Economic Tradeoffs between Shoreline Treatments:

Phase I – Assessing Approaches

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EXECUTIVE SUMMARY

The goal of the Sustainable Shorelines Project's economic assessment is to generate information that decision-makers can use to compare the long-term costs of different shore treatments. When considering costs, we ideally want to include not only the direct costs of installation and maintenance, but also ecosystem service values that currently are not incorporated into most cost-benefit analyses.

In this report, I have set forth a framework for the economic assessment, distilled a broad list of ecosystem services down to a more manageable number, and characterized key elements of these final services. My objective was to create a defined information set that economists could use to recommend next steps. The report's main points are summarized below and graphically shown in Appendix 1.

- The shore zone is the area approximately three feet above and three to six feet below the intertidal zone and does not include most of the Hudson River Estuary's floodplain. The reasons for excluding the floodplain are (a) shore treatments being considered by the Sustainable Shorelines Project are designed to mitigate erosion, not to keep flood waters off the floodplain; and (b) the ecological and engineering components of the Sustainable Shorelines Project are not considering the floodplain, so are not generating information on floodplains that could be used in an economic assessment.
- The Hudson River National Estuarine Research Reserve has identified nine shore types to be considered by the economic assessment:

- Bulkhead	- Revetment	- Riprap
- Timber cribbing	- Live crib wall	- Green (bio) wall
- Live stakes/joint planting	- Vegetated geogrid	- Living shoreline

- Government regulators and permitting/compliance officials are the core audience for the Sustainable Shorelines project. Additional audiences are: (a) elected officials; (b) media outlets and the general public; (c) property owners; (d) experts/consultants; and (e) funders.
- Climate change will challenge shore zone managers with permanent inundation by sea level rise and periodic flooding driven by more frequent, more intense storms. For sea level rise, I recommend that we consider two rates: those projected in the rapid ice melt scenario and those seen historically. Although the shore treatments being considered are not intended to stop flooding, severe floods in the future could trigger the installation of treatments that do. As such, I recommend that we include both storm-driven flooding and inundation by sea level rise as adaptation elements of the engineering cost assessment.
- The economic assessment should be split into two parallel tracks. The first track would assess the costs and benefits of different shore zone engineering options, particularly installation, maintenance, adaptation, and replacement. The second track would assess the values of ecosystem services.
- The ideal economic analysis would generate values for all ecosystem services. Based on a literature review and input from the Sustainable Shorelines Project Team, I identified the following ecosystem services delivered or supported by the shoreline:

- Wave & ice protection	- Education	- Water quality improvement
- Aesthetic enjoyment	- Sediment stabilization	- Spiritual fulfillment
- Flood protection	- Commercial shipping	- Commercial fishing

  - Recreation (hunting, trapping, fishing, bird watching, walking, boating, swimming)

- We should focus our valuation efforts on the seven recreation ecosystem services.
- There are seven recreational user groups to consider, but few datasets that reveal their numbers and interactions with the shore zone. That said:
  1. Boaters – approximately 25,000 motorboat users traveled the Hudson River Estuary in 2003. No data are available for kayak, canoe, or sailboat users.
  2. Anglers – spent more than 350,000 days plying the Lower Hudson River in 2007.
  3. Walkers – nearly 500,000 people visited eight state parks with Hudson River Estuary shoreline in state fiscal year 2008-09.
  4. Bird Watchers – in 2011, nearly 5,000 birders are members of the six National Audubon Society Chapters whose boundaries include the Hudson River Estuary.
  5. Swimmers – in 2005, there were four public beaches with the collective capacity to serve 1,800 people per day, a 20-foot diameter river pool, and more than 100 informal swimming sites along the estuary.
  6. Hunters – about 500 waterfowl hunters use the Hudson River Estuary shoreline annually.
  7. Trappers – about 100 trappers work the Hudson River Estuary shoreline each year.
- Surveys or focus group interviews will be necessary to determine what aspects of shorelines are of particular interest to (and in turn influence the value for) the seven user groups. As a starting point, however, I have suggested an initial set of aspects that are likely important to some or all of the user groups:

- access	- aesthetic enjoyment	- abundance of fish
- site suitability for fishing	- presence of birds	- visibility of birds
- abundance of waterfowl	- site suitability for hunting	- abundance of furbearers

- The engineering treatments used along the Hudson's shores will affect the shoreline aspects of interest and in turn influence how much the user groups value the shore zone. Although detailed studies have not been conducted to determine precisely what these effects are, key considerations appear to be how steep the shore type is, whether or not the shore type includes vegetation, and how the shore type affects the adjacent river bed, mud flats, and submerged aquatic vegetation beds.
- If the Sustainable Shorelines Project is to undertake an economic assessment of the changes in recreational ecosystem service values with nine different shore types, our next step is work with economists to answer the following questions:
  1. Should we assess all or a subset of the seven services?
  2. Do we need to determine dollar values or would rankings suffice?
  3. What additional background information is necessary?
  4. How serious are the risks of not assessing cumulative economic impacts?
  5. What methods should be used?
  6. How much would each method cost, and how long would it take to get results?
  7. How useful would the results be?

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INTRODUCTION

The Sustainable Shorelines project originated from the recognition that increased armoring of the shore zone would almost certainly result from renewed development along the Hudson River Estuary and accelerated sea level rise due to climate change. If only traditional engineering approaches were used, this armoring would further degrade the estuary's ecological functions and ecosystem services. If more progressive shoreline stabilization treatments were applied, however, these functions and services could be maintained while still allowing for erosion mitigation and adaptation to rising sea levels.

The goal of the Sustainable Shorelines Project's economic assessment is to generate information that decision-makers can use to compare the long-term costs of different shore treatments. When considering costs, we ideally want to include not only the engineering costs of installation, maintenance, replacement, and the like, but also ecosystem service values that currently are not incorporated into most cost-benefit analyses.

In this report, I have set forth a framework for the economic assessment, distilled a broad list of ecosystem services down to a more manageable number, characterized key elements of these final services, and recommended next steps. The report's main points are graphically shown in Appendix 1. The report is broken into several key sections:

- framing the assessment
- considering climate change
- assessing engineering and ecosystem services separately
- reviewing ecosystem valuation methods
- serving different audiences
- selecting ecosystem services
- breaking out key considerations
- identifying next steps

Because it is so complex, valuing ecosystem services is the focus of this report. The importance of these services is increasingly being recognized by policy makers and regulators, and to some degree the general public, but estimating their values remains difficult and, in most cases, controversial. As such, I have endeavored in this report to set forth a strategy for selecting which ecosystem services to analyze and to create a defined information set that economists can use to recommend next steps.

This report sets forth a strategy for pursuing economic assessments of ecosystem services. The hardest part of strategic decision-making is deciding what <u>not</u> to include, but it is also the most important. The majority of this report is therefore dedicated to explaining why certain ecosystem services and aspects of the shore zone, vital as they may be, are not the best foci for an economic assessment at this time.

FRAMING THE ASSESSMENT

Before we can undertake an assessment, we first need to frame its boundaries. Specifically, we need to define key concepts, lay out the time frame, and select the shore types that will be considered.

VALUE

Debate invariably follows any mention of value because the term is so loaded with conflicting concepts, uses, and nuances that it can be more of a challenge than a tool. Yet value is a fundamental component of economics, so unlike the ecological and engineering portions of the Sustainable Shorelines Project, we cannot limit our focus to function.

For the purposes of this study, economic valuation relates to goods or services that an ecosystem provides to people (Limburg *et al.* 2002; National Research Council 2005). These services can be tangible, like fish and boating sites. They can be measurable but less discrete, like protection against flooding and regulation of water quality. They can also be conceptual, like aesthetic enjoyment and spiritual fulfillment. The key is that economic values are anthropocentric.

Many have argued that the anthropocentric approach to environmental valuation is flawed because it ignores intrinsic values.[1] Intrinsic values are different from conceptual values because they exist regardless of people. The intrinsic value of Atlantic sturgeon, for example, will persist even if all people were to disappear. The conceptual values of aesthetic enjoyment and spiritual fulfillment will not exist without people because no one would be left to experience them.

Unfortunately, intrinsic values are so difficult, if not impossible, to measure in a meaningful way that they cannot be incorporated into cost-benefit analyses. Further, if shoreline decision-makers do not already consider ecosystem services to be intrinsically valuable, they are unlikely to incorporate them into their shore use decisions and current regulations cannot require them to do so. As such, intrinsic values are best left out of the Sustainable Shoreline's economic assessment – at least at this stage.

Ecosystems services and their economic values are fundamentally anthropocentric

ECOSYSTEM SERVICES

Ecosystem services are the benefits people obtain from ecosystems (de Groot *et al.* 2002; Millennium Ecosystem Assessment 2005; Wilson and Farber 2009). To recognize the incredible complexity within this simple definition, the Millennium Ecosystem Assessment divided ecosystem services into four groups: (1) provisioning, such as food and timber; (2) regulating, including flood and climate regulation; (3) cultural, such as recreational, spiritual, and aesthetic benefits; and (4) supporting, like nutrient cycling and soil formation. All of these goods, functions, and benefits are at play when the term "ecosystem services" is used in this report.

SHORE ZONE

For the ecological analysis, Strayer *et al.* (2011) defined the shore zone as the area one meter above and below the intertidal zone, though Strayer and Findlay (2010) qualified this by noting that different ecological functions required somewhat different definitions. For the engineering assessments, neither Allen *et al.* (2006) nor Rella and Miller (2010) specifically defined shore zone or shoreline. Their reports, however, focused on the area along the Hudson that was subject to scour and therefore likely to be targeted for erosion mitigation.

[1] See Brennan and Lo (2007) for a historical tour of environmental ethics and Dietz *et al.* (2005) for an overview of environmental values.

Since the Sustainable Shorelines Project is fostering the increased use of more ecologically beneficial shoreline management techniques, I recommend focusing the economic assessment on the shoreline areas most likely to be managed against erosion. While we do not need to have a precise definition of shore zone, we should recognize up front that the shore zone being considered excludes the estuary's watershed and land uses upslope from erosion mitigation areas.

The Sustainable Shorelines Project, however, is also designed to consider the future consequences of sea level rise. For the economic analysis, therefore, I recommend defining the shore zone to be roughly three feet below the current low water level and three to six feet above the current high water mark. Projected rates of sea level rise are discussed below.

This definition of shore zone does not include most of the Hudson River Estuary's floodplain for two reasons. First, with a few exceptions, shoreline engineering on the estuary is currently designed to address scour by currents, waves, and ice. The engineered treatments are not designed to keep flood waters off the floodplain. As such, it would be meaningless to compare the differing effects of these shoreline treatments on flooding when they are not designed to address flooding challenges. Second, the ecological and engineering components of the Sustainable Shorelines Project are not considering the floodplain. Without information from them about the effects of shoreline treatments on the floodplain, we do not have information about the floodplain to integrate into economic assessments.

That said, I have recommended that the consequences of sea level rise – with the associated impacts of permanent inundation and more frequent episodic flooding – be integrated into the adaptation aspect of the engineering cost assessment. This recommendation is discussed more fully below.

