New Hampshire Living Shoreline Site Suitability Assessment

Technical Report

New Hampshire Coastal Program

Great Bay Stewards

New Hampshire Department of Environmental Services

The Nature Conservancy New Hampshire

NERACOOS

State of New Hampshire Fish and Game

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TRIDEC Technologies

NH Smart Shorelines — Protecting our coast for People + Nature

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New Hampshire Living Shoreline Site Suitability Assessment:
Technical Report

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Project team

The project team provided valuable guidance throughout the course of this project. Project team members helped define the research questions, management goals and information needs addressed by the living shoreline site suitability assessment (L3SA). The project team met four times to review the progress of the L3SA and to make sure that it is relevant and useful for its end-users. Project team members also assisted by providing data and guidance in one-on-one meetings with the project leads.

Project team members include:

- Steve Couture, New Hampshire Department of Environmental Services Coastal Program
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Technical team

The technical team provided extensive expertise related to technical aspects of L3SA development. Technical team members provided data sources, scored attributes, weighted factors and reviewed results.

The technical team for this project includes the following members:

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0.0 Executive summary

A recent inventory of New Hampshire's tidal shoreline protection structures showed that approximately 12% of the state's tidal shoreline is armored by some type of engineered erosion control structure (Blondin 2016). With rising seas and intensifying storm surges, erosion is expected to get worse and consequently, demand for shoreline stabilization is expected to increase (Field, Dayer and Elphick, 2017). However, traditional armored shoreline structures have been shown to impede salt marsh migration, negatively impact shoreline stability and habitat condition, and potentially fail during major storms if built poorly or not maintained (Gittman et al. 2014; Sutton-Grier, Work, and Bamford 2015; Smith et al. 2017; Thieler and Young 1991).

Recognizing the need to protect and enhance the resilience of coastal community shorelines, the New Hampshire Department of Environmental Services Coastal Program (NHCP) and its partners are advancing the practice of living shorelines as an erosion control strategy that works with nature. For the purposes of this report, a "living shoreline" means a management practice that provides erosion control benefits, protects, restores or enhances natural shoreline habitat, and maintains coastal processes through the strategic placement of plants, stone, sand fill and other structural organic materials, maintaining the continuity of the natural land-water interface while providing habitat value and protecting against coastal hazards (RSA 482-A; Env-Wt 600 DRAFT).

However, coastal New Hampshire does not have a long history of living shoreline implementation and evaluation and although permitting is shifting to favor living shorelines (RSA 482-A; Env-Wt 600 DRAFT), the process is untested (Woods Hole Group, 2017). Additionally, because of unique conditions in the Northeast including a short growing season, ice and nor'easters, and a large tidal range, living shoreline projects