The Hudson River Sustainable Shorelines Project

Jon K. Miller, Ph.D. and Andrew Rella
Stevens Institute of Technology

And a cast of thousands including: Betsy Blair, Emilie Hauser, Dan Miller, Stuart Findlay, Dave Strayer, Kristen Marcell, Ona Ferguson, Nickitas Georgas, and …

Cary Institute of Ecosystem Studies, Consensus Building Institute, Hudson River National Estuarine Research Reserve, New York State Department of Environmental Conservation, Stevens Institute of Technology, and other partners

The Hudson River National Estuarine Research Reserve, with the involvement of many partners, launched the Sustainable Shorelines Project in 2008 to provide ***science-based information about the engineering, economic, and ecological tradeoffs*** among shoreline management options, given likely future conditions. New work is focusing on how aspects of structures that can be manipulated, such as the roughness of the substrate used, and the vegetative cover, to increase ecological benefits. The project will also increase our understanding of how physical forces are reshaping shorelines, develop innovative shoreline demonstration sites, and integrate project results into a decision support tool.

Overarching objectives

1. Characterize present and future estuary and shoreline conditions
2. Determine ecological, engineering, and economic trade-offs of shoreline management options
3. Characterize shoreline decision-making arenas and opportunities
4. Demonstrate innovative shorelines and best management practices
5. Create shoreline decision tools and communicate results

Hudson River Estuary Tidal Wetlands

Some of the tasks to date:

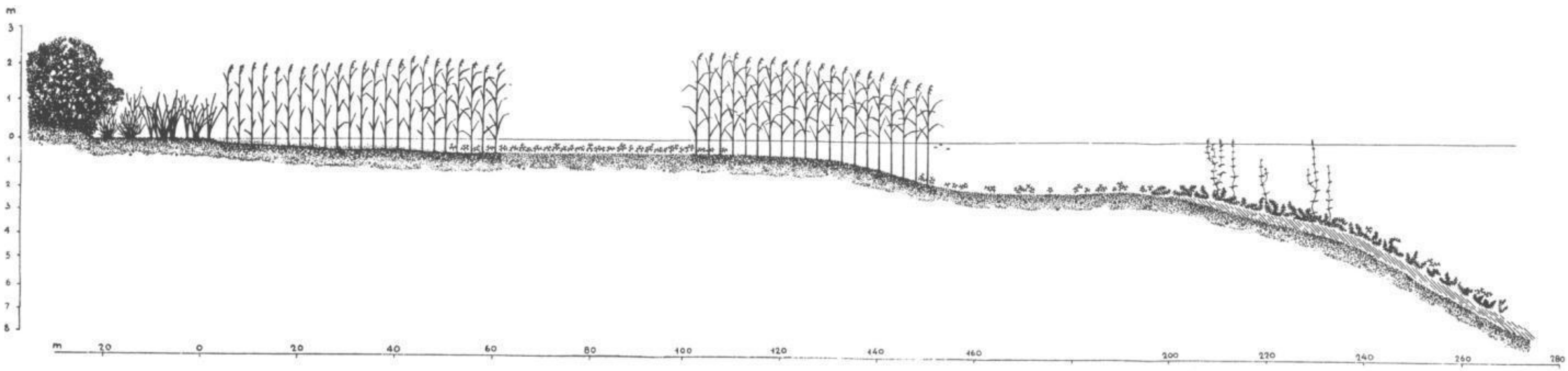
- Review of legal instruments for shore zone protection (Pace University)
- Models of storm surges following sea level rise (Jery Stedinger, Cornell)
- Terminology defined (Emilie Hauser, HRNERR/DEC)

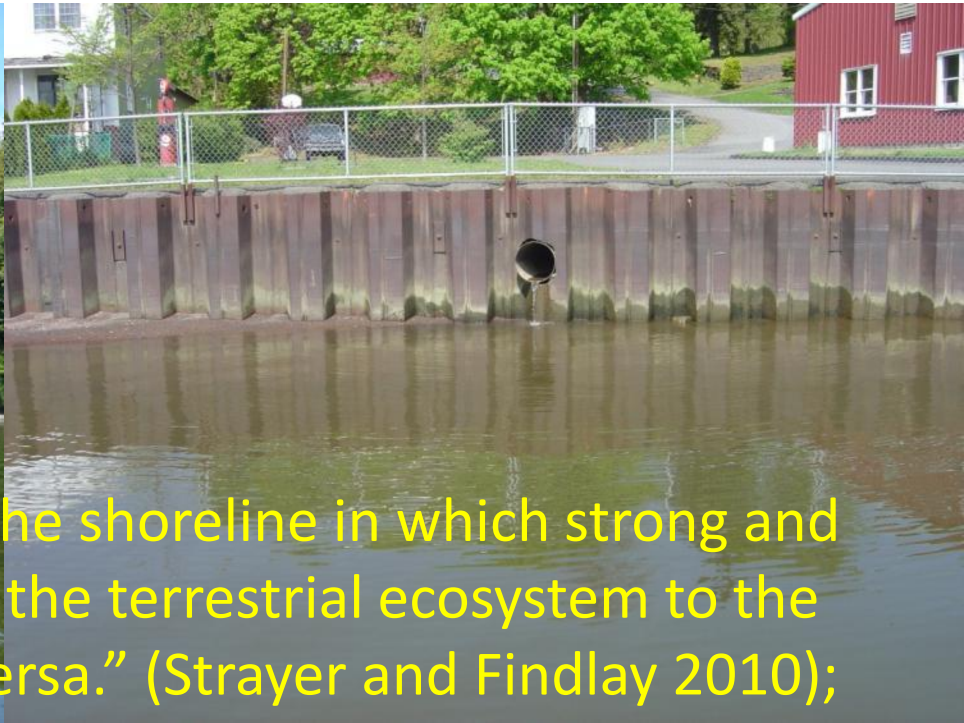
“Sustainable Shorelines”

Shoreline management practices that seek to protect the shore zone’s wildlife habitat, ecological benefits, outdoor recreation, community quality of life, and water-dependent businesses for future generations.

Should be: adaptable & ecologically enhanced
Includes: “soft” and “hard”

“Shore Zone”





The “region closely adjoining the shoreline in which strong and direct interactions tightly link the terrestrial ecosystem to the aquatic ecosystem, and vice versa.” (Strayer and Findlay 2010);

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Hudson River Tidal Shorelines

- Over 300 miles:
  - – Natural 47%
  - – Riprap 30%
  - – Bulkhead, cribbing 11%
  - – Remnant engineered 12%

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- Review of shore zone ecology (Cary)
- Ecological field studies (Cary)

Summary of ecological findings

- Ecological characteristics/functions vary widely across Hudson River shore zones
  - different functions do not vary in parallel
- Some of this variation is explained by shore type
  - engineered shores tend to have poorer ecological function than “natural” shores
- Some of this variation is explained by physical characteristics of the shore zone
- Much of this variation is unexplained

Ten steps to better shore zones

1. Preserve physical diversity

Complex habitats usually support more species and ecological functions than those that are simple. Resist the urge to grade everything smooth, use the same materials everywhere, and build straight shorelines. Shore zones that have uneven topography, varied soils and vegetation, and irregular shorelines are likely to provide better ecological value.

2. Resist tidiness

"Debris" such as driftwood and windrows of vegetation along the shore provide perching spots for birds, cover for fish and other animals, nursery areas for young plants and animals, and food for the little animals that feed birds and fish. It's ok to pick up garbage like plastic, paper, and glass, but messy shore zones are better for ecological function than shore zones that look like Martha Stewart's living room.