Shore treatments being considered in the Hudson River Sustainable Shorelines Project mitigate erosion but do not stop flooding

TIME FRAME

In the initial proposal to NOAA, the Sustainable Shorelines Project scoped the economic assessment to consider a time frame 50 to 100 years in the future. Using 2010 as a benchmark, we have refined the time frame to run 70 years broken into 10-year increments.

Taking the economic assessment out 70 years accomplishes several things. First, it recognizes that land uses adjacent to the shoreline are expected to persist for longer than the 10-30-year lifespan of most engineering treatments. Second, it allows us to incorporate climate change impacts more effectively since the rate of sea level rise is projected to accelerate steadily as we move through the century. Third, breaking the time frame into 10-year increments allows us to better compare the life spans and maintenance requirements of different shoreline treatments and to show economic considerations in a time frame accessible to most decision-makers (Aldrich *et al.* 2009).

Shore Types

In an overview of engineering techniques that could be used to control erosion on the Hudson, Rella and Miller (2010) described 29 different treatments. On a parallel track, Strayer *et al.* (2011) defined six shore types for the Sustainable Shoreline Project's ecological component. While these two lists have significant overlap, they are not directly comparable in many cases because the ecological study cannot assess shore types that are not currently in the estuary.

For the purpose of the economic assessment, the Hudson River National Estuarine Research Reserve refined the list of 29 potential treatments down to nine types that were either commonly found along the Hudson in 2011 or that could meet erosion-control standards while also providing ecological benefits. The shore types are:

- Bulkhead
- Revetment
- Riprap
- Timber cribbing
- Live crib wall
- Green (bio) wall
- Live stakes/joint planting
- Vegetated geogrid
- Living shoreline

Appendix 2 contains brief descriptions of each shore treatment from Rella and Miller (2010) and Strayer *et al.* (2011).

CONSIDERING CLIMATE CHANGE

The primary consequences of climate change on the Hudson River Estuary's shore zone are expected to be accelerating rates of sea level rise and more frequent periodic flooding due to more intense storms. There may also be changes in ice scour due to warmer winters, but no studies have addressed this issue so I do not recommend integrating it into the economic assessment.

Sea Level Rise

I recommend that the Sustainable Shorelines Project consider sea level rise at two rates: rapid ice melt and historical.

Projections of sea level rise along New York's coasts were developed by Columbia University's Center for Climate Systems Research for several state climate assessments (Buonaiuto *et al.* 2010; NYS Sea Level Rise Task Force 2010). One of the projections they developed (using the results of several global general circulation models) was a rapid ice melt scenario which accounted for current rates of land-based ice melt in the polar regions. In 2010, the NYS Department of Environmental Conservation's Office of Climate Change recommended using this scenario when considering sea level rise in New York (Marcell, pers. comm. 2011). The projection for the Hudson River Estuary was divided into two geographic regions because the land is subsiding south of Kingston but rising to the north.

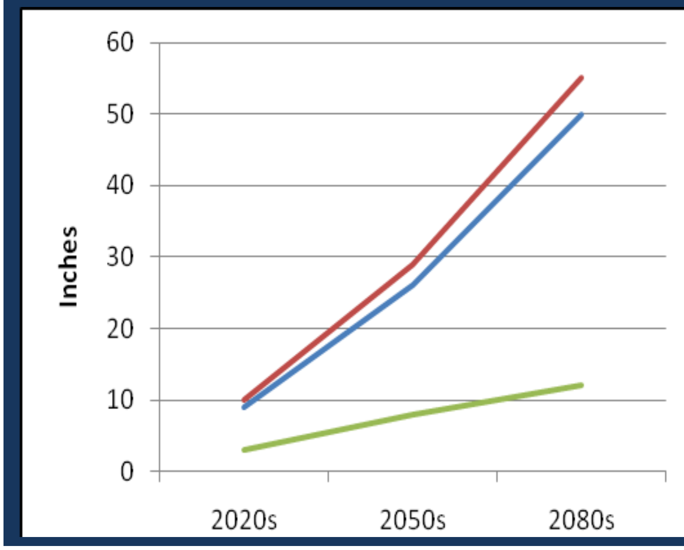
As many members of the public, presumably including decision-makers, are concerned about climate change but view it as a secondary issue (Leiserowitz 2005; Lorenzoni and Pidgeon 2006), I suggest it would be wise to also consider shorelines in a scenario using historical changes. In my experience, decision-makers who do not perceive climate change as a pressing local issue also tend to assume that sea-level rise and weather patterns are static. Historical data, however, show otherwise. At the Battery in New York City (the only station in the Hudson River Estuary with ocean elevation data going back to the mid-twentieth century), sea level rose 4-6" from the 1960s to 2000s (Colle *et al.*. 2010). Sea level rise projections with and without climate change are shown in Table 1.

From the historical records at the Battery and the rapid ice melt projections, I extrapolated general decadal amounts of change with rapid ice melt and historical rates of change. These decadal rates, shown in Table 2, demonstrate that (a) sea level will continue to rise notably even at historical rates and (b) with climate change the rates will accelerate in the middle part of the century. These decadal rates will be important when considering adaptation and replacement costs in the engineering assessment.

Table 1. Two projections of sea level rise in the Hudson River Estuary relative to average 1970-2000 levels.

	2020s	2050s	2080s
With Rapid Ice Melt			
Kingston north to Troy	4-9"	17-26"	37-50"
Kingston south to the Battery	5-10"	19-29"	41-55"
Without Rapid Ice Melt			
Historical at the Battery	2-3"	5-8"	8-12"

The chart graphically shows sea level rise at the highest rates:
Red = Kingston south to the Battery *(with rapid ice melt)*
Blue = Kingston north to Troy *(with rapid ice melt)*
Green = Historical at the Battery *(without rapid ice melt)*



More Frequent Storm-driven Flooding

In addition to permanent inundation by sea level rise, climate change is projected to cause stronger storms that occur more frequently (Buonaiuto *et al*.. 2010). Unfortunately, the degree to which future storms will affect flood regimes through greater precipitation or storm surge has not yet been reliably modeled for the Hudson. In fact, historical records have not been assessed (as of 2011) to show what the past flood regime has been, and modelers have only recently demonstrated that storm surge could reach the Troy Dam (Stedinger and Yi 2010).

With the exception of levees (which were not selected for the economic assessment), all of the shore treatments presented in Rella and Miller (2010) are designed to reduce shoreline erosion, not to stop periodic flooding by storms or permanent inundation by rising sea levels. As a result, flooding of upland areas will happen regardless of the shore treatment, making economic comparisons of flooding between treatments meaningless.

That said, more severe periodic flooding in the future – whether caused by storm surge or precipitation – could trigger the installation of engineered shorelines designed to reduce flooding in addition to erosion. Also, more severe flooding could strain the effectiveness of shore treatments, especially if they are not properly maintained or have exceeded their life cycles. As such, I recommend that we include both storm-driven flooding and inundation by sea level rise as adaptation elements of the engineering assessment.

Table 2. Two projections of decadal rates of sea level rise in the Hudson River Estuary (rounded).

	2010s	2020s	2030s	2040s	2050s	2060s	2070s	2080s
With Climate Change								
Kingston north to Troy	2-5"	4-6"	4-6"	4-6"	7-8"	7-8"	7-8"	7-8"
Kingston south to the Battery	3-5"	5-6"	5-6"	5-6"	7-9"	7-9"	7-9"	7-9"
Without Climate Change								
Historical at the Battery	1-2"	1-2"	1-2"	1-2"	1-2"	1-2"	1-2"	1-2"

ASSESSING ENGINEERING AND ECOSYSTEM SERVICES SEPARATELY

The economic assessment should be split into two parallel tracks. The first track would assess the costs and benefits of different shore zone engineering options, particularly installation, maintenance, adaptation, and replacement. These are discrete costs which, while necessarily presented as ranges because costs will vary between sites, can be expressed in dollars. The second track would assess the values of ecosystem services. As most of the ecosystem services provided by the shore zone have non-market values, we will need to consider carefully which ecosystem services to assess and the most effective methods for undertaking these assessments.

The engineering assessment should describe a series of expenses, specifically the costs of: (a) planning and permitting, (b) installation, (c) maintenance, and (d) replacement. Further, maintenance over the 70-year time frame should be considered in the context of both historical and accelerated rates of sea level rise due to climate change, including the costs of adapting or replacing the shore treatments in response to changing river conditions. Calculating these costs should not require the assistance of economists.

Dollars are the most effective metric for communicating estimated ecosystem values, but these values can be misinterpreted

Valuing ecosystem services will require participation by economists. The ideal valuation effort would capture the full suite of services delivered by the Hudson ecosystem – that is, its Total Economic Value. Obtaining the Total Economic Value, however, requires multiple studies using techniques that are tailored for the particular services being evaluated. As each economic study can be expensive and take many years to complete, this ideal is not pragmatic.

An alternative approach is to estimate values for a selection of ecosystem services. The benefits of this approach are lower costs, more rapid results, and numbers or ranks that could replace the zero valuation effectively placed on them now. The risk, however, is under-representing the actual value of ecosystem services. This would leave us vulnerable to having the economic values we deliver mistakenly interpreted to be the full value for all ecosystem services (Johnston *et al.* 2002).

Another consideration is the units in which we value ecosystem services. The National Research Council (2005) recommended the use of dollars because they are the most easily understood unit for assessing the tradeoffs of policy and management decisions. Farber *et al.* (2002) also highlighted how monetary valuation was the standard unit of measure.

King (1998), on the other hand, advised against valuing ecosystem services in terms of dollars because the results might be turned to justify environmental damage. King related, as an example, an anecdote in which a home on the Chesapeake Bay adjacent to a wetland was determined to be worth $10,000 more than an identical home without the wetland. But, the argument was turned to justify eliminating the wetland when it was shown that the value of the house increased by $50,000 when the wetland was filled and the shoreline protected by a bulkhead.

CUMULATIVE IMPACTS & BENEFITS

Environmental regulations focus on the individual effects of projects locally. Because cumulative impacts are not considered, environmental advocates often invoke the "death by a thousand cuts" analogy to characterize the broader consequences of shoreline management.

Recognizing this challenge, the Project Team in April, 2011 expressed interest in having the economic assessment consider cumulative impacts on ecosystem services. This interest was complemented by a concern that a focus on selected ecosystem services would understate the cumulative values delivered by all ecosystem services.

A paucity of information precludes an economic assessment of cumulative impacts on ecosystem services in the Hudson River Estuary. We are still in the early phases of characterizing the ecological functions of shorelines and how different shore treatments affect them (see Strayer *et al*. 2011 for details). As a result, it will be difficult to summarize local impacts and sheer speculation to describe cumulative consequences. Therefore, until we have an ecological foundation for understanding shoreline functions and a better understanding of what aspects of the shoreline are priorities for user groups, we cannot determine cumulative effects on ecosystem services with any confidence.

Until we have an ecological foundation for understanding shoreline functions, we cannot determine cumulative effects on ecosystem services

As mentioned earlier, it would be ideal to undertake a comprehensive economic assessment of all ecosystem services. Unfortunately, the combination of limited resources and limited data make such a goal infeasible at this time. Assessing the economic value of selected ecosystem services will give decision-makers more information than they currently have when interpreting regulations and guiding shoreline activities. While this approach will undervalue ecosystem services, I contend it nonetheless presents a greater opportunity for advancing ecologically friendly shore treatments than a risk of supporting more traditional hard engineering techniques.

