Ossining's Waterfront on the Rise

Climate-adaptive Design Studio

Town and VIllage of Ossining

2019

Acknowledgments

We would like to express our deep appreciation for the dedication and input from the Town and Village of Ossining, especially Town Supervisor Dana Levenberg and staff member Victoria Cafarelli, Village Mayor Victoria Gearity, Village Manager Karen D'Attore and Project Manager Jaimie Hoffman. The CaD studio would not have been possible without the insights of the Ossining stakeholders who participated in the process, providing guidance and feedback to the students.

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We would also like to thank the students who participated in the Fall 2019 graduate LA7010 CaDStudio, whose work is displayed here, including Gabriel Curran, Jihany Hassun Catherine Kana, Yuyao Liu, Juwan McIntyre, Marco Rangel, Mark Shrader, Akshai Wilkinson, Lingyi Xu, Dean Yeah, Zikun Zhang and Teaching Assistant Kevin Kim. We recognize the contributions of the engineering students who collaborated with us from Professor Todd Walter's fall 2019 Watershed Engineering course.

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Sincerely,

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Cover Image:
Ecoline, 2019
Zikun Zhang

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Lingyi Hsu

The Climate-adaptive Design (CaD) studio

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The CaD team meets with key community members

Early in the semester
Students collect and review site information

Back on campus
Student design teams begin developing design concepts

Design development
Key stakeholders participate in on-campus studio reviews

Post-semester meeting
The CaD team meets with stakeholders to review designs and discuss next steps

August | September | October | November | December | January

First site visit
The class visits the host community to meet stakeholders and conduct field visits

Design concept workshop
Students meet with stakeholders to discuss early design ideas

Open house
Students share their final designs with stakeholders

Who We Are

Inspiring change for waterfront communities

The Climate-adaptive Design (CaD) studio is a course created by Cornell University Associate Professor Joshua F. Cerra that links landscape architecture and engineering students with Hudson riverfront communities to explore design ideas for more climate resilient and connected waterfront areas.

The CaD studio is an education and research effort made possible by a partnership between the Department of Landscape Architecture, the NYS DEC Hudson River Estuary Program, the NYS Water Resources Institute and host communities in the Hudson Valley.

What We Do

The CaD team wants to help your community...

- Start the conversation on what change could look like on your waterfront.
- Feel inspired and knowledgeable about adapting to climate change, especially by using natural and nature-based solutions.
- Apply CaD concepts and principles in planning and decision making.
- Access new funding and resources.
- Communicate with regulatory agencies.
- Increase public awareness and support for climate adaptation projects.

What's Next

- ☐ Appoint a committee to advance CaD concepts.
- ☐ Host a public event to display CaD materials and inform residents of the CaD design principles.
- ☐ Seek to apply CaD design principles to current projects.
- ☐ Identify CaD design ideas for further study and seek funding to advance designs toward implementation.
- ☐ Seek opportunities to increase local knowledge and capacity for increasing resilience.
- ☐ Consider pursuing Climate Smart Community certification or strive for a higher level of certification.

The Town & Village of Ossining

Making strides toward greater sustainability and resilience

Ossining is a Village of approximately 30,000 people, located in the Town of Ossining in Westchester County on the east side of the Hudson River and north of New York City. The Ossining waterfront hosts a wide variety of uses including residential, industrial, recreational and transportation-related activities. Additionally, the county waste water treatment facility and Sing Sing Correctional Facility are located on the waterfront. A Village-owned park adjoins a Town-owned park and boat club, which are all publicly-accessible amenities. All of these uses are at risk of flooding from the tidal Hudson and its tributary the Sing Sing Kill.

The Town and Village jointly hosted the Ossining CaD studio in the fall of 2019. Both municipalities are making great strides toward greater sustainability and resilience by pursuing or completing comprehensive plans and Local Waterfront Revitalization Plans. The Town is pursuing certification through the NYS Climate Smart Communities Program, and both municipalities recently participated in a Nature Conservancy Community Resilience Building workshop to better understand climate risks.

Bird's-eye view of Ossining Form the Hudson River. Source: *Googe Earth, Landsat/Copernicus*

Climate Risk in Ossining

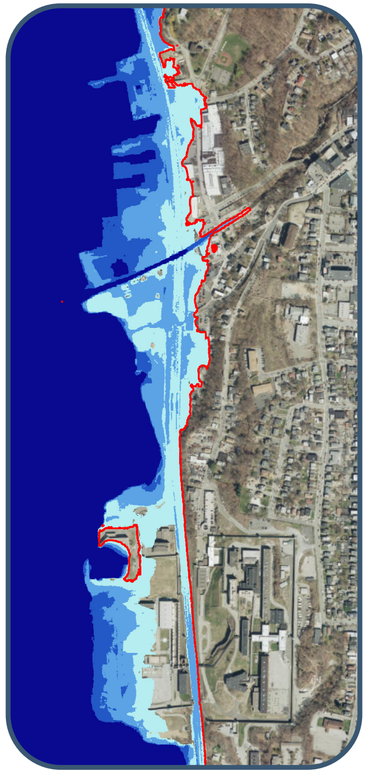
Flooding due to extreme precipitation, stormwater runoff, storm surge and sea-level rise.

Temperature extremes impacting seasonal conditions and causing dangerous heat waves.

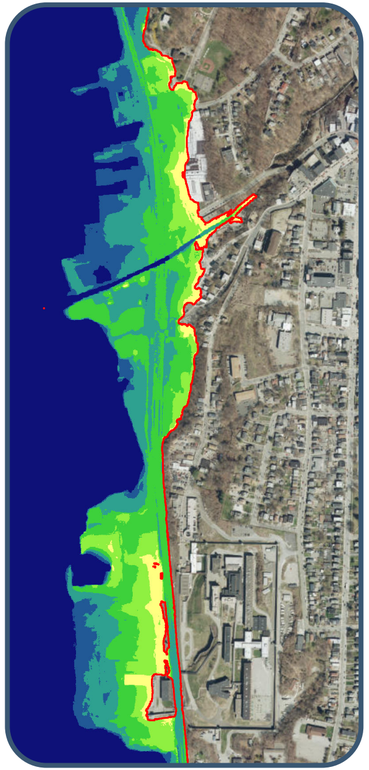
Disrupted precipitation patterns leading to greater likelihood of short-term drought.

