as good uses of the floodplain because they often do not contain expensive assets and can easily be designed to flood, which is the purpose of this handbook.

For river access sites, flood insurance is available for a walled and roofed building. This could include restrooms, park offices, concession buildings, and equipment storage buildings. Non-walled structures like an open-sided pavilion would not be insurable. All eligible structures should be built to flood zone standards and should have flood insurance. In the event of a federal disaster declaration, any federal assistance for a publicly owned building in a special flood hazard area would subtract from that assistance the value of the damaged portion that should have been covered by flood insurance.

6.3. Physical Strategies

Physical strategies include both hard infrastructure and living, nature-based methods to protect river access sites, either at the water's edge or at the perimeter of certain facilities, sometimes by keeping water out, sometimes by carefully allowing water in. Their capital intensity ranges from moderate to high. The choice of strategies will be heavily dependent on the size of the site and the adjacent river conditions such as deep water or shallow water, ice conditions, and the impacts of waves and wakes.

Edge Strategies – Natural and Nature-Based

Natural features which reduce erosion and can reduce flood risk include submerged aquatic vegetation, tidal wetlands, beaches, banks and upland vegetation including riparian areas and forests. Natural features are also discussed in Chapter 5: Access Site Types. Natural features should be conserved and protected at access sites. Sometimes edges may need intervention, to restore, enhance the features themselves or to prevent erosion to protect built infrastructure further away from the shore.

Nature-based shoreline techniques mimic, accommodate or enhance natural shoreline processes to reduce the risk of erosion to human assets on estuarine shorelines. Depending on the site location, scale and design, they may also reduce the risk of flooding. Nature-based shoreline techniques rely on vegetation alone or may be combined with grading, fill or addition or removal of structural components. These techniques fall into three general categories: bank stabilization, in-water features and floodplain reconnection.

Nature-based shoreline techniques generally do the following:

- Utilize natural materials and designs to achieve objectives
- Stabilize banks to prevent or minimize erosion, when needed
- Allow for access to an adequate floodplain, when possible
- Improve or create stable shoreline habitat
- Allow access to the water

Nature-based shoreline techniques should be considered before implementing hard-structural protection features such as bulkheads.[49]

In-water structures can be combined with planting of vegetation or features that attenuate waves and protect aquatic habitat or the inland shore from erosion. In the Hudson estuary, low profile

Figure 6.3 Marsh sill at Habirshaw Park, Yonkers. Rock sill protects an intertidal pool. (Source: DEC)

[49] DEC (unpublished). Using Natural Resilience Measures to Reduce Risk of Flooding and Erosion in New York State.

sills are sometimes used. Low profile sills are nearshore wave attenuators and may be used in medium to low energy environments within estuarine systems. These low-crested continuous or discontinuous structures are placed parallel to the shore to protect landward vegetation. They can be either temporary, to allow vegetation to establish, or permanent.

Natural and nature-based edge strategies should be monitored to understand how they are performing over time and whether any aspects need to be adjusted. Please see guidance documents in the Additional Resources Appendix.

Nature-Based Bank Stabilization

Bank stabilization techniques can be used to prevent erosion from the face and the toe of a bluff or slope and foster the re-establishment of a stable bank. Techniques include regarding the slope, revegetating the bank and use of vegetation combined with other materials such as logs, rock or manmade materials. In existing literature and in current practice these techniques may also be referred to as hybrid, biological, bioengineered, bio-mechanical, ecologically-enhanced, living, and/or soft and green.

> Note: Proactive measures to address erosion should not be taken in natural areas. Shoreline erosion is a natural process that needs to happen along the River. DEC is reluctant to allow shoreline stabilization measures where it is not threatening property or infrastructure. Portions of the river, especially in natural areas, need to be allowed to evolve with the changing environment, including sea level rise.

There are many methods to stabilize the bank, working with nature. These methods come from stream bio-engineering and are illustrated in the body of work of the Hudson River Sustainable Shoreline Project. Landscape architects and restoration practitioners may design the bank stabilization using a variety of techniques with the help of engineers who can size the structural components. The reader is referred to the following references for details on bank stabilization.

1. **Hudson River Sustainable Shorelines Project**
    - Rella, A. & Miller, J. (2012a). Engineered Approaches for Limiting Erosion along Sheltered Shorelines. In association with and published by Stevens Institute the Hudson River Sustainable Shorelines Project,
    - Allen, G., Cook, T., Taft, E., Young, J., & Mosier, D. (2006). Hudson River Shoreline Restoration Alternatives Analysis. Prepared by Alden Research Laboratory, Inc. and ASA Analysis and Communications, Inc. for the Hudson River National Estuarine Research Reserve
2. **Tidal Wetlands Guidance Document:** Living Shoreline Techniques in the Marine District of New York State (DEC, 2017) A guidance aimed at the DEC staff, as well as professionals and property-owners, to promote understanding and use of nature-based shoreline protection tactics for habitat enhancement and storm risk reduction. Provides information on types of living shorelines, reviews how tidal wetland and protection of waters permit standards relate to living shorelines, and speaks to proper siting, maintenance, and monitoring considerations.
3. **Living Shorelines Engineering Guidelines** (NJ DEP, 2016): A guidance document on the engineering components involved in the design of living shorelines projects, prepared

for the New Jersey Department of Environmental Protection by Stevens Institute of Technology.

Beaches and Slope Regrading

Natural or restored (slope regrading) banks and beaches are inherently more resilient than engineered shoreline protection. The Hudson River has a variety of natural shoreline types from steep bedrock to sloped vegetated banks or beaches composed of cobbles, broken bricks, or mud at the toe of bank. Natural, low sloped banks and beaches occur in the northern reaches of the estuary and are valuable habitat, forming a transitional area from terrestrial to aquatic ecosystems as well as a corridor for wildlife movement. They also provide important access to the water for birdwatchers, anglers, paddlers, stone-skippers, and in some cases swimmers. The Hudson River has few natural sandy beaches, located mostly in the northern stretches of the estuary. However, rock cobble beaches or pebble peaches (see figures below) sometimes called shingle beaches, are more prevalent. See also the section on beaches in Chapter 5.

How to make a natural river beach more resilient:

The best resiliency strategy for a natural beach is to leave it in place and direct foot traffic and vehicle activity to the least sensitive areas. A good example of this is provided in the Haverstraw Bay County Park case study in Chapter 7.

Key considerations:

- If possible, leave in natural condition
- Regrade if beach slope is too high
- Use designated paths to the shore, to avoid trampling of stabilizing vegetation
- Establish or maintain vegetation behind the beach

Figures 6.4 and 6.5 Sloped vegetated bank, left. (Source: C. Holzworth) Driftwood at Charles Rider Park, right. (Source: DEC)

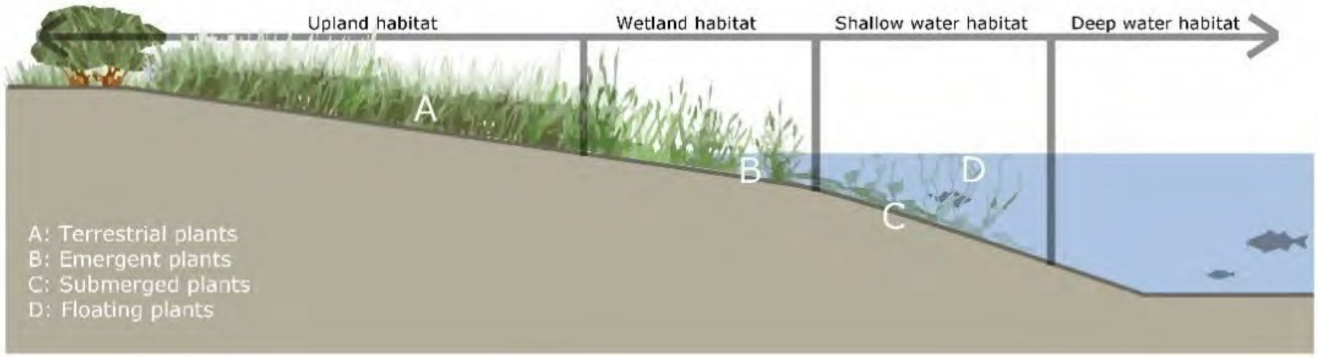
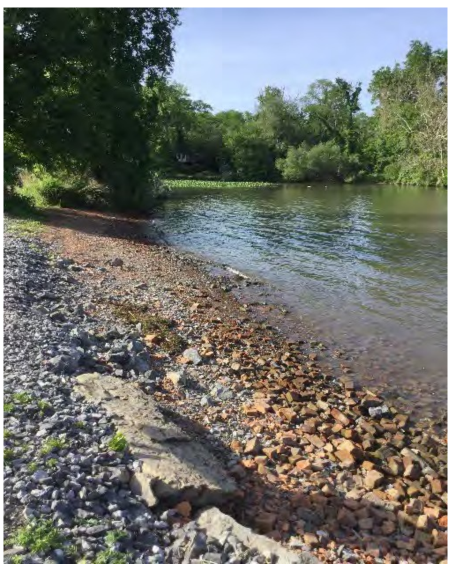


Figure 6.6 The gradient of a typical natural bank and its vegetation, from the upland to underwater (A-D). (Source: L. Potter)



Figures 6.7 and 6.8 Cobble, brick strewn beach at Robert Post Park, left. Gravel and pebble beach, right. (Sources: DEC)

Erosion of banks is caused by overland flow from the top of bank, groundwater seep or wave, wake, and current energy at the toe. Signs of unstable steep banks are trees leaning over the water, exposed roots, gullies in the slope and undercutting at the base of the bank. Erosion is a natural process.

Grading a steep bank can reduce erosion, without expensive interventions. Also, vertical or steep-sloped, hard engineered shore defenses can be removed, and the shore restored to a more natural slope. Lower slopes allow for waves to run-up and dissipate wave energy and reduce the velocity of surface run-off.

For an example of removal of a bulkhead and slope regrading read the case study at Esopus Meadows water trail site and described as a Hudson River Sustainable Shorelines demonstration project at: www.hrnerr.org/wp-content/uploads/sites/9/2018/11/Esopus-Final-11-19-18.pdf

Considerations in re-grading and planting the slope include:

- Slopes should be regraded to a horizontal to vertical ratio of 6:1 to 3:1 and prevention of surface run-off at top of bank should be planned. The slope should be graded toward the upland (see figure on next page). However, this will cause the loss of upland area for other uses.
- Appropriate vegetation that holds the soil and is water tolerant should be planted. In brackish parts of the estuary, salt tolerant species should be selected. Soil type (natural vs fill) and sun exposure are factors affecting the success of vegetated shorelines.
- Access to the site for construction equipment needs to be planned.
- NYS law regulates what can be done within fifty feet of a river or stream bank. A permit is required to disturb the bank. The NYS regulatory definition of a bank is that "land area immediately adjacent to and which slopes toward the bed of a watercourse, and which is necessary to maintain the integrity of a watercourse".[50] See Chapter 4: Land Use and Permitting for information on permits.
- Adjacent shoreline stabilization will affect the success of the regrading of shoreline because vertical bulkheads can cause erosion of the land adjacent.
- Additional Resources: The DEC Divisions of Marine Resources, the Hudson River Estuary Program, the HRNERR (Hudson River Sustainable Shorelines Project) and NYS Sea Grant can provide guidance how to plan a natural shoreline edge and where it is appropriate.

[50] Article 15 Protection of Waters regulations www.dec.ny.gov/permits/6042.html

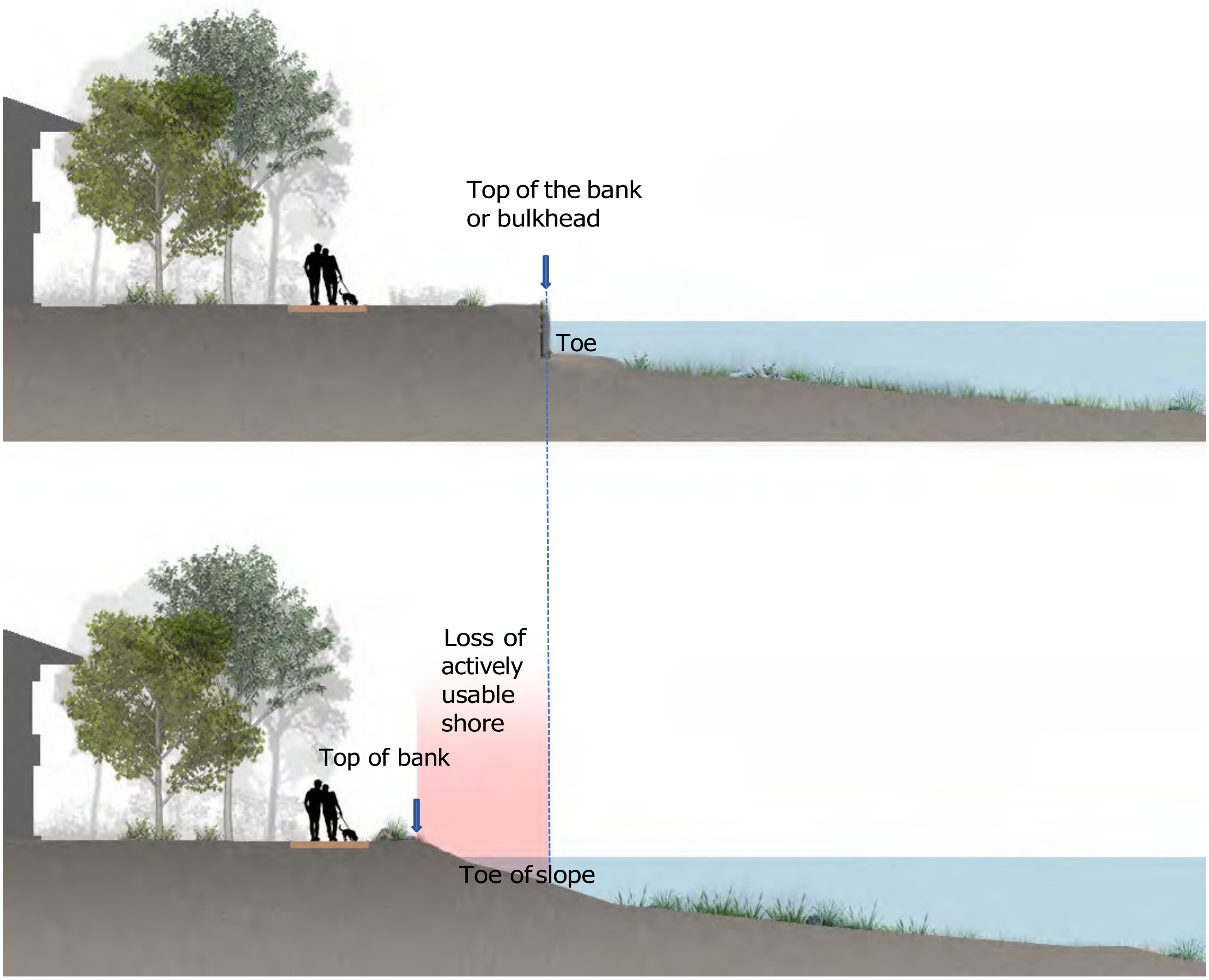


Figure 6.9 Above, Cross-section of bulkhead. Below: Cross-section of gently sloped bank. (Source: WSP)

Vegetating the Bank

Trees, shrubs, and other vegetation on a riverbank can prevent erosion, protect water quality, and improve habitat. Healthy buffers can withstand flooding and provide the highest level of protection. They typically consist of multiple zones with a variety of plant species.

Buffers provide the following benefits:

- Bank stabilization by controlling erosion and sediment
- Reduced impact from floods
- Filtration of nutrients and other pollutants

- Habitat and food for wildlife and pollinators
- Shade for cooling / user comfort

For sites directly on the tidal Hudson, vegetation should be carefully selected to provide erosion control, beauty, and shade.

- Salt tolerance is a factor to consider in the lower reaches of the estuary as far north as Newburgh and Beacon
- Diversity of plants and choice of plant material is key to provide resilience to severe weather (drought or extreme storms) protection from disturbance by deer or rodents, and avoidance of invasive species or pests.
- Monitoring and maintenance is required for 3-5 years (if a permit is required) until vegetation is firmly established (which may present challenges associated with careful and continued watering).
- Native plants are preferred. For information on plants see:
    - www.dec.ny.gov/docs/lands_forests_pdf/factnatives.pdf

Restoring and Constructing Wetlands

Wetlands serve as a transitional environment between the water and the shore. They are most effective as a shoreline edge when there is a large distance between open water and upland areas. The distance will vary depending on multiple factors: water body size (width, depth, tidal fluctuation), slope and condition of the buffer (soil, vegetation), and rainfall/runoff. The appropriate width is very dependent on the circumstances of each wetland. While there is no recommended width, there is a positive correlation between larger wetlands and both flood and erosion protection.[51]

Wetlands function as natural sponges that trap and slowly release water including flood waters. They buffer upland areas from minor effects of coastal storms by attenuating wave action. They also serve as a critical ecological resource, providing natural habitat for a large number and diversity of plants, fish, and wildlife.

The cost of natural protection systems like wetlands can be cheaper than hard structures due to the use of fewer materials, lower construction costs, and natural selection. However, their effectiveness is in part determined by the density of vegetative growth, which can take several years to reach full maturity in new installations.

Wetlands are resilient, requiring very little management once established. They continue to provide important ecosystem services as sea level rise – if they aren't damaged too frequently by storms or ice floes and if they can migrate up slope, or build up vertically by accretion of sediment, organic matter and root mass.

[51] Reeda, Denis et al., Tidal flat-wetland systems as flood defenses: Understanding Biogeomorphic Controls, Estuarine, Coastal and Shelf Science 213 (2018) 269-282.

Wetlands do not prevent damage from large floods but may attenuate wave heights. They can absorb wave action and reduce impacts to the shoreline from an average storm. Wetlands provide recreational benefits such as boating, fishing, and birding.