REVIEWING ECOSYSTEM VALUATION METHODS

There are many methods for valuing ecosystem services, each with individual strengths and weaknesses. In general, these methods fall into two broad categories: revealed preference (typically based on market prices) and stated preference (typically based on survey results). I briefly present nine methods from both categories below.

The ***market price*** and ***productivity methods*** both use marketed goods as the basis for estimating ecosystem service values. The Hudson River Estuary today has relatively few natural goods that are sold on the commercial market. Once large fisheries for American shad and Atlantic sturgeon declined dramatically around the turn of the twentieth century due to overfishing and other factors (Limburg *et al.* 2006); in 2011, only small herring (for bait) and blue crab fisheries persisted. Ice harvesting was a vibrant industry on the Hudson from the late nineteenth to early twentieth centuries, but it disappeared with the introduction of electric refrigerators (Huey 1997). Due to the lack of commercial goods, the market price and productivity methods are unlikely to be viable approaches for the Sustainable Shorelines Project.

The ***hedonic pricing method*** is a revealed preference approach that is commonly used to see how environmental variables affect real estate values. By showing how prices shift relative to each variable, the method can implicitly show the economic value of that variable or consumers' willingness to pay for marginal changes. For example, Leggett and Bockstael (2000) assessed home sales in the Chesapeake Bay relative to fecal coliform counts to show what people were willing to pay for better water quality. In New York, Johnston *et al.* (2002) compared home sales in Southold to show that buyers were willing to pay more for homes near open space but less for comparable homes beside farmland. While the hedonic pricing method can show differences in values, it does not necessarily show the causal, behavioral factors behind these differences. Regardless, results from well designed studies using the hedonic pricing method can be quite robust because they are derived from actual market prices.

The ***travel cost method*** is another revealed preference approach typically used to assess recreational values. The core assumption of this approach is that the value of a place or activity can be revealed by determining how much people pay to travel to it. Number of trips, time, and various expenses all can be fed into the valuation, with the information being gathered through surveys and supplemented with other tools such as GIS analyses. Surveys can be employed to distinguish further between what people actually paid and what they would be willing to pay. A report issued every five years by the U.S. Fish & Wildlife Service and the U.S. Census Bureau (2008) uses the travel cost method to showcase the economic values of hunting, fishing, and wildlife-associated recreation in New York. Connelly *et al.* (2004) used this method to assess the economic impacts of motorized boating in New York State. Results from the travel cost method are often combined with results from stated-preference methods to deliver more comprehensive or insightful results. The method is widely used, so values from well designed studies should be generally accepted.

Despite a robust history of use, few marketed goods are extracted from the Hudson River Estuary today

The ***replacement cost*** and ***avoided cost methods*** assess ecosystem service values by estimating the costs of replacing them or of keeping them from being damaged or eliminated. Because they are calculated using market prices, they are revealed preference methods. The methods have been used for a variety of purposes, such as justifying land-protection measures in the New York City watershed over building a new filtration plant (Heal 2000). Pendleton (2009) described avoided costs for protecting coastal wetlands as buffers against storm surge, and Jin (2009) described the benefits of watershed protection to avoid the costs of dredging a harbor.

The methods, however, appear to be controversial, with both the National Research Council (2005) and the National Center for Environmental Economics (2010) advising against their use.

There are a variety of stated preference methods, with ***contingent valuation*** and ***conjoint analysis*** most commonly referenced for ecosystem valuation (Heal 2000; de Groot *et al.* 2002; Johnston *et al.* 2002; National Research Council 2005; Coastal Services Center 2009; Kildow 2009; Pendleton 2009). In the contingent valuation method, survey respondents state how much they would be willing to pay for an ecosystem service. In conjoint analysis, respondents choose between hypothetical scenarios, with their choices later analyzed to estimate relative values. Stated preference methods are important tools because they allow researchers to develop dollar or ranked values for ecosystem services with no clear markets. For example, Kotchen and Reilly (2000) estimated the willingness of Maine respondents to pay to protect two endangered species, while Daniel *et al.* (1989) assessed the effect of scenery on the willingness of visitors to pay to stay at different campgrounds. The challenge with these methods is designing surveys that meet a variety of quality control thresholds, such as the phrasing of questions (Hanemann 1994). Perhaps for this reason the accuracy of results is often criticized (National Research Council 2005).

The ***benefit transfer method*** takes values established for one place and applies them to another. Most famously, Costanza *et al.* (1997) used this approach to estimate the global economic values of 17 ecosystem services. The advantage of this method is it draws upon work that has already been done so is considerably less expensive. The challenge is finding studies of sites and services that are truly comparable. As this is rarely the case, the benefit transfer method is vulnerable to generalization error (National Center for Environmental Economics 2010). This problem may particularly apply to the Hudson River Estuary as the system is ecologically quite different from other estuaries. In general, the National Research Council (2005) and other authors (such as Plummer 2009) recommended that it be used with caution.

The Hudson River Estuary's narrow profile and steep rocky shores make it difficult to compare to other estuarine systems which typically have shallow shorelines and extensive intertidal wetlands

SERVING DIFFERENT AUDIENCES

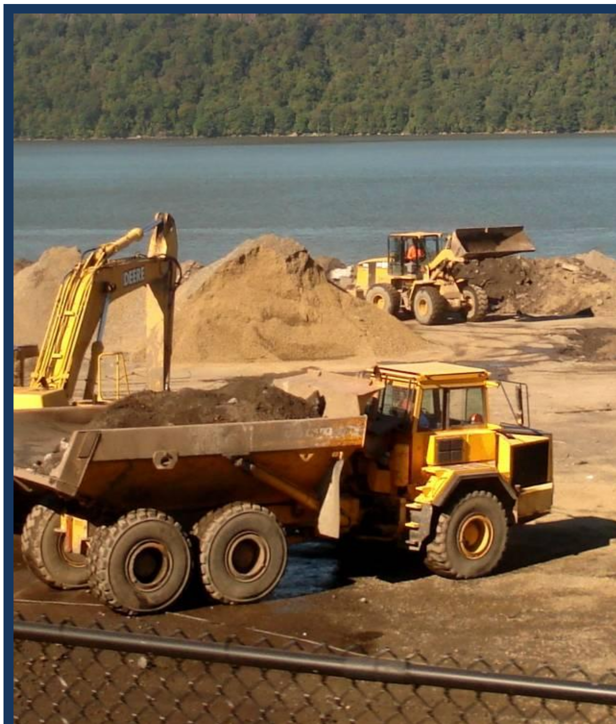
When deciding which valuation methods to employ for particular ecosystem services, we will need to consider our audience(s) and our communication and information objectives.

Government regulators and permitting/compliance officials are the core audience for the Sustainable Shorelines project. These officials work directly with shore managers and owners, interpret laws and regulations pertaining to the shore zone, and are responsible for finding the legal balance between protecting public goods and enabling individual land-use objectives.

Interpretation is an important responsibility for these officials because laws and policies are usually ambiguous. Cost/benefit assessments, whether done formally or informally, typically factor into their decisions. Economic information can help agency staff with these assessments and, in turn, help them consider or justify decisions that are more environmentally beneficial. The rigor they would need for ecosystem service valuations would depend on the projected uses. Numbers that would have to stand up in court would obviously need to be robust, so would likely have to be estimated with revealed preference methods. We would have greater flexibility with numbers intended to inform decisions but not to dictate them.

There are a variety of additional audiences who could benefit from ecosystem service valuations: (a) elected officials; (b) media outlets and the general public; (c) property owners; (d) experts/consultants; and (e) funders.

Elected officials create bills, revise laws, and influence how aggressively regulations are or are not implemented. Economic information can provide elected officials with a clearer picture of the consequences of their decisions regarding shoreline laws and regulations. Two types of values are useful for this audience. Rigorous numbers, like those developed for regulators and permitting/compliance officials, could be used internally when crafting or revising laws. They could also be used to push for more rigorous implementation of existing regulations. Sound bite values could deliver the wow-factor so useful when communicating through different media outlets and directly to constituents. As such, elected officials will likely be most interested in ecosystem services with big dollar values, that directly connect to regulations, and that clearly relate to people and politically sensitive issues.



Government regulators and permit/compliance officials who oversee shoreline activities are our primary audience

Regulatory decisions can be decried as unfair in media and political settings even though they are legally justified. Economic information can clarify the bases for regulatory decisions in ***media outlets*** and help members of the ***general public*** understand why decisions were made. Economic information can also be used proactively to educate people about ecosystem services that most overlook. As these are primarily public-relations audiences, they will likely be most interested in ecosystem services with big numbers, that can be easily understood, and that clearly benefit people.

Dalton (2011) indicates that ***property owners*** are guided by ***experts/consultants*** (particularly engineers and landscape architects) who base their recommendations on regulatory and technical considerations. Engineering considerations regarding access, longevity, and costs are the primary concerns for these audiences. For example, Dalton (2011) notes:

> Most respondents indicated that habitat value of potential installations is either not considered at all or at the bottom of the list of priorities. The rare cases where the response on this differed were because the consultants knew that the regulators were beginning to require proponents to manage their shoreline parcels to improve or protect habitat, so were able to convince their clients that it would be advantageous (i.e., more efficient and easy to get their permits) if they included this value from the outset.

The above insights indicate that property owners and experts/consultants will mostly benefit from the engineering cost assessment, but will also be strongly influenced (albeit indirectly) by valuations designed for regulators.

Funders of shoreline management projects are, according to Dalton (2011), primarily concerned with longevity. This interest will be best served by the engineering cost assessment. That said, some funders (particularly government agencies) might also find ecosystem services to be a positive when considering project applications, but their decisions will not necessarily be driven by them.

SELECTING ECOSYSTEM SERVICES

Before we can develop values for ecosystem services, we first have to identify the suite of services provided by the shore zone. Based on a review of a variety of articles and reports (including Costanza *et al.* 1997; de Groot *et al.* 2002; National Research Council 2005; Millennium Ecosystem Assessment 2005; Brown *et al.* 2007; Coastal Services Center 2009; Pendleton 2009) and the input of the Shoreline Project Team on April 11, 2011, I have developed the following list of ecosystem services:

- Wave & ice protection
- Water quality improvement
- Sediment stabilization
- Flood protection
- Commercial shipping
- Commercial fishing
- Recreation (hunting, trapping, fishing, bird watching, walking, boating, swimming)
- Education
- Aesthetic enjoyment
- Spiritual fulfillment

The ideal economic analysis would generate values for all ecosystem services. Unfortunately, generating ecosystem service values is expensive and time consuming (Johnston *et al.* 2002), and results can be controversial. We therefore need to select a subset of the above services based on the following considerations:

- ***Overall Importance*** – Ecosystem services that are largely supported by the shore zone should be considered for analysis. Services for which shore zone contributions are relatively insignificant should be set aside.
- ***Change*** – Ecosystem services whose values will change between different shore types should be included. Services that will remain the same, or change only slightly, when shores are shifted from one type to another (particularly from a natural to an engineered treatment) should be excluded. Change is a fundamental component of economic analyses, especially as they pertain to policy and management decisions (National Research Council 2005; Heal 2000).
- ***Utility of Results*** – The goal of valuing ecosystem services is to foster improved decision-making that leads to better use of natural capital (Daily *et al.* 2009), in this case shore zones. As discussed above, some valuation methods are more controversial than others. We therefore have to consider the utility of values generated relative to our communication objectives and budget.