Flooding and Sea-level Rise

- The 1% or "100-year" floodplain is defined as a waterfront area that has a 1% chance of flooding in any given year, based on historical data.
- Added up over time, there is a 25% chance of such a flood happening over the span of a 30-year mortgage, making floodplain properties vulnerable to damage.
- These floods are likely to occur more frequently and impact more of the waterfront by the 2050's due to projected sea-level rise and intense precipitation.
- NYS has adopted official projections for sea-level rise that are up to 58" higher than current levels by the the 2080's.



Depths of temporary flooding anticipated in the "100-year" or 1% flood zone on the Ossining waterfront for the present-day baseline condition.



Inundation depths (blue) and temporary flooding depths (green) for the "100-year" or 1% flood condition on the Ossining waterfront with 60"of projected sea-level rise during the 2080's.

Data source: Columbia University Hudson River Flood Impact Decision Support System Version 2

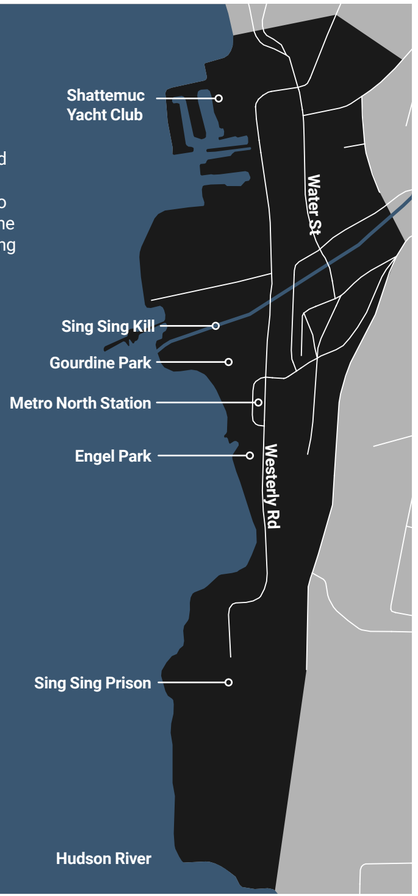
Project Study Area

Westchester County, New York State

Ossining is on the east side of the Hudson River in central Westchester County

Study area is located on the waterfront in the Village of Ossining

The CaD studio focused on the Ossining waterfront during the fall semester of 2019. The study area stretched from Shattemuc Yacht Club in the north, to Sing Sing Correctional Facility to the south and included sites on Water Street, located east of the waterfront. The study area included the Metro North Rail Station, the Village's Henry Gourdine Park, the Town's Louis Engel Park and Ossining Boat & Canoe Club and the future site of the Sing Sing Prison Museum.



Initial meetings with stakeholders helped student teams identify key themes, challenges and opportunities for the study area:

Key Themes

- Enhancing waterfront access and circulation, including elevating key infrastructure.
- Improving connections between the waterfront and the Downtown Business District.
- Ossining is a diverse community and the waterfront is used by residents and visitors alike.
- The Metro North commuter rail line is important to Ossining, as many residents work in NYC.
- Adequate, well-located parking, improved pedestrian mobility and way-finding signage are needed.

Challenges

- Most of the study area is already at flood risk.
- In particular, Sing Sing Correctional Facility west of the train tracks, the Westchester County Wastewater Treatment Facility and Metro North Railroad are at acute flood risk, posing public health and safety challenges.
- New York State official sea-level rise projections indicate that some areas will be inundated in the future.
- Steep slopes to the east of the waterfront pose constraints to addressing circulation and relocation options.

Opportunities

- Tourism and residential development are increasing.
- The Sing Sing Prison Museum, which is under development on the waterfront, is expected to attract thousands of visitors.
- Recent improvements to boating infrastructure have enhanced access for non-motorized boaters and larger vessels.
- The Village is seeking to convert a site on Water Street into a mixed-use/mixed-income development.
- The Town is seeking support to create a Master Plan and upgrade facilities at their waterfront park.

Section 1

Section 2

Design Strategies

Section 3

Sing Sing Fugue, 2019
Jihany Hassun

CaD Principles

The CaD studio focuses on five key principles in its approach to waterfront design. These principles guide student work and inform the concepts they develop.

Design a Destination
Maximize the value of what a waterfront can be

Design for Flooding
Working with water may be better than working against it

Design with Community
Waterfronts should be universally accessible and decidedly memorable

Design with Nature
A healthy Hudson is good for us and the greater ecology

Design for Change
Build value into waterfronts as they change over time

Ten student teams created comprehensive designs for the study area, which can be viewed in detail at https://trophic.design/cad/. In their designs, students explored a number of strategies that employ the CaD principles. The following pages provide brief introductions to design strategies that Ossining can explore.

Before You Turn the Page...

Each strategy comes along with Actions to Take -some that you can do today and others that will take more time and planning to implement.

Each strategy also features student work to visualize possible ways they could be used in Ossining.

Five icons flag important facts about each strategy. Descriptions about these types of information are detailed here:

+ This section describes how the strategy can create benefits both for people and the ecosystems in Ossining.

$ Click here or go to page 29 to find sources of funding.

! Important considerations for each strategy are indicated by this icon.

CSC These numbers correspond to Climate Smart Community Actions that can earn points for your city. Click on the icon or visit page 30 to learn more.

? For more information about a strategy, explore the references in this section, located on page 28.

If you are viewing the LookBook on the computer, click the icon to see more information!

Resilient Waterfront Parks

Waterfront parks are an excellent choice for flood-prone areas - they offer recreational opportunities, shoreline access and wildlife habitat, while reducing vulnerability and risk. Waterfront parks should be designed with input from end-users to meet the needs of the community and be universally accessible to people of diverse abilities, needs and resources. The park landscape can accommodate floodwaters and be graded to quickly drain after storm events.