In the estuary, north of the Mario M. Cuomo bridge, common wetland types include freshwater and brackish tidal marshes, freshwater tidal swamps, tidal creeks, mud and sand flats, and freshwater submerged aquatic vegetation (SAV). Below the bridge near the NY-NJ border, there are salt marshes at Piermont. Creating a wetland edge could involve any of these wetland types, depending on salinity levels and other local conditions.

Additional Resources: The DEC Divisions of Marine Resources, the Hudson River Estuary Program, the HRNERR, and the NYS Sea Grant can provide guidance on how to plan a wetland edge and where it is appropriate.

Reconnecting the Floodplain

Reconnecting floodplains may be feasible in larger natural areas. This practice encourages habitat restoration and can help to manage both overland flow and inundation from estuarine flooding where connections have been restricted by roads, limited-sized culverts or other development. Expanding culverts, particularly as roads near shorelines are raised, or even rerouting roads, may provide opportunities for hydrologic and ecological connections. Reconnecting floodplains to give “room to the river” often requires modeling to determine the potential increases and decreases in flood risk as existing water channels and patterns are altered.

Edge Strategies - Structural

Bulkheads and revetments are commonly used to protect the edge of urban access sites and where the railroad hugs the shore – anywhere facilities and infrastructure are very close to the water. Designers and planners of hard shorelines should work to ensure damage and/or disturbance to natural systems is minimized as much as possible. This will be a key consideration in the state permitting process. Any structural applications on the waterfront should also consider how their placement may affect water and sediment so as to reduce erosion adjacent to the project site.

Bulkheads

Constructed vertical walls built along shorelines are meant to provide enough height to protect the shoreline and upland assets against erosion, wave action, and sea level fluctuation. Such structures are often considered in places with limited space for more natural resiliency strategies.

Bulkheads are vertical erosion protection structures – retaining walls between land and water, and may be constructed of timber, steel or concrete. These structures maximize usable land area along the waterfront by their vertical face. When erosive forces are severe and critical structures are threatened, a new or replacement retaining wall may be the appropriate solution.

Figure 6.10 Bulkhead at a brownfield under remediation. (Source: DEC)

There are many possible structural configurations for bulkheads, but the most common are gravity walls, and cantilevered or anchored sheet-structures.

Gravity walls resist the lateral forces of the retained earth by their mass. Such structures are suitable where firm bearing strata are available close to the river bottom.

Cantilevered sheet pile structures resist lateral forces by deep embedment into the underlying soils. These structures are typically only economical to a height of about 20 feet above the bottom of the waterbody, depending on soil conditions.

Anchored sheet pile structures require less embedment into the bottom of the waterbody. The top portion of the wall is anchored by buried components located well inboard of the wall face and are tied to the wall with buried tie rods or cables.

How to design bulkheads to make a river access site more resilient to flooding and sea level rise:

- Key consideration: To be effective as flood protection, the bulkhead must extend above the flood level.
- The retained land may also be elevated above flood level; however, raising the land surface increases the lateral pressure on the wall, requiring a sturdier (and thus more expensive) bulkhead.
- The bulkhead can project up beyond the ground surface to act as a flood wall; however, this may cut off view corridors to water, and may be objectionable to some stakeholders on that basis. And, flood waters can still enter the site at the ends of the bulkhead.
- Ideally, the land should pitch toward the river's edge and allow storm water to exit the site via surface runoff.
    - In instances where hard engineered edges, such as bulkheads, may be elevated, water management via drainage structures becomes particularly crucial to avoid a "bathtub" effect, in which upland storm runoff or water from tidal flooding or wave overtopping becomes trapped behind a barrier, exacerbating damage to anything behind it.
- Bulkhead structures (typically sheet steel, concrete, wood or large stone) tend to reflect wave energy rather than dissipate it. This may result in erosion of the river bottom in front of the "fix." Where this is likely, rock scour protection should be placed at the toe to reduce the adverse effects of reflected wave energy. Whenever possible, replacement structures should be installed behind or on the same footprint as the existing structure, not by encroaching into the water. The existing structure and all fill in the intervening areas should be removed, and the exposed bed restored.

- Bulkheads typically produce a sterile, vertical, flat-faced surface which is of little use to aquatic organisms and other wildlife. It is the least ecologically friendly design and should be used only where necessary.

Rip Rap and Other Revetments

Revetments are sloped structures that armor the bank with concrete slabs, pavers, boulders, rip-rap, or other hard materials. They absorb the energy of incoming water and aid in reducing or halting erosion of a shoreline. The slope and spaces between rip-rap (i.e., permeability) of a rip-rap allows tidal and wave energy to be more easily attenuated. As with other hard engineering interventions, revetment should consider effects on erosion at adjacent sites and the effect on habitat. Rip rap stabilization designs should include appropriate bank slope and rock size to protect from wave, ice and current action and to prolong the life of the bank.

Key considerations include:

- A final slope ratio of at least 1:2 (vertical to horizontal) is recommended; a more stable 1:3 slope should be used where possible.
- A layer of gravel, small stone or bio-degradable filter cloth placed under and/or behind the rock helps prevent failure caused by loss of underlying soil material through the structure. It also prevents the release of sediment—which can be harmful to fish, their eggs and their food supply—into the water body.
- In many cases where wave and current energy are low, only the toe of the slope may need rock reinforcement and the remainder of the bank can be planted with native vegetation.
- The rock or other armoring material must be clean, free of silts and organic debris, exhibit resistance to freeze-thaw and chemical attack. Concrete slabs such as old sidewalks are not effective or attractive for revetments.
- Vegetation, especially deep-rooting species planted above and immediately behind the rock, will greatly increase the stability of the slope and provide additional habitat, food supply and hiding spaces for a greater variety of species.
- Revetments can be modified by a method called **joint planting,** which involves modification of a rip rap or rock covered slope by driving live stakes between the joints or spaces between the rip rap and rock. The live stakes take root and create a vegetated revetment.

Figure . A rip rap shore edge with vegetation, foreground, and without in Ossining. (Source: DEC)

Resilience Strategies for Ice Loads

The location and orientation of the shoreline protection site are key parameters when developing an ice-resilient strategy. A site located in calm waters, out of the main current, is typically less vulnerable to water-driven moving ice. A site exposed to a long fetch (distance along open water over which the wind blows) is more likely to experience ice stacking.

The strategies below are typical best practices and mirror the trade-offs between accommodating and protection, nature-based and hard engineered solutions described for flood resilience.

- Accommodate ice movement rather than trying to protect against a dynamic load. Use inclined structure faces and mild slopes to promote ice ramping. It promotes ice ramping over crushing and thus reduces horizontal forces.
    - A slope of 3:1 or even milder is common for natural shoreline protection.
- For nature-based protection, select vegetation that is adapted to local climate and develops a robust root network. Consider a rock toe protection for nature-based solutions. Always use shoreline and in-water material that can withstand cold temperatures and ice forces.
- Use water bubblers to keep ice from building up around in-water fixed piers and docks.
- For high-risk sites, hard-engineering methods (i.e., bulkhead, steel sheet pile, stone revetments) are required. The design of these structures includes stability analysis, including normal and extreme ice load scenarios.
- For in-water structures, use round piles instead of square piles. Round piles help reduce the load by promoting ice cracking and square corners are more easily damaged by ice. Use group of piles, instead of single piles, to divide ice loading.

Note that for shorelines, taking no action, followed by nature-based protection should always be considered before hard armoring (bulkhead, sheet piles, stone revetments). The Hudson River Sustainable Shorelines Project has several case studies of nature-based edge protection that have survived many winters successfully. Species of vegetation must be carefully selected based on their adaptive abilities, including developing a robust root network. Also, the time required for the vegetation to grow and be fully competed must be considered. In other words, a protection method that includes vegetation may not be fully resistant during the first years or following an extreme event (i.e. drought, freeze-thaw, erosive event).

Upland Strategies

Upland strategies described below are ways to live with water or re-direct water on site.

Floodable Land

Sites with large areas in the floodplain may be best served by an accommodating strategy that lets the River easily enter and exit the site. Moving water can be very strong and destructive, however, and areas where water will enter and exit the site may require design alterations to protect from scour. Floodplain plants have evolved to experience periodic flooding and may be a useful component of this strategy. Examples of floodable land are case studies for Long Dock Park and Esopus Meadows.

Elevating Land

Increasing the elevation of land by using fill is in contrast to accommodating buildings for flooding. Smaller, more urban river access sites may consider elevating land, either partially or entirely. Note that this may be limited to small critical elements of public access, such as an access road. A berm (discussed below) can be used to elevate features or structures or be built parallel to the shore to elevate the bank.

Elevating land by placing fill is a significant action and the costs and benefits should be carefully weighed including whether it is allowable. For example, fill placed in a special hazard flood area (SHFA) is considered development by FEMA and requires permits from a local floodplain administrator to ensure that flooding within the floodplain is not exacerbated. Fill is prohibited as a structural measure for buildings in V zones. Flood modeling may be required as part of the permit process. In places where this is contemplated and allowed, the river access site should be assessed to determine where the water is predicted to go, what infrastructure should stay, what priority areas need to be protected from flooding, and if any land on higher ground could be acquired for future public use.

Berms

A berm is an artificially raised ridge or bank intended to direct water flow and, in some instances, block raised water levels from the area behind the berm. They are not designed to withstand wave action or scour. Berms are featured in two of the case studies. In Chapter 7, at Kingston Point Park, a berm is being designed to stop tidal flooding from overtopping the access road hundreds of feet from the shore. At Long Dock Park, berms are used to direct and retain stormwater runoff to keep other areas dry.

Green Infrastructure for Stormwater Management

Stormwater management is the practice of capturing and conveying stormwater runoff from impermeable surfaces which typically produces high volumes of fast-moving water that can cause erosion, flooding, and pollution. Both “grey” infrastructure or stormwater “green” infrastructure can be used to manage stormwater. Constructed stormwater green infrastructure techniques mimic, accommodate or enhance the natural capture and infiltration of rainwater into the ground to reduce the risk of flooding and erosion. Infiltration allows water to soak into the ground rather than run off into low-lying areas or flow directly into waterbodies.

River access sites are ideal settings to use these techniques to manage stormwater from nearby roads, parking lots and buildings. Green infrastructure can be designed or “sized” to manage small or large storms, depending on soil characteristics, depth to groundwater and watershed area. Berms and swales are two techniques of constructed stormwater green infrastructure, sometimes used together to direct the flow of water as described above.

Key considerations & helpful resources:

- Understand site drainage: where and how water flows and pools.
- Understand soil characteristics. This is particularly important where the original site may have been constructed using fill which has now been found to be contaminated.
- Decide the size of rain event to design for, knowing that the probability of a rare event increases the longer the life span of the asset.

- Use a variety of techniques including rain gardens, swales, recharge basins and pervious pavement. Detailed specifications for all practices can be found in the NYS Stormwater Management Design Manual (NYS DEC 2015): http://www.dec.ny.gov/docs/water_pdf/swdm2015entire.pdf
- NYS DEC Hudson River Estuary Program Green Infrastructure Program: http://www.dec.ny.gov/lands/58930.html
- Environmental Facilities Corporation Green Innovation Grant program: www.efc.ny.gov

Building Protection Strategies

The strategies below focus on protecting buildings using permanent approaches. Under FEMA guidelines, flood-resistant construction standards require existing buildings located within the 1% annual chance floodplain that were substantially damaged, or are undertaking substantial improvements, to be raised above the Design Flood Elevation (DFE). DFE is determined by adding freeboard (additional height for safety depending on the use occupancy type) to the Base Flood Elevation (BFE) as determined by flood-resistant construction standards.

Typically, damage to a building, regardless of the cause, for which the total cost of repair is 50 percent or more of the building's market value before the disaster occurred, is considered "substantial damage." Similarly, any repair, reconstruction, addition, or improvement with a cost of 50 percent or more of the market value of the building is considered a "substantial improvement."

Dry Floodproofing

Dry floodproofing requires making a structure watertight by sealing exterior walls at a minimum to the design flood elevation (DFE) to prevent floodwaters from entering. [52] Making a structure watertight requires permanently sealing walls and windows with waterproof coatings, impermeable membranes, or a supplemental layer of masonry or concrete according to FEMA guidelines (see figure below).

Dry floodproofing modifications can also include temporary installation of flood walls, watertight shields over openings extending below DFE, interior drainage systems to collect any water leaks around sealants or shields, strengthening walls and installing backflow valves in sanitary and storm sewer lines. For structures with basements, walls and floors need to be specifically designed to resist hydrostatic pressure. However, FEMA guidelines underline the fact that dry floodproofing below grade spaces, such as cellars and basements, is challenging due to higher hydrostatic pressure and additional pressure from saturated soil during flood events.

National Flood Insurance Program (NFIP) standards require any new construction or substantially improved building to be elevated above DFE. Therefore, dry floodproofing may not be used to bring substantially damaged or substantially improved structures into compliance with a floodplain management ordinance or law. However, dry floodproofing is an important alternative to elevation. One of the benefits of dry-floodproofing ground floors, is that it allows active uses to be kept at grade, keeping public spaces inviting and accessible.

Dry floodproofing may include permanent, but moveable devices like flip-up barriers or flood gates that have fixed and mobile or removable elements.

[52] FEMA, Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems (1999), www.fema.gov/pdf/fima/pbuffd_appendix_b.pdf

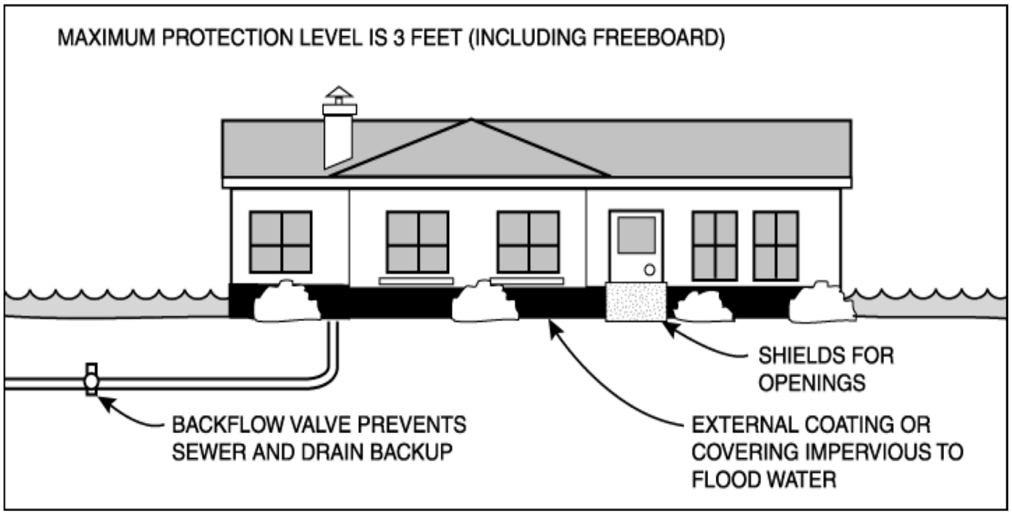


Figure 6.12 Dry Floodproofing Diagram (Source: FEMA 551/FEMA 312)

Wet floodproofing

Wet floodproofing measures are designed to minimize damage to a structure by allowing the passage of floodwater within parts of the structure that are located below the DFE. Unlike dry floodproofing, wet floodproofing is a strategy that works with nature as opposed to trying to fight it while also ensuring that the structure resists water loads. Damage to the overall structure is reduced due to balancing of hydrostatic pressure on both sides of the walls, floors, and supports (see figure below).

Wet floodproofing does not reduce flood insurance premium rates on residential structures unless, the habitable lowest level is not above the Base Flood Elevation. Non-residential structures can reduce flood insurance premium rates through other forms of floodproofing as mentioned above.

Spaces that are wet-floodproofed can only be used for parking, storage and building access or as crawl space to access the first occupiable floor. As such, residential buildings are not allowed to have below grade spaces, such as basements and cellars, and all mechanical and electrical equipment must be located above the DFE. Examples of wet flood proofing is shown in the case studies for Long Dock Park and Esopus Meadows Preserve.

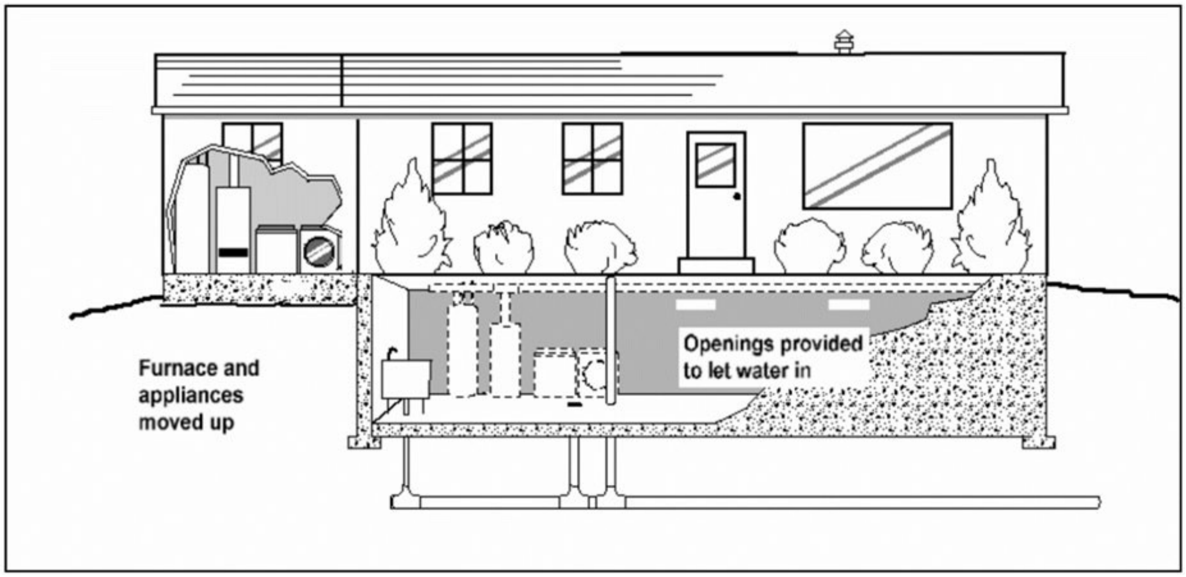


Figure 6.13 Wet Floodproofing Diagram (Source: FEMA 551)

Elevation

Elevation is the process of raising a building above flood levels, usually by putting it on stilts or by building a mound from fill and placing the building on the mound. Important equipment such as HVAC, pumps, electrical panels can also be elevated even if the building is not.