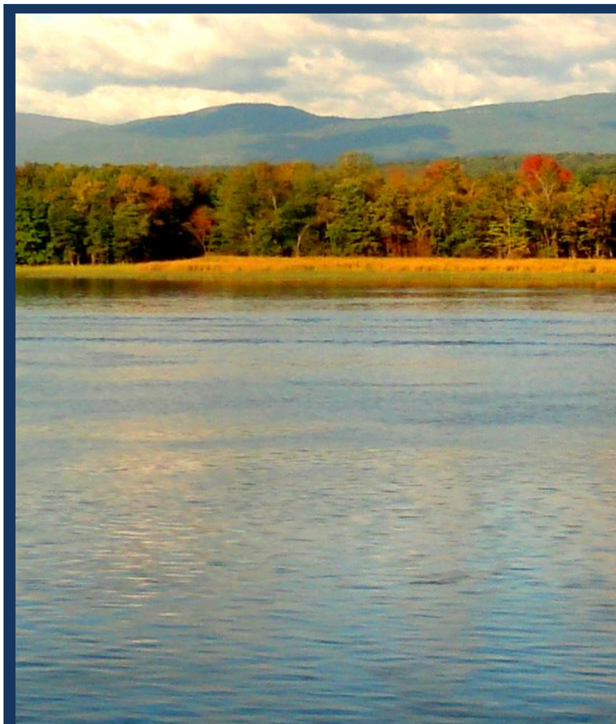
With these considerations in mind, I recommend that we cull the following ecosystem services from our list. Removing these services does not mean that they are not important or that they do not have value. Instead, these are the services for which the shore zone plays a relatively minor role, that are not notably affected by different shore types, or that are unlikely to generate numbers that will influence shore zone decision-makers.

- ***Wave & Ice Protection*** – This ecosystem service should be addressed through the engineering assessment, as all shore types being considered must meet a minimum threshold against wave, current, and ice scour (Allen *et al.* 2006).
- ***Water Quality Improvement*** – Water quality in the Hudson River Estuary is determined primarily by land uses in the watershed that influence point and non-point runoff, including outflow from wastewater treatment plants (Abood *et al.* 2006; Howarth *et al.* 2006). While intertidal wetlands and submerged aquatic vegetation beds provide some water quality improvement in the estuary, the shore zone in which most shore treatments would be installed has relatively little effect compared to the watershed.
- ***Sediment Stabilization*** – The estuary's sediment dynamics are complex, with new sediment entering the system through tributaries but relatively little coming from shoreline erosion (Bokuniewicz 2006). At the regional scale, transport in the estuary, including erosion and deposition, is determined primarily by bedrock morphology, tributary inputs, hydrodynamics, and large-scale dredging and historical channel realignment (Nitsche *et al.* 2007). At this scale, the shore zone plays a relatively minor role in stabilizing sediments. At the site scale, however, some shore types can increase scour on neighboring shorelines and the nearby riverbed (Rella and Miller 2010). In this context, sediment stabilization can be best considered as a component of the engineering assessment (specifically, scour that could undermine stability) and other ecosystem service values, particularly recreation services that rely upon sub-tidal and intertidal vegetation.

Water quality is an important issue in the Hudson River Estuary, but the shoreline plays a relatively small role in regulating it

- ***Flood Protection*** – The Hudson River Estuary's shore zones provide much less storm surge and flood protection to adjacent uplands than estuaries with extensive intertidal wetlands and flatter shorelines. More importantly, the shore treatments being considered by the Sustainable Shorelines project primarily mitigate erosion and generally do not affect flooding. As such, this service (which can include both periodic flooding and inundation resulting from sea level rise) is best considered in the engineering assessment as a component of adaptation to climate change.
- ***Commercial Shipping*** – In other estuaries, extensive intertidal wetlands protect shipping infrastructure along relatively flat shorelines, giving the wetlands significant economic value (Jin 2009). As the Hudson River Estuary is a narrow fjord with steeper slopes and much less intertidal wetlands acreage, the shore zone here does not provide comparable benefits.

- ***Commercial Fishing*** – Although once a vibrant part of the Hudson Valley economy, today only small commercial fisheries persist for blue crab and seasonally for river herring (for bait). This ecosystem service is currently too small to merit initial inclusion in the economic assessment. That said, restoration of American shad and river herring to sustainable, economically viable levels is an important goal of the NYS Department of Environmental Conservation's Hudson River Estuary Program (Hudson River Estuary Program 2010). Assessment of the economic impacts of different shore types on the recovery of these species would likely be worthwhile when we have a better understanding of the habitat needs of each species.
- ***Education*** – Education is widely mentioned as a service, but I could not find any journal articles or reports that attempted to estimate values for it.[2] Like the arts (Throsby 2003), we can argue that the market is not effectively capturing its value. That said, I do not think that shore treatments play a large role in how effectively educational programs can be implemented, at least at the large scale. At the local scale, different shore types can affect the ease of access to the waterline and the species that would be captured by fishing or seine netting. But these are specific activities within a very broad ecosystem service. As such, the change in value between shore types is likely too small to merit assessment.
- ***Aesthetic Enjoyment*** – Aesthetic enjoyment can be considered as a separate ecosystem service or as a component of other services, such as recreation (Boxall *et al.* 1998) and property values (Zhang and Boyle 2010). Estimating the value of aesthetic enjoyment as a separate ecosystem service would likely be more controversial (due to the valuation methods) than when included in other ecosystem service values. As aesthetic enjoyment is an important attribute of the recreation ecosystem services, I recommend that we value it there. That said, I believe valuing this ecosystem service will be particularly difficult because people's perceptions of the shore may be influenced as much or more by the land uses above the shore zone than the shoreline itself.



Aesthetic enjoyment of the shore may be influenced more by the land uses above the shore zone than by the shoreline itself

- ***Spiritual Fulfillment*** – Like many other cultural goods, valuing spiritual fulfillment is easier said than done (Noonan 2003). Although it is repeatedly identified as an ecosystem service, I could not find any articles that assessed it in the ecological or cultural economics literature (just as with education). Some of the spiritual value of the shore zone may be captured in assessments of the recreation ecosystem services, and I do not recommend considering it on its own.

[2] I conducted searches in Google Scholar using a variety of search themes relating to education and spiritual fulfillment and gleaned more than 30 citation lists for potential leads.

BREAKING OUT KEY CONSIDERATIONS

In the previous sections, I refined the framework of the proposed economic assessment and transitioned us from the cloud of ideal assessments to a much shorter, more practical list of ecosystem services to consider. In this section, I endeavor to break out key considerations that a team of economists could use to recommend approaches, costs, and timelines for conducting economic assessments of the remaining ecosystem services (or a further subset thereof). These services are all centered on recreation:

- Hunting
- Trapping
- Fishing
- Bird watching
- Walking
- Boating
- Swimming


There are few datasets available for many user groups, so it is difficult to determine their numbers in relation to use of the shore zone

In the following sub-sections, I lay out the user groups for the above ecosystem services, give an indication of participant numbers and economic impacts, and identify the shoreline aspects likely to be important to them. Next, I present initial rankings of the quality of the shoreline aspects with each shore treatment. Finally, I set forth a series of questions and next steps for the assessment process.

USER GROUPS & SHORELINE ASPECTS OF INTEREST

There are seven groups of recreational shoreline users to consider. While there is some overlap between them (e.g., anglers may also be boaters), we can nonetheless discuss them separately. The user groups are ordered below based on my estimate of their relative importance. These estimates are based on participant numbers and their economic impact, which I drew from regional studies of a few user groups, studies from other areas, and personal communications with state agency staff that work regularly with the user groups. No detailed data sets are available for any of the user groups, so it may be appropriate to reorder the groups.

Surveys or focus group interviews will be necessary to determine what aspects of shorelines are of particular interest to (and in turn influence the value for) the seven user groups. As a starting point, however, I have suggested an initial set of aspects that are likely important to some or all of the user groups. These suggestions are based on a limited set of articles and personal communications, as there appear to have been few efforts to identify the characteristics that different user groups use to select places to recreate, and those that have been done do not necessarily line up cleanly with the Hudson River Estuary. In addition to the discussion below, I have briefly summarized the shore aspects of interest to each user group in Table 4.

- **Boaters** – This user group operates motor-, sail-, and paddle-powered boats from marinas, public launches, and private properties. In a statewide assessment of pleasure boat owners, Connelly *et al.* (2004) estimated that approximately 25,000 motorboat users traveled the Hudson River Estuary (not including New York Harbor) in 2003 with related total expenditures of more than $48 million. The NYS Department of Motor Vehicles does not require registration of non-motorized craft such as kayaks, so there are no state-maintained databases on these users.

Shoreline aspects of interest to boaters appear to be as diverse as the boating community itself. According to the President of the Hudson River Boat & Yacht Club Association (Bergman, pers. comm. 2011), motorboat operators typically go into the estuary to cruise or to travel to selected destinations. Cruisers are usually just enjoying the water and the view. Destination travelers are commonly going to a population center to dock and enjoy the town, or to a quiet area to relax or gather with friends.

I could not locate any studies of kayak, canoe, or sailboat operators in the Hudson River Estuary, but the organization of the Hudson River Water Trail Guide (Giddy 2003) may provide insights. Descriptions of each reach of the river emphasized access (both to and from the water), sights along the way (both natural and manmade), and onshore facilities.

Based on this limited information, access to and from the water and aesthetic enjoyment appear to be the two primary shoreline features of interest to boaters.

- **Anglers** – With professional guide services for striped bass, nearly 70 competitive black-bass tournaments in 2001 (Normandeau Associates 2003) and 20 in 2004 (Magron 2005), and regular angling for other species, fishing is a major recreational activity on the Hudson. Connelly and Brown (2009) estimated that anglers spent more than 350,000 days plying the Lower Hudson River with total expenses in 2007 from $5-10 million.

  In a survey of freshwater anglers in Mississippi about fishing site choices, Schramm *et al*. (2003) found that clean environment (particularly fish being safe to eat, water quality, and the water and access areas being clear of litter and debris) and catch (particularly catching desired fish species and knowing large fish were available to be caught) were the most important site attributes. Easy access to the water and natural beauty of the surroundings were secondary considerations. Given that the shore zone plays a relatively minor role in water quality, I suggest that the key shore zone aspects for anglers are abundance of fish, site suitability for fishing, access, and aesthetic enjoyment.

Table 3. Visitor numbers to eight state parks with Hudson River Estuary shoreline during the state fiscal year 2008-09.

Facility	Visitors in 2008-09
Schodack Island	43,000
Hudson River Islands	9,000
Staatsburgh	19,000
Margaret Lewis Norrie	237,000
Fort Montgomery	15,000
Stony Point Battlefield	28,000
Hook Mountain	27,000
Nyack Beach	118,000
Total	496,000

- **Walkers** – I have combined the different types of shoreline visitors who are not engaged in one of the other recreational activities into the general user group of walkers. Walkers interact with the shore zone mostly at public properties, such as state parks, historic sites, and municipal parks. Hikers in uplands with views of the shoreline might also be notable, though they may be too far away to really see the shore type, instead being more affected by upland land uses along the shore zone.