The Ossining waterfront includes the Town's Lewis Engel Park and Boat & Canoe Club and the Village's Henry Gourdine Park. The properties experience flooding today and are projected to become more vulnerable in the future. The Town is pursuing funding for an Engel Park master plan and will consider sea-level rise in designs.

Actions To Take

- ☐ Consult resources such as the Guidelines for NYC Parks to analyze the resilience and accessibility of current waterfront parks.
- ☐ When establishing new parks and promenades in future flood-prone areas, identify flood-adapted uses and features that can recover quickly from storm impacts.
- ☐ The design of a floodable park should include recommendations for flood-resilient plants and trees.
- ☐ Review policies and procedures of the parks department and revise as needed to require more climate-adaptive and sustainable practices.
- ☐ Evaluate the feasibility of installation of green infrastructure to capture stormwater when designing or evaluating waterfront parks.

+ Naturalized land cover helps to keep urban areas cooler and allows stormwater to infiltrate while providing habitat for wildlife and health benefits for people.

$ DEC HREP || DEC CSC || EFC GIGP || DOS LWRP || OPRHP || Hudson River Valley Greenway

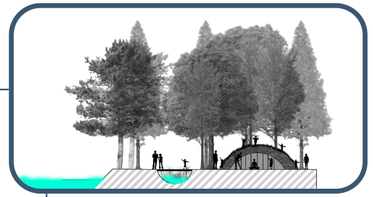
! The term "green gentrification" describes inequities caused by environmental improvement projects. Greening of urban areas may increase local property values, which displaces lower-income residents. Municipalities can protect residents by enacting rent control laws, increasing affordable housing availability and working with a Community Land Trust to promote home ownership.

CSC 7.12 Conserve, Re-vegetate & Reconnect Floodplains || 7.14 Strategic Relocation Of Non-Water Dependent Uses || 7.16 Green Infrastructure for Stormwater Management || 7.18 Nature-Based Shoreline Protection

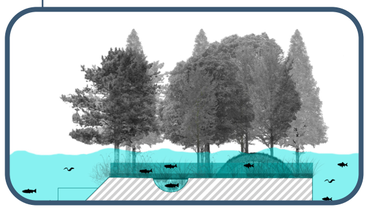
? Design and Planning for Flood Resiliency: Guidelines for NYC Parks
High Performing Landscape Guidelines: 21st Century Parks for NYC
Naturally Resilient Communities

Ecoline, 2019
Zikun Zhang

Flexible open space can be periodically inundated by flooding without major infrastructure impacts. Flood-tolerant vegetation provides habitat and aesthetic benefits.



True Urban, 2019
Juwan McIntyre



Anticipating that site conditions will change over time, students speculated on the potential for park improvements to have evolving purposes with changing conditions. In this example, land shaping and specialized equipment has recreational uses in the near term. Later, as sites undergo projected inundation due to sea level rise, these same improvements could provide aquatic habitat.

Josh Cerra

Waterfront park & promenade at Hunter's Point South, Long Island City, provides an example of a flood-resilient park that is accessible and provides a memorable destination for visitors.

A Latent Buffer for Ossining, 2019
Lingyi Xu

Park spaces can have a flexible program and compatible infrastructure that allows for periodic flooding.

Sustainable Shorelines

Nature-based shoreline techniques provide erosion control using methods that incorporate living material and limit disturbance of existing habitat. These design techniques often provide ecological benefits, recreational assets and opportunities for water-dependent businesses. In wide, gently sloped areas, sustainable shorelines can provide pathways for wetland migration as sea levels rise.

Much of the shoreline of Ossining in the study area has been hardened with bulkheads and riprap. Previously hardened shorelines that are protecting dense development or key infrastructure may be not be suitable for nature-based shoreline techniques but can still be enhanced with ecological features.

Actions To Take

- ☐ Read *Managing Shore Zones for Ecological Benefits* on the Hudson River Sustainable Shoreline website.
- ☐ Explore the NYS Department of State's Living Shorelines page on the Geographic Information Gateway.
- ☐ Check out shoreline habitats with the Hudson Valley Natural Resource Mapper.
- ☐ Consider recommendations in the Waterfront Alliance's Waterfront Edge Design Guidelines (WEDG).
- ☐ Track changes in your shoreline using the Rapid Assessment Protocol Manual and Field Sheets found on the Sustainable Shorelines website.
- ☐ Consider the need for ongoing monitoring and maintenance.

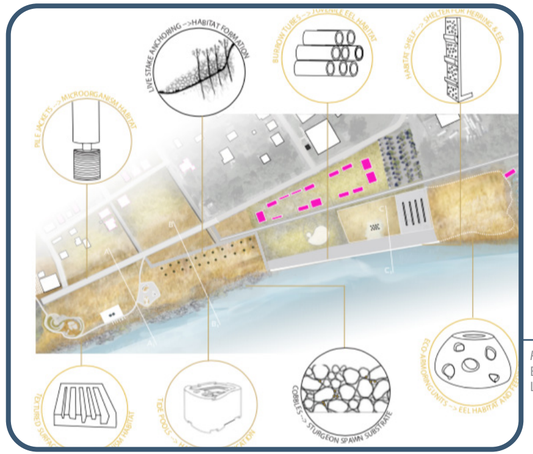
+ Sustainable shorelines can provide cost-effective erosion control while enhancing aesthetics, ecological function and habitat value of a waterfront area.

$ DEC HREP || DOS LWRP || OPRHP || Hudson Valley Greenway

! Designing a sustainable shoreline is a methodical and intentional practice that considers the needs of people, wildlife and the natural systems upon which we all depend.