Anchoring

Without a stable foundation or a strong connection between the foundation and the building frame, elevated buildings can suffer damage from a flood event or storm surge due to lateral movement, uplift, debris impact, erosion, or settling.

NFIP regulations provide performance standards for anchoring new buildings and foundations in V Zones, defined by FEMA as "areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves." Particularly for wet-floodproofed buildings, proper anchoring of the building and accessory structures minimizes damage during flood events or storm surges.

An example of anchoring is described in the case studies for Long Dock Park and Esopus Meadows Preserve.

7. Case Studies

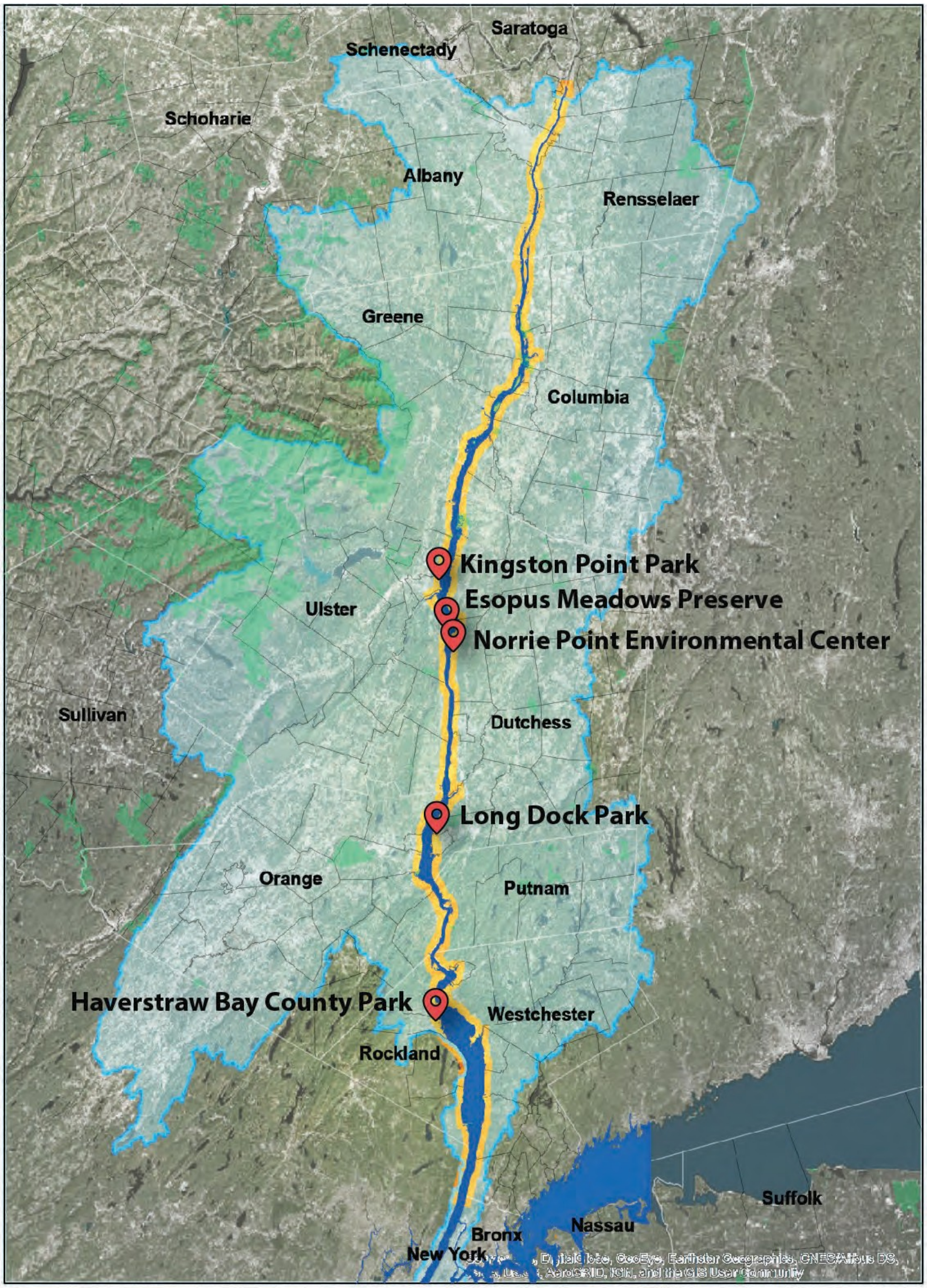


Figure 7.1 Map of The Hudson River Valley along with the location of case study sites. (Source: WSP)

7.1. Long Dock Park

Figure 7.2 **Long Dock Park features a wet floodproofed kayak shed. Note accumulation of wrack and woody debris on the shore** **(Source: WSP)**

Location: City of Beacon, Dutchess County

Chapter 5 Access Types: Wetlands; Beach for River Viewing; Hand Launch; Recreation Center and Other Buildings

Project Overview

Scenic Hudson's Long Dock Park project is a transformation of a derelict, post-industrial brownfield to a resilient riverfront park that embodies concepts of recovery, remediation, and re-purpose.

When Superstorm Sandy hit in the fall of 2012, the park's valuable trees and vegetation died after being soaked in salty water. This project showcases various flood-adapted structures and nature-based solutions that offer stormwater and flood mitigation.

The project's redevelopment included remediation of contaminated soils, rehabilitation of degraded wetlands, new public access to the river, and restored ecological diversity to upland, wetland, and intertidal zones. The wetland restoration included plants that have tolerance to saltier conditions.

Having earned Sustainable Sites Initiative (SITES) certification[53], Long Dock Park continues to adjust and adapt to changing circumstances of ecology, culture, flooding, climate change, and sea level rise.

BROWNFIELD TRANSFORMED

Owner: Scenic Hudson

Site Manager: Scenic Hudson

Cost: $16 M

Project Timeframe: 10 years; 3 phases

Project Funding Source: Public Private Partnership

Resilience Strategies:
Wet Flood Proofing
Restored and Constructed Wetlands
Ice Dynamics

[53] www.sustainablesites.org/ and www.scenichudson.org/wp-content/uploads/legacy/parktour-longdock.pdf

Site Description

The 19-acre Long Dock Park site features a floodable kayak storage structure, a pavilion, boat launch, beach, river overlook deck, a restored 19th century barn for meeting and educational opportunities (Scenic Hudson's River Center), a major art installation demonstrating the river's tidal action, and trails with educational signage that lead through rehabilitated wetlands and meadows. Arcing pathways and graded landforms not only frame views of the mountains and the Hudson River, but also function to capture, retain, treat, and release storm runoff and surge inundation. All access across the site is ADA compliant.

Project Challenges

- **Legacy Uses:** The peninsula was made artificially from fill and construction debris. Industrial uses, including as a junkyard, contaminated the soil. Vegetation was mostly invasive.
- **Erosion:** The site experienced significant erosion due its vulnerable position projecting 1,000 feet out into the river, exacerbated by sea level rise.
- **Storm surge:** storm events like Superstorm Sandy and Hurricane Irene had flooded the site and damaged infrastructure, reduced accessibility, and impacted shoreline structures.
- **Ice damage:** winter ice floes can be particularly destructive at the site.

Planning and Design

Long Dock Park has taken decades to plan, remediate, design, and build. The initial phase of the project included a boardwalk, arts and environmental education center, historic red barn and a pavilion for kayak storage and rentals. In 2011, while construction was in progress flooding from Hurricane Irene flooded the entire site for several days.

The storm event forced a reorganization of the degraded wetlands to optimize ecological function. The landscape architects on the project transformed the flat landscape of the site into a series of berms and reconfigured marshes that hold and filter stormwater and tidal surges in storms events. Due to porous soil types, extensive earthwork was performed. Discarded concrete slabs found on site were redeployed as paving for parking and a plaza near the new kayak pavilion.

Vertical wall shoreline stabilization was employed for repair and maintenance of existing vertical walls along the water's edge. This is an example of a site manager working within the conditions present at the site and is unique in that a park would not typically be able to obtain vertical sheet piling without good justification. Even then DEC may recommend the shoreline be sloped instead of repairing vertical walls or bulkheads.

In the next phase, the established meadow, the trails network and boardwalks, wetlands with swales and the dynamic intertidal zone was completed. The two distinct wetland areas surrounded by marsh grasses and wet meadow plants are designed to have a connection to equalize the water level.

As the park continues to adjust and adapt to a changing climate, the park received Sustainable-SITES certification for its integration of hydrology, and the establishment of native plant communities and social sustainability features.

Figure 7.3 Scenic Hudson constructed bio swales and berms to direct and capture stormwater, left. (Source: WSP)

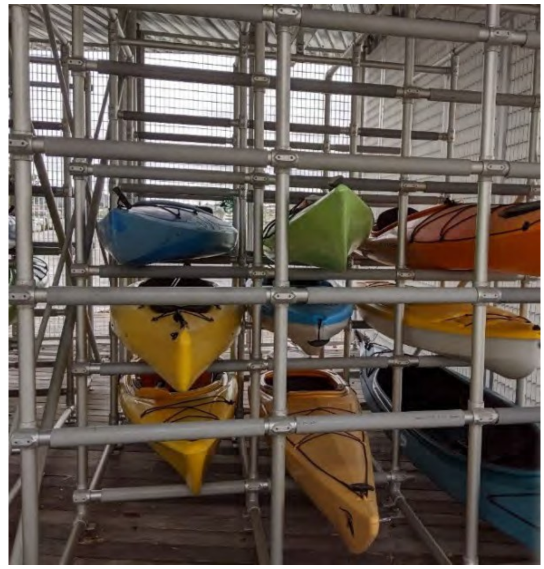


Figure 7.4 Kayak storage facility allowing water to pass through, securing the kayaks and protecting them from larger debris, right. (Source: WSP)

Resilient Design Approach	Resilient Planning Approach
Wet Flood Proofing: To create the new kayak pavilion close to the water edge, the structure is essentially a cage – allowing water to pass through, securing the kayaks and protecting them from larger debris.	**Long term Vision and Community Engagement:** The project planning process engaged the Beacon community through a series of meetings and workshops to articulate its vision for sea level rise and ice and flood resiliency on the transformed riverfront.
Restored and Constructed Wetlands: Plants with higher tolerance to salt water were chosen and different tidal zones were interconnected to balance the water level between them.	**Assess Permitting and Land Use Regulations:** A former oil storage depot and junkyard, the brownfield required extensive clean-up, receiving a final EIS through the SEQR process. The project team worked with U.S. Army Corps of Engineers to remove invasive species and rehabilitate two tidally influenced wetlands that had developed on fill and construction debris. The created wetland was combined with educational opportunities.
Ice Dynamics: The new beach allows for ice ramping, reducing the load from ice stacking.	

Benefits and Lessons Learned

- Native wetland plants thrive on nutrients from run-off and protect water quality by removing the pollutants through phytoremediation.
- Facilities built with water resilient materials and designed to allow water to pass through (i.e. “wet” floodproofing) are typically less expensive than protection measures that keep water out (i.e. “dry” flood proofing).

7.2. Haverstraw Bay County Park

Figure 7.5 Haverstraw Bay County Park. From left to right, a new accessible bridge, rip rap with joint planting, bulkhead, boat and accessible kayak launch (Source: DEC)

Location: Village of West Haverstraw, Rockland County

Chapter 5 River Access Types: Picnic Site, Walkway and Greenway Trail, Boat Launch, Fishing Access, Playground

Project Overview

When Superstorm Sandy flooded the entire park in 2012 – including the sandbag-lined park office building 100 feet from the river – large amounts of debris littered the park and plants were torn from the ground. The pedestrian bridge that was built to cross the southern embayment was destroyed due to wave impact and a steel cap of the bulkhead was lifted off.

In the aftermath of Sandy, the damaged park shoreline was redesigned and engineered to have a wide buffer zone of native vegetation between the mowed park lawn and pebble beach at the water's edge. The new design reduced repair costs and ongoing maintenance needs, providing significant cost savings for the county park. The sustainable shoreline[54] includes use of native vegetation (e.g. false indigo bush), driftwood, and a gradual slope to protect and enhance shoreline habitat, provide erosion control, accommodate public access to the water, and allow for recreational activities. The new pedestrian bridge is designed to detach (deck from beams) to minimize structural damage in severe storm events.

REDUCE COSTS WITH RESILIENCY

Owner: County of Rockland

Site Manager: Allan Beers, Coordinator, and Mike DiMola, County Park Operations Manager, Rockland County Division of Environmental Resources

Project Timeframe: 2 years

Resilience Strategies:
Slope Regrading
Sacrificial Elements
Operations & Maintenance

[54] https://www.hrnerr.org/wp-content/uploads/sites/9/2018/09/Haverstraw-Bay-Park-Case-Study.pdf

Site Description

The 27-acre park is home to a variety of water-based activities, passive recreational opportunities, and tranquil memorials, including the Rockland County September 11th Memorial. The site includes picnic facilities, an open-air pavilion, large playground, walking trails, Parks office, fishing piers, freshwater pond, and a protected area to launch boats at a double-lane concrete trailered boat launch and canoe/kayak hand launch. All facilities on the site are ADA accessible.

Project Challenges

- **Increased erosion:** shoreline erosion due to wave action and extreme storms.
- **Storm surge:** protecting park infrastructure, accessibility, and shoreline structures from storm events.
- **Debris displacement:** storm surge, winds, and flooding inundated areas and shifted sediment.
- **Funding:** securing matching funds for grant applications. Misalignment between park budget cycle and grant application process was also a challenge.
- **Permitting:** changing needs for permitting process resulted in project delays. A change in the bridge design increased square footage of the deck and altered the shadows cast on the river below, triggering additional fish and wildlife studies and permitting requirements.


Figures 7.6 and 7.7 Pedestrian bridge in 2010, left, and after Superstorm Sandy 2012, right (Source: Rockland County)

Planning and Design

Routine maintenance of the manicured lawn and planting beds were becoming an operations and staffing issue by the time that Superstorm Sandy damaged the park in 2012. Learning that the section of shoreline without rip-rap fared better than other areas after Sandy, the County ended its practice of cutting back plants along the shoreline. After receiving funding from Sandy relief funds and FEMA to restore the shoreline and damaged pedestrian bridge, a separate application for DEC Hudson River Estuary Program grant funding was submitted for the construction of an accessible kayak and canoe launch.

Figure 7.8 The site contains sections of natural, nature-based, and structural edges. (Source: DEC)

Figure 7.9 New ADA-accessible bridge features decking designed to break away, keeping the metal bridge structure in place (Source: DEC)

Resilient Design Approaches	Resilient Planning Approaches
Slope Regrading: Undercut banks were regraded, and native plants were added instead of replacing lost rip-rap. Scouring has developed a natural slope along the river's edge. Undercut banks caused by erosion were regraded to smooth the slope between the upland and low land elevations using clean fill, compost, and sand mixture.	**Permitting and Land Use Regulations:** worked with local public agencies to understand the permitting process and requirements in advance of and during the preliminary design phase.
Greening a rip-rap revetment Vegetation that self-seeded such as false indigo can grow between the rip rap. It is trimmed to allow vistas.	**Operation and Maintenance:** changed policy for cleaning the shoreline. All wrack and driftwood are left on the shore and vegetation allowed to grow naturally. This reduces maintenance costs.
Sacrificial Elements Designing the bridge decking to break away reduces pressure on the beams and helps protect it.	**Interactive Design and Community Engagement:** Desired trails to the water were created by people before they were formalized.

Benefits and Lessons Learned

- Natural beach and vegetated areas can withstand large storm events in some areas.
- Buffer zones of native plants, wrack (decaying vegetation washed in by the water), and woody debris are ecologically valuable, providing both habitat and erosion protection. Maintenance costs can be reduced, and habitat value increased if accumulated wrack is not removed.
- Repair costs to docks can be minimized by moving docks out of the water to high elevation areas before a storm.

7.3. Esopus Meadows Preserve

Figure 7.10 Esopus Meadows Preserve: flood-proof pavilion and natural shoreline, March 2020. (Source: WSP).

DESIGN FOR FUTURE FLOOD

Owner: Scenic Hudson Land Trust, Inc.

Site Manager: Scenic Hudson

Resilience Strategies:
Building/System Elevation
Wet Floodproofing
Education & Communication
Floodplain Reconnection

Location: Hamlet of Ulster Park, Ulster County

Chapter 5 River Access Types: Nature Preserves and Wetlands, Walkways and Greenway Trails

Project Overview

Esopus Meadows Preserve includes a flood-proof educational pavilion, interpretive signage, hiking trails and a designated Greenway water trail site with nature-based shoreline stabilization techniques.

Prior to Hurricane Irene, Tropical Storm Lee and Superstorm Sandy, there was a house located at the entrance to the Preserve which served as an education center run by Hudson River Sloop Clearwater. This house was damaged beyond repair during Superstorm Sandy.

Site Description

The 96-acre preserve is home to one of the largest tidal flats in the Hudson River Estuary and is easily accessed from the ADA-compliant parking area. There are two miles of woodland trails. The Greenway water trail site can be accessed by these trails or by water by paddling craft. The site is widely used for bird watching, fishing, environmental education, kayaking, hiking, and public gatherings. The site combines beauty and resiliency, designed through community visioning sessions and workshops. The site floods and recovers approximately 6-8 times per year, thus reduced maintenance costs were a key driver for this site's resiliency measures. A description of the shoreline stabilization completed in 2006 at the Greenway water trail site can be found at: www.hrnerr.org/wp-content/uploads/sites/9/2018/11/Esopus-Final-11-19-18.pdf

Project Challenges

- **Flood Damage:** existing facilities experienced irreparable damage in previous storms.
- **Maintenance:** regular nuisance flooding left debris on the site.
- **Storm surge:** storm surge and high-water levels inundated the peninsula regularly.
- **Debris displacement:** storm surge, winds, and flooding caused debris to collect at an upstream culvert and along the river's edge.