3. Don't squeeze the shore zone!

It seems obvious that if you squeeze the shore zone out of existence by dredging or filling the shallows and wet areas, building vertical walls, and destroying vegetation, you will eliminate its ecological value. However, that's just what people have been doing for thousands of years. So don't.

4. Prevent pollution

Pollution released into the shore zone can both damage the shore zone itself and easily move into nearby waters. Try to avoid land uses in and adjacent to the shore zone that could release or spill pollutants. It's also a good idea to use as little fertilizer and pesticide as possible in the shore zone.

5. Reduce wave damage

Large waves, whether from the wind or passing boats, can damage shore zones. Offshore dredging and shoreline hardening can increase wave damage by removing the natural structures that absorb wave energy. Reduce the damaging effects of waves by limiting these activities, and consider imposing no-wake zones near sensitive shorelines.

6. Tread lightly

Shore zones are popular places for fishing, swimming, bird-watching, boating, hiking, and other recreational activities. Unfortunately, these activities can sometimes damage shore zones by frightening away animals, trampling plants and animals, and eroding shores and soils. So watch for signs of overuse, consider protecting parts of your shore zone as refuge areas where human activities are restricted, or prohibit some activities during sensitive times such as breeding seasons.

7. Don't make dead ends

Animals (and plant seeds, too) use shore zones as highways when they're migrating, seeking sites to nest or feed, or recolonizing areas that were disturbed by nature or humans. When we put sterile habitat like a seawall or a parking lot along the shore, or build walls or roads that keep animals from moving between the water and the land, we block those highways and so damage shore zone biodiversity. Try to preserve continuity of habitat along the shore zone both above and below the water line, and avoid building walls, curbs, and other barriers that block shore zone animals

8. Don't make it so hard!

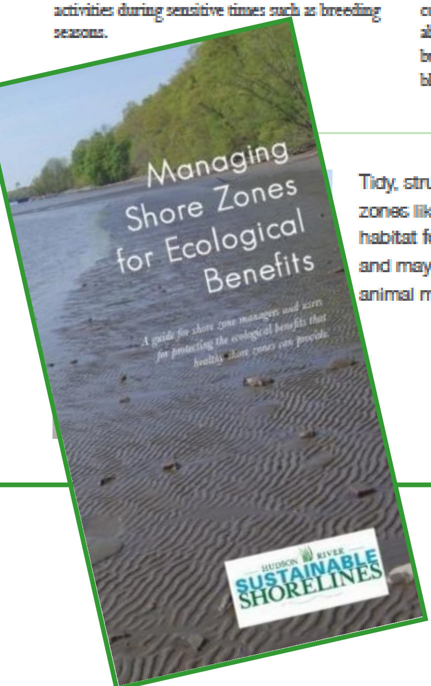
Many natural shore zones are made of a mixture of materials, including "soft" materials such as sand, mud, and gravel, often covered with vegetation. Humans frequently replace such soft materials with large stone, concrete, or steel. These hard materials change habitats and reflect waves, leading to erosion offshore and on adjacent properties. Where possible, try not to replace naturally soft shores with hard materials, and try to soften existing hard shorelines.

9. Give the shore room to move

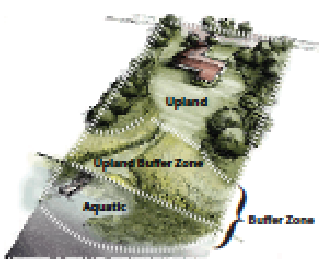
If you hem in a shore zone by building right up to its edges, it will be squeezed away when water levels rise. This will reduce or eliminate its ecological value, so wherever possible, give shore zones room to move. Because we've already hemmed in many shore zones with homes and other valuable infrastructure, this will be hard to do for many sites. But where it is possible, this is an important strategy to preserve ecological functioning in the face of rising water levels in the coming century.

10. Be careful about building in the shore zone

If you must build in the shore zone, reduce ecological impacts by using permeable materials that let water soak into the ground, minimizing roads, walls, and curbs that block animal movement, and limiting bright lights that attract emerging aquatic insects.



Tidy, structurally simple shore zones like this one offer little habitat for plants and animals, and may be inhospitable to animal migration.



Leaving intact vegetation above and below the water line provides good habitat for plants and animals.

Vertical walls can block animal migrations and reflect wave energy, and should be avoided.

Nature trails and parks may be better uses of the shore zone than buildings and hard structures.

www.hrnerr.org/hudson-river-sustainable-shorelines/publications-resources/

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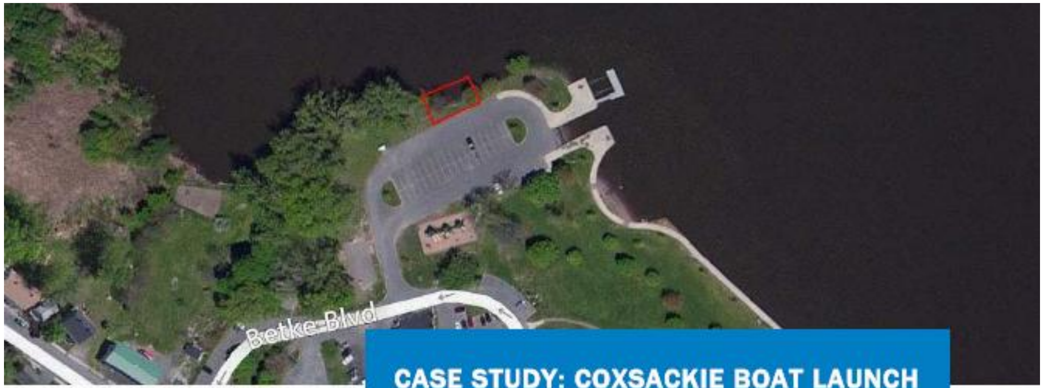
- Review of shore zone ecology (Cary)
- Ecological field studies (Cary)
- Analysis of Case Studies (HRNERR)

Case Studies

- Facts, figures & parties involved
- How it started
- Ecology & engineering specifics
- Lessons learned

Incentive for companies & organizations to have their work highlighted!

Case Studies



CASE STUDY: COXSACKIE BOAT LAUNCH

HUDSON RIVER SUSTAINABLE SHORELINES

The Hudson River Sustainable Shorelines Project is a multi-year effort lead by the New York State Department of Environmental Conservation Hudson River National Estuarine Research Reserve, in cooperation with the Greenway Conservancy for the Hudson River Valley.

The Project is supported by NOAA through the National Estuarine Research Reserve System Science Collaborative.

Hudson River Sustainable Shorelines Project
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hrssp@gw.dec.state.ny.us.

OVERVIEW

Improve eroding shoreline consisting predominately of historical dredge fill in order to protect the nearby parking lot. Demonstrate the functionality of restored natural shoreline features at providing erosion protection and improved habitat, as well as human access.

LOCATION & ACCESS

Village of Coxsackie, New York Boat Launch at the corner of Betke Boulevard and South River Street. The site is publicly accessible.