CSC 7.11 Adopt A Floodplain Management Protection Ordinance || 7.12 Conserve, Re-vegetate & Reconnect Floodplains || 7.13 Conserve Natural Areas || 7.18 Use Nature-Based Shoreline Protection

?
Hudson River Sustainable Shorelines
NYS DOS Geographic Information Gateway Living Shorelines
Hudson Valley Natural Resource Mapper
Waterfront Alliance's WEDG
Rapid Assessment Protocol Manual and Field Sheets



Ponckhockie's Working Waterfront, 2018
Eve Anderson
Liz Fabis

A student design team during a prior Kingston studio proposed adding habitat complexity to bulkheads and sheet pilings with enhancements that add textured surfaces and shelf and burrow tube retrofits to bulkheads and pilings.

Tracing Place; Shifting Shores, 2019
Marco Rangel

Combining 'soft' features, such as tree and shrub plantings, along with 'hard' features like riprap can help stabilize shorelines while adding ecological benefits.

Josh Cerra

Waterfront park & promenade at Hunter's Point South, Long Island City. Riprap protecting the shoreline is gently sloped and is adjacent to plantings.

Strategic Relocation & Adaptive Reuse

Key assets at high risk for damage or permanent loss under current and projected flooding and sea-level rise should be relocated out of the flood zone. Alternatively, some structures may be repurposed or adapted to reduce flooding and inundation impacts. These kinds of interventions may benefit from enhanced zoning ordinances, policy measures or incentive programs to facilitate the transition of waterfronts to more adaptive and resilient uses and features.

The Village of Ossining can begin exploring options for funding strategic relocation of at-risk infrastructure and properties now to be prepared for future flooding. Options such as FEMA buy-outs and Transfer of Development Rights may provide solutions for repetitive loss properties.

Actions To Take

- ☐ Identify municipally-owned assets that are at high risk from flooding.
- ☐ Identify properties that have been repetitively damaged from flooding.
- ☐ Explore potential for Transfer of Development Rights (TDR) to steer development toward safe locations.
- ☐ Create a plan for the relocation of municipally-owned assets, (see Westchester County Hazard Mitigation Plan) to improve funding options through FEMA.
- ☐ Identify partnerships and funding opportunities to relocate municipally-owned assets and assist private property owners with relocation efforts.

+ Transitioning residences, businesses, infrastructure and services out of the flood zone reduces risk. Returning floodplain functions provides benefits to people, wildlife and waterways.

$ DEC HREP || DEC CSC || DOS LWRP || FEMA || HUD CDBG

! A just and equitable approach to strategic relocation is critical to its successful implementation.

CSC 7.14 Strategic Relocation Of Non-Water Dependent Uses

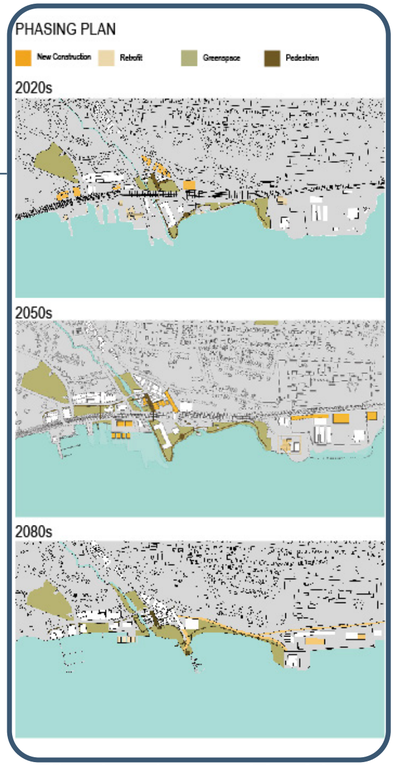
? Climigration Network
NYS Governor's Office of Storm Recovery Buyout & Acquisition Programs
NYS Department of State Transfer of Development Rights Technical Bulletin

River Guards, 2019
Cat Kana

This drawing visualizes a future waterfront that has transitioned from flood susceptible infrastructure at the mouth of the Sing Sing Kill to a public plaza, wetlands and a naturalized shoreline, along with flood-adapted and strategically-located waterfront uses.

Step Back, Step Up, Move Forwards, 2019
Mark Schrader

In this vision of the 2080 waterfront the oil transfer facility, county waste water treatment plant and the east section of Sing Sing Correctional Facility have all been relocated to higher ground. The marina has moved to the former site of the correctional facility to maintain water-dependent, recreational opportunities along the waterfront.



This student project proposed phased plans to move buildings and infrastructure out of areas at greater risk of flooding and inundation due to projected sea-level rise.

Flood-Adapted Structures

If a structure is located in a flood-prone area, there are a number of actions that can be taken to reduce risk of damage. Options range from elevating an entire structure above the reach of floodwaters, to raising utilities within a building to keep them dry under flood conditions. Property owners can take steps to seal a building off from water or create conditions that allow the floodwaters to enter and exit with minimal disruption. Flood insurance rates may be reduced by flood-proofing or elevating buildings.

At-risk buildings in the current and/or future 100-year floodplain can be retrofitted using flood adaptation techniques if strategic relocation is not feasible.

Actions To Take

- Become familiar with the NYS official sea-level rise projections.
- Conduct or update vulnerability assessments to identify key assets located in the current and future flood zones.
- Raise utilities (outlets, HVAC, etc.) to the 2080's 500-year flood height on municipal properties on the waterfront.
- Evaluate the long-term costs and benefits of flood-adapting vs. strategic relocation in flood-prone areas.
- Consider extending where additional two-foot freeboard restrictions on first-floor uses are required by local zoning code.
- See the NYS Community Risk and Resiliency Act (CRRA) guidance for model local laws.

+ Increasing the resilience of structures located in flood-prone areas has many benefits including reduction of hazards during and after floods, greater ability to return to functionality after a flood event and cost savings from avoided damages.

$ DEC OCC || WQIP (for waste water treatment plants) || FEMA || HUD CDBG

! Communities should consider sea-level rise projections when planning for future flood risk. FEMA recommends considering raising new residential structures to the 500-year flood elevaton in high-risk flood zones.