Planning and Design

Scenic Hudson and their consultants worked to assess site conditions, including future sea level rise scenarios and soil conditions relevant to the need for a well-anchored foundation for the newly constructed educational pavilion at the site.

The pavilion and storage facilities were elevated with freeboard above the base flood elevation. The facilities are designed to ADA standards.

The pavilion was designed with rust-proof corten steel to reduce maintenance and limit the possibility of corrosion. The open design of the pavilion utilizes a wet floodproofing strategy to allow waters and moderately sized debris to pass through easily and wash out, reducing staff and volunteer time for clean-up.

Resilient Design Approach	Resilient Planning Approach
Building or System Elevation: The pavilion was elevated above the 100-year floodplain.	**Stakeholder Engagement:** Conducted workshops with local community and Scenic Hudson members. Held public meetings at very early stage of project development.
Climate-Adapted Infrastructure: For the pavilion and storage structure, weathering steel was selected to reduce maintenance costs. Material resilience and life span were key considerations in the design.	**Historic Data and Site Analysis:** Historic data, maps, aerial imagery were used to understand the evolution of the changing shoreline.
Wet Floodproofing: Infrastructure was designed to withstand flooding and accommodate it. The pavilion foundation was tested by geotechnical engineers to withstand hydrostatic pressure from storm surge and flooding.	**Climate Risk Assessment:** To address storm surge challenges, the pavilion, and storage facility were designed for the 100-year flood.

Resilient Design Approach	Resilient Planning Approach
Green Edge Strategies: Variety of vegetation was chosen to ensure survivability and to decrease the chance of a complete die-off due to natural forces, disease, or predation from local species such as muskrats and beavers.	**Resiliency Education & Communications:** Signage and flood level height diagrams are installed on site to educate visitors about adaptive infrastructure and sea level rise.
Floodplain Reconnection: A culvert upstream of the site was resized for a 500-year flood event.	

Benefits and Lessons Learned

- Creating a list of assets and identifying which are "floodable" versus needing flood protection assists site managers in developing operational protocols for storm preparedness. Assets that can't get wet (e.g. generators) would be placed in floodproof compartments ahead of time to minimize the risk of damage.
- Scheduling a pre-application meeting with permit agencies before and during project implementation is recommended to understand sea level rise risks and collaboratively plan for resiliency measures, requirements of activities, use, and impacts along the larger shoreline.
- Implementing maintenance measures is cost-effective compared with repairs from flood damage.
- Prioritizing reduced maintenance cost, use of local materials, and longevity of materials and structures in the design can result in significant cost savings over the long run.

7.4. Preparations for Impending Storms at Norrie Point

Figure 7.11 Norrie Point Environmental Center at River Mile 75 east, looking north on the Hudson. (Source: DEC)

Location: Dutchess County

River Access Types: Pier, Recreation and Other Buildings, Wildlife viewing

Project Overview

To prepare and respond to the storm surge from Superstorm Sandy, the Norrie Point program staff took emergency operational measures by anchoring and elevating their key instrumentation and amenities like picnic tables and weather stations and weather proofing the environmental center by using plastic, plywood and sandbags.

The staff spent the day before landfall preparing and implementing resilient measures to prevent damage from floating or wind driven debris. Although Sandy flooded the site over eight feet above sea level, the emergency management measures taken helped to reduce the damage impact.

Site Description

Norrie Point Environmental Center is the headquarters of the DEC Hudson River National Estuarine Research Reserve. The center is owned by NYS Parks and is in the Mills-Norrie State Park. The patio with picnic tables is a popular river access site for viewing scenery and wildlife and for fishing. The Environmental Center has conference and classroom space, interpretive exhibits (including numerous fish tanks), a research lab, and a weather station and water quality monitoring instrumentation.

DESIGN FOR FUTURE FLOOD

Owner:
New York State Parks Recreation & Historic Preservation

Site Manager:
Kristina Schoepher
(845) 889-3881
millsnorrie@parks.ny.gov

Design: N/A
Cost: N/A
Project Timeframe:
Immediate response

Project Funding Source:
N/A

Resilience Strategies:
Systems Elevation
Dry Floodproofing
Anchoring
Operational Planning and Policies
Emergency Planning and Communications

Project Challenges

- **Storm surge:** protecting park infrastructure immediately before Superstorm Sandy.
- **Debris displacement:** storm surge flooding and winds bring debris on to the site that can cause damage and requires clean-up.

Planning and Design

Storm surge was predicted for Superstorm Sandy. The program Staff moved the weather station instrumentation box on the patio up nearly 18 inches (one rung on the tower) and instrumentation for water monitoring on the dolphin was also raised to protect it from storm surge.

Before the Hurricane, staff spent the day preparing the site for flooding and took measures to protects its infrastructure. A number of resilient actions were taken including:

- The south side entry from the patio was barricaded with plywood to prevent damage from floating or wind-driven debris, Figure 7.12.
- All doors were covered with plastic and sandbags were placed at the base. Floor to ceiling windows at the east side entrance were also covered with plywood.
- Wooden picnic tables on the patio were tied to metal railings.
- DEC vehicles in the parking lot were moved to the hamlet of Staatsburg at Taconic Park headquarters building.

After the storm, the floating docks for the Norrie Point marina, which had been removed for the season and stacked as usual on the edge of the parking lot, Figure 7.13, were strewn around the parking area and lawn. The picnic tables on the patio held fast to where they were tied. Vehicles at Taconic Headquarters, moved from the tidal Hudson parking area, were flooded by a small upland stream which had become dammed with debris.

Figure 7.12 Barricaded entry and picnic tables tied to railing. Arrow indicates maximum water level. (Source: OPRHP)

Figure 7.13 Floating docks for marina stored for season in parking lot, floated by flood because they were not anchored. (Source: OPRHP)

Figure 7.14 Weather station at corner of patio. White instrumentation box was moved up one rung on tower the day before surge. Arrow indicates benchmark and approximate high water. (Source: DEC, HRNERR)

Figure 7.15 Flooded patio and fixed pier soon after Sandy surge. (Source: OPRHP)

Resilient Design Approach	Resilient Planning Approach
Elevating and Dry Floodproofing: The weather station continued to operate during the storm, the instrumentation box had been raised sufficiently to be above the water height.	**Operational Planning and Policies:** A checklist of actions should be taken for other storms and reviewed annually.
Anchoring: The picnic tables on the patio held fast to where they were tied.	**Emergency Planning and Communications:** Use real time data sources and alert systems to understand level of preparation and to communicate risk to staff. (http://hudson.dl.stevens-tech.edu/sfas/; hrecos.org and https://maps.waterdata.usgs.gov/mapper/wateralert/

Benefits and Lessons Learned:

- Tie-down and secure objects capable of floating, such as picnic tables, kayaks and floating docks.
- Protect windows and doors with plastic sheeting, sand bags and plywood to protect from wind and water borne debris and water entering the facility area. Adopt dry/wet flood proofing techniques.

- Return to the flooding location as soon as safe after storm surge to assess damage and begin clean-up.
- Raise important instrumentation above flood risk level.
- Create a check list of actions that should be taken for other storms and review them annually.

7.5. **Kingston Point Park**

Figure 7.16 Kingston Point Park Beach. (Source: DEC)

Location: City of Kingston, Ulster County

River Access Types: Beach, Esplanades, Trails, Playground

Project Overview

Kingston Point Park is vulnerable to flooding from the Rondout Creek and storm surge and sea-level rise on the Hudson River. In 2012, Superstorm Sandy flooded the entire park, including the parking lot and storage facility more than 50 feet from the river. A large amount of debris littered the beach and all the facilities were flooded up to two feet.

Since 2016, the City has been working with Cornell University students through the Climate-Adaptive Design (CAD) project, community members, and other stakeholders to protect the diversity of site uses from flooding associated with rising sea levels and more extreme weather events. The City is taking a multi-phased approach by creating a wetland and vegetated berm to reduce flooding impacts in the parking lot and soccer field from Rondout Creek and storm surge. In addition, the city plans to elevate the parking lot and Delaware Avenue access road. Existing park infrastructure at the beach has been elevated by two feet and dry floodproofed for a 100-year flood.

ACCOMODATING THE FLOOD

Owner: City of Kingston

Site Manager: Kingston Parks and Recreation Department

Cost: $1.3 M

Project Timeframe: 3 years

Project Funding Source: Environmental Protection Fund

Resilience Strategies:
Dry Floodproofing
Constructed Wetlands
Berms
Strategic Relocation
Operational Planning & Policies
Emergency Planning & Communications

Site Description

Kingston Point has over 87 acres of open space and is a complex site with a mix of upland habitat, infrastructure, wetlands, and a private oil terminal. The site offers activities like swimming, fishing from the shoreline, kayaking and recreational boating, kite flying, bird watching, parties and events, volleyball, BMX, and hiking. The site has many areas for picnicking, several pavilions, sports fields, and a dog park. The site has an ADA accessible mat for accessing the beach and water by wheelchair during the summer swimming season, newly built ADA ramps for the elevated bathroom and accessible changing stalls.

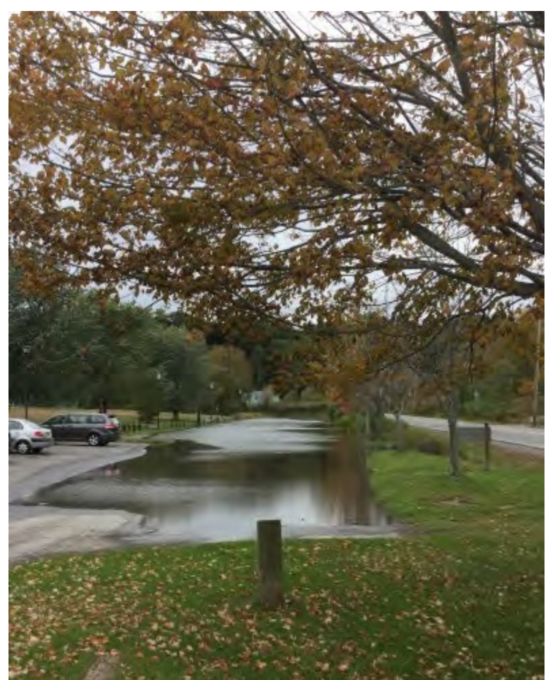
Project Challenges

- **Wave action and debris displacement:** Waves – including those from the wakes of barges, storm surge, and winds – bring debris onto the beach that requires routine cleanup and maintenance.
- **Storm surge and tides:** Protecting park infrastructure, accessibility, and shoreline structures from storm events like Superstorm Sandy and high waves are important for maintaining public access to the park. The parking lot is frequently inundated, often rendering half the spaces inaccessible. The tide change variability is high, approximately 4 feet, which can cause the lifeguard stand to be halfway under water during high tide.
- **Funding:** Securing matching funds for grant application and estimating the repair/maintenance costs.

Planning and Design

Superstorm Sandy struck Kingston Point Park with hurricane force winds and heavy precipitation. The storm surge flooded the entire park site including the beach area, pavilion, parking lot, and access road to the park.

In partnership with the Kingston Waterfront Flooding Taskforce, Hudson River Estuary Program, Weaving the Waterfront partnership, and Cornell University, the City of Kinston has been investigating resilient planning and design strategies for the Kingston Point Park area. The projects employed the climate-adaptive design framework approach to understand projected climate change impacts, risks, and potential climate adaptation opportunities. After analyzing the site-wide flood risk, the design team proposed different measures to protect the park site from sea level rise, wave action, and flooding from the Rondout Creek and storm water.



Figures 7.17 Frequently flooded parking lot that is being designed to transition to a wetland. (Source: DEC)

On the beach site, site infrastructure such as the storage facility/garage and bathroom stalls were elevated, and flood gates were installed in attempt to dry flood poof the facilities. The vegetated berm adjacent to Delaware Avenue and wetland construction on a portion of the parking lot are still in

Figure 7.18 The bottom several feet of a utility shed were replaced with concrete cinder blocks which will not get damaged in a flood and utilities were raised above flood level. (Source: DEC)

the early visioning phase, thus the City of Kingston is working with permitting agencies for wetland regulations and road elevation. In the past, Kingston has not faced many issues with permitting and notes that resilience projects are infrastructure improvements, thus the permitting process is similar. It must be noted however that Kingston Point does not have permits yet, at the time of this handbook's publication.

Site managers recommend setting up pre-application meetings and an open channel of communication with DEC for permitting projects.

The City also has a program in place to monitor recovery from storms and track the vitality of submerged aquatic vegetation (SAV).

Resilient Design Approach	Resilient Planning Approach
Elevating Land and Dry Floodproofing: Site infrastructure such as storage facility/garage, stalls and bathroom were elevated by two feet to protect from sea level rise and flood proof gates were installed.	**Operational Planning and Policies:** The Department of Parks and Recreation and the City maintain a separate budget for site recovery, clean ups, log removals, and sand displacement. The City plans to line up separate funding for the park/beach to explore real-time data of its services.
Constructed Wetland and Berm: The parking lot is currently subsiding and increasingly impacted by flooding. The City plans to design a vegetated berm south of Delaware Ave and transform a portion of the parking lot to a wetland to accommodate the flooding.	**Emergency Planning and Communications:** Kayaks are removed from the shed and access to the park is closed during storm events. The Fire Department, and Parks and Recreation help to provide a warning/alert system to prepare for storms.
Vision for the Future: Site managers are envisioning how the park will look with flooding in 20 years and beyond and are designing to that potential future – for example, designers are considering where potential future bridges could be located to preserve connectivity across the site.	**Strategic Relocation and Development Strategies:** The project looked at site-wide, neighborhood-scale, and regional-scale strategies being incorporated along Kingston's shoreline and integrated its design concepts into its 2050 vision plan. The design strategies were selected that would complement regionwide resiliency.
	Stakeholder Engagement and Partnership: The City partnered with Cornell University for the development of a CAD framework, environmental education and sustainability initiatives. Numerous open houses, meetings and webinars were held to gather community input.

Benefits and Lessons Learned

- Site managers should think about how their site will be used and function in the long term and how it will complement other projects along the shoreline.
- A pre-application meeting with permitting agencies is recommended to understand sea level rise risks and collaboratively plan for resiliency measures, requirements of activities, use, and impacts along the larger shoreline.
- While doing sea level rise and wave action assessment, impacts from large wakes must be considered as they can cause damage over a period of time.
- Sea level rise impact, wave action, and wakes should be studied and their impact incorporated into the design for the entire shoreline and not just for a specific segment of the site.

7.6. Hypothetical Site

Figure 7.19 Hypothetical Site Rendering: Before or existing condition. (Source: WSP)

Location: Hudson River Waterfront

River Access Types: Pier, Boat Launch, Boardwalk and Natural Trail, Picnic site, Wetlands

Hypothetical Site Overview

This case study is designed to show how stakeholders and site managers could assess the risk of flooding, sea level rise and climate change for a hypothetical Hudson River waterfront access site and how this handbook can be used. This hypothetical site features the most common challenges we found from discussions with the managers of the case study sites and participants in stakeholder meetings.

This hypothetical site highlights the process of estimating risk and implementing resilient design and planning solutions. It is formatted to match the style of the previous case studies.

Site Description

The hypothetical site includes picnic facilities, an open-air pavilion, a large playground, walking trails, parks office, fishing piers, marina and a boat launch. Not all facilities on the site are ADA accessible.

RESILIENT DESIGN

Resilience Strategies:
Equipment Mobility
Slope Regrading
Dry Floodproofing
Facility Elevation
Restored/Reconstructed Wetlands

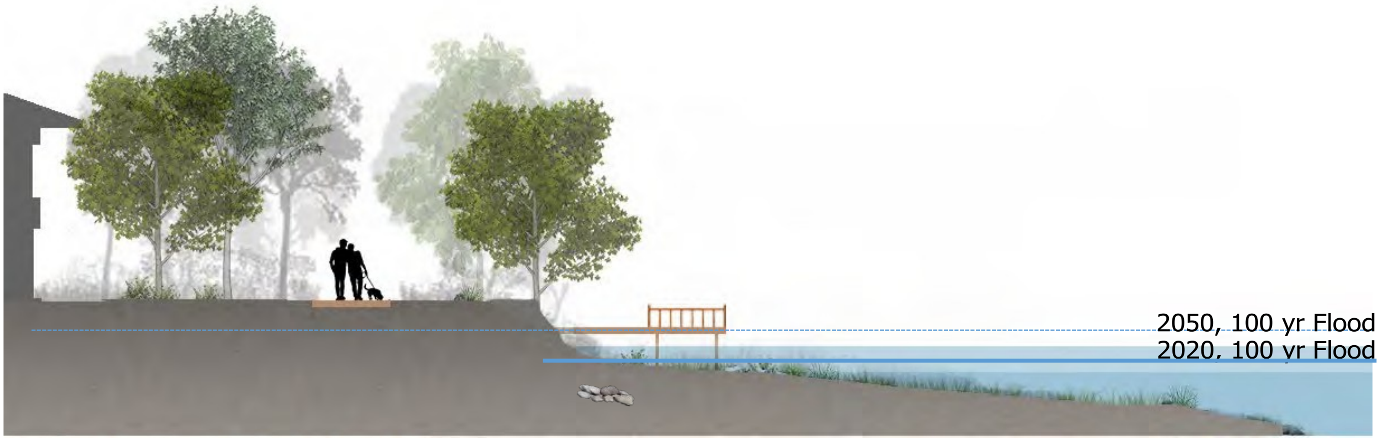


Figure 7.20 Hypothetical Site Sectional Rendering: Before or existing condition, Section A-A. (Source: WSP)

Project Challenges

- **Increased erosion:** There is shoreline erosion occurring due to wave action and sea-level rise
- **Storm Surge:** There is a need to protect park infrastructure, accessibility, and shoreline structures from storm-induced flooding.
- **Debris displacement:** Even small flood events leave sediment and wrack. Large driftwood and trash have floated in during large storms and moved around equipment.
- **Funding:** Aligning the municipal park budget cycle with grant application processes, and securing matching funds are a continuing challenge.