PARTICIPANTS

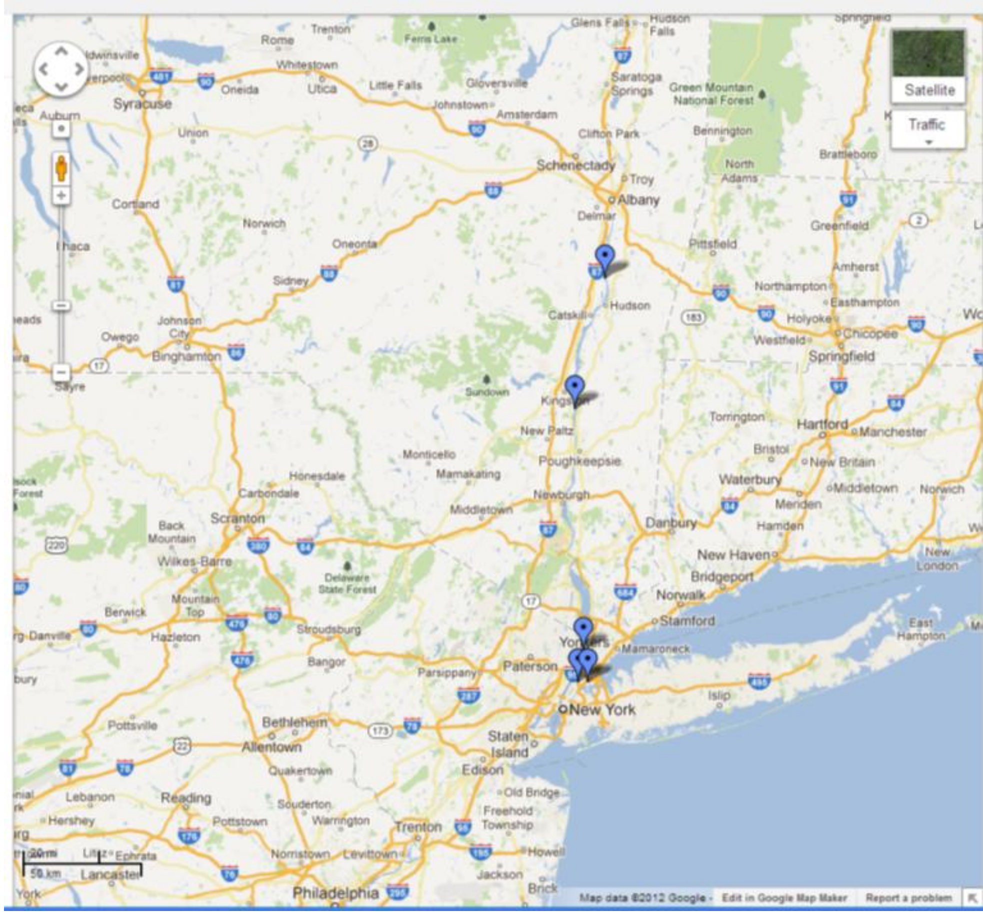
Owner: New York State Office of Parks, Recreation and Historic Preservation (OPRHP)
Manager: Village of Coxsackie
Design: New York State Office of Parks, Recreation and Historic Preservation (OPRHP), Hudson River Sustainable Shorelines Project (HRSSP), and Stevens Institute of Technology
Contractor: Moy Enterprises, OPRHP/HRNERR in-house
Cost: $20,000
Contact: Casey Holzworth, NYS Office of Parks, Recreation and Historic Preservation
Website: http://www.dec.ny.gov/outdoor/23893.html

Current Case Studies

[Coxsackie Boat Launch – Coxsackie, NY](#)
[Harlem River Park – New York, NY](#)

[Hunts Point Landing – New York, NY](#)
[Habirshaw Park and Tidal Marsh- Yonkers, NY](#)
[Esopus Meadows Preserve- Esopus, NY](#)

[Foundry Dock Park- Cold Spring, NY –](#)
[COMING SOON, JUNE 2013](#)



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- Ecological field studies (Cary)
- Analysis of Case Studies (HRNERR)
- Engineering Analyses (Stevens)

A Literature Review of Existing Methods for Limiting Erosion along Sheltered Shorelines

29 Techniques Identified

❑ **Traditional Approaches**
- Bulkheads
- Gabions
- Groins
- Revetments

❑ **Hybrid Approaches**
- Sills
- Live Crib Wall
- Joint Planting
- Biowalls

❑ **Natural Approaches**
- Living breakwaters
- Coconut Fiber Rolls

Finished Product

Branch Packing

Approach						Construction Cost				
Soft				Hard		Low				High
Maintenance Cost						Adaptability				
Low				High		Low				High

Description

The branch packing technique employs alternating layers of live branches and compacted soil to repair gaps or holes on stream bank slopes. The branch packing approach not only repairs missing sections of the shoreline but also aids in the prevention of erosion and scouring.

Branch packing can only be used at sites that have an area less than 4 feet deep and 4 feet wide that need to be filled and supported. The technique is generally ineffective at sites with side slopes in excess of 2:1.

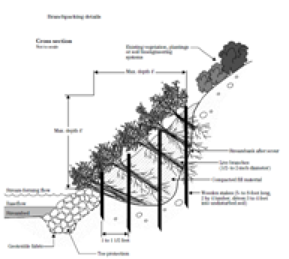


Figure 30: Typical branch packing cross-section.

Design and Construction

Some of the important design considerations when applying the branch packing technique include: the size of the hole being filled, the steepness of the side slope, and the water level. Water level must be considered as the ends of the plants must be able to reach the water, while not receiving so much water as to exceed their flood tolerance.

Figure 31: Shoreline stabilized with branch packing

Branch packing can employ a variety of materials, including: live stakes, live fascines, live branches, dormant post plantings, dead stout stakes, string, smooth wire, wooden stakes, and rebar.

Construction consists of driving wooden stakes vertically into the ground, then placing a four to six inch layer of living branches between the stakes, with their growing tips orientated towards the slope. Construction should begin at the lowest point and proceed up the bank. Subsequent layers of live branches and soil are then added until the structure conforms to the existing slope.

Detailed cost information was not available, however branch packing is expected to be inexpensive compared to other shoreline stabilization alternatives based on the minimal material and/or specialized labor requirements.

Adaptability

The branch packing approach can be extended vertically under potential sea level rise scenarios; however the overall fragility of the structure will make it highly susceptible to dislodgement under increasing flows and/or wave activity.

Advantages

Branch packing has many advantages over other engineered shore protection approaches, among them are:

- It is an inexpensive method of erosion prevention.
- Vegetation grows quickly and offers immediate protection.
- As the plants grow, the system becomes more efficient in reducing runoff and erosion.
- The branches can encourage sediment deposition along the shore.

Disadvantages

Branch packing has many disadvantages compared to other engineered shore protection approaches, among them are:

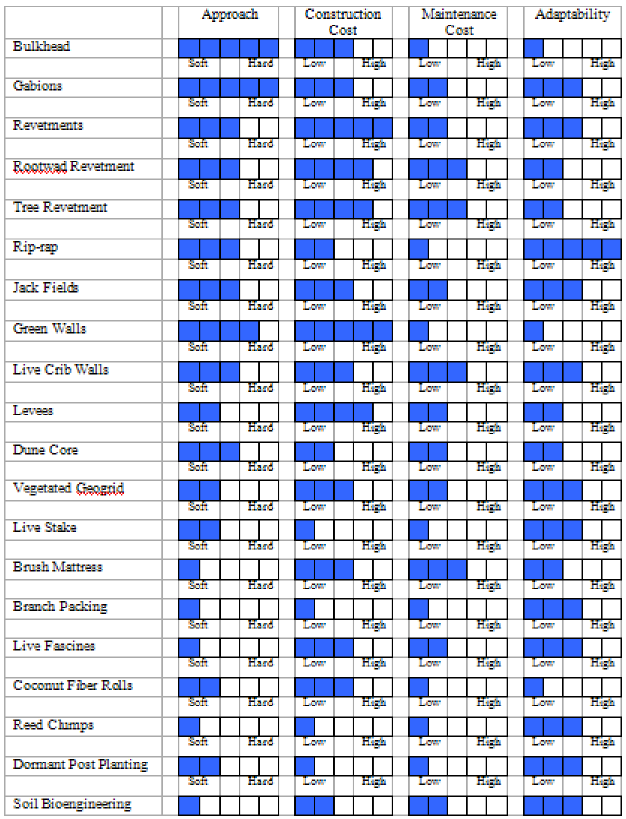
- They are ineffective in holes that are larger than 4 feet deep by 4 feet wide.
- Stream flow must be diverted if branch packing is being considered at a site that was previously damaged by high velocity flow.
- Scouring can occur if branch packing is not flush with the existing bank.