CSC 7.1 || 7.14 || 7.19

? NYS DEC Community Risk & Resiliency Act Model Local Laws
FEMA: Floodproofing Non-Residential Buildings
FEMA: Designing For Flood Levels Above Base Flood Elevation (BFE)

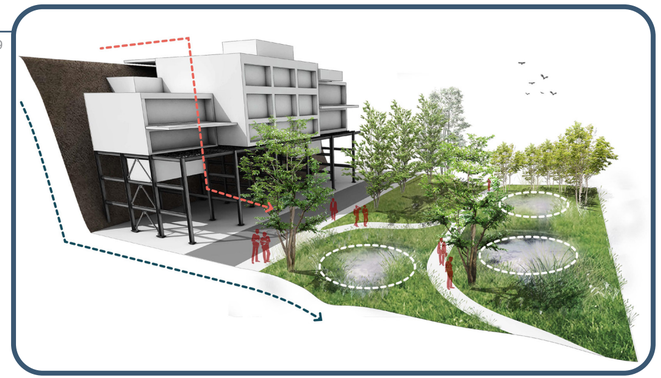
A Latent Buffer for Ossining, 2019
Lingyi Xu

The drawing depicts a possible retrofit of Harbor Square apartments to improve flood resilience. The first floor of the building is converted to non-residential uses that accomodate floods while minimizing damage to life and property. Several techniques can be used to adapt first floors to floodable uses including elevating all utilities to higher floors, installing vents or large doors to allow outflow of water as a floods recede and using water-resistant materials for walls and floors.

Libby Zemantis

The Clearwater Home Port in Kingston is an example of a flood-adapted structure. Note the large doors that can be opened to allow floodwaters to move in and out of the building. Concrete floors and other water-resistant materials aid in rapid recovery after a flood.

Ecoline, 2019
Zikun Zhang



This schematic drawing depicts a proposed sunken garden that captures stormwater from buildings and paved areas. New construction is elevated, allowing for potential floodable uses below such as parking and gathering spaces.

Resilient Roadways and Infrastructure

Roadways and rail lines can be vulnerable to flooding if they are located in close proximity to waterways. Bridges and culverts may contribute to flooding by restricting water flow during heavy precipitation. Infrastructure that is frequently flooded may need to be elevated or relocated to improve safe access under all conditions. A 'complete street' approach to new roadway design considers pedestrians, bicyclists and other users in addition to motor vehicles. Nature-based features, like rain gardens and bioswales, can be strategically placed to absorb stormwater from paved roadways and parking lots.

Students considered the resilience of infrastructure, such as the rail line and Metro North Train Station, the Westchester County Wastewater Treatment Plant and roads connecting the waterfront to downtown.

Actions To Take

- Identify vulnerable roadways and infrastructure.
- Develop an inventory and prioritization plan for infrastructure upgrades.
- Include upgrades in your municipality's capital improvement plan.
- Make sure that infrastructure upgrades are included in your municipality's FEMA Hazard Mitigation Plan.
- Consider use of pervious surfaces when designing roadways, paths and parking lots.
- Learn more about the Hudson Estuary Culvert Prioritization Project, which may provide assistance in identifying culverts that are contributing to flooding and/or pose barriers to aquatic migration.

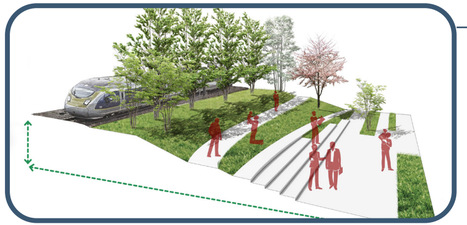
+ Green street design tools, which integrate stormwater control and management within the right-of-way, are a critical component of complete street design, ensuring the street remains usable and safe for all people during storm events, regardless of mode.

$ DEC HREP, DEC CSC, WQIP (aquatic connectivity restoration), EFC GIGP, FEMA

! Communities that identify flood-prone roads and infrastructure in their Hazard Mitigation Plans may be eligible for FEMA funding to mitigate these problems after a declared disaster.

CSC 7.21

? Hudson Estuary Culvert Prioritization Project
U.S. Climate Resilience Toolkit: Rebuilding Roadways to Maximize Resilience
NYS DEC Stream Crossings Best Management Practices



Ecoline, 2019
Zikun Zhang

This drawing depicts a proposed terraced levee system for raising the railroad tracks to limit increased risk of flooding due to sea level rise.

Unlocking the Ossining Waterfront, 2019
Dean Yeh

A "complete streets" approach offers non-motorized transportation options and includes trees and other plantings help absorb storm water while increasing shade.

A Latent Buffer for Ossining, 2019
Lingyi Xu

These images envision elevating tracks to allow water to flow freely beneath them during flooding while community uses can take place beneath the rail during dry periods.

Green Infrastructure

Green infrastructure (GI) enhances or mimics characteristics and processes of the natural landscape. These practices employ naturalized land cover to maintain or restore the pre-development flow patterns of stormwater at a site by allowing runoff to soak into the soil. On a regional scale, green infrastructure includes preserving and restoring natural landscape features, along with reducing impervious cover. At the site scale, green infrastructure includes practices that capture stormwater runoff such as vegetated swales, infiltration planters, green roofs, pervious pavement and rain barrels. These practices allow water to soak into the soil to be used by plants or to recharge groundwater. Nature-based features typically provide additional co-benefits like improving water quality or providing habitat.

Actions To Take

- ☐ Become familiar with GI techniques by reviewing chapter 5 of the *NYS Stormwater Management Design Manual.*
- ☐ Visit GI in the Hudson Valley using the *NYS DEC's Green Infrastructure Examples* website to identify locations.
- ☐ Read Newburg's *GI Feasibility Report* for an example of planning for GI.
- ☐ Complete an analysis to prioritize locations that would benefit the most from GI.
- ☐ Require new development to conserve existing natural features and use GI before traditional pipe-and-gutter solutions.
- ☐ Add GI to municipal properties.

+ Green infrastructure can improve water and air quality, store carbon, enhance habitat diversity and cool urban areas during hot times of the year.