  It is difficult to project the number of individuals in this user group, let alone the number actually interacting with the Hudson River Estuary shoreline. Nonetheless, the number is likely relatively high. In the 2008-09 state fiscal year, for example, eight state parks and historic sites with Hudson shoreline were visited by nearly 500,000 people (Nelson A. Rockefeller Institute 2010). Table 3 shows the number of visitors to each of these parks.

I was not able to locate any studies or reports about this user group in the Hudson Valley. Access to the waterline may be an issue for some walkers, though many or most might be more drawn to views of the water and not concerned about the shore treatment they are standing above. Walkers may actually be more affected by treatments on the opposite shore as they are more in their line of sight. With these presumptions in mind, aesthetic enjoyment and access may be good starting points for listing shoreline aspects of interest to walkers.

- **Bird Watchers** – The U.S. Fish & Wildlife Service and the U.S. Census Bureau (2008) estimated that New York had 1,260,000 wildlife watchers in 2006. Wildlife watchers are people who take a special interest in wildlife around their homes or travel specifically to see them; people who make incidental observations while driving or participating in other activities like hunting are not included. While statewide numbers are high, as of 2011 there were no efforts to track their activity levels at more local scales (Connelly, pers. comm. 2011).

  Wildlife watchers are principally bird watchers, so I have focused the following discussion on them. In 2011, there were just under 5,000 members in the six National Audubon Society Chapters whose boundaries included the Hudson River Estuary (McCarthy, pers. comm. 2011). Membership in this organization, however, is not a prerequisite to birding, so the actual number of birders active in the Hudson Valley is surely higher.

  Access is an important shoreline function for most user groups, but some users are interested in access to and from the waterline while others may just want to reach a view of the water

  In a survey of birders at a national park in Thailand, Hvenegaard (2002) determined that the presence of birds and the natural environment were the two strongest factors affecting site selection. Experienced birders were overwhelmingly influenced by the bird fauna, while generalist birders also cared strongly about scenery and the natural environment. In a study of bird watcher motivations, McFarlane (1994) found that advanced birders were most interested in achievement, such as building their skills and seeing new species, while intermediate birders were typically motivated by appreciation, such as being outdoors. The Cornell Lab of Ornithology noted that participants in their eBird program tended to bird in areas that were easily accessible (Fink, pers. comm. 2011).

  With the above considerations in mind, the key shore zone aspects for bird watchers appear to be presence of birds, visibility of birds, aesthetic appeal, and access. That said, “access” for birders may not be so much about reaching the waterline as getting to a spot where shorebirds, waterfowl, and eagles can be viewed (Burger, pers. comm. 2011). As such, the impacts of shoreline engineering on waterline access are probably not very important to most birders.

- **Swimmers** – In an assessment of public swimming beaches along the Hudson River Estuary, Lawler *et al*. (2005) identified three active beaches and one closed beach (due to water chestnut) that had the collective capacity to serve 1,800 people per day. The report also noted that respondents to a NYS Department of Environmental Conservation survey in 2000 identified more than 100 informal swimming sites along the estuary. In addition to these beaches, there is a 20-foot diameter river pool in Beacon.

I did not find any studies of swimmer preferences in the Hudson River, but the NYS Department of Environmental Conservation's Hudson River Estuary Program considers swimming in several of their Action Agenda goals (Hudson River Estuary Program 2010). Objectives for the Program include improving water quality, increasing accessibility, and improving facilities (e.g., changing rooms and showers) at existing sites. As the shore zone plays a relatively small role in water quality, and as swim facilities are not part of the shoreline, I suggest that access and aesthetic enjoyment are likely important shore zone aspects for this user group.

- **Hunters** – Hunting along the Hudson's shoreline is primarily for waterfowl, with participation estimated at about 500 annually (Swift, pers. comm. 2011). All waterfowl hunters must register for the federal Harvest Information Program which the U.S. Fish & Wildlife Service uses to generate take numbers – but only at the state level.

  When selecting sites, waterfowl hunters consider how attractive a spot is, isolation from other hunters, ease of access, site characteristics such as low current for decoys and habitat quality for target species, and harvest success (Swift, pers. comm. 2011). A study by the Cornell University Human Dimensions Research Unit (Enck *et al*. 1993) found that the appreciative aspects of hunting ("sense of peace, belonging, and familiarity they associate with hunting") were far more important to most hunters than actually harvesting waterfowl. From these, we can project that important site aspects are aesthetic enjoyment, site suitability for hunting, access, and abundance of waterfowl.

Although there are only about 500 waterfowl hunters along the Hudson River Estuary, this user group interacts very closely with the shoreline

- **Trappers** – There are around 100 trappers working the Hudson River Estuary shoreline, mostly for beaver, raccoon, muskrat, and mink (Batcheller, pers. comm. 2011). The NYS Department of Environmental Conservation conducts surveys to estimate harvest levels, but only to the scale of Wildlife Management Units, which in the Hudson Valley are slightly smaller than counties.

  When selecting sites, trappers consider habitat quality, evidence of a species' presence (such as trails, beaver cuttings, and muskrat houses), and accessibility from and to the waterline. Many trappers are also active because they enjoy the landscape (Batcheller, pers. comm. 2011). We can therefore safely assume that important shoreline aspects for trappers include abundance of furbearers (which is also an indicator of habitat quality), access, and aesthetic enjoyment.

Table 4. Summary of shoreline aspects likely to be of interest to the seven user groups. Surveys or focus group interviews will be necessary to correct or confirm the accuracy of this table.

	access	aesthetic enjoyment	abundance of fish	site suitability for fishing	presence of birds	visibility of birds	abundance of waterfowl	site suitability for hunting	abundance of furbearers
Boaters	both from upland to water and from water to upland	yes, but natural shore isn't necessarily preferred							
Anglers	to water line, but could also just be to get fishing lines into water	yes	yes	easy to get lines into water and to get fish from water to shore					
Walkers	to places with good views, not necessarily to the water's edge	possibly as or more concerned about treatments on the opposite shore							
Bird Watchers	to places where birds can be seen, not necessarily to the water's edge	yes			particularly eagles, shorebirds, & waterfowl	particularly in the water & along the shoreline			
Swimmers	yes	yes							
Hunters	yes	yes					particularly ducks & geese	yes	
Trappers	yes	yes							particularly beavers, raccoons, muskrats, & mink

QUALITY OF SHORELINE ASPECTS OF INTEREST WITH DIFFERENT SHORE TREATMENTS

The engineering treatments used along the Hudson's shores will affect the shoreline aspects of interest to each of the user groups and in turn affect how much each user group values the shore zone. Unfortunately, the ecological and engineering components of the Sustainable Shorelines Project are not directly determining how each of the shore treatments will affect these shoreline aspects. Given all the research that has been done, however, I believe we can make informed assessments of the quality of the shoreline aspects of interest with each of the shore treatments.

These assessments are summarized below and in Table 5. I filled out the table in consultation with the individuals below, who are very knowledgeable about the ecology of the shore zone and the preferences of different user groups, and based on the information presented earlier in this report. With that in mind, however, the rankings in Table 5 are estimates that have not been tested to confirm or adjust their accuracy.

Anglers can catch fish just about anywhere along the Hudson River Estuary, though sizes and species will vary with site conditions, according to Ryan Coulter (pers. comm. 2011) of the NYS Department of Environmental Conservation's Division of Fish, Wildlife, & Marine Resources. The key for fish is not so much what the shore treatment is as the riverbed structure, including submerged aquatic vegetation beds, adjacent to it. Intertidal wetlands and associated waters are also important nursery habitats for many species. While shoreline vegetation can be an important component of the food web, fishing lines can become tangled in it, thus making sites with vegetated shore types less suitable for fishing. Shore types that are too steep or slippery for walking can also make it difficult for anglers to bring fish from the water to shore.

According to Mike Burger (pers. comm. 2011) of Audubon New York, the key habitat considerations for shorebirds and waterfowl are not the shore habitat but what is adjacent to it, particularly mud flats, intertidal wetlands, and shallow water with vegetation. For birders, shore types with vertical drops (like bulkheads) or tall vegetation make it difficult to see birds that may be against the shoreline, while unvegetated, sloped shore types (like revetments) provide clear views of shorebirds and waterfowl.

Waterfowl congregate in shallow areas with aquatic vegetation and low currents, according to Bryan Swift (pers. comm. 2011) of the NYS Department of Environmental Conservation's Division of Fish, Wildlife, & Marine Resources. Key food resources are in shallow water, not along the shore, so shore type is not a key consideration for waterfowl unless the treatments directly or indirectly degrade submerged aquatic vegetation beds. For waterfowl hunters, concealment is key, as is proximity to boat launching sites and waters that are safe for navigation.

According to Gordon Batcheller (pers. comm. 2011) of the NYS Department of Environmental Conservation's Division of Fish, Wildlife, & Marine Resources, transient species like raccoons, mink, and otters will move through engineered shorelines but likely won't spend much time on them. In turn, trappers will move on too. Shore types with dense vegetation will provide some habitat for furbearers and cover in which traps can be concealed, and sloped shores that support wrack development can provide food for species like raccoons.

Access is a complicated shoreline aspect of interest because it means different things to different users. For most, however, access is the ability to move safely from the upland to the water's edge. Shore types with vertical walls, steep slippery slopes, and/or dense brushy vegetation will typically not be good for access, while shores with shallower slopes and less dense or brushy vegetation will be easier to traverse.

Table 5. Quality of shoreline aspects of interest with nine shore treatments.

	access	aesthetic enjoyment	abundance of fish	site suitability for fishing	presence of birds	visibility of birds	abundance of waterfowl	site suitability for hunting	abundance of furbearers
Bulkhead	poor	unknown	moderate	good	poor	poor	poor	poor	poor
Revetment	poor	unknown	moderate	moderate	moderate	good	poor	poor	poor
Riprap	poor	unknown	moderate	moderate	moderate	good	poor	poor	poor
Timber cribbing	poor	unknown	moderate	good	moderate	poor	poor	poor	poor
Live crib wall	poor	unknown	moderate	poor	good	moderate	moderate	moderate	moderate
Green (bio) wall	poor	unknown	moderate	moderate	moderate	good	moderate	poor	poor
Live stakes/ joint planting	moderate	unknown	moderate	poor	good	moderate	moderate	moderate	moderate
Vegetated geogrid	moderate	unknown	moderate	poor	good	moderate	moderate	moderate	moderate
Living shoreline	good	unknown	moderate	good	good	good	good	good	good

Aesthetic enjoyment is even more complicated than access because it reflects individual preferences in addition to user group tendencies. Studies using surveys or focus groups are necessary to determine how different shore types tend to affect this shoreline aspect with different user groups.

IDENTIFYING NEXT STEPS

In the previous sections, I clarified our framing of the shoreline project, refined the broad and complex list of ecosystem services to a subset focused on recreation, and broke down some of the component parts of these services. My objective was to create a defined information set that economists could use to recommend next steps. Appendix 1, with Tables 4 and 5, concisely summarizes the key points from this report.