Similar Techniques

Alternatives include: joint planting, live fascines, brush mattresses.

Finished Product

Summary



Glossary of Terms

Artificial Dune Cores – Artificial reinforcement added to the core of dunes or sloped banks to increase stability during erosional events. Typically, constructed of sand filled geotubes, artificial dune cores remain hidden within the dune/bank only becoming "active" during extreme events.

Artificial Vegetation - Artificial vegetation works identically to natural vegetation by decreasing wave/current energy at the shoreline, reducing erosional pressure, and encouraging sediment deposition. Unlike natural vegetation, artificial vegetation can be used in most areas, regardless of water quality/growth conditions.

Bio/Green Walls - Walls or barriers that incorporate living plants or stakes into their design. This term is used to refer to a collection of approaches, all of which attempt to soften a traditionally hard edge through the introduction of ecologically friendly modifications.

Bulkhead – Traditionally, the most common shoreline hardening technique used to protect vulnerable and eroding shorelines. Used at the base of bluffs or steep shorelines, bulkheads are vertical walls which prevent the loss of soil and the further erosion of the shore.

Branch Packing - Branch packing consists of segments of compacted back fill separated by layers of live branches. This approach is a relatively inexpensive technique used to fill in missing areas of the shoreline, which also provides a succession of barriers to prevent further erosion and scouring.

Breakwater - A breakwater is a structure that is built within a water body to reduce wave energy and erosion in its lee. Types include rubble mound breakwaters, floating breakwaters, and living breakwaters.

Brush Layering - Brush layering consists of placing branch cuttings along a sloped shoreline to serve as a covering and protection against erosion. Brush layering may also stabilize the shoreline by capturing sediment.

Brush Mattress - A brush mattress is a combination of live stakes, live fascines, and branch cuttings that form a protective cover on an eroding shoreline that acts to protect the shoreline against oncoming waves, capture sediment during floods, and enhance habitat for vegetation.

Coconut Fiber Rolls - Coconut fiber rolls are long cylindrical structures composed of coconut husks that are laid parallel to the shore. These structures are intended to help prevent minor slides while encouraging sediment deposition and plant growth.

Dormant Post Planting - Dormant post are installed into an eroded bank at or above the waterline. Rootable vegetative material is added to form a permeable revetment along the shoreline.

A Comparative Cost Analysis

- 9 Stabilization Approaches
  - Wood and Steel Bulkheads
  - Crib Walls
  - Live Crib Walls
  - Revetments
  - Rip-Rap
  - Joint Planting
  - Bio Wall
  - Sill
  - Vegetative Geogrid
- 3 sites
  - Poughkeepsie,
  - Henry Hudson Park (Albany),
  - Bowline Point Park (Haverstraw)
- 2 Sea Level Rise Scenarios
  - Current Rate (2.77mm/yr),
  - Rapid Ice Melt (48" by 2080)

Cost analysis includes:

- **Initial Costs (IC)**
  - Material and labor costs to construct the stabilization measure
- **Maintenance and Repair Costs (M&R)**
  - Costs associated with routine maintenance and repairs (i.e. not associated with any given storm)
- **Damage Costs (DC)**
  - Costs associated with restoring a structure to its original function after a specific storm causes damage
- **Replacement Costs (RC)**
  - Costs of replacing a structure once it reaches the end of its serviceable life. (Typically associated with material decay/degredation)

Finished Product

Current Sea Level Rise Scenario

	Poughkeepsie	Henry Hudson Park	Bowline Point Park
Wooden Bulkhead	$ 375,292	$ 271,348	N/A
Steel Bulkhead	$ 1,255,906	$ 989,845	N/A
Revetment	$ 340,984	$ 315,930	$ 313,642
Rip rap	$ 318,896	$ 143,292	$ 325,113
Crib Wall	$ 308,531	$ 232,515	N/A
Live Crib Wall	$ 372,794	$ 287,733	N/A
Joint Planting	$ 491,088	$ 231,799	$ 496,511
Vegetated Geogrid	$ 300,315	$ 269,136	N/A
Bio Wall	$ 1,102,131	$ 569,330	N/A
Sill	N/A	$ 241,874	$ 173,106

Rapid Sea Level Rise Scenario

	Poughkeepsie	Henry Hudson Park	Bowline Point Park
Wooden Bulkhead	$ 688,203	$ 497,593	N/A
Steel Bulkhead	$ 2,372,407	$ 1,869,818	N/A
Revetment	$ 1,081,098	$ 1,001,664	$ 994,407
Rip rap	$ 1,133,764	$ 509,442	$ 1,077,429
Crib Wall	$ 765,821	$ 577,137	N/A
Live Crib Wall	$ 1,074,401	$ 829,252	N/A
Joint Planting	$ 1,826,545	$ 862,150	$ 1,846,714
Vegetated Geogrid	$ 648,316	$ 581,007	N/A
Bio Wall	$ 2,185,780	$ 1,129,114	N/A
Sill	N/A	$ 464,930	$ 332,745

- Several alternatives exist at each site for which the costs are relatively similar.
- Alternative solutions can be cost competitive with traditional approaches

(Consistent with NOAA's "Weighing Your Options" report.)

Urban Solutions

Green/Bio Walls: a collection of approaches, which attempt to soften a traditionally hard edge through the introduction of ecologically friendly modifications.

Walls or barriers that have been enhanced in any way to encourage habitat development.

<u>Example Projects</u>

Designing The Edge

Cuyahoga

Alternative Concrete Solutions

NYC Dept. of Parks and Recreation Designing the Edge

Objectives:

- Improve ecological value of urban shore
- Modify the waterfront edge to enhance safe access to the water by the public
- Increase compatibility with recreational users

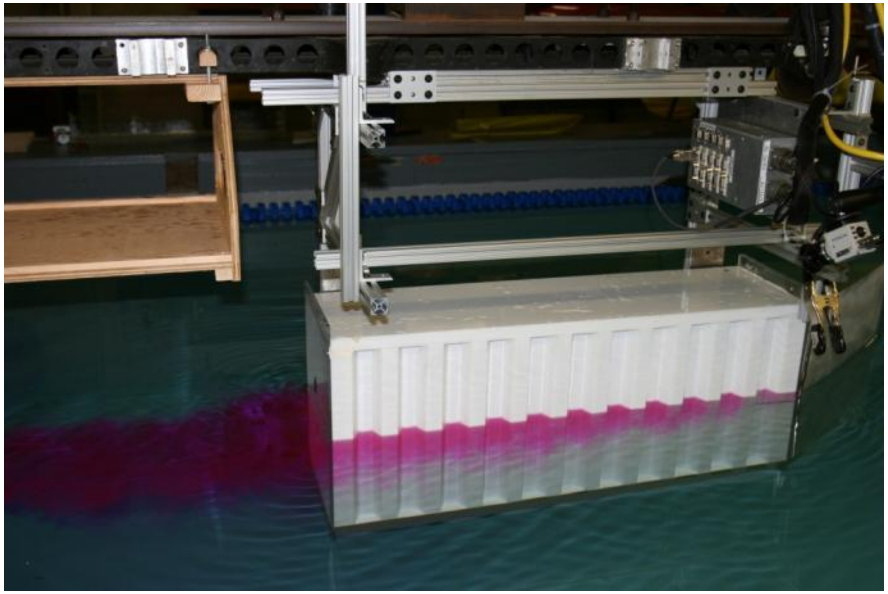
http://www.hrnerr.org/files/2012/07/HarlemRiverPark_CaseStudy.pdf