$ DEC HREP || DEC CSC || DEC WQIP || EFC GIGP

! Green infrastructure projects should be sited in locations that will maximize stormwater benefits and minimize the potential for gentrification of nearby neighborhoods.

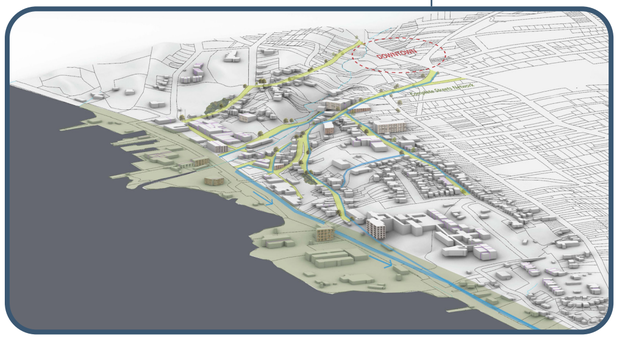
CSC 6.8 Green Parking Lots || 6.9 Complete Streets || 7.8 Shade Structures in Public Places || 7.16 Green Infrastructure for Stormwater Management

?
NYSDEC's GI in the Hudson River Valley
NYS's Stormwater Management Design Manual
A GI Guide for Small Cities, Towns and Rural Communities
City of Newburgh's Green Infrastructure Feasibility Report

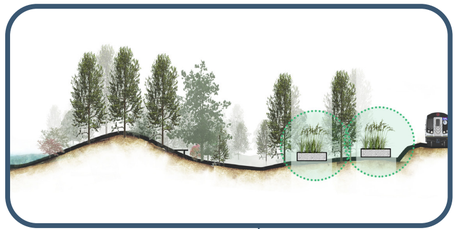
Sing Sing Fugue, 2019
Jihany Hassun

This image depicts a wetland area that can enhance habitat value and add aesthetic interest on waterfronts.

Remix of GI, 2019
Yuyao Liu



A "green corridors" concept that includes installation of green infrastructure along roadways within new development projects to connect the Downtown Business District to the waterfront.



Remix of GI, 2019
Yuyao Liu

Sections of the railroad tracks are protected by a combination of berms and nature-based features including trees and stormwater planters.

Kingston Riverway, 2016
Mark J. Hirschbeck
Ilia Savin

This image from a prior studio in Kingston, NY depicts urban trees and other types of green infrastructure that contribute to the aesthetic and vitality of a neighborhood.

Section 2

Section 3

Looking Ahead

Sing Sing Fugue, 2019
Jihany Hassun

Next Steps

- ☐ Learn more about protecting and restoring the Hudson River estuary on pages 26 & 27.
- ☐ Explore the design strategy references on page 28.
- ☐ Research funding opportunities listed on page 29.
- ☐ Share this Look Book with municipal staff, elected officials, planning boards, waterfront stakeholders and other interested people.
- ☐ Consider joining the Hudson River Flood Resilience Network of municipalities.
- ☐ Stay in touch and contact us with ideas, questions or if you are in need of assistance.

Keep in Touch!

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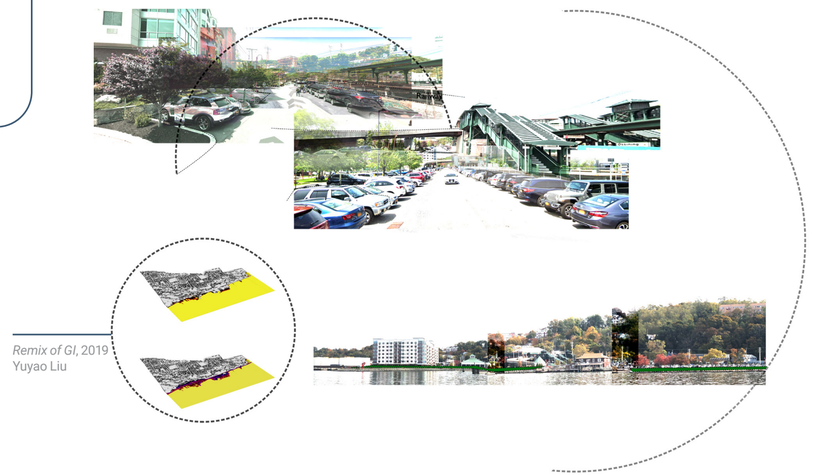


Remix of GI, 2019
Yuyao Liu

Protecting The River That Connects Us

The Hudson Estuary

The Hudson flows for 314 miles from the Adirondack Mountains to New York Harbor. For half of its length, the Hudson is an estuary, a place where salt and fresh water mix. Tides from the Atlantic Ocean reach over 150 miles upstream of New York City to the City of Troy.

Estuaries are nurseries for ocean fish like striped bass, American shad and Atlantic sturgeon, which swim into the river to lay their eggs each spring. In this way, the health of the Hudson is directly connected to the abundance of fish in the ocean.

In the past, much of the Hudson shoreline was characterized by shallow water habitats that provided ample food and shelter for fish and wildlife, which also supported the well-being of human inhabitants[1].

A History of Human Development

The Hudson's natural shorelines have been altered by human development over the past 200 years. An inventory of shoreline types by NYSDEC found that nearly half of the shoreline from the Mario M. Cuomo Bridge to the Troy dam has been altered by bulkheads and riprap, dikes and other hard structures intended to protect property from erosion or to facilitate industry, transportation or cultural use[2].

Comparisons between modern and historic maps have estimated that 71 miles of shoreline in the upper estuary were eliminated when shallows and backwaters were filled during construction of the federal navigation channel. The loss of natural shorelines and shallow water habitats have impacted ecosystem function and fish populations[2].

Looking Into the Future

How communities respond to sea-level rise will affect the health of the Hudson. Protecting against flooding by building hard structures like sea walls and levees can lead to unintended consequences. When barriers are overtopped by floodwaters serious damage can occur. Hard structures may increase erosion and flooding of adjacent areas and do not commonly provide habitat value.

If your community has critical infrastructure that may require the protection of hard structures, a good reference to start with is 10 Questions to Ask When Building Defenses to Protect Hudson River Shorelines.