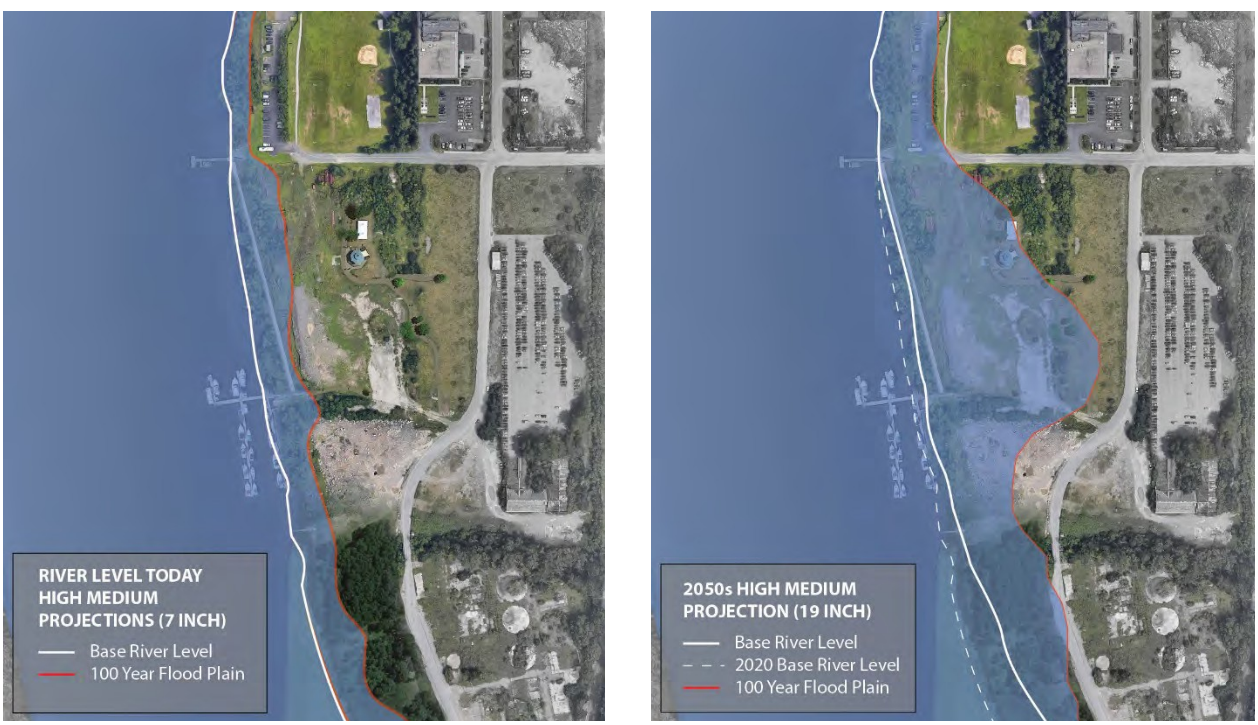


Figure 7.21 Hypothetical Site Flood Projections: 2020 and 2050. (Source: WSP)

Planning and Design Process

The following are the unique steps and processes considered for planning and designing sites along the waterfront and in the floodplain.

1. **Developed a problem statement and initial concept** – The project team worked with stakeholders to identify resiliency needs and understand how it affects the desired public uses. The clear project vision and goals identified were to develop resilient docks and marina, to restore wetlands and to control erosion.
2. **Gathered baseline information about the site, including its history of flooding and damage** – The engineering team conducted a climate risk assessment and used existing sea level rise projections to estimate the extent of flood, and thus defined the areas of intervention. The results from site inspections and the sea level rise study helped to shape project phasing, determining any needed interim or emergency repairs.
3. **Engagement with community** – Through the community engagement workshop, the project team gathered additional information on the existing site conditions, potential future usage and established project champions/local leadership. Also, it was identified that protecting shoreline from erosion and hardening the boat launch was the most critical for the community. The level of risk acceptable to site managers and community was determined.
4. **Assessed site-specific hazards, asset criticality, vulnerability, risks & opportunities** - A comprehensive list of all assets on the site were listed and their exposure to risk, hazards and vulnerability from ice, floods, increasingly intense rainfall, and sea- level rise was estimated. The vulnerable assets were prioritized. A gazebo at risk in 2050 was deemed more appropriate to address in future planning.
5. **Evaluated costs benefits and alternatives** – Different design alternatives and the cost of each alternative was considered, including doing nothing. The project team decided to invest in hardening the boat launch, extending the area available for wetlands, and using a joint planted revetment on a portion of the site's shoreline. The marina was reoriented and a new piling clustering sequence was designed to withstand ice loading.
6. **Identified funding sources:** Several funding sources available for Hudson River access sites to design and/or implement resiliency upgrades were explored using New York State Grant Opportunities. The team held discussions with the granting agencies prior to submitting applications.
7. **Planning and Design Approaches**: The project team requested and met with local and State permitting staff for a pre-application jurisdictional review meeting to confirm what permits may apply and to rule out any strategies that may not be appropriate for the site's conditions.

Resilient Design Approaches	Design Implementation
Equipment mobility	Equipment to support the marina is pre-placed on a trailer bed to allow for easy movement.
Nature–based shoreline erosion protection.	A section of the shoreline edge is designed to have a nature-based green infrastructure solution for addressing shoreline erosion. The living shoreline also provides a cost-effective technique for coastal management while restoring wildlife habitat.

Resilient Design Approaches	Design Implementation
Banks, Beaches and Slope Regrading	The slope is regraded to have vegetation to improve slope stability. The tidal marsh protects the shoreline from wave action, slows runoff, and acts as a filter to catch sediment.
Joint Planted Revetments	A combination of rock and plants are used to stabilize the shoreline. This technique is used in areas of transition from living shoreline to concrete docks.
Dry Floodproofing	A small building shown in the section below is dry floodproofed taking into account sea level rise and freeboard above the BFE
Anchoring	The fishing pier is anchored to have additional strength for strong wave action or hurricane events
Restored and Reconstructed Wetlands	Non-native tree species are removed, and wetlands are replanted. Site modeling indicates that the extent of future sunny day flooding of the adjacent access road may be reduced.
Facility Elevation/Ice Dynamics	The marina is rebuilt slightly closer into the shore, and floating docks are placed on higher piers. The marina is reoriented, and a new piling clustering sequence is designed to withstand ice loading.

Proposed Design Solutions

Figure 7.22 Hypothetical Site Plan Rendering: Proposed condition. (Source: WSP)

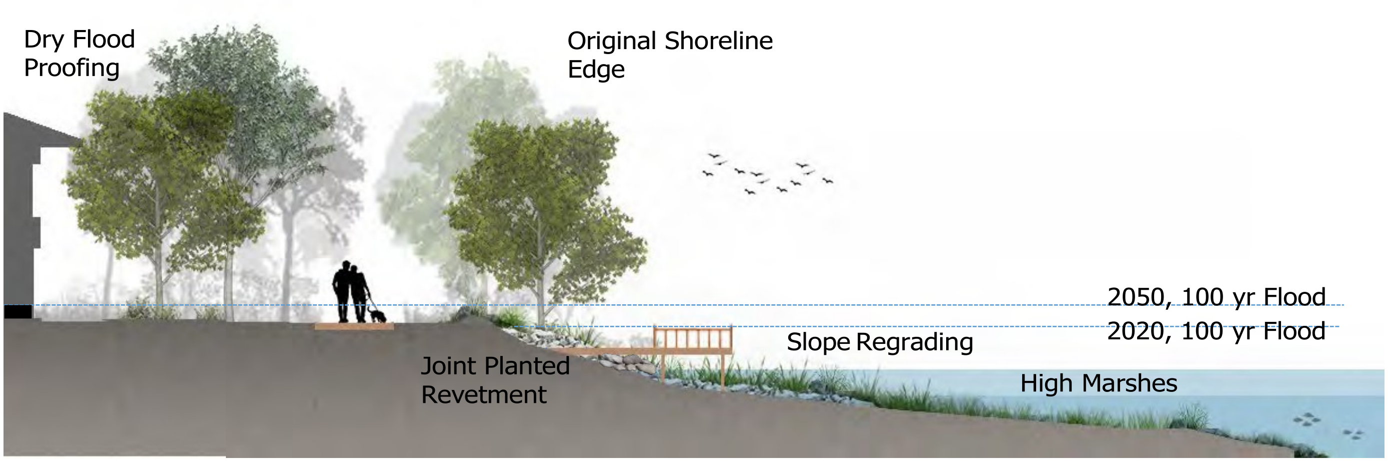


Figure 7.23 Hypothetical Site Sectional Rendering: Proposed condition, Section B-B. (Source: WSP)

Glossary[55]

Accretion/Aggradation
The increase or extension of land, including beach, wetlands, and sub-tidal areas by accumulation of waterborne sediment, particularly at a greater rate than erosion/degradation.

Adaptation
Adjusting to expected climate change and its physical, social or economic effects to mitigate harm or exploit beneficial opportunities.

Americans with Disabilities Act (ADA)
Federal Legislation passed in 1990 that prohibits discrimination against people with disabilities in all areas of public life. Under the Act, amended in 2008, discrimination against a disabled person is illegal in employment, access to government services, public accommodations and in commercial facilities, telecommunications, and other areas. The 2010 Standards provide the current guidelines.

Backflow Prevention Device
A mechanism or valve used to prevent water in drainage pipes from flowing up against gravity. Used to prevent high water levels from tides or storm surge flowing back up pipes.

Base Flood Elevation (BFE)
The computed elevation to which floodwater is anticipated to rise during a 100-year storm. BFEs are shown on FEMA Flood Insurance Rate Maps (FIRMs) and on the flood profiles. The BFE is the regulatory requirement for the elevation or flood-proofing of structures.

Bathymetry
The shape of the underwater land, usually represented on a map. Bathymetric maps show depths of landforms below sea level. (See Topography)

Bioretention areas
“Bio” or living/landscape features adapted to “retain” or store stormwater runoff. Surface runoff is directed into shallow, landscaped depressions that are designed to mimic natural processes. During storms, runoff infiltrates the soil and is stored in the system. The remaining runoff ponds above soil in the system. Runoff from larger storms is generally diverted past the facility to the storm drain system.

Biotechnical erosion control
The use of plants, plant materials, and engineered structures that use plant materials for protecting against water pollution, soil loss, wildlife habitat loss, and human property loss.

Breakwater
An offshore barrier to protect a shoreline, coast, or harbor from the force of wave action.

[55] Definitions have been adapted from the Community Risk and Resiliency Act (CRRA) Natural Resilience Measures (NRM) document "Using Natural Resilience Measures to Reduce Risk of Flooding and Erosion in New York (unpublished, in review), the CRRA “New York State Flood Risk Management Guidance” (2018 draft), the US Department of Agriculture Natural Resources Conservation Service Glossary of Landform and Geologic Terms (Part 629 of the National Soil Survey Handbook), and elsewhere.

Bulkhead
An engineered shoreline protection technique comprising a shore-parallel structure completely separating water from land designed to dissipate the energy of larger waves and/or hold back floodwaters. It can be made of a variety of materials including rock, sheet pile steel, concrete and wood.

Climate change
Climate change refers to a significant change in the state of the climate that can be identified from changes in either the average state or variability of weather and that persists for an extended time period, usually decades, centuries, or longer. The typical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.

Climate hazard
A weather or climate state such as a flood, heat wave, high wind, heavy rain, drought, etc., that can cause harm to people and damage property, infrastructure, land, and ecosystems.

Cloudburst
An extraordinarily heavy rainfall event occurring over a relatively short period of time.

Combined sewer overflow (CSO)
The discharge of a mix of excess storm water and untreated wastewater into a waterbody (rivers, streams, estuaries, and coastal waters).

Constructed stormwater green infrastructure (CSGI) or Green Infrastructure (GI)
A hybrid engineered and nature-based approach to water management that protects, restores, or mimics the natural water cycle. Techniques mimic, accommodate or enhance the natural capture and infiltration of rainwater into the ground to reduce the risk of flooding and erosion to human assets in upland areas. Infiltration allows water to soak into the ground. These techniques rely on vegetation alone or combined with grading, fill or addition or removal of structural components.

Critical root zone
An area on the ground beneath a tree that corresponds with the dripline of that tree, sometimes called the tree protection zone. This zone is used in determining allowable disturbance to the area around an existing tree during construction. Since the dripline is very irregular, the trunk diameter is often referred to for calculating CRZ.

Erosion
The natural wearing away of land caused by wind, waves, currents, ice and rainwater over time.

Estuary
Tidal water bodies where salt water and freshwater meet. The Hudson River Estuary is a 150-mile estuary from the Troy dam south to New York Harbor, with average tides of 4 feet. It contains freshwater, brackish water and salt water, with the location and extent of salt and brackish water being influenced by the season and by rainfall in the watershed.

Fetch
The distance that wind travels across open water in one direction. A longer fetch increases wave formation and the possibility of ice build-up.

Flood Insurance Rate Maps (FIRMs)
Maps produced by the Federal Emergency Management Agency (FEMA) that identify Base Flood Elevations (BFEs). Preliminary Flood Insurance Rate Maps, or P-FIRMs may be used for planning purposes on an interim basis, where they exist.

Flood zone
Defined geographic areas with varying levels of flood risk that encompass different parts of the floodplain, determined with an analysis resulting in projections of varying levels of flood risk.

Floodplain
Any land area susceptible to being inundated by floodwaters from any source.

Floodproofing, Dry
Protecting a building by sealing its exterior walls to prevent the entry of flood waters.

Floodproofing, Wet
Protecting a building by allowing flood waters to enter so that internal and external hydrostatic pressures are equalized. Usually, only enclosed areas used for parking, storage, or building access are wet floodproofed.

Functional Ecosystem
Robust, self-sustaining biological communities composed of interacting organisms and their physical environments.

High-Water Level
Maximum water level that can be reached during winter when ice is present.

Hurricane
A tropical cyclone consisting of a rotating low-pressure system with winds exceeding 74 mph.

Hydrostatic load
The pressure that a fluid substance exerts.

Ice Floe
Piece of floating river ice.

Ice Jam
Accumulation of fractured river ice that cause an increase of the upstream water level.

Ice Load
Load on a structure induced by ice (static or dynamic).

Ice Ramping
Action of ice that goes upward over an inclined solid element.

Ice Regime
The general description of the ice conditions and behavior on a river.

Ice Run
The sudden movement of river ice, typically during break-up.

Ice Scour
Damage caused by river ice to erodible material.

Ice Stacking
Action of ice that accumulates on a structure or shoreline.

Integrated Flood Protection System (IFPS)
A set of distinct coastal protection measures composed of a variety of flood intervention strategies that are combined and customized to create a line of protection against flooding.

Intertidal zone
The waterfront land area between low and high tide marks that is exposed to air during low tide and is submerged during high tide. Also known as the littoral zone.

Inundation
The total water covering of normally dry ground with water. Inundation is expressed in terms of height of water, in feet, above ground level. Temporary inundation refers to short-lived conditions as a result of storm surge or land-side floods. Permanent inundation refers to ongoing conditions as a result of sea level rise.

Live stake
A stake or pole fashioned from a dormant cutting of a live woody plant used for soil, sediment, or revetment stabilization.

Living shoreline
A type of soft coastal edge that incorporates combinations of terrestrial and submerged aquatic vegetation, sand fill, stones, intertidal shellfish reefs, and other structural and organic materials.

Marine District
The marine and coastal district waters of New York state refers to all ocean waters that are within three nautical miles from the state's coastline, including the Atlantic Ocean, Long Island Sound and embayments, as well as the tidal Hudson River waters running south of the Mario M. Cuomo Bridge (formerly Tappan Zee Bridge).

Nor'easter
A type of storm that occurs along the northeastern part of the United States that typically causes storm surge, heavy precipitation, rain or snow, usually between the months of September and April. Nor'easters derive their name from the direction of the northeastern winds that drive them.

Nourishment
In contrast to naturally occurring accretion/aggradation (see above) and specifically for beaches, the process of mechanically adding large volumes of sand from an outside source to widen and/or move the shoreline out of an eroding beach

Resilience
The ability to anticipate, prepare for, absorb, accommodate, recover from, and adapt to the effects of hazardous events quickly and efficiently, including through ensuring the preservation, restoration, or improvement of essential basic structures and functions.

Revetment
An engineered, sloping structures replacing a natural shoreline and often partially submerged, positioned on banks or cliffs in such a way as to absorb the energy of wave action.

Riprap
Rock or other material used to armor shorelines, streambeds, bridge abutments, pilings, and other shoreline structures against scour and water or ice erosion.

Saltwater inundation
Flooding by salt water which, over time, can lead to corrosion and other damage due to the deposition of salt on vulnerable surfaces.

Scour
Localized loss of soil often around a foundation element, causing a structure to become unstable.

Sea Level
A measure of the average height of the surface of an ocean, sea, or estuary.

Sea Level Rise
An increase in the height of the sea caused by warming water (thermal expansion) and ice melt. Relative sea level rise incorporates the relative change in the height of land.

Sewer, combined
A sewer system that collects sewage and surface runoff (stormwater) into a single pipe system.

Sewer, separated
A sewer system that conveys sewage and surface runoff (stormwater) in separate pipes.

Sheet-drain
Flow or runoff that occurs without being directed into a defined channel. Also known as sheet flow or overland flow.

Storm surge
The temporary increase, at a particular locality, in the height of a waterbody due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from tidal variation or predicted river or lake levels.

Structural pilings
A long, slender foundation member made either of timber, structural steel or concrete, which may be cast in-place or driven, that acts as a structural member to transfer the load of the structure to a required depth.