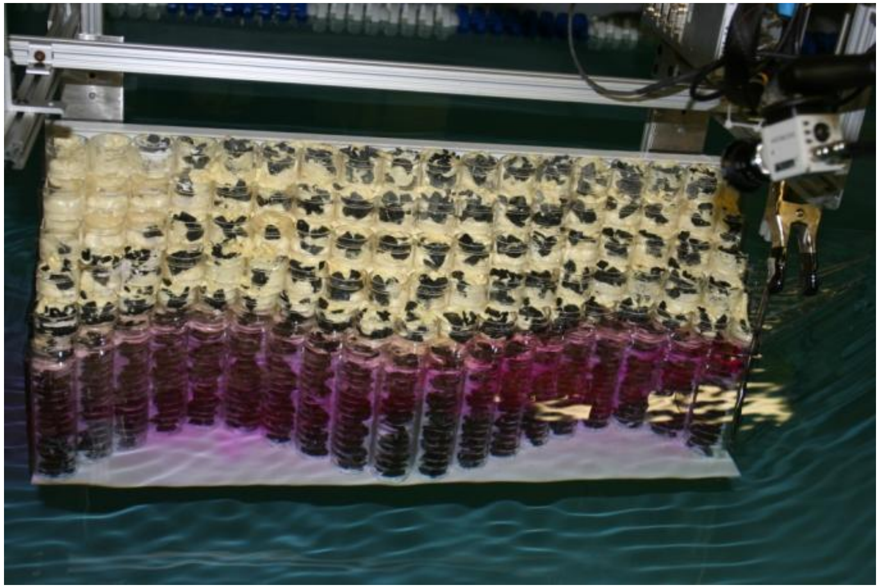
Physical Model Testing

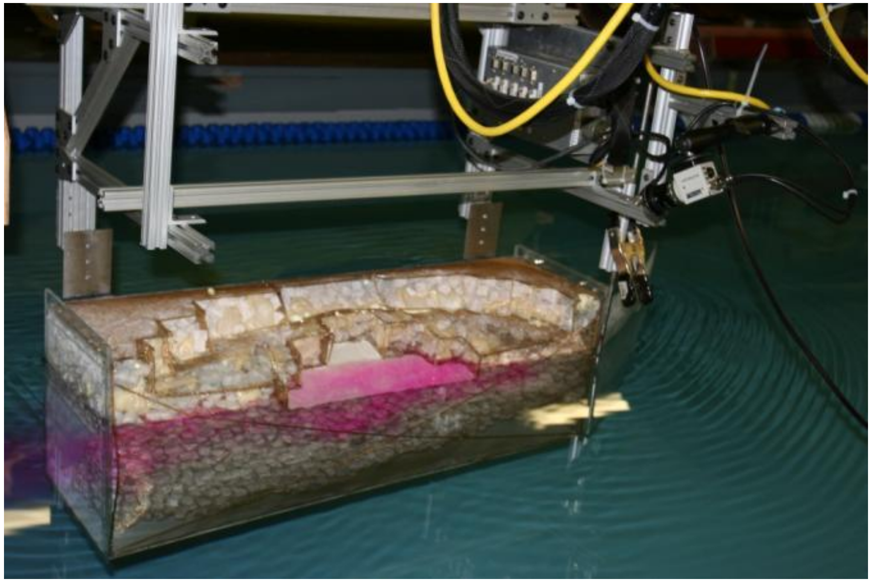
Took Place at Stevens Institute of Technology, Davidson Lab

Tested the effect the wall had on;

- % Current Reduction
- Wake Dissipation

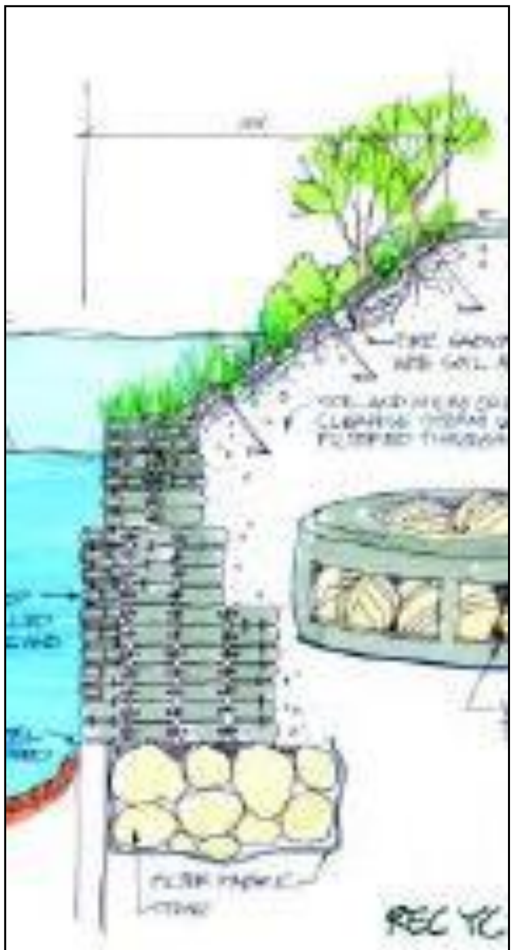






Finished Product

- Removal of the vertical bulkhead
- Creation of a sloped, reveted shoreline
- Creation of a large tidal pool



Cuyahoga River Green Bulkhead Project

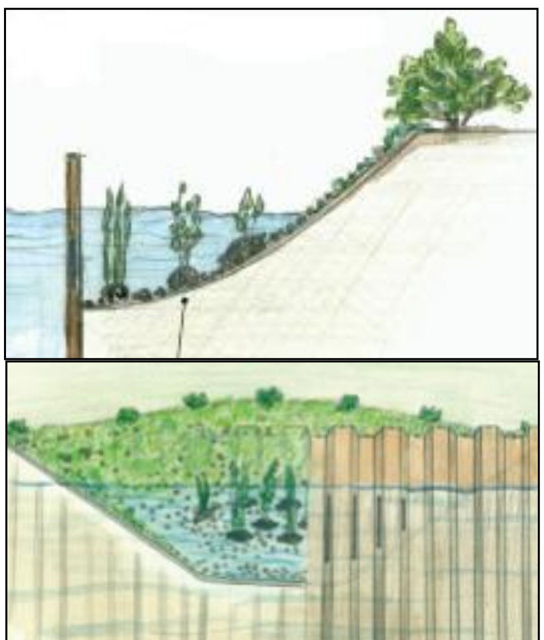
- One of the most heavily polluted waterways in the U.S.
- Heavily utilized industrial shipping channel
- Unhealthy environment for its natural marine inhabitants.
  - high degree of pollutant contamination
  - left native fish with a lack of food, shelter, and oxygen.

Option 1 – CHUBS (Cuyahoga Habitat Underwater Baskets)

system uses plant pillows which sit in baskets that hang by chains at various heights, nestled within the wall's corrugations

Option 2 - Pocket Habitat

CHUBS are planted in locations with damage or corrosion but have sound lower portions.