It is important to meet with the NYSDEC Regional Permits Program early in the planning stage of any waterfront project to understand shoreline protection regulations.

Flicker Filmworks

Sources:
1- Miller, Daniel E., 2013. Hudson River Estuary Habitat Restoration Plan. NYSDEC, Hudson River Estuary Program. https://www.dec.ny.gov/docs/remediation_hudson_pdf/hrhrp.pdf
2- Partners Restoring the Hudson. 2018. Hudson River Comprehensive Restoration Plan: Recommendations for the NY-NJ Harbor & Estuary Program Action Agenda and the NYS Hudson River Estuary Action Agenda. NY, NY The Nature Conservancy. http://thehudsonweshare.org/wp-content/uploads/2018/07/Hudson_River_Report_Final_August-2018_s.pdf

The Future of Hudson Habitats

Sea-level Rise and Tidal Marshes

The Hudson estuary currently includes over 7,000 acres of tidal wetlands, which protect shorelines, trap greenhouse gases that contribute to climate change, and help keep water clean. Freshwater, tidal wetlands - like those in the northern reaches of the estuary - are globally rare and very valuable to young fish and other animals.

Sea-level rise is influencing where tidal wetlands can flourish, with some mudflats and marshes likely to become submerged by rising waters. If sediment accumulation, or accretion, keeps pace with rising waters, wetlands may persist. Marsh plants may be also be able to migrate inland to maintain optimal conditions as sea-level rises. In many areas --like the Ossining waterfront - marsh migration is at odds with human uses, requiring thoughtful decisions about where to site and maintain waterfront development.

Protecting Marsh Migration Pathways

Scenic Hudson's Protecting the Pathways is a climate change adaptation initiative for tidal wetlands in the Hudson River Estuary. Their Hudson River Sea-level Rise & Marsh Migration Mapper predicts wetland areas that will be gained or lost under different sea-level rise and sediment accretion scenarios. The mapper also indicates where development could prevent marshes from migrating inland to maintain viability.

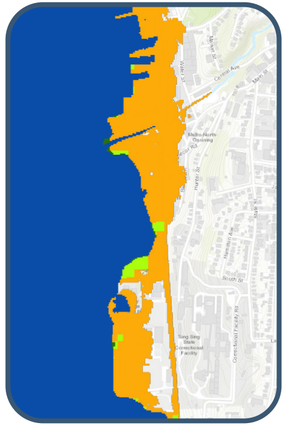
We recommend that communities consult the Sea-level Rise and Marsh Migration Mapper when contemplating development decisions on their waterfronts. This tool can be used to prioritize areas to protect in an effort to conserve current and future marsh habitats.

Restoring Hudson's Habitats

Initiatives to protect natural landscapes and to restore critical habitats are ongoing. Land use ordinances, dam removals, re-vegetating stream banks and wetland restoration efforts are important to the future of the estuary.

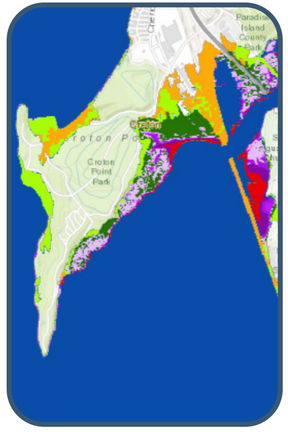
The Hudson River Comprehensive Restoration Plan, was produced in 2018 by a consortium of NGO's, public agencies, municipalities and academic institutions. The plan includes an assessment of current conditions and sets goals for ecosystem restoration and community resilience.

Learn more at http://thehudsonweshare.org/.



This map depicts the potential for marsh migration in the Ossining CaD study area. The color green depicts areas of new wetland and orange depicts areas where develoment conflicts with the establishment of new wetlands, even though the topography is ideal for the growth of marsh plants as sea-level rises.

Map source: Scenic Hudson Sea-level Rise & Marsh Migration Mapper



Projected conditions just upriver on Croton Point in 2100 under a high sea-level rise, high sediment accumulation scenario. Light green indicates new wetland and dark green indicates persistent wetland. Purple indicates potential wetland loss - the darker shades indicate greater chance for wetland loss, with the red areas most likely to be lost. Map source: Scenic Hudson Sea-level Rise & Marsh

Design Strategy References

Resilient Waterfront Parks	Design and Planning for Flood Resiliency: Guidelines for NYC Parks	tinyurl.com/NYCParks-DesignforFloods
	High Performing Landscape Guidelines: 21st Century Parks for NYC	tinyurl.com/NYCParksSustainableDesign
	Naturally Resilient Communities	nrcsolutions.org/
Sustainable Shorelines	Hudson River Sustainable Shorelines	tinyurl.com/SustainableShorelines
	NYS DOS Geographic Information Gateway Living Shorelines	http://opdgig.dos.ny.gov/index.html#/storyTemplate/11/1/1
	Hudson Valley Natural Resource Mapper	www.dec.ny.gov/lands/112137.html
	Rapid Assessment Protocol Manual	https://tinyurl.com/RapidAssessmentProtocol
	Waterfront Edge Design Guidelines (WEDG)	http://wedg.waterfrontalliance.org/resources/#manual-and-guidelines
Strategic Relocation & Adaptive Re-use	Climigration Network	www.climigration.org/
	NYS GOSR Buyout & Aquisition Program	https://stormrecovery.ny.gov/housing/buyout-acquisition-programs
	NYS DOS Transfer of Development Rights Technical Bulletin	www.dos.ny.gov/lg/publications/Transfer_of_Development_Rights.pdf
Flood Adapted Structures	NYS Community Risk and Resilience Act Model Local Laws	https://tinyurl.com/NYSCRRA
	FEMA: Floodproofing Non-Residential Buildings	https://www.fema.gov/floodproofing
	FEMA: Designing for Flood Levels Above the BFE	https://tinyurl.com/elevateBFE
Resilient Roadways & Infrastructure	Hudson Estuary Culvert Prioritization Project	https://tinyurl.com/y4kywkok
	U.S. Climate Resilience Toolkit: Rebuilding Roadways to Maximize Resilience	https://toolkit.climate.gov/case-studies/rebuilding-roads-maximize-resilience
	NYS DEC Stream Crossings: Best Management Practices	https://www.dec.ny.gov/permits/49066.html
Green Infrastructure	GI Examples for Stormwater Management in the Hudson Valley	https://www.dec.ny.gov/lands/58930.html
	NYS's Stormwater Management Design Manual	https://www.dec.ny.gov/chemical/29072.html
	A GI Guide for Small Cities, Towns and Rural Communities	https://tinyurl.com/roeo8hc
	City of Newburgh GI Fesibility Report	https://tinyurl.com/yytv4tg3