Sunny Day Flooding:
Flooding that occurs without the presence of a storm, often from high tide events that exceed the norm, such as during the full or new moon. known as tidal flooding, nuisance flooding, or blue-sky flooding,

Tide:
Long-period waves that move through the oceans in response to the gravitational forces exerted by the positions of the moon and sun in relation to Earth.

Ebb tide: the period between high tide and low tide, during which water flows toward the sea.
Flood tide: The period between low and high tide, during which water is rising, flowing away from the sea.
Neap tide: Tide just after the first or third quarters of the moon when there is least difference between high and low water.
"Spring" high tide: Tides of increased range or tidal currents of increased speed occurring semimonthly as the result of the Moon being new or full. These occur all year, not just in spring.

Topography
The shape of the surface of the landscape such as hills, valleys and plains, usually represented on a map. Topographic maps show elevation of landforms above sea level; bathymetric maps show depths of landforms below sea level.

Universal Design
Universal Design builds on the requirements of the ADA to ensure an environment and its facilities are accessible to all people, regardless of age, ability or other factors.

Wave attenuation
The weakening of the strength or intensity of waves, reducing wave height. A mechanism that attenuates waves is a wave attenuator or wave attenuation device.

Wetlands, Non-tidal (Freshwater) Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions. The presence of water-adapted vegetation is a primary indicator of a wetland. Non-tidal wetlands generally include swamps, marshes, bogs, embayments.

Wetlands, tidal
Tidal wetlands (or marshes) are areas that are regularly inundated or saturated by saline water at frequency and duration sufficient to support vegetation typically adapted for life in saturated soil conditions. These areas can be either inundated twice daily by tides or only periodically flooded during high or "spring" tides a few times a month. Along the Hudson River estuary, tidal wetlands range from brackish to freshwater conditions. Note: there is a regulatory definition of tidal wetlands in the Marine District of New York under Article 25 Tidal Wetlands Act. South of the Governor Mario M. Cuomo Bridge, wetlands are designated as tidal wetlands. North of the bridge, they are called tidally influenced freshwater wetlands. Along New York's marine coastline the most typical tidal wetland types are salt marshes and mudflats or tidal flats.

Appendix A: Additional Resources

Hudson River

1 / Hudson River Sustainable Shorelines Project Information and Resources for the Hudson River and Beyond

Hudson River National Estuarine Research Reserve

This website has information on nature-based shoreline erosion protection techniques including case studies of demonstration sites, monitoring protocols, lessons learned from storms, terminology, engineering literature reviews, recordings of webinars, design considerations, planting guides and list of resources relevant to Hudson River, Long Island and Great Lake coasts and other regions of the United States.

https://www.hrnerr.org/hudson-river-sustainable-shorelines

2 / Scenic Hudson Sea Level Rise Mapper

Scenic Hudson

Scenic Hudson has developed an interactive map showing estimated water depths and the extent of predicted future permanent inundation for each increment of sea level rise along the Hudson River.

arcg.is/1HOOen

3 / Climate Central's Surging Seas Tools

Climate Central

The Coastal Risk Screening Tool enables users to explore sea level rise and coastal flood risk over time, for New York City and the Hudson and under multiple greenhouse gas emissions scenarios.

https://sealevel.climatecentral.org/maps/

4 / Hudson River Flooding Decision Support System

Center for International Earth Science Information Network (CIESIN), Columbia University

The Hudson River Flooding Decision Support System mapping tool is meant to inform municipal planning decisions. It is not intended for storm preparations, navigation, permitting, or legal purposes. The data and maps in this tool are provided "as is. The data, maps, and information in the Hudson River Flood Impact Decision Support System version 1 illustrate the scale of potential flooding for tidally-affected shorelines of the Hudson River Valley and Westchester County under multiple sea level rise and storm scenarios to assist individual residents, communities, and municipal and regional lanners. The sea level rise scenarios available within the tool range from 0 to 6 feet (0 to 1.83 m) above the base mean sea level of 1983-2001, a standard sea level used by the National Oceanic and Atmospheric Administration (NOAA).

http://www.ciesin.columbia.edu/hudson-river-flood-map/

5 / Hudson River Risk Areas Mapper

NYS Department of State

The risk area maps define areas at risk from coastal hazards by looking at the exposure of the landscape and its susceptibility to damage. The risk areas assign a level of risk to areas according to the likelihood and severity of flooding, erosion, overtopping from storm or high water events within the project area.

*The risk areas are only for the Coastal Area portion of the Hudson River Estuary, meaning that they are cut off by our coastal area boundary and do not extend farther inland.

https://opdgig.dos.ny.gov/

6 / Hudson River Flood Resilience Network

Cornell University and Hudson River Estuary Program

The Hudson River Estuary Program supports municipal resilience planning to study flood risks and solutions for their waterfronts. A group of leading communities meet as a Flood Resilience Network to share insights and lessons learned, and work together on solutions.

https://wri.cals.cornell.edu/hudson-river-estuary/climate-change-hudson-river-estuary/helping-communities-become-climate-resilient/

7 / Hudson River Water Trail Guide

Ian Giddy and Scott Keller, Hudson River Watertrail Association

The official guide to the Hudson River Greenway Water Trail. The meticulously researched “roadmap” for paddlers and small boaters contains both practical and fascinating information about the Hudson River Valley Greenway, including suggestions for day and weekend trips, tides and currents, and much more. In addition to detailing access points, the 240-page guide provides useful navigation chartlets, and even more detailed exploration of the ecology, environmental resources, and cultural and natural history of the Hudson River and its valley. The guide was first published in 1993.

http://hudsonrivergreenwaywatertrail.org/buymaps.php

8 / Hudson River Greenway Water Trail Four Map Set

Hudson River Valley Greenway

Four map set covering the Hudson River and Champlain Canal from Whitehall to

Manhattan. http://hudsonrivergreenwaywatertrail.org/buymaps.php

9 / Hudson River Greenway Water Trail Website

Hudson River Valley Greenway

Website on the 256-mile Hudson River Greenway Water Trail, a National Water Trail.

http://hudsonrivergreenwaywatertrail.org

10 / Hudson River Environmental Conditions Observing System

Website with real-time data on weather and water observations from New York City to Troy.

https://hrecos.org/

11 / The New York Harbor Observing and Prediction System

Website from Stevens Institute that provides flood forecasts and hindcasts for the Hudson River and harbor.

http://hudson.dl.stevens-tech.edu/maritimeforecast/ http://hudson.dl.stevens-tech.edu/maritimeforecast/

12 / Climate Summary for Communities

New York State Department of Environmental Conservation

This document provides information for community-level land use planning and decision making. It identifies historic climate trends and introduces future projections and strategies to address the climate hazards most likely to affect Hudson Valley communities.

http://www.dec.ny.gov/docs/remediation_hudson_pdf/csfc2.pdf

13 / Climate Change in the Hudson Valley: Summary

New York State Department of Environmental Conservation

This document provides a document for the public with the latest on climate change in the Hudson Valley area and how community members can get involved.

http://www.dec.ny.gov/docs/remediation_hudson_pdf/ccinthehvms.pdf/

14 / DEC Info Locator

New York State Department of Environmental Conservation

DECinfo Locator is an interactive map that lets you access outdoor recreation information, including boat and hand launch facilities along the Hudson River.

https://www.dec.ny.gov/pubs/109457.html

15 / Commissioner's Policy: Climate Change and DEC Action

New York State Department of Environmental Conservation

This policy includes the components that are intended to integrate climate change considerations into DEC activities.

https://www.dec.ny.gov/regulations/65034.html

16 / Conservation and Land Use Program for the Hudson River Estuary Watershed

New York State Department of Environmental Conservation

This program provides resources to help communities incorporate natural resources into land-use planning and decision making by providing tools, training, and technical assistance.

https://www.dec.ny.gov/lands/5094.html

17 / DECinfo Locator

New York State Department of Environmental Conservation

DECinfo Locator is an interactive map with more than 65 data layers that lets you access DEC documents and public data about the environmental quality of specific sites in New York State, as well as outdoor recreation information. The Locator has useful environmental quality data (remediation sites, MS4s, wastewater treatment facilities and outfalls) and also the state regulated tidal wetlands (Hudson River south of the Mario Cuomo Bridge) labelled with links to the 1974 tidal wetland maps.

https://www.dec.ny.gov/docs/administration_pdf/dilfactsheet.pdf

18 / Ecological Communities of New York State

New York State Department of Environmental Conservation - New York Natural Heritage Program

First published in 1990 and most recently published in 2014, Ecological Communities of New York State became the primary source for community classification. The book attempts to include all ecological communities of the state, even those created by humans, and reflects the research and findings for over 1,800 community occurrences totaling 3.5 million acres.

http://www.dec.ny.gov/animals/29384.html

19 / Environmental Resource Mapper

New York State Department of Environmental Conservation

The Environmental Resource Mapper is an interactive mapping application that can be used to identify some of New York State's natural resources and environmental features that are state or federally protected, or of conservation concern. Most useful for stream classifications, state regulated freshwater wetlands, and rare animals/plants.

https://www.dec.ny.gov/animals/38801.html

20 / Financing Flood Resilience (2015)

New York State Department of Environmental Conservation

This document provides an overview of state and federal agency assistance programs and indicates the agencies which offer financial assistance or information.

https://wri.cals.cornell.edu/sites/wri.cals.cornell.edu/files/shared/documents/2015_Financing%20_Flood_Res.pdf

21 / Financing Waterfront Resilience

New York State Department of Environmental Conservation

This document provides an overview of assistance programs offered by New York State and federal agencies, how to apply to these programs, and examples.

http://www.dec.ny.gov/docs/remediation_hudson_pdf/financewr2019.pdf

22 / How to Set Up a Climate Smart Coordinator Task Force

New York State Department of Environmental Conservation

This document provides information to establish a task force to determine how climate change will affect the local community.

https://www.dec.ny.gov/energy/65489.html

23 / Hudson Estuary Program Website

New York State Department of Environmental Conservation

The Hudson River Estuary Program helps people enjoy, protect, and revitalize the Hudson River and its valley. The mission of the Estuary Program is built around clean water, resilient ecosystems, vital estuary ecosystem, natural scenery, education, river access, recreation, and inspiration.

https://www.dec.ny.gov/lands/4920.html

24 / Hudson River Climate Resilience Case Studies

New York State Department of Environmental Conservation

The Hudson River Estuary Program developed Flood Resiliency Task Forces in four riverfront communities to understand and prepare for the risk of future floods. This page outlines key issues and solutions identified in each community.

http://www.dec.ny.gov/energy/93950.html

25 / Hudson River Estuary Program Coordinators Report (2020)

New York State Department of Environmental Conservation

This document highlights the steps the NYC DEC is taking to ensure the status of the Hudson waterfront communities. It includes investments in clean water, land conservation, and habitat restoration.

https://www.dec.ny.gov/docs/remediation_hudson_pdf/hrep2020report.pdf

26 / Hudson River Estuary Program Climate Change Program for the Hudson River Estuary

New York State Department of Environmental Conservation

The Climate Change Program for the Hudson River Estuary helps communities to adapt to climate change and become more resilient to climate risks.

http://www.dec.ny.gov/lands/39786.html#Stormwater

27 / Hudson Valley Natural Resource Mapper

New York State Department of Environmental Conservation

The Hudson Valley Natural Resource Mapper is an online, interactive tool designed to help identify and understand important habitat and water resources, the connections between them, and their broader regional context. The mapper also highlights Hudson River recreation sites and other areas where residents and visitors can enjoy the region's natural beauty. By bringing together information about natural features such as streams, wetlands, and large forests, as well as recreation amenities and existing protected lands, communities can begin to identify conservation priorities and strategies that can be incorporated into local land-use planning. Includes important layers like bathymetry, tidally influenced wetland areas broken down by vegetation type (not a regulatory layer), documented SAV, NYS DOS Significant Coastal Fish and Wildlife Habitats, FEMA Flood Hazard Zones, and numerous other regulatory and non-regulatory layers that are useful for property managers.

https://www.dec.ny.gov/lands/112137.html

28 / Permits, Licenses, and Registrations Resource Page

New York State Department of Environmental Conservation

This page provides links to popular permits, licenses, registrations, or certifications in New York State.

http://www.dec.ny.gov/63.html

29 / Protection of Waters Program

New York State Department of Environmental Conservation

The webpage describes the policies set forth in Title 5 of Article 15 of the Environmental Conservation Law (ECL) , to preserve and protect these lakes, rivers, streams and ponds. Classification of waters is explained. Information and resources on obtaining permits is provided.

https://www.dec.ny.gov/permits/6042.html

30 / Protection of Waters Program Shoreline Stabilization Information Page

New York State Department of Environmental Conservation

This information was developed to increase awareness of the ecological importance of natural shorelines, and to promote more enlightened approaches to shoreline stabilization.

https://www.dec.ny.gov/permits/50534.html

31 / Tidal Wetlands Guidance Document for Living Shoreline Techniques

New York State Department of Environmental Conservation

This guide provides information regarding the issuance of permits for living shoreline techniques in the Marine and Coastal District Waters of New York. The purpose of the document is to encourage the appropriate use of living shorelines in place of hardened approaches and to encourage modification of existing shoreline erosion control structures into living shorelines.

http://www.dec.ny.gov/docs/fish_marine_pdf/dmrlivingshoreguide.pdf

32 / Using Natural Resilience Measures to Reduce Risk of Flooding and Erosion in NYS

New York State Department of Environmental Conservation

This document, published in 2020, describes natural resilience measures and how they can be used to mitigate the risks of flooding and erosion; provides definitions for different types of natural resilience measures and distinguishes among conserved, restored, nature-based and hard structural approaches; provides information on the value and benefits of using natural resilience measures, along with information on the co-benefits they provide; lists key factors to consider in the restoration, design and construction of natural resilience measures; provides background to support the development of state agency guidance on natural resilience measures in the future.

https://www.dec.ny.gov/docs/administration_pdf/crranaturalmeasuresgndc.pdf

33 / New York State Department of State Geographic Information Gateway

New York State Department of State

The Geographic Information Gateway is a one stop, state-of-the-art website providing public access to data, real-time information, interactive tools, and expert knowledge relevant to the Office of Planning and Development's activities throughout New York State. Interactive map viewers enable users to easily download, visualize, and explore geographic data.

http://opdgig.dos.ny.gov/#/map

34 / New York State Water Resources Institute

Cornell University College of Agriculture and Life Sciences

The New York State Water Resources Institute at Cornell University supports research initiatives, outreach and educational efforts, and relationship-building across stat agencies, professional organizations, and citizen stakeholder groups. The Water Resources Institute's Climate Change Program has supported the implementation of the Climate Smart Communities Certification Program, generated climate fact sheets, produced research and maps for climate adaptation strategies at Piermont Pier, and supported the planning and organization of the Weaving the Waterfront event in Kingston, NY.

https://wri.cals.cornell.edu/

35 / New York State Water Resources Institute Climate Change Program

Cornell University College of Agriculture and Life Sciences

This program identifies climate risks in the Hudson River Estuary and provides information on resiliency strategies.

https://wri.cals.cornell.edu/hudson-river-estuary/climate-change-hudson-river-estuary/

36 / Plant Resource Document - Lower Passaic River Restoration Project

US Army Corps of Engineers - New York District, US Environmental Protection Agency -Region 2, and the New Jersey Department of Transportation

This document provides recommendations for vegetation to be planted or seeded during restoration of the diverse habitats in the study area including tidal brackish, tidal transitional, tidal freshwater, forested, and freshwater forested. Species suitable for tidal and freshwater bioengineering, freshwater forested understory enhancement, and riparian buffer (seeding) are identified as well.

https://passaic.sharepointspace.com/Public%20Documents/2008-10-01%20FINAL%20Plant%20Resource%20Document.pdf

37 / Stevens Institute of Technology Flood Advisory System

Stevens Institute of Technology

Provides water levels and flood predictions for stations along the Atlantic Coast including up the Hudson River to Troy.

http://hudson.dl.stevens-tech.edu/sfas/

38 / Woody Shrubs for Stormwater Retention Practices

Cornell University Department of Horticulture

This document summarizes results of a three-month study in Ithaca, NY, focused on testing the flood and drought tolerances of six shrub species. This list should be cross-referenced with the Native Species Planting Guide for New York City to rule out species that are more appropriate to upstate climates and higher elevations.

hort.cornell.edu/uhi/outreach/pdfs/woody_shrubs_stormwater_hi_res.pdf

New York City

39 / Design and Planning for Flood Resiliency: Guidelines for NYC Parks

New York City Department of Parks & Recreation

This interdisciplinary manual was developed by NYC Parks and released in November 2017 to provide guidance for developing and renovating coastally resilient waterfront parks. The Guidelines are specifically tailored for NYC Parks with the hope that other planners, designers, consultant firms, agencies, communities, and homeowners can use them as a reference for coastally resilient park planning and design.

https://www.nycgovparks.org/planning-and-building/planning/resiliency-plans/flood-resiliency

40 / Building the Knowledge Base for Climate Resiliency

New York City Panel on Climate Change (February 2015)

A report produced by the New York City Panel on Climate Change that provides climate projections for the City through the end of the century. These projections form the basis of an assessment of the resilience of the City's infrastructure, as well as suggestions for how that resilience can be improved.

onlinelibrary.wiley.com/doi/10.1111/nyas.2015.1336.issue-1/issuetoc

41 / Coastal Green Infrastructure Plan for New York City

Arcadis (December 2014)

In 2014 the New York State Department of Environmental Conservation Hudson River Estuary Program, the New England Interstate Water Pollution Control Commission, and NYC Department of City Planning released a Coastal Green Infrastructure (CGI) research plan, which defined CGI as nature-based strategies for protecting shorelines from coastal flooding. The strategies include such things as constructed wetlands and breakwaters to ecologically-enhanced bulkheads

and revetments. The plan summarizes the latest scientific understanding of ecological and risk reduction benefits of various CGI strategies, as well as knowledge gaps and research priorities.