Option 3 – Tiered Wall

An sheltered area is created and only a portion of a bulkhead is replaced.

Finished Product

Instead of replacing the existing bulkheads at a high cost (up to $100 million), the decision was made to pursue an alternative approach that would:

- Continue to accommodate commercial freight movement
- Protect Land areas
- Promote restoration of natural river functions along the edge

Alternative Concrete Solutions

- Durable material that is frequently used to construct marine structures
- Poor material for biological recruitment
- Can be altered physically and chemically
  - Decrease the ph of the concrete
  - Texturize the surface

Current research efforts for developing concrete into an urban living shoreline

- SeArc
- Andrew Rella

Concrete infrastructures can be altered in three levels:

- concrete composition
- surface texture
- macro-design

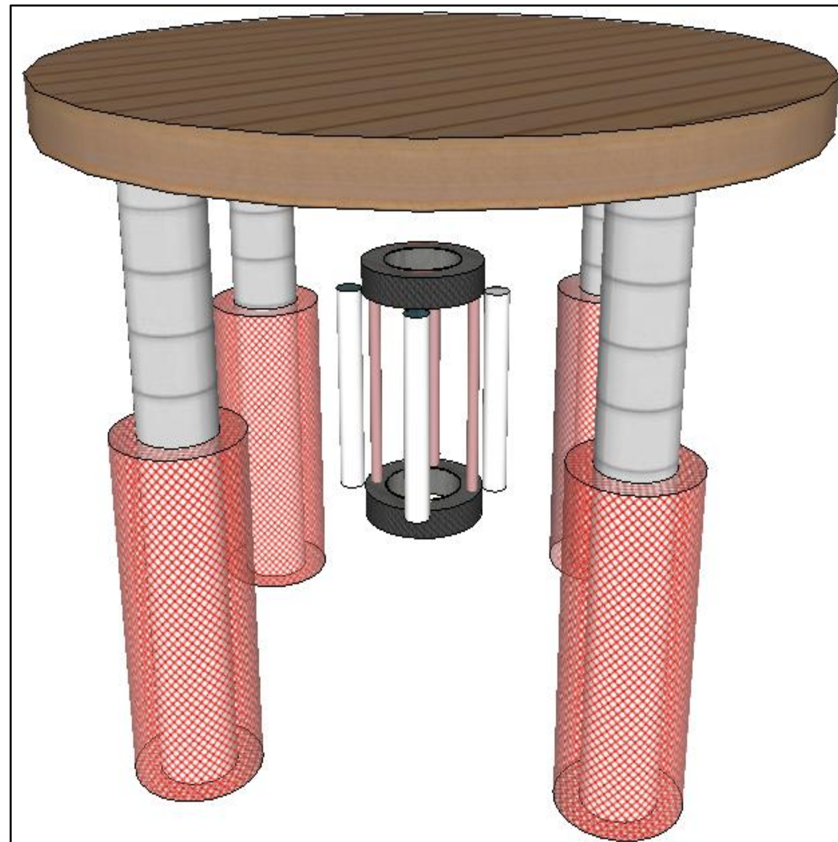
Concrete with an elevated ability to provide valuable ecosystem services such as

- nursing grounds
- hubs for filter feeding organisms
- shallow water habitats.

Such ecological advancements will increase the operational life span and stability of marine infrastructures by encouraging biogenic build-up that protects them from damages associated with aggressive marine environments.

Andrew Rella: Dissertation Research

Development of oyster reefs around new/degrading pile encasements in order to prevent erosion of the concrete.



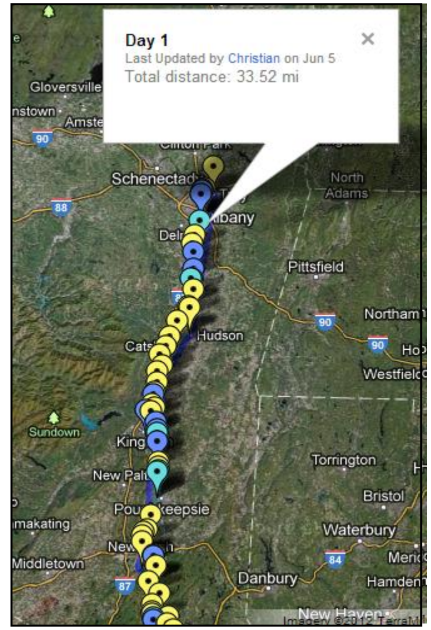
Physical Forces Characterization

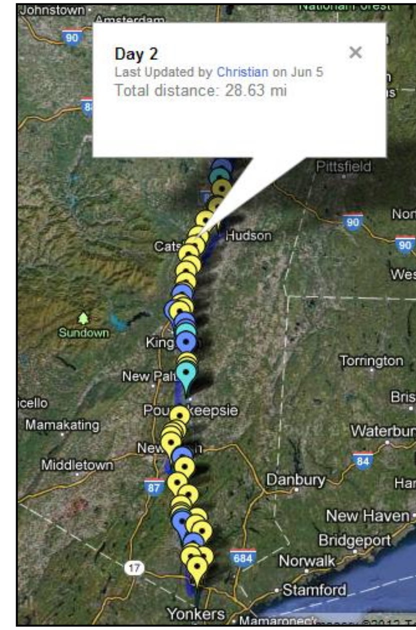
Characterization of the physical environments of the Hudson River

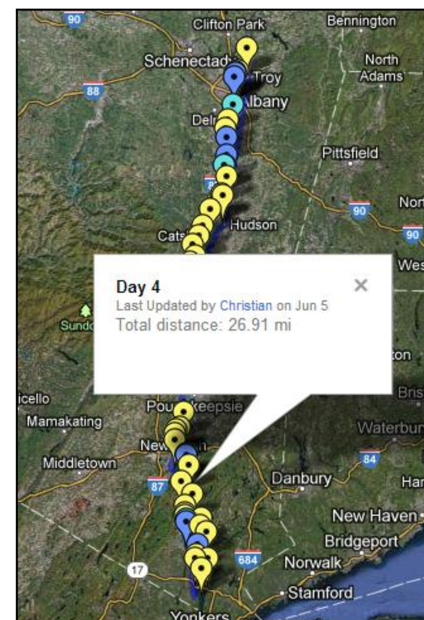
- Wakes
- Ice
- Water Levels
- Currents
- Stresses
- Surface wind waves

Wakes Analysis

- Wakes were observed at a final number of 32 sites over the course of 4 days
- Analytical approach will be utilized to supplement data