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% match	•	•			•	•
	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	•	•				
	Public Assistance	N/A			•			
	Community Rating System (CRS)	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						•

Relevant Climate Smart Community Actions

Get points and funding projects related to CaD concepts through the state's Climate Smart Communities certification program. See related actions below and learn more at: https://climatesmart.ny.gov/

Pledge Element 6: Reduce greenhouse gas emissions through use of climate-smart land-use tools

6.1	Develop and adopt a comprehensive plan with sustainability elements
6.2	Incorporate smart growth principles into land-use policies and regulations
6.3	Adopt a renewable energy ordinance
6.4	Establish green building codes
6.5	Create resource-efficient site design guidelines
6.6	Incentivize renewable energy and energy efficiency projects
6.7	Adopt land-use policies that support or incentivize farmers' markets, community gardens and urban and rural agriculture
6.8	Adopt green parking lot standards
6.9	Adopt a complete streets policy
6.10	Implement strategies that support bicycling and walking
6.11	Install electric-vehicle infrastructure
6.12	Implement strategies that increase public transit ridership and alternative transport modes
6.13	Implement a Safe Routes to School program
6.14	Implement traffic calming measures
6.15	Adopt and enforce an anti-idling ordinance
6.16	Implement transportation technology solutions
6.17	Develop a natural resource inventory
6.18	Develop a local forestry or tree planting project or program
6.19	Preserve natural areas through zoning or other regulations

Pledge Element 7: Plan for adaptation to unavoidable climate change

7.1	Conduct a vulnerability assessment
7.2	Develop a climate resilience vision and associated goals
7.3	Review existing community plans, policies and projects to identify climate adaptation strategies and policies or projects that may decrease vulnerability
7.4	Develop climate adaptation strategies
7.5	Incorporate climate resiliency vision, goals, and strategies into local plans and projects
7.6	Update the multi-hazard mitigation plan to address changing conditions and identify specific actions to reduce vulnerability to natural hazards
7.7	Develop and implement a heat emergency plan
7.8	Require shade structures and features in public spaces
7.9	Open new or expand existing cooling centers
7.10	Create or update a watershed assessment to identify flooding and water quality priorities
7.11	Adopt a floodplain management and protection ordinance to reduce vulnerability to flooding and erosion
7.12	Conserve, revegetate and reconnect floodplains and buffers in riparian areas
7.13	Conserve natural areas for species migration and ecosystem resilience
7.14	Facilitate a strategic relocation of uses that are not water dependent from flood prone areas
7.15	Promote community flood prevention strategies through the National Flood Insurance Program Community Rating System
7.16	Use green infrastructure to manage stormwater in developed areas
7.17	Conserve wetlands and forests to manage stormwater, recharge groundwater and mitigate flooding
7.18	Use natural, nature-based or ecologically enhanced shoreline protection
7.19	Extend areas in which the two foot freeboard requirement applies
7.20	Require consideration of sea-level rise in planning coastal development
7.21	Right-size bridges and culverts and remove unnecessary and hazardous dams
7.22	Develop or enhance early warning systems and community evacuation plans
7.23	Implement a water conservation and reuse program
7.24	Encourage xeriscaping
7.25	Implement a source water protection program

More Information on Climate Change in the Hudson River Valley

Websites	URL
Resources for resilience	tinyurl.com/resilienceres
Hudson River Sustainable Shorelines	hrnerr.org/hudson-river-sustainable-shorelines
NY Climate Smart Communities	climatesmart.ny.gov/
Hudson River Estuary Program grants	www.dec.ny.gov/lands/5091.html
Adaptation Clearinghouse	adaptationclearinghouse.org/
NY Community Risk and Resiliency Act (CRRA)	www.dec.ny.gov/energy/102559.html
Estuary Program's Climate Resilience webpage	www.dec.ny.gov/lands/39786.html
CaD studio Designs fromr host communites	https://trophic.design/cad/

Interactive Maps	
Hudson River Flood Mapper	www.ciesin.columbia.edu/hudson-river-flood-map/
Protecting the Pathways, Scenic Hudson	https://arcg.is/1jbXG4
Sea-level Rise Mapper, Scenic Hudson	scenichudson.org/slr/mapper
NYS Department of State Geographic Information Gateway	http://opdgig.dos.ny.gov/index.html#/map/resilience

Publications	
Financing waterfront resilience fact sheet	tinyurl.com/finres
Revitalizing Hudson Riverfronts, Scenic Hudson	tinyurl.com/CSCvideoSLR
New York City's Urban Waterfront Adaptive Strategies	http://goo.gl/7swlpa
Flood Adaptation Strategies for Hudson Riverfront Communities	www.slideshare.net/hrepclimate/flood-adaptation-strategies
NYSERDA's Responding to Climate Change in New York ClimAID	www.nyserda.ny.gov/climaid
Hudson River Estuary Habitat Restoration Plan	https://www.dec.ny.gov/docs/remediation_hudson_pdf/hrhrp.pdf
Hudson River Comprehensive Restoration Plan	http://thehudsonweshare.org/about-the-plan/

Videos	
Sustainable Shorelines	tinyurl.com/CSCvideoSS
Planning for Sea-level Rise	tinyurl.com/CSCvideoSLR
Climate-adaptive Design	tinyurl.com/CSCvideoCAD