dec.ny.gov/lands/100057.html

42 / Climate Resiliency Design Guidelines

NYC Mayor's Office of Recovery and Resiliency

Guidelines for New York City capital projects which incorporates more specific, regional, and forward-looking climate science than historic sources of this data. The Guidelines provide a consistent methodology for engineers, architects, and planners to design facilities that are resilient to changing climate conditions.

https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v3-0.pdf

43 / Cloudburst Resiliency in New York City

Ramboll and the NYC Department of Environmental Protection

This report analyzes best-available data related to NYC rainfall, recommends methodologies for incorporating findings into ongoing resiliency planning initiatives, and identifies best practices for considering climate change in future neighborhood-specific planning studies. Opportunities for intervention are identified within the designated study area in southeast Queens.

issuu.com/ramboll/docs/nyc_cloudburst_resiliency_planning_

44 / Designing for Flood Risk

NYC Department of City Planning (June 2013)

This report identifies key design principles to guide flood-resistant construction in urban area. It provides an overview of regulatory requirements for construction in flood zones under the National Flood Insurance Program, and explores the impacts of flood-resistant construction standards

on built form and the creation of a vibrant streetscape and public realm. The report also lays out recommendations for how zoning can incorporate these principles to enable more versatile and desirable design solutions for flood-resistant construction.

www1.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/designing_flood_risk.pdf

45 / High Performance Landscape Guidelines: 21st Century Parks for NYC

Design Trust for Public Space and NYC Parks (2010)

This is a comprehensive manual for the design and construction of sustainable parks and open space. It contains best practices for water management, resilient plantings, durable materials, and efficient operations within parks.

nycgovparks.org/greening/sustainable-parks/landscape-guidelines

46 / Native Species Planting Guide for New York City (2nd Edition)

NYC Parks (2014)

This guide is written primarily to assist those doing restorations, or plantings in natural areas in the New York City metropolitan area, with the goal of preserving genetic diversity within the New York region. Planting recommendations are provided for low and small salt marsh, and maritime beaches, dunes, grassland and shrublands.

http://growingwildnyc.org/wp-content/uploads/2016/03/nrg-native-species-planting-guide-091714.pdf

47 / Retrofitting Buildings for Flood Risk

NYC Department of City Planning (October 2014)

This document is the most comprehensive analysis of retrofit options available for buildings in the New York City floodplain to date.

www1.nyc.gov/site/planning/plans/retrofitting-buildings/retrofitting-buildings.page

48 / Urban Waterfront Adaptive Strategies

NYC Department of City Planning (June 2013)

This is a resource to help guide planners and policy makers in New York City and beyond in identifying and evaluating potential coastal protection strategies. The report lays out a framework by which communities can narrow the list of strategies to consider for a given geography and identify which strategies provide the greatest range of benefits with respect to direct and indirect costs. This information is intended to provide guidance for the challenging decisions coastal communities face about how to foster resilient communities that can withstand and recover from climate hazards with minimal harm, while retaining a vibrant economy and a high quality of life for their residents.

nyc.gov/html/dcp/html/sustainable_communities/sustain_com7.shtml

Federal Emergency Management Agency

49 / FEMA FIRM and PFIRM Data Viewers

Federal Emergency Management Agency

The FEMA Flood Map Service Center is the official online resource for all flood hazard mapping products created under the National Flood Insurance Program (NFIP), including community flood maps, called Flood Insurance Rate Maps (FIRMs).

msc.fema.gov/portal/home

If you want to explore your community's current effective flood hazard data in a digital map, the best tool to use is FEMA's National Flood Hazard Layer Viewer.

msc.fema.gov/nfhl

To view preliminary flood hazard data for your community and see how your proposed flood hazards compare to your current effective flood hazards, use FEMA's Flood Map Changes Viewer.

https://msc.fema.gov/fmcv

50 / FEMA Flood Zone Designations- Definitions

Federal Emergency Management Agency

This document provides definitions of FEMA flood zone designations.

https://snmapmod.snco.us/fmm/document/fema-flood-zone-definitions.pdf

Other

51 / Clean Marina Guidebook

National Park Service (March 2012)

This guidebook is intended to help marinas develop practices that go beyond required regulatory and contractual compliance and implement best management practices to create cleaner, more environmentally-friendly facilities.

nps.gov/commercialservices/docs/concessioner%20tools/National_Clean_Marina_Initiative_2012.pdf

52 / Digital Coast

National Oceanic and Atmospheric Administration (NOAA) – Office for Coastal Management

Digital Coast is a NOAA-sponsored website that is focused on helping communities address coastal issues providing not only coastal data, but also the tools, training, and information needed to make these data truly useful. Content comes from many sources, all of which are vetted by NOAA. Data sets range from economic data to satellite imagery. The site contains visualization tools, predictive tools, and tools that make data easier to find and use. Training courses are available online or can be brought to the user's location and include tools like a quick reference guide for having effective meetings including good planning, strong facilitation, and activities that help participants reach meeting goals.

coast.noaa.gov/digitalcoast/

53 / Introduction to Planning and Facilitating Effective Meetings

National Oceanic and Atmospheric Administration (NOAA) – Office for Coastal Management

This guidebook provides the basic techniques used by professionals for meeting planning and facilitation, and while facilitation is as much an art as a science, familiarity with these concepts can help even novice facilitators plan and bring about more effective meetings.

https://coast.noaa.gov/digitalcoast/training/effective-meetings.html

54 / Introduction to Stakeholder Participation

National Oceanic and Atmospheric Administration (NOAA) – Office for Coastal Management

This document briefly examines several important aspects of stakeholder participation. While little consensus exists on stakeholder participation methods and procedures, and there is no "one-size-fits-all" approach, this guide presents a set of procedural elements common to many effective stakeholder participation projects and programs.

https://coast.noaa.gov/data/digitalcoast/pdf/stakeholder-participation.pdf

55 / IPCC Assessing and Managing Risks of Climate Change (2014)

Intergovernmental Panel on Climate Change

This document provides a summary of observed impacts, future risks, and how to build resilience for policymakers across the world as a result of climate change.

https://www.ipcc.ch/site/assets/uploads/2018/03/WGIIAR5_SPM_Top_Level_Findings-1.pdf

56 / Logical Lasting Launches

National Park Service

Design guidance for canoe and kayak launches.

https://npgallery.nps.gov/RTCA/GetAsset/86bb0d45-8417-4904-97ae-771c8eba5a42/original

57 / National Oceanic and Atmospheric Administration Products

National Oceanic and Atmospheric Administration

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) gathers oceanographic data, such as water-level and current measurement data, along the nation's coasts, and publishes the data on a Tides and Currents Station Map that can be accessed through their website.

https://tidesandcurrents.noaa.gov/about.html

58 / Prepare to Launch

River Management Society

Guidelines for assessing, designing, and building launch sites for carry-in watercraft.

https://www.river-management.org/prepare-to-launch

59 / Measuring Success: Monitoring Natural and Nature-based Shoreline Features in NYS

National Oceanic and Atmospheric Administration (NOAA), New York State Department of State, New York State Energy Research and Development Authority

The manual provides guidance on how to monitor both natural and hybrid shoreline features, including on the Hudson River, on Long Island, and Great Lakes.

dos.ny.gov/opd/pdf/Monitoring_Framework_Report_2020.pdf

60 / Hudson River Sustainable Shorelines Rapid Assessment Protocol

S.E.G Findlay, J.K. Miller, A. Williams, and E.E. Hauser

In association with and published by the Hudson River Sustainable Shorelines Project, the manual provides guidance on how to determine shoreline conditions.

http://hrnerr.org

61 / Room for the River Program, Netherlands

This national program creates tailor-made design and infrastructure measures to provide Dutch rivers with more physical space to facilitate naturally occurring floods in a safe manner.

ruimtevoorderivier.nl/English

62 / Standard 24-05 for Flood Resistant Design and Construction

American Society of Civil Engineers (July 2015)

This document is a referenced standard in the International Building Code®. Buildings and structures within the scope of the IBC proposed to be constructed in a flood hazard area should be designed in accordance with these standards.

fema.gov/media-library-data/20130726-1643-20490-4974/asce24_highlights_dec2010.pdf

63 / Waterfront Edge Design Guidelines (WEDG)

Metropolitan Waterfront Alliance (2015)

These guidelines include a voluntary, incentive-based ratings system for waterfronts. WEDG is a tool to encourage waterfront innovation and best practices and allow developers, property and business owners, and design professionals to differentiate themselves in the marketplace.

waterfrontalliance.org/WEDG

64 / Constructing Wetland Boardwalks and Trails

Jon Kusler, Association of State Wetland Managers, Inc. (2006)

Descriptions of when boardwalks are recommended and how to site them and choose materials.

https://www.aswm.org/pdf_lib/2_boardwalk_6_26_06.pdf

65 / USGS Water Alert

U.S. Geological Survey WaterAlert service sends e-mail or text (SMS) messages when certain parameters, as measured by a USGS real-time data-collection station, exceed user-definable thresholds.
https://maps.waterdata.usgs.gov/mapper/wateralert/

Appendix B: Permit Issuance Standards

The decision to issue an environmental permit for a shoreline or in-water project is based on the permit issuance standards outlined in each implementing regulation. Because the permit issuance standards differ depending on permit type and the varying agencies involved, it is best to discuss the issuance standards directly with the regulatory agencies.

Resiliency strategies are discussed in Chapter 6 and offer many choices and alternatives to consider and discuss with DEC and other agencies. As a rule, projects should be designed to minimize impacts to ecological functions, critical habitat areas, recreational activities, and to protect human health and welfare. If it is not possible to avoid these impacts entirely, projects must seek to first minimize their impacts to the greatest extent practical. If impacts cannot be avoided or minimized, additional actions might be necessary to meet permit issuance standards and must be discussed with the appropriate permitting agency. See Chapter 4: Land Use Regulations and Permitting on permitting for additional information.

Regional Permit Programs

DEC strongly urges applicants unfamiliar with DEC permitting procedures to request a pre-application conference, to obtain preliminary answers to questions about wetland and adjacent area boundaries, application procedures, standards for permit issuance, and other potential regulations and compliance issues such as historic preservation, endangered species, or hazardous waste disposal sites. Applications to OGS, DOS, or OPRHP are processed by the agency offices in Albany, but most DEC applications are processed in one of the Regional Offices. If an applicant requires a pre-application conference, a preliminary project plan and a written request for a pre-application conference should be submitted to the appropriate Regional Permit Administrator. A list of regional contacts can be found at: https://www.dec.ny.gov/about/558.html. The general information for Regions 3 and 4 are provided below.

Region 3

Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster & Westchester E-mail: dep.r3@dec.ny.gov	Environmental Permits DEC 21 South Putt Corners Rd. New Paltz, NY 12561-1620 845-256-3054

Region 4

Albany, Columbia, Greene, Montgomery, Rensselaer, Schenectady & Schoharie E-mail: dep.r4@dec.ny.gov	Environmental Permits DEC 1130 North Westcott Rd. Schenectady, NY 12306-2014 518-357-2069

Permitting Requirements and Standards

Permit Program	Rules and Regulations	Description
Article 24- Freshwater Wetlands	6 NYCRR § 663;	Permit required for certain activities in freshwater wetlands. Regulated wetlands are identified on the Freshwater Wetland Regulatory Maps
Article 25- Tidal Wetlands	6 NYCRR § 661	Permit required for certain activities in tidally-influenced wetlands and their regulated adjacent areas. Regulated wetlands are identified on Tidal Wetland Regulatory Maps.
Article 15, Title 5- Protection of Waters	6 NYCRR §§ 608	Permit required for activities including disturbance of the bed or banks of protected streams; construction, reconstruction or expansion of docks, platforms, and mooring facilities; or excavation or placement of fill below MHW.
Federal Consistency / State Consistency / Coastal Zone Management Act	15 CFR Part 930 Subpart D and 19 NYCRR Part 600;	Consistency determination and review conducted by New York State Department of State (DOS) for actions, including permit review, in a coastal area[56]; State agency consistency review (done by all other NYS agencies when undertaking an action in the Coastal Area) [57]
New York State Office of General Services (NYSOGS)	Public land law, Article 6	Title to the bed of numerous bodies of water is held in trust for the people of the State of New York. Structures, including fill, located in, on, or above state-owned lands under water may require authorization from the state.
NYS Office of Parks, Recreation and Historic Preservation (OPRHP), Floating Objects	Navigation Law Article 3, Section 35-a	A permit is required for all floating objects other than aids to navigation.

[56] See the New York State Coastal Management Program at: https://www.dos.ny.gov/opd/programs/pdfs/NY_CMP.pdf
[57] See 19 NYCRR Part 600 and Article 42 (910 – 923) Waterfront Revitalization of Coastal Areas and Inland Waterways

Regulatory Standards for Permit Issuance

All projects must meet the standards for permit issuance for each permit required. The standards for permit issuance can be found at:

- Tidal Wetlands, 6 NYCRR § 661: https://www.dec.ny.gov/permits/6353.html
- Freshwater Wetlands, 6 NYCRR § 663: https://www.dec.ny.gov/permits/6273.html
- Use & Protection of Waters, 6 NYCRR § 608: https://www.dec.ny.gov/permits/6329.ht
- Coastal Consistency: https://www.dos.ny.gov/opd/programs/consistency/index.html
- State Lands Now or Formerly under Water: https://ogs.ny.gov/real-estate/lands-now-or-formerly-underwater
- Floating Objects: https://parks.ny.gov/recreation/boating/navigation-law.aspx#floatingobjects

Other State Permits

State Pollutant Discharge Elimination System (SPDES) – Stormwater

Projects involving the disturbance of 1 acre or more of land will require a SPDES permit for the discharge of stormwater. Most projects will be able to qualify for coverage under the DEC's general permit for Stormwater Discharges from Construction Activity; see http://www.dec.ny.gov/chemical/43133.html for more information.

Environmental Remediation

The entire Hudson River south of the dam at Troy is part of a Superfund site associated with polychlorinated biphenyls (PCBs). Sediments in areas of the river may also be contaminated with heavy metals, petroleum products, or other hazardous materials. Area of historic fill along the river may be contaminated with solid or hazardous waste. Dredging or excavation of historic fill may require testing of the material and disposal at a solid or hazardous waste facility or obtaining a Beneficial Use Determination for reuse.

Appendix C: Funding Opportunities

State and Federal funding opportunities are available through the grants listed below.[58] Many have their own criteria. New York State's Consolidated Funding Application (CFA) is designed to reduce the effort of applicants. Most New York State and Federal funding programs require the applicant to provide some matching funds. In some, but not all cases, the applicant must be a municipality.

New York State Consolidated Funding Application (CFA)

The CFA was created to empower public agencies and non-profits with the ability to navigate New York State's multitude of grants with a single application process.

The following is a list of agencies and grants/programs available through the CFA, several of which can fund access sites.

- Climate Smart Communities (CSC) Grants
- Water Quality Improvement Project (WQIP)
- Non-Agricultural Nonpoint Source (NANS) Planning Grant Program
- Local Waterfront Revitalization Program (LWRP)
- Brownfield Opportunity Area (BOA)
- Green Innovation Grant Program (GIGP)
- Clean Water (CWRSF) and Drinking Water (DWRSF) State Revolving Funds
- NYS Office of Parks, Recreation & Historic Preservation (OPRHP) Parks
- NYS Office of Parks, Recreation & Historic Preservation (OPRHP) Recreational Trails
- US Department of Housing and Urban Development (HUD) Community Development Block Grant Program (CBDG)
- Empire State Development (ESD)

CFA applications are usually due in July of each year so it is important to be poised to apply. A Hudson River access site municipality or non-profit organization must register online to begin a new application process. This will generate a single project application to then subsequentially select as many relevant grants as possible with one submission. In addition to manually selecting all available grants that are relevant to a river access site and waterfront resiliency project, the application process boasts a "Program Wizard" that will suggest grants and programs related to the selections made during the application process.

There are several resources online to guide applicants through the CFA including free webinars, a schedule of in-person workshops (located throughout NYS), an extensive manual, and list of regional contacts for assistance. These resources are another enhanced utility of the CFA that prioritizes it as a valuable starting point for municipalities and non-profits to initiate waterfront resiliency projects.

It is recommended that municipalities consider taking the Climate Smart Communities pledge and pursue certification. This will enable them to participate in grant programs aimed at improving resilience at their waterfront sites.

[58] Updated June 2020

DEC Hudson River Estuary

Although not included in the CFA, the DEC Hudson River Estuary Grants in the River Access category can support many aspects of access site resilience, including plans, designs and implementation projects.

The grant opportunities are announced as Request for Applications (RFA's) through the Hudson River Estuary Grants Program. Subscribers to the program's e-newsletter RiverNet will automatically be notified of these opportunities.

Applicants must be pre-qualified in the NYS Grants Gateway. Step-by-step on-line tutorials and guides to registration and prequalification in the NYS Grants Gateway are available at NYS Grants Management.

Federal Emergency Management Agency (FEMA)

FEMA manages three major grant programs under the Hazard Mitigation Assistance fund including: Hazard Mitigation Grant Program (HMGP), Pre-Disaster Mitigation (PDM), and the Flood Mitigation Assistance (FMA). Each of these programs is tailored toward different focuses on where and when resiliency is applied. Although these grants are targeted towards state, territorial, tribal, and local governments, parks departments and non-profit organizations can apply as "subapplicants" along with the eligible local government.

- Hazard Mitigation Grant Program (HMGP) – is a reactive funding mechanism triggered by nationally declared disasters and provides financial assistance to impacted municipalities to protect damaged facilities from future events.
- Pre-Disaster Mitigation (PDM) – the PDM grant does not require an existing disaster to implement relief, and instead focuses on funding for hazard mitigation pre-planning with additional attention to public awareness. River access sites located in the Hudson River Valley would be great candidates for this funding as their facilities provide public access to waterfronts, and hazard mitigation projects would likewise provide a public awareness of resilience hazard mitigation planning for reducing future losses before disaster strikes. PDM grant applications can also reference Hazard Mitigation Projects for guidance from the HMGP, as PDM focuses on pre-disaster planning while HMGP identifies existing disasters for funding.
- Flood Mitigation Assistance (FMA) Grant Program – if a building located on or owned by a river access site is insured by the National Flood Insurance Program (NFIP), the park department can apply as a sub-applicant with the local municipality for projects and planning that reduces or eliminates long-term risk of flood damage to the insured structure(s).

The matrix below displays how the CFA, DEC Hudson River Estuary Program, and FEMA PDM (among others) can provide financial grants to Hudson River Valley river access sites for all major components of resiliency from municipal planning to floodplain protection. Check the Estuary Program's webpage for summaries of many of these programs: http://www.dec.ny.gov/lands/39786.html#Grants

Overview of Funding Opportunities for Flood Resilient Parks (Source: DEC)

Funding Opportunities

State and federal agencies offer financial assistance to municipalities and non-profit organizations for activities building resilience to waterfront flooding, sea-level rise and other climate risks.

Agency	Assistance Program	Grant amounts, required match	Municipal Planning	Resilient Structures	Emergency Management	Collaboration and Public Outreach	Waterfront Economy	Floodplain protection
Department of Environmental Conservation (DEC)	Hudson River Estuary Program (HREP)	$10,500-$50,000, 15%	•	•			•	•
	Climate Smart Communities (CSC)	$10,000-$2M, 50% match	•	•				•
	Water Quality Improvements Program (WQIP)	25-60% match		•				•
	Trees for Tribs	N/A						•
Environmental Facilities Corporation (EFC)	Wastewater Infrastructure Engineering Planning	≤$100,000, 20% match	•	•				
	Clean Water Revolving Loan Fund	N/A	•	•				•
	Green Innovation Grant Program (GIGP)	10-60% match						•
Federal Emergency Management Agency (FEMA)	Hazard Mitigation Assistance (HMA)	Over $3M, 25% match	•	•				
	Pre-Disaster Mitigation Program (PDM)	N/A			•			
	Flood Mitigation Assistance Grant Program (FMA)	N/A	•	•				•
Department of State	Local Waterfront Revitalization Program (LWRP)	15-25% match	•	•		•		
Other	New York State Energy Research and Development Authority (NYSERDA)	≤$250,000, no match	•	•		•		
	NYS Office of Parks, Recreation and Historic Preservation (OPRHP)	≤$500,000, 25-50% match					•	•
	US Housing and Urban Development (HUD)	$50,000 - $900,000, 0-5%	•	•			•	
	Empire State Development	80% match for soft costs		•			•	
	Hudson River Greenway	$5,000 - $10,000+					•	•
	Open Space Funding Options	N/A						•

Appendix D: Ice Dynamics

Introduction

River ice can cause significant damage to the shoreline and in-water structures of Hudson River access sites.[59] This document provides a general description of the ice regime on the Hudson River and describes risks associated with ice, along with best practices and resilience design strategies. While design can reduce the risks from ice, not all ice damage can be completely mitigated: some level of pre-season preventive activities and post-season maintenance should be planned.

Ice Regime

The river ice on the Hudson River is dynamic and can impede navigation, impact the stability of the shoreline and in-water structures, and exacerbate flooding.[60] The winter ice season on the Hudson River is typically from mid-December to late March. During a very cold winter, the upper portion (from Troy to West Point, a 100-mile-long reach) can freeze from bank to bank. In such conditions, the US Coast Guard opens a navigation channel in the ice cover to maintain commercial traffic.[61]

During milder winters, the River does not entirely freeze over, but ice still forms in protected coves, shorelines and bays. The water level fluctuation created by tides and changes in river flow promote cracking and breaking of the ice into smaller pieces. These pieces float near the water surface and their movement is driven by current and wind. In some areas, the fractured ice can accumulate and stack on the shoreline.

Downstream of West Point, the River does not completely freeze over in typical years, because of its width and salinity there. In the narrow passage between West Point and Jones Point, no stable ice cover forms, even during very cold winters, likely due to higher velocity currents and increased salinity. Several locations are prone to broken ice accumulation along the river, including West Point (see photo of choke point), and Esopus Meadows (Georgas et al. 2015). In these areas, the ice transport capacity of the river is reduced because of river narrowing or curves. The ice also tends to accumulate in large bays and anchorages areas.

The ice thickness tends to increase upstream in the river, under the influence of several factors including salinity, tidal effect, temperature and hydraulic conditions. For instance, the 95th percentile ice thickness calculated by Georgas et al. (2015) over the period 2004-2015 was 6 inches at George Washington Bridge, about 8 inches near West Point, and 12 inches at Esopus Meadows. Georges et al. (2015) found that in 2014-2015, ice thickness records were broken for the months of February and March for most regions of the tidal Hudson.

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[59] In-water structures may include piers, fixed docks, wave attenuators and dolphins.

[60] The following information is taken primarily from (Georgas et al, 2015). In addition, geo-spatial ice data from 2006-2012 can be found on the NYS Clearinghouse Website.

[61] John Sperr, on his Hudson River Ice Yacht Club website, www.hriyc.org, maintains an annotated archive of aerial photographs published by the Coast Guard that show winter ice conditions from Shrewsbury, New Jersey north to Troy, New York. Records go back to 2007. Weather and Coast Guard budgetary constraints limit the frequency and range of this coverage in most years.

The ice starts breaking up naturally without any intervention typically in February. During breakup, the ice sheets fracture and start moving under the influence of currents and wind. The size of the ice floes on the Hudson River is highly variable; from a dozen feet to more than 1,500 feet (Georgas et al. 2015). The Coast Guard will also break up ice if warranted to prevent ice jams, the accumulation of fractured river ice that causes an increase of the upstream water level. The sudden movement of river ice, typically during break-up, is called an ice run because of its speed.

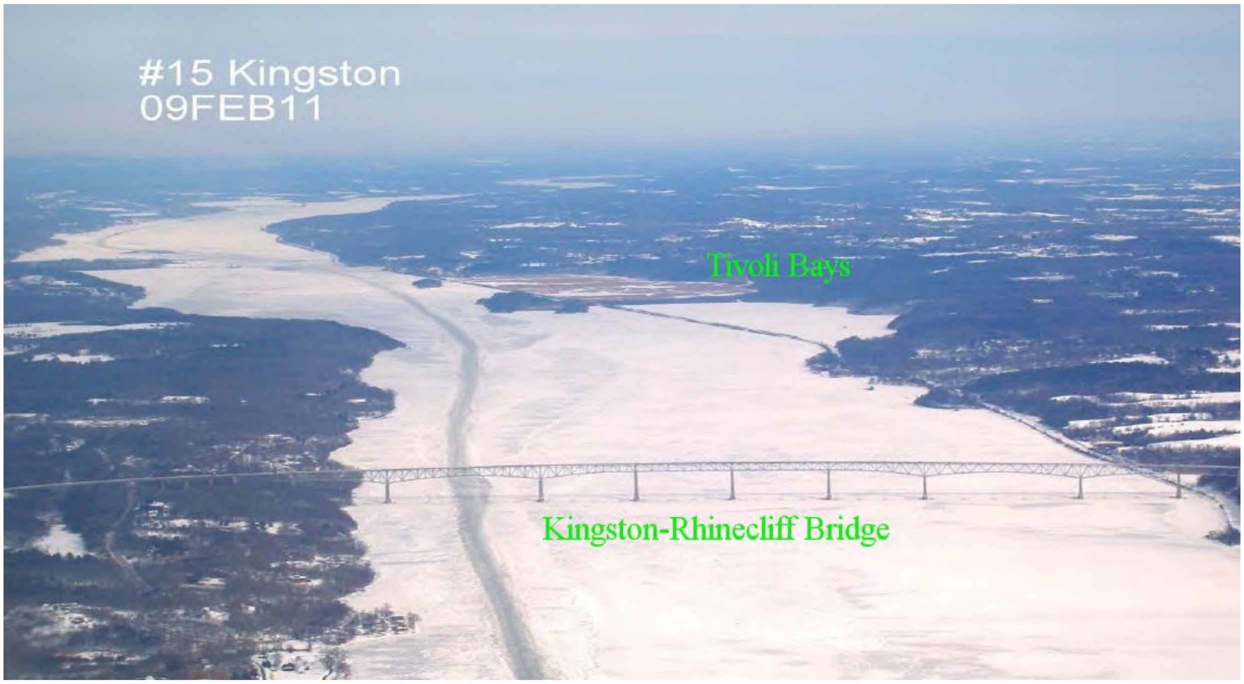

Figure 1. Navigation channel (at left) and ice conditions looking north toward Saugerties over the Kingston-Rhinecliff Bridge. February 9, 2011. Source: Coast Guard modified by John Sperr.

Figure 2. Ice accumulation at West Point choke point looking West.
Source: Coast Guard modified by John Sperr.

Figure 3. Rhinecliff steel sheet bulkhead at waterfront park showing ice build-up at high tide, February 2011.

Source: E. Hauser.

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Figure 4. Ice accumulation at Norrie Point, NY, 85 miles north of New York City.

Source: NYS Department of Environmental Conservation.

Risk Associated with Ice

River ice can cause shoreline erosion and damage existing edge protection structures and in-water structures. It can also increase water levels across the River or in parts of it. At some shoreline locations, the ice-related risk could be greater than during ice-free conditions. The ice-related risk is defined by a combination of hazard, exposure and vulnerability, as described below.

The following section pertains to shoreline armoring structures such as bulkheads and revetments as well as in-water structures such as piers.

Hazards

Ice-related hazards include excessive ice load, ice jam flooding, ice scour of the shoreline, and ice ramping or overtopping.

Two types of loads - static and dynamic - can be generated by ice on a structure. Both types of loads can inflict damage. A *static load* is generated when a structure, already in contact with an ice field, resists its movement. This load can result from thermal expansion, constant wind/current action or water level variation. Ice attached to a structure can apply vertical forces upward or downward as water levels vary with tides.

A *Dynamic* load is created when a (water or wind-driven) moving ice floe hits a structure. In this situation the ice can either break by crushing or bending (from Carter, 2003). Ice stacking is a type of dynamic load that occurs when ice floes accumulate against a structure or shore. Floating ice can be pushed by wind or current against and over a structure. In some extreme conditions such as storms and unusually high-water events, ice pieces can be transported far inland.

Along the shore, ice can also interact with soil, vegetation and rock. For instance, ice can move a large portion of a shoreline by ramming into it (*dynamic*). Also, when moving along a shoreline with significant velocity, ice scour can create sliding/shear forces that erode and entrain shoreline material. Finally, ice can “pluck” shore materials. This occurs when shoreline materials become entrained within ice as it freezes, then transports the material from the site when driven by tides, currents or wind. These hazards are magnified since the River flows in both directions.

Accumulating ice can form ice-jams, particularly on the Hudson’s tributaries, causing flooding upstream above the expected ice-free flood levels. With warming temperatures and water movement, ice floes can break apart and collect against a structure, obstructing flow. Flooding can occur either upstream of the ice jam and/or downstream when the ice jam breaks and releases a burst of water.

Climate Change

Climate change will modify the ice regime on the Hudson River and the risk associated with ice, however, in contrasting ways.

For instance, the expected rise of sea level will increase the elevation of the zone where the ice and shoreline/in-water structures interact. In future climate, winter thaw and mid-winter breakup events are expected to be more frequent. These events could cause additional stress to the shoreline, by generating more ice movement on the river and more ‘freeze-thaw’ cycles in the shore material. An increase in the frequency of breakup events increases the risks of ice jams and winter flooding.

On the other hand, climate change and sea level rise may dampen ice risks. Greater salt intrusion higher upstream in the Hudson River would modify the structure of the ice that does form. So-called marine ice is typically less resistant than river ice. Also, higher temperatures due to climate change, particularly the expected increase in low temperatures, could shorten the duration ofthe winter season and the occurrence and thickness of the ice.

Exposure

The exposure corresponds to the period during which ice can adversely impact the exposed area of a shoreline or structure. During an ice run, the period when ice moves along a site describes the exposure. A site set back from the main current of the river (i.e. in a bay or behind a natural barrier) is typically less exposed to dynamic forces than one directly exposed to a long river fetch or located near a narrowing in the river – even though the site will have higher incidences of ice build-up.

An area where ice movement is possible (water or wind-driven) is subject to a dynamic ice load. Where an ice field can form, adjacent areas are subject to static ice load. Many locations on the Hudson have both ice movement and ice field formation.

Vulnerability

The vulnerability of a shoreline to river ice depends on several factors, including the robustness of the sediment and vegetation, or armoring material, the slope of the shore or shoreline structure, and the site exposure.

Land use and inland infrastructures will also determine the vulnerability of the site.

The vulnerability of in-water structures depends on the size, shape and materials of the structure, its anchoring or footings, its orientation to the main direction of dynamic loads, and the height of elements above high-water levels.

Planning & Design

For every project along the Hudson River, the challenges associated with ice dynamic should be addressed based on a site-specific analysis. The location and orientation of the shoreline protection site are key parameters when developing an ice-resilient strategy. A site located in calm waters, out of the main current, is typically less vulnerable to water-driven moving ice. A site exposed to a long fetch (distance along open water over which the wind blows) is more likely to experience ice stacking.

Structures intended specifically for shoreline protection are civil structures that must be designed by a qualified engineer. Many shorelines not intended exclusively for protection are designed by a landscape architect or restoration biologist familiar with Hudson River vegetation. Piers must be designed by structural engineers. Ice will impact all of the above and should be assessed as part of the planning and design process.

Planning and design steps are the following:

- Understand the use of the site and what infrastructure or assets should be protected.
- Collect and review ice and winter hydrology data.[62] This step provides background for understanding ice behavior at project sites. Additional data to be reviewed include ice thickness, air temperature, and ground, aerial, and satellite photos.

[62] In addition to the ice cover climatology, Stevens Institute produced geospatial data for 2005-2012, available as a compilation of observed ice data probabilistic statistics (ice thickness, percent ice cover, and ice types) based on Coast Guard daily ice reports along the tidal Hudson River during ice season. See https://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/ice-conditions

- Describe the site-specific ice regime. This step provides a description of how the ice is forming and moving at the project site. Where existing, results of hydraulic modeling in ice-free conditions (even though it does not integrate river ice) can be used to describe the expected ice movements and ice floe velocity in the area. The static and dynamic loads are defined at this step.
- For structures, calculate ice loads using standard equations and include conservative safety factors in the stability analysis to account for extreme ice load scenarios.
- Assess ice-related risk. This step defines the level of risk for the area based on the hazard, exposure and vulnerability, as described in section 3.0 above.
- Determine the high-water level, the maximum water level that can be reached during winter when ice is present, and maximum ice height. This is done preferably through a combination of historical hydrological data and on-site observational data. The definition of a high-water level should be based on winter water level measurements and observations – not only ice-free hydrology. At some locations, winter water levels could be higher than ice-free flood levels, due to ice roughness and ice jam conditions (Georgas (2012).

The above steps should result in the proper selection of vegetation; sizing of structures and other construction details.

Note that for shorelines, taking no action, followed by nature-based protection should always be considered before hard armoring (bulkhead, sheet piles, stone revetments). The Hudson River Sustainable Shorelines Project has several case studies of nature-based edge protection that have survived many winters successfully. Species of vegetation must be carefully selected based on their adaptive abilities, including developing a robust root network. Also, the time required for the vegetation to grow and be fully competed must be considered. In other words, a protection method that includes vegetation may not be fully resistant during the first years or following an extreme event (i.e. drought, freeze-thaw, erosive event).

Best Practices

- Take site understanding seriously. Observe nearby natural shores for ice scour lines to understand typical conditions. Assess maximum ice elevation (including potential ice stacking) and design structures accordingly.

- Accommodate ice movement rather than trying to protect against a dynamic load. Use inclined structure faces and mild slopes to promote ice ramping. It promotes ice ramping over crushing and thus reduces horizontal forces. A slope of 3:1 or even milder is common for natural shoreline protection.

- If elements can be designed to be moved, do so. Operations and maintenance costs from removing docks and equipment during the winter season is less expensive over the lifetime of an asset and prevents it from becoming debris with its own dynamic load.

- For nature-based protection, select vegetation that is adapted to local climate and develops a robust root network.

- Consider a rock toe protection for nature-based solutions. Always use shoreline and in-water material that can withstand cold temperatures and ice forces.

- Use water bubblers to keep ice from building up around in-water fixed piers and docks.

- For high-risk sites, hard-engineering methods (i.e., bulkhead, steel sheet pile, stone revetments) are required. The design of these structures includes stability analysis, including normal and extreme ice load scenarios.

- For in-water structures, use round piles instead of square piles. Round piles help reduce the load by promoting ice cracking and square corners are more easily damaged by ice. Use groups of piles, instead of single piles, to divide ice loading.

Summary

Ice issues have always been experienced along the river. The river ice conditions are highly variable from one year to the next and are very site-specific. For every new project on the shoreline, planning should include understanding site-specific uses of the site and what needs to be protected. Ice related risk should be assessed at the project's onset and be included in the design.

Determining the level of risk for the site is based in part on the use and the assets that need to be protected behind the shoreline. This will determine what type of shoreline is most appropriate, from nature-based to a hard-engineered solution.

Compared to other hazards, ice is rarely fully understood at a given site. Therefore, a prudent approach should always be taken when designing a new structure. Ice damage can rarely be completely mitigated, which means that some level of pre-season operational and preventive methods as well as post-season maintenance should be planned.

Glossary

- High-Water Level: maximum water level that can be reached during winter when ice is present.
- Ice Floe: piece of floating river ice.
- Ice Jam: accumulation of fractured river ice that cause an increase of the upstream water level.
- Ice Load: load on a structure induced by ice (static or dynamic).
- Ice Ramping: action of ice that goes upward over an inclined solid element.
- Ice Regime: general description of the ice conditions and behavior on a river.
- Ice Run: sudden movement of river ice, typically during break-up.
- Ice Scour: damage caused by river ice to erodible material.
- Ice Stacking: action of ice that accumulates on a structure or shoreline.

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