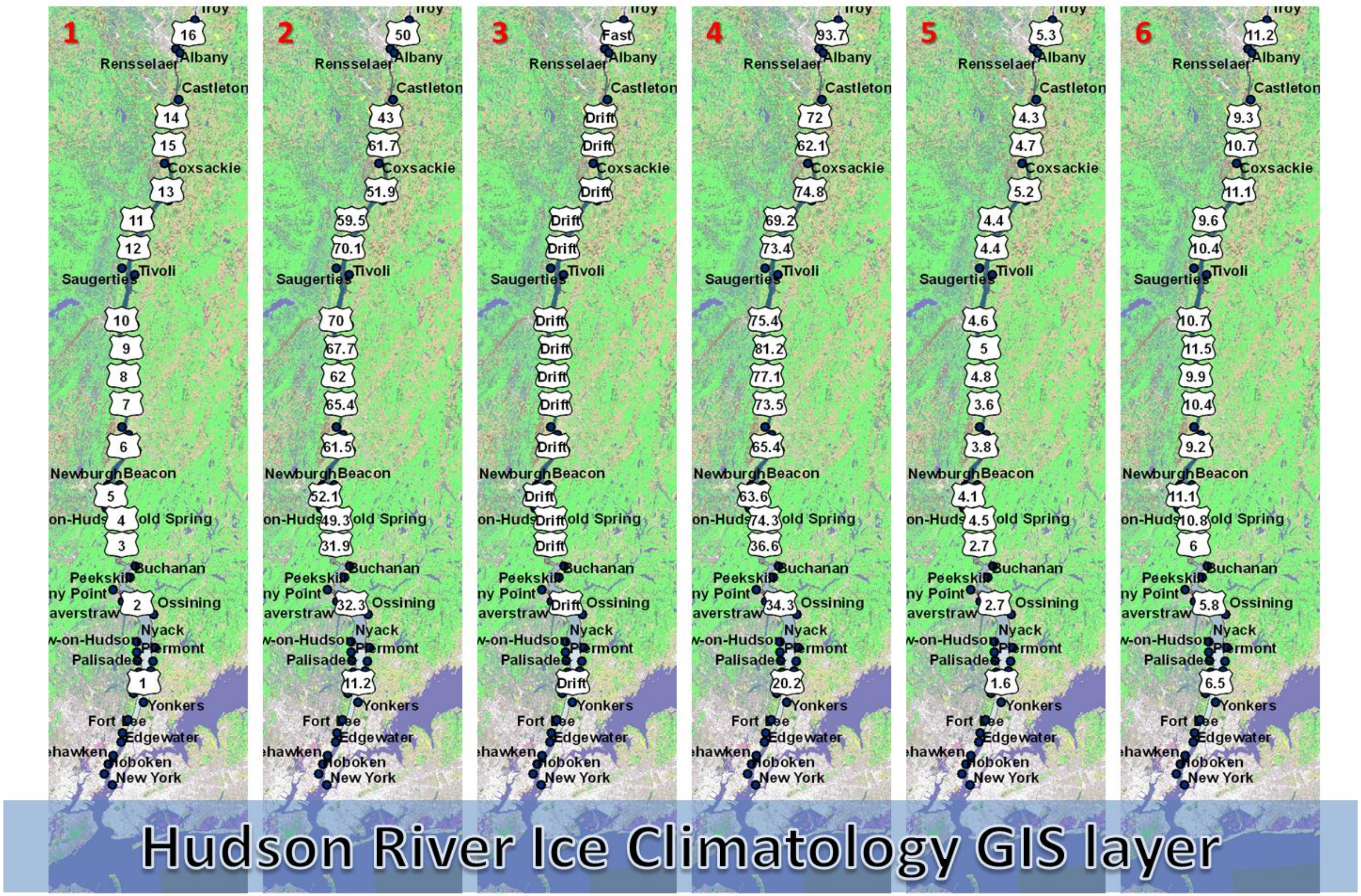




http://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/

Ice Reports

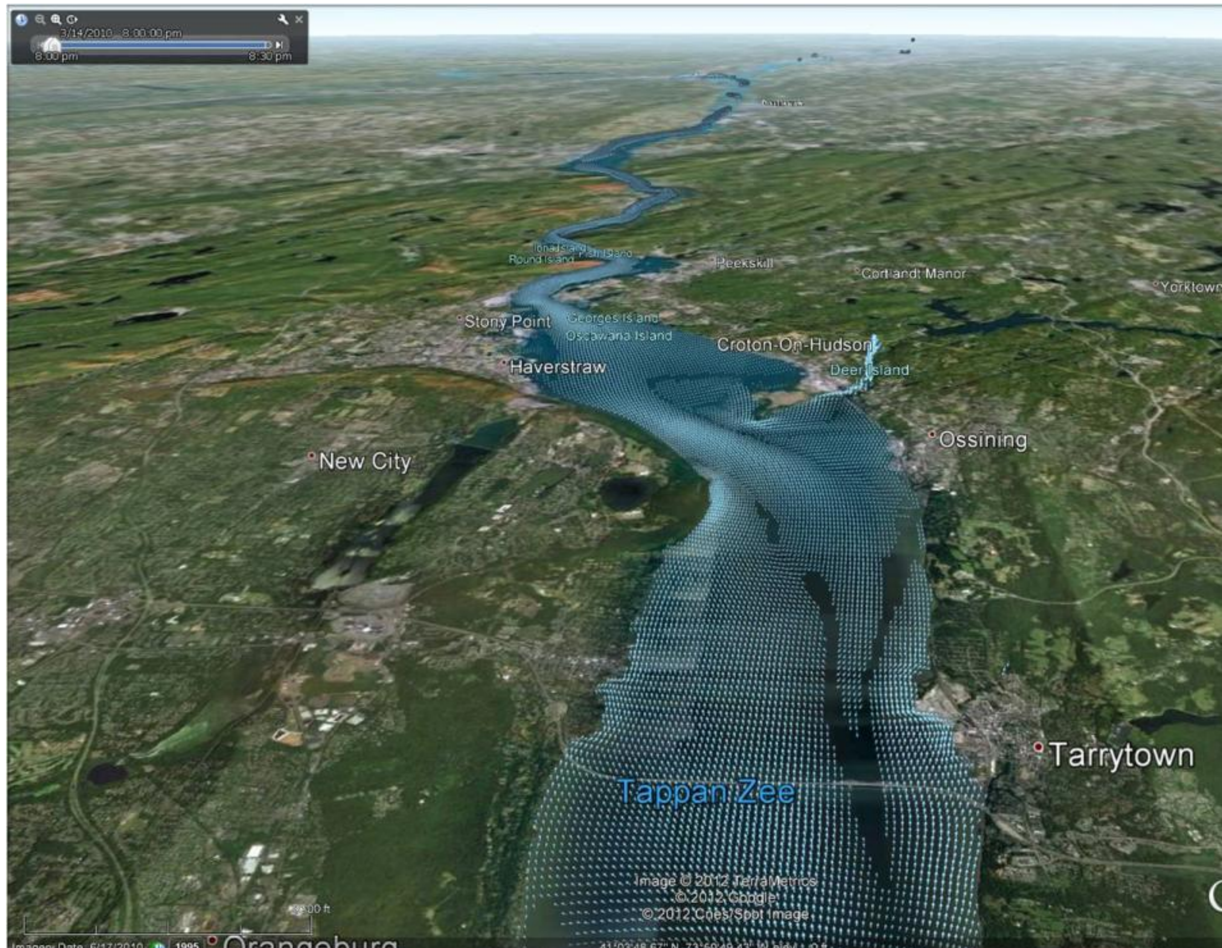
Ice climatology developed based on Coast Guard reports