To quickly recap, the Sustainable Shorelines Project's goal is to generate information that decision-makers can use to compare the tradeoffs of different shore treatments. While engineers can summarize the costs of installation, maintenance, adaptation, and the like, we need economists to lead studies that show changes in ecosystem service values between different shore types. The results of these studies do not necessarily need to be suitable for publication in top-tier economics journals, but they do need to be solid enough to share with government regulators, elected officials, consultants, and property owners. They ideally would also be compelling enough to capture the attention of media outlets and interested members of the general public.

The following key questions need to be answered before the Sustainable Shorelines Project can move forward on an economic analysis of the seven recreational ecosystem services relative to the nine different shore treatments:

1. Should we assess all or a subset of the seven services?
2. Do we need to determine dollar values or would rankings suffice?
3. What additional background information is necessary?
4. How serious are the risks of not assessing cumulative economic impacts?
5. What methods should be used?
6. How much would each method cost, and how long would it take to get results?
7. How useful would the results be?

In this report, I have proposed a series of recommendations and refinements that can be used as the basis for an economic assessment of values for selected ecosystem services. Hopefully, the discussions that follow this report will help the Sustainable Shorelines Project launch focused economic assessments that not only support Hudson Valley decision-makers but also serve as models for estuary managers nationally.

APPENDIX 1.
Graphic Display of Key Points and Considerations from the Economic Assessment Phase 1 Report

Value
Focusing on values as they relate to people (i.e., instrumental value).
We are not including intrinsic values.

Shore Zone
Generally 3 feet below and 3-6 feet above intertidal zone.
(area does not include the floodplain)

Time Frame
70 years (2010 to 2080) broken into 10-year increments

Audiences
Government regulators and permitting/compliance officials.
Secondary audiences are (1) elected officials, (2) media outlets, (3) general public, (4) property owners, (5) experts/consultants, and (6) funders

Climate Change
Sea level rise using (1) projected rates under rapid ice melt scenario and (2) historical rate between 1960s and 2000s.
We are only including projections of more intense/more frequent storms and related flooding in the adaptation portion of the engineering cost assessment.

9 Shore Types
Bulkhead
Revetment
Riprap
Timber cribbing
Live crib wall
Green (bio) wall
Live stakes/joint planting
Vegetated geogrid
Living shoreline

Engineering Cost Assessment
Include costs of
(a) planning/permitting,
(b) installation,
(c) maintenance,
(d) replacement, and
(e) adaptation

Ecosystem Service Assessment
Generate values for recreation ecosystem services only:
Boating
Fishing
Walking
Bird Watching
Swimming
Hunting
Trapping

At this time, we are not directly considering:
Wave & ice protection
Water quality improvement
Flood protection
Sediment stabilization
Commercial shipping
Commercial fishing
Education
Aesthetic enjoyment
Spiritual fulfillment

7 User Groups
Boaters
Anglers
Walkers
Bird Watchers
Swimmers
Hunters
Trappers

9 Shoreline Aspects of Interest
Access
Aesthetic Enjoyment
Abundance of Fish
Site Suitability for Fishing
Presence of Birds
Visibility of Birds
Abundance of Waterfowl
Site Suitability for Hunting
Abundance of Furbearers

Which of the 9 Shoreline Aspects Each of the 7 User Groups Cares About
See Table 4

Quality of the 9 Shoreline Aspects with Each of the 9 Shore Types
See Table 5

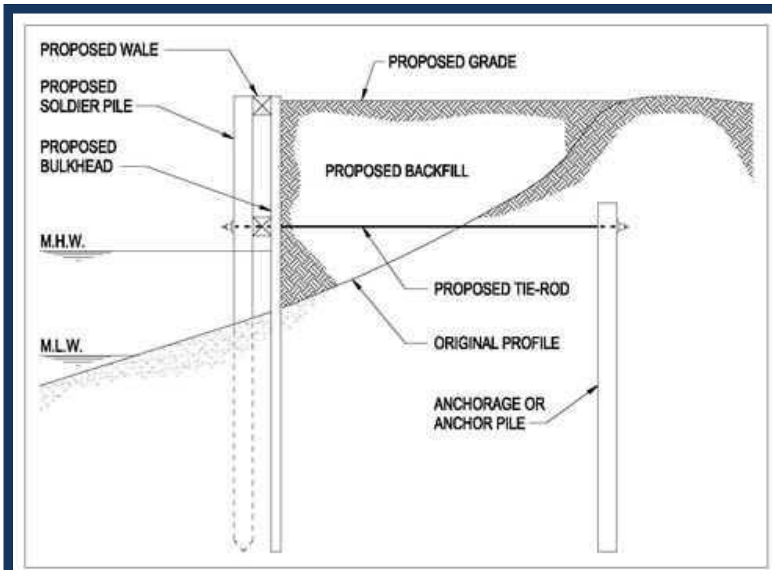
Next Steps
Economists and knowledgeable individuals meet to decide:
1. Should we assess all or a subset of the seven services?
2. Do we need to determine dollar values or would rankings suffice?
3. What additional background information is necessary?
4. How serious are the risks of not assessing cumulative economic impacts?
5. What methods should be used?
6. How much would each method cost, and how long would it take to get results?
7. How useful would the results be?

APPENDIX 2.
SUMMARY OF THE NINE SHORE TYPES.

The following shore-type descriptions, except for timber cribbing, are drawn verbatim from Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods by Rella and Miller (2010). The description of timber cribbing is taken from Biodiversity in Hudson River shores zones: Influence of shoreline type and physical structure by Strayer *et al*. (2011).

BULKHEAD

Bulkheads are perhaps the most common structure found along sheltered shorelines. The primary purpose of a bulkhead is to prevent the loss of soil by encapsulating it behind an often impervious vertical wall. Bulkheads are most common at the base of bluffs or steep shorelines, in areas where land has been reclaimed, and in locations where space is limited (marinas for example). Bulkheads are frequently found near mooring facilities, in harbors and marinas, and along industrialized shorelines. One of the major drawbacks associated with bulkheads is that they can increase erosion on adjacent shorelines due to flanking effects and at their base due to wave reflection.



Typical bulkhead cross-section
(North Carolina Division of Coastal Management 2008)

REVETMENT

Revetments are sloping structures built parallel to the shoreline to protect the coastline against erosion caused by waves and currents. Revetments typically use large rocks or concrete armor units to dissipate wave energy and prevent further recession of the shoreline. Because the individual units are susceptible to movement under the right combination of forces, revetments are most effective in low-moderate wave conditions. Revetments can be used as a supplement to a seawall or dike at locations where both erosion and flooding is a problem.

Typical revetment cross-section
(U.S. Army Corps of Engineers, St. Paul District)

RIPRAP

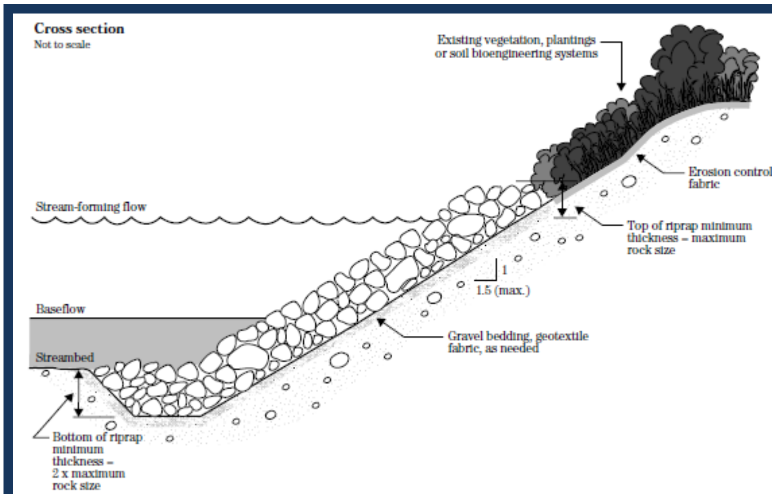
Rip-rap is frequently utilized to stabilize shorelines when the level of protection required is less than that which would require a revetment. Rip-rap stabilized shorelines utilize material that is significantly smaller and therefore less costly than the large stones used in the construction of a revetment. Unlike revetments, rip-rap slopes retain a high degree of flexibility and can shift freely without destabilizing the entire structure. A graded slope is normally covered with a fabric filter and then backfilled with appropriately sized rocks up to the top of the slope. Vegetation is frequently added to the top of the slope to provide additional erosion resistance as well as to increase the aesthetic and ecological value of the project.

TIMBER CRIBBING

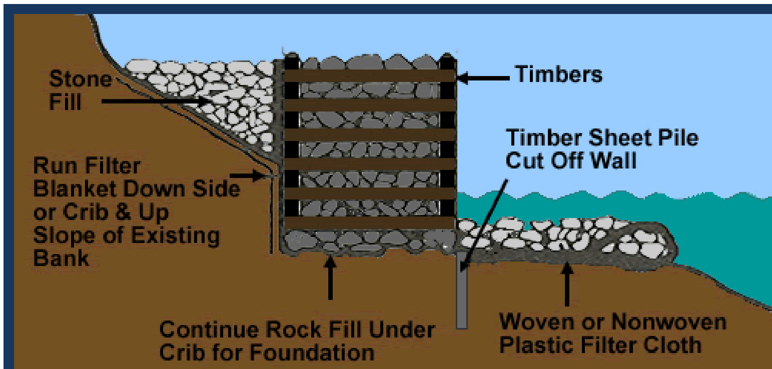
[Timber] cribbing shores consist of wooden pilings (typically ~25 cm diameter) back-filled on the land side with crushed stone 15-25 cm in diameter.

LIVE CRIB WALL

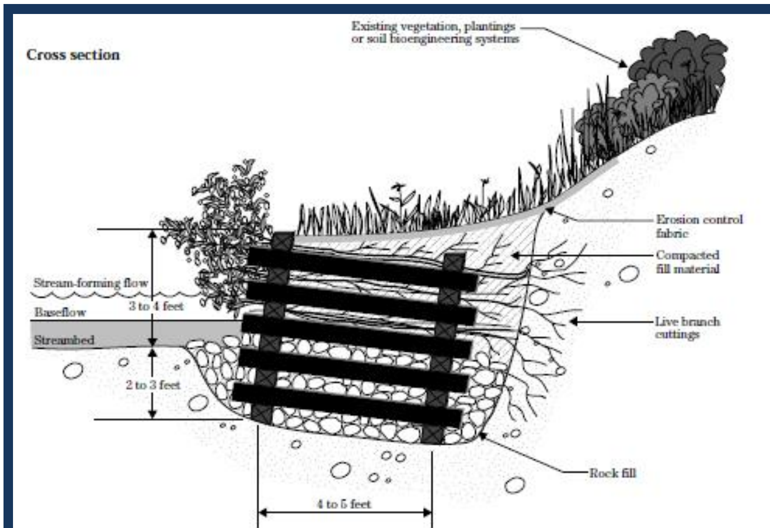
A crib wall is a three dimensional boxlike chamber constructed out of untreated log or timber, that is filled with alternating layers of soil or other fill material. A live crib wall incorporates live branches into the design, which eventually take root inside the box and extend into the slope of the bank. These earthen structures are constructed at the base flow level, and are very effective in preventing bank erosion and retaining soil. Once the vegetation becomes established, the stability of the structure is enhanced and an important habitat is created along the shoreline. The root system of the vegetation binds the structure into a single large mass. Live crib walls are typically used in situations