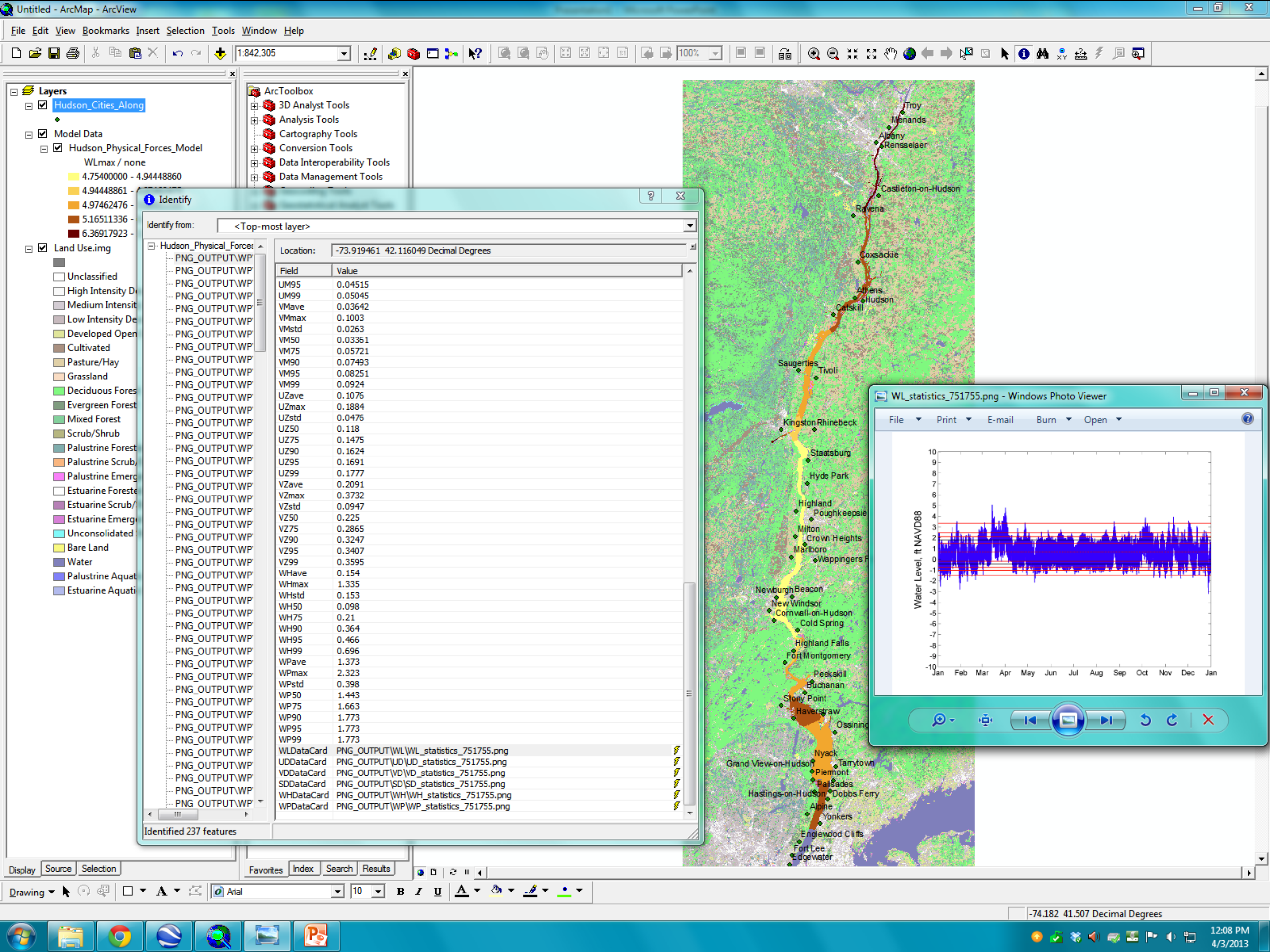
1) The 16 ice regions of the tidal Hudson. 2) % of ice season days (December-March) with ice present, by region. 3) Prevalent Ice Type when ice present. 4) Median Ice covered area; % of each region, median of all days with ice reported. 5) Median ice thickness; inches of ice by region, median of all days with ice reported. 6) 95th percentile of ice thickness; inches of ice by region, 95% of all days with ice reported had ice thinner than this value. (http://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/ice-conditions/)

Currents

Ultra high resolution version of NYHOPS developed for understanding wave & current variability



http://www.hrnerr.org/hudson-river-sustainable-shorelines/shorelines-engineering/physical-forces-statistics/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Pasture/Hay
Grassland
Deciduous Fores
Evergreen Forest
Mixed Forest
Scrub/Shrub
Palustrine Forest
Palustrine Scrub
Palustrine Emerg
Estuarine Foreste
Estuarine Scrub/
Estuarine Emerg
Unconsolidated
Bare Land
Water
Palustrine Aquat
Estuarine Aquati
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Data Interoperability Tools
Data Management Tools
Identify
Identify from: <Top-most layer>
Hudson_Physical_Forces
PNG_OUTPUT\WP
Location: -73.919461 42.116049 Decimal Degrees
Field Value
UM95 0.04515
UM99 0.05045
VMave 0.03642
VMmax 0.1003
VMstd 0.0263
VM50 0.03361
VM75 0.05721
VM90 0.07493
VM95 0.08251
VM99 0.0924
UZave 0.1076
UZmax 0.1884
UZstd 0.0476
UZ50 0.118
UZ75 0.1475
UZ90 0.1624
UZ95 0.1691
UZ99 0.1777
VZave 0.2091
VZmax 0.3732
VZstd 0.0947
VZ50 0.225
VZ75 0.2865
VZ90 0.3247
VZ95 0.3407
VZ99 0.3595
WHave 0.154
WHmax 1.335
WHstd 0.153
WH50 0.098
WH75 0.21
WH90 0.364
WH95 0.466
WH99 0.696
WPave 1.373
WPmax 2.323
WPstd 0.398
WP50 1.443
WP75 1.663
WP90 1.773
WP95 1.773
WP99 1.773
WLDataCard PNG_OUTPUT\WL\WL_statistics_751755.png
UDDataCard PNG_OUTPUT\UD\UD_statistics_751755.png
VDDataCard PNG_OUTPUT\VD\VD_statistics_751755.png
SDDataCard PNG_OUTPUT\SD\SD_statistics_751755.png
WHDataCard PNG_OUTPUT\WH\WH_statistics_751755.png
WPDataCard PNG_OUTPUT\WP\WP_statistics_751755.png
Identified 237 features
Troy
Menands
Albany
Rensselaer
Castleton-on-Hudson
Ravena
Coxsackie
Athens
Hudson
Catskill
Saugerties
Tivoli
Kingston
Rhinebeck
Staatsburg
Hyde Park
Highland
Poughkeepsie
Milton
Crown Heights
Marlboro
Wappingers F
Newburgh
Beacon
New Windsor
Cornwall-on-Hudson
Cold Spring
Highland Falls
Fort Montgomery
Peekskill
Buchanan
Stony Point
Haverstraw
Ossining
Nyack
Grand View-on-Hudson
Tarrytown
Piermont
Palisades
Hastings-on-Hudson
Dobbs Ferry
Alpine
Yonkers
Englewood Cliffs
Fort Lee
Edgewater
WL_statistics_751755.png - Windows Photo Viewer
File Print E-mail Burn Open
Water Level, ft NAVD88
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Display Source Selection
Favorites Index Search Results
Drawing
Arial
10
-74.182 41.507 Decimal Degrees
12:08 PM
4/3/2013

Some of the tasks to date:

- Review of legal instruments for shore zone protection (Pace University)
- Models of storm surges following sea level rise (Jery Stedinger, Cornell)
- Terminology defined (Emilie Hauser, HRNERR/DEC)
- Shores surveyed from Troy to Tappan Zee (Dan Miller, HRNERR, NYSDEC)
- Review of shore zone ecology (Cary)
- Ecological field studies (Cary)
- Analysis of Case Studies (HRNERR)
- Engineering Analyses (Stevens)
- Outreach & Tool Development (All)

Outreach

- **Reach out to various user communities to encourage use of these recommendations**
  - Experts and consultants
  - Government regulators
  - Policy and law makers
  - Municipal officials
  - Property owners
  - Advocates
- Today!

Partners & Advisors

Questions?

For More Info

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