Typical rip-rap slope cross-section
(U.S. Dept. of Agriculture 1996)



Timber crib cross-section
(U.S. Army Corps of Engineers 1995)

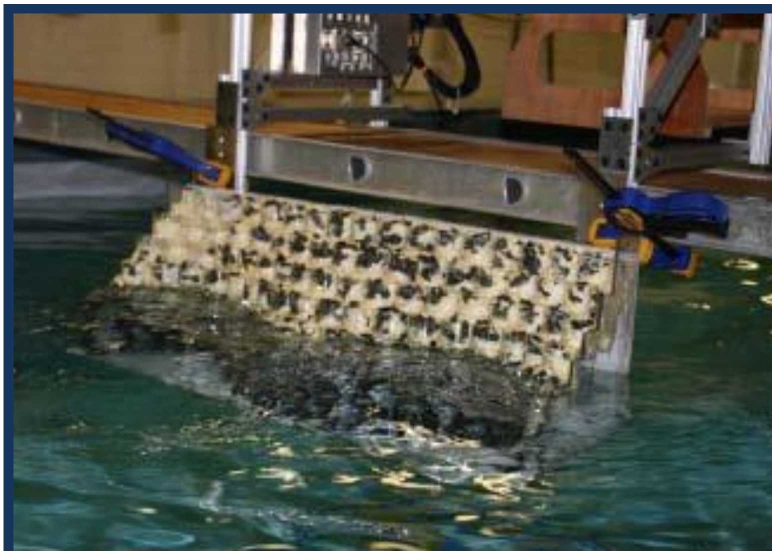


Typical live crib wall cross-section
(U.S. Dept. of Agriculture 1996)

where the toe of a slope needs to be stabilized and where a low wall may be needed to reduce the steepness of a bank. They are normally used in small rivers or streams; however by adding anchors for additional support, they can be adapted for use in more extreme conditions.

GREEN (BIO) WALL

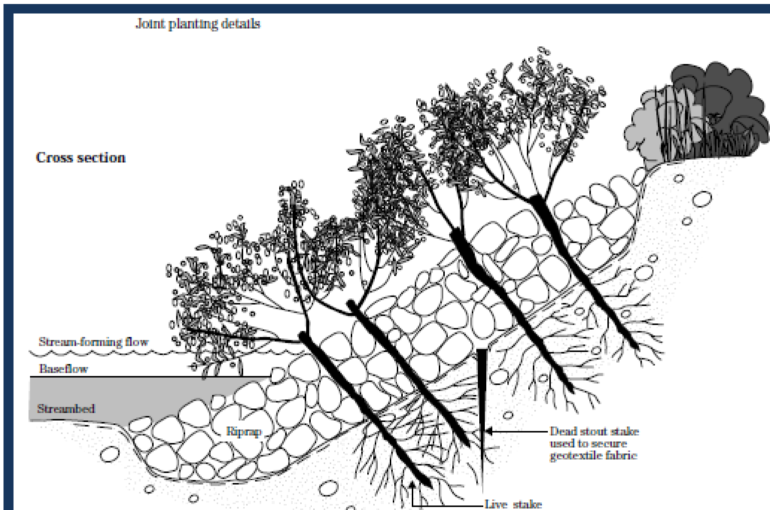
A green or bio wall is a generic term used to describe hard sheer structures which are softened using a variety of techniques. Bulkheads, gabions, or keystone walls frequently serve as the base for a green wall. The methods used to soften these hard structures range from the incorporation of minimalistic vegetation, to variations in the form of the structure itself. Examples include incorporating terraced or rough edges, using alternate materials, or introducing undulations along the length of a structure. The purpose of these modifications is to improve both the aesthetic and ecological value of the structure, while providing the same high-level of protection afforded by the base structure. Green walls have been used increasingly in urban settings where a high level of protection is required and where space is limited.



Laboratory study of wave run-up along a green wall (Herrington *et al*. 2005)

LIVE STAKES/JOINT PLANTING

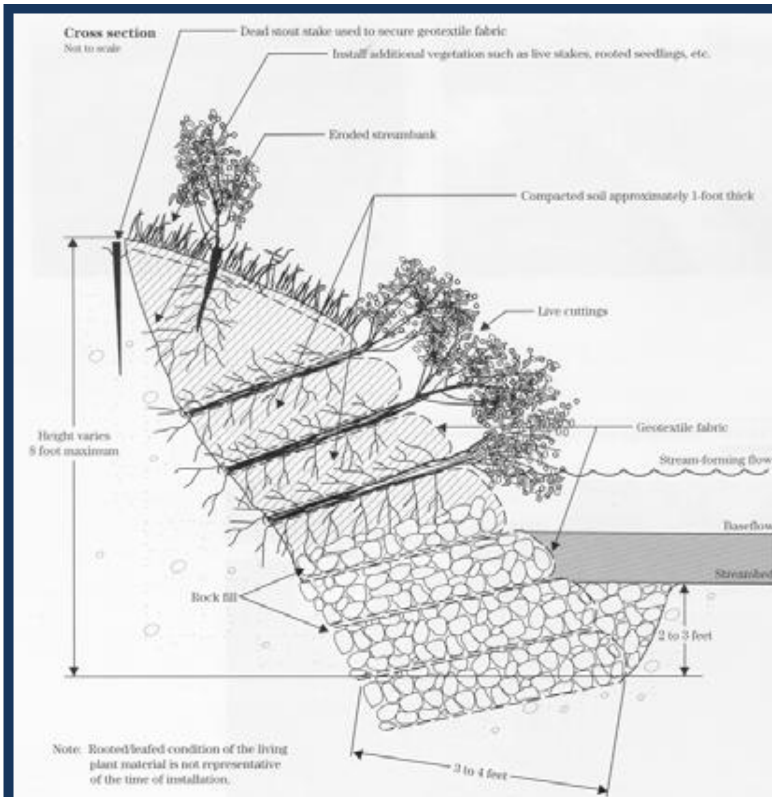
Joint planting consists of adding live stakes or vegetation into the open spaces, or joints, of an existing rip rap or rock covered slope. Alternatively, the stakes can also be placed at the same time as the rock reinforcement. When the system of roots from the live stakes develops it creates a living root mat beneath the rocks, binding the soil and preventing washout of the soil and fine material.



Typical joint planting (U.S. Dept. of Agriculture 1996)

VEGETATED GEOGRID

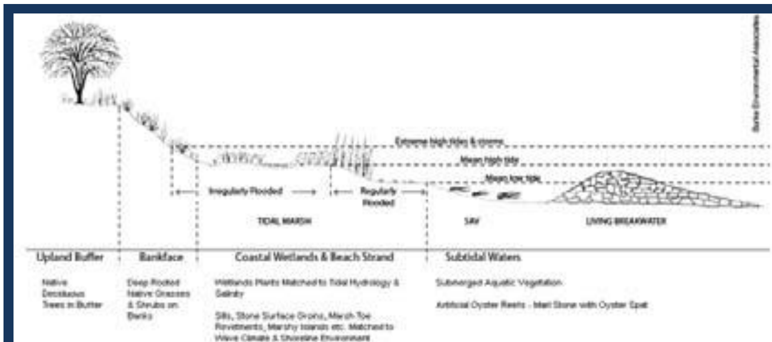
A vegetated geogrid is a soil wall that can be placed on a bank or shore that has been severely eroded. The wall is made up of successive soil lifts that are separated by and wrapped in a synthetic control fabric. Branch cuttings are then placed between each layer. The live branch cuttings serve several practical purposes. The cuttings act as a buffer to reduce wave energy and shear stress at the face of the wall. In addition, having the branch cuttings present before the completion of the wall enables the vegetation to grow as rapidly as possible. Finally, once established the branches serve to bind the geogrids together and provide a root structure behind the wall, attaching it more securely to the shore. The toe of the structure at the bank of the river or stream is further supported by layers of rock on top of the soil lifts.



Typical vegetated geogrid
(Iowa Dept. of Natural Resources 2006)

Living Shoreline

"Living shorelines" is a term that is often used broadly to represent a system of protection that incorporates many of the individual approaches identified elsewhere in [Rella and Miller, 2010]. Living shorelines involve bank stabilization and habitat restoration to reduce shoreline erosion, and maintain coastal and estuarine processes through natural approaches. Living shorelines are considered a "soft" approach to shoreline stabilization, because of the use of non-structural, natural and often biodegradable techniques. The use of vegetation often plays a significant role in developing a living shoreline where the vegetation is used to help anchor the soil and prevent erosion, and at the same time trap new sediment. The vegetation also provides shelter and habitat for wildlife living along the shoreline and can act as a natural filter for removing pesticides and fertilizers. Aquatic vegetation can be used as a part of a living shoreline project to increase the bottom roughness and dissipate wave and current energy along the shoreline. Natural buffers such as oyster and/or mussel reefs are also frequently used to dissipate energy, and create submerged habitats. Other materials frequently used along living shorelines include sand fill, and biodegradable materials such as natural fiber "bio-logs" and organic matting. Along some higher energy shorelines, a hybrid of solutions may be implemented, where low-profile rock structures may be used to dissipate energy.



Typical cross-section of a living shoreline
(National Oceanic & Atmospheric Administration)

REFERENCES

Abood, K.A., T.L. Englert, S.G. Metzger, C.V. Beckers, Jr., T.J. Groninger, and S. Mallavaram, 2006. Current and evolving physical and chemical conditions in the Hudson River Estuary. IN J.R. Waldman, K.E. Limburg, and D.L. Strayer (editors). Hudson River Fishes and Their Environment. American Fisheries Society Symposium 51:39-61.

Aldrich, S., M. Dunkle, and J. Newcomb, 2009. Rising Waters: Helping Hudson River Communities Adapt to Climate Change, Scenario Planning 2010-2030 Final Report. The Nature Conservancy and bio-era. 67 pp.

Allen, G., T. Cook, and J. Young. 2006. Hudson River Shoreline Restoration Alternatives Analysis. Report prepared for NYS DEC and NEIWPCC by Alden Research Laboratories, Inc. and ASA Analysis and Communications, Inc. 135 pp.

Batcheller, G., NYS Department of Environmental Conservation, May 3, 2011, June 7, 2011, June 16, 2011, June 22, 2011, and July 19, 2011. Personal communications by telephone and email regarding hunting and trapping along the Hudson River Estuary.

Bergman, F., Hudson River Boat & Yacht Club Association, June 21, 2011. Personal communication by telephone regarding boating in the estuary.

Boxall, P.C., J. Englin, and W.L. Adamowicz, 1998. Valuing Undiscovered Attributes: A Combined Revealed-Stated Preference Analysis of North American Aboriginal Artifacts. 25th Workshop of the W-133 Project in Portland, OR in March 1997.

Brennan, A. and Y.S. Lo, 2007. Environmental ethics. IN E.N. Zalta (editor). The Stanford Encyclopedia of Philosophy (Fall 2007 Edition). URL = <http://plato.stanford.edu/archives/fall2007/entries/ethics-environmental/>.

Brown, T.C., J.C. Bergstrom, and J.B. Loomis. 2007. Defining, valuing, and providing ecosystem goods and services. Natural Resources Journal 47: 331-376.

Buonaiuto, F., L. Patrick, V. Gornitz, and E. Hartig, 2010. Coastal Zones. IN Rosenzweig, C., W. Solecki, A. DeGaetano, S. Hassol, P. Grabhorn, and M. O’Grady. (editors). ClimAID: Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State. DRAFT. Report for the New York State Energy Research and Development Authority.

Burger, M., Audubon New York, July 22, 2011. Personal communication regarding birding on the Hudson River Estuary.

Coastal Services Center, 2009. Introduction to Economics for Coastal Managers. National Oceanographic and Atmospheric Administration. 17 pp.

Colle, B.A., K. Rojowsky, and F. Buonaito, 2010. New York City storm surges: climatology and an analysis of the wind and cyclone evolution. Journal of Applied Meteorology and Climatology 49: 85-100.

Connelly, N.A., Cornell University Human Dimensions Research Unit, June 16, 2011. Personal communication by telephone regarding state and federal surveys of wildlife watching activity levels.

Connelly, N.A. and T.L. Brown, 2009. New York Statewide Angler Survey Summary 2007, Report 1: Angler Effort and Expenditures. NYS Department of Environmental Conservation. 121 pp.

Connelly, N.A., T.L. Brown, D.L. Kay, 2004. Recreational Boating Expenditures in 2003 in New York State and Their Economic Impacts. Report submitted to NY Sea Grant by the Cornell University Department of Natural Resources. 81 pp.

Costanza, R., R. d'Arge, R. de Groot, S. Farberk, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt.1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

Coulter, R., NYS Department of Environmental Conservation, July 21, 2011. Personal communication regarding fishing on the Hudson River Estuary.

Daily, G.C., S. Polasky, J. Goldstein, P.M. Kareiva, H.A. Mooney, L. Pejchar, T.H. Ricketts, J. Salzman, and R. Shallenberger. Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment 7(1): 21–28.

Dalton, S. 2011. Hudson River Sustainable Shorelines Project: Preliminary report on experts and consultants interviews. Thrive Consulting. 12 pp.

Daniel, T.C., T.C. Brown, D.A. King, M.T. Richards, and W.P. Stewart, 1989. Perceived scenic beauty and contingent valuation of forest campgrounds. Forest Science 35(1): 76-90.

de Groot, R.S., M.A. Wilson, R.M.J. Boumans, 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393-408.

Dietz, T., A. Fitzgerald, and R. Shwom, 2005. Environmental values. Annual Review of Environment and Resources. 30: 335-72.

Enck, J.W., B.L. Swift, and D.J. Decker, 1993. Reasons for decline in duck hunting: Insights from New York. Wildlife Society Bulletin 21(1): 10-21.

Farber, S.C., R. Costanza, and M.A. Wilson, 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics 41: 375-392.

Fink, D., Cornell Lab of Ornithology, June 28, 2011. Personal communication by email regarding participant tendencies in their eBird program.

Giddy, I.H., 2003. The Hudson River Water Trail Guide. Sixth Edition. Hudson River Watertrail Association. 160 pp.

Heal, G. 2000. Valuing ecosystem services. Ecosystems 3(1): 24-30.

Herrington, T.O., R. Datla, and R. Royce, 2005. Alternative Shoreline Stabilization Structures: Physical Model Tests. Davidson Laboratory, TR SIT-04090284. IN Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.

Howarth, R.W., R. Marino, D.P. Swaney, and E.W. Boyer, 2006. Wastewater and watershed influences on primary productivity and oxygen dynamics in the Lower Hudson River Estuary. IN J.S. Levinton and J.R. Waldman (editors). The Hudson River Estuary. Cambridge University Press. pp. 121-139.

Hudson River Estuary Program, 2010. Hudson River Estuary Action Agenda 2010-2014. NYS Department of Environmental Conservation. 61 pp.

Huey, P.R., 1997. Historical and Archeological Resources of Castleton Island State Park, Towns of Stuyvesant, Columbia County, New Baltimore, Greene County, and Schodack, Rensselaer County, New York: A Preliminary Phase I Cultural Resources Assessment. NYS Office of Parks, Recreation, and Historic Preservation. 35 pp.

Hvenegaard, G.T., 2002. Using tourist typologies for ecotourism research. Journal of Ecotourism 1(1): 7-18.

Iowa Department of Natural Resources, 2006. How to Control Streambank Erosion. IN Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered

Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.

Jin, D., 2009. Economic Benefits of Coastal Restoration to the Marine Transportation Sector. IN L.H. Pendleton (editor). The Economic and Market Value of Coasts and Estuaries: What's At Stake? Restore America's Estuaries. pp. 97-115.

Johnston, R. J., T. A. Grigalunas, J. J. Opaluch, M. Mazzota and J. Diamantedes. 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. Coastal Management Journal 30: 47-65.

Kildow, J.T., 2009. The Influence of Coastal Preservation and Restoration on Coastal Real Estate Values. IN L.H. Pendleton (editor). The Economic and Market Value of Coasts and Estuaries: What's At Stake? Restore America's Estuaries. pp. 116-139.

King, D. 1998. The dollar value of wetlands: Trap set, bait taken, don't swallow. National Wetlands Newsletter 20(4): 7-11.

Kotchen, M.J. and S.D. Reiling, 2000. Environmental attitudes, motivations, and contingent valuation of nonuse values: a case study involving endangered species. Ecological Economics 32: 93–107.

Lawler, Matusky & Skelly Engineers and The Hudson Group, 2005. Swimming in the Hudson River Estuary: Feasibility Report on Potential Sites. Report prepared for the NYS Department of Environmental Conservation and NYS Office of Parks, Recreation, and Historic Preservation. 131 pp.

Leggett, C. G, and N. E Bockstael, 2000. Evidence of the Effects of Water Quality on Residential Land Prices. Journal of Environmental Economics and Management 39: 121-144.

Leiserowitz, A. 2007. Communicating the risks of global warming: American risk perceptions, affective images and interpretive communities. IN Moser, S.C. and L. Dilling (editors). Creating A Climate For Change: Communicating Climate Change and Facilitating Social Change. Cambridge University Press. pp. 44-63.

Limburg, K.E., K.A. Hattala, A.W. Kahnle, and J.R. Waldman, 2006. Fisheries of the Hudson River Estuary. IN J.S. Levinton and J.R. Waldman (editors). The Hudson River Estuary. Cambridge University Press. pp. 189-204.

Limburg, K.E., R.V. O'Neill, R. Costanza, and S. Farber. 2002. Complex systems and valuation. Ecological Economics 41:409-420.

Lorenzoni, I. and N.F. Pidgeon, 2006. Public views on climate change: European and USA perspectives. Climatic Change 77: 73-95.

Magron, R. , S. Zappala, and J. Duschang. 2005. 2004 Hudson River Estuary Black Bass Tournament Monitoring Study. Report submitted by Lawler, Matusky & Skelly Engineers LLP to the NYS Department of Environmental Conservation. 50 pp.

Marcell, K., NYS Department of Environmental Conservation, April 6, 2011. Personal communication regarding rates of sea level rise.

McCarthy, L., Audubon New York, June 22, 2011. Personal communication by email regarding membership in the National Audubon Society.

McFarlane, B.L., 1994. Specialization and motivations of bird watchers. Wildlife Society Bulletin 22:361-370.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. 155 pp.

National Center for Environmental Economics, 2010. Guidelines for Preparing Economic Analyses. Office of Policy Economics and Innovation, US Environmental Protection Agency. 297 pp.
National Oceanic and Atmospheric Administration. Living Shorelines. NOAA Restoration Portal. IN Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.
National Research Council, 2005. Valuing Ecosystem Services: Toward Better Environmental Decision-Making. The National Academies Press, Washington, DC. 291 pp.
Nelson A. Rockefeller Institute of Government, 2010. 2009 New York State Statistical Yearbook. State University of New York. 770 pp.
New York State Sea Level Rise Task Force, 2010. Report to the New York State Legislature. 103 pp.
Noonan, D.S., 2003. Contingent Valuation and Cultural Resources: A Meta-Analytic Review of the Literature. Journal of Cultural Economics 27: 159-176.
Normandeau Associates, 2003. Assessment of Hudson River Recreational Fisheries: Executive Summary. Report prepared for the NYS Department of Environmental Conservation. 6 pp.
North Carolina Division of Coastal Management, 2008. Coastal Hazards & Storm Information: Estuarine Shoreline Stabilization Options. IN Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.
Pendleton, L.H., 2009. The Economic Value of Coastal and Estuary Recreation. IN L.H. Pendleton (editor). The Economic and Market Value of Coasts and Estuaries: What's At Stake? Restore America's Estuaries. pp. 140-175.
Plummer, M.L. 2009. Assessing benefit transfer for the valuation of ecosystem services. Frontiers in Ecology and the Environment 7(1): 38–45.
Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.
Schramm, Jr., H.L., P.D. Gerard, and D.A. Gill, 2003. The importance of environmental quality and catch potential to fishing site selection by freshwater anglers in Mississippi. North American Journal of Fisheries Management 23: 512-522.
Stedinger, J.R. and W. Yi, 2010. Modeling Sea Level Rise in the Hudson River Estuary. A PowerPoint report submitted to the Hudson River Estuary Program. School of Civil and Environmental Engineering, Cornell University.
Strayer, D.L. and S.E.G. Findlay, 2010. Ecology of freshwater shore zones. Aquatic Sciences 72: 127-163.
Strayer, D.L., S.E.G. Findlay, D.M. Miller, H.M. Malcom, D.T. Fischer, and T. Coote. 2011. Biodiversity in Hudson River shores zones: Influence of shoreline type and physical structure. In manuscript.
Swift, B., B., NYS Department of Environmental Conservation, June 9, 2011, June 20, 2011, and July 27, 2011. Personal communications by email and telephone regarding waterfowl hunters on the Hudson River Estuary.
Throsby, D., 2003. Determining the value of cultural goods: how much (or how little) does contingent valuation tell us? Journal of Cultural Economics 27: 275-285.

U.S. Army Corps of Engineers. 1995. Engineering and Design: Design of Coastal Revetments, Seawalls, and Bulkheads. Engineer Manual. 1110-2-1614. 110 pp.

U.S. Army Corps of Engineers, St. Paul District. Revetments. Fact Sheets, Low Cost Shore Protection. IN Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.

U.S. Department of Agriculture, 1996. Engineering Field Handbook, Chapter 16: Streambank and Shoreline Protection. Natural Resources Conservation Service. IN Rella, A.J. and J.K. Miller, 2010. Engineered Approaches for Limiting Erosion along Sheltered Shorelines: A review of existing methods. Stevens Institute of Technology, Center for Maritime Systems. 80 pp.

U.S. Fish and Wildlife Service and U.S. Census Bureau, 2008. 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: New York. U.S. Department of Interior and U.S. Department of Commerce. 91 pp.

Wilson, M.A. and S. Farber, 2009. Accounting for Ecosystem Goods and Services in Coastal Estuaries. IN L.H. Pendleton (editor). The Economic and Market Value of Coasts and Estuaries: What's At Stake? Restore America's Estuaries. pp. 14-36.

Zhang, C. and K.J. Boyle, 2010. The effect of an aquatic invasive species (Eurasian watermilfoil) on lakefront property values. Ecological Economics 70(2): 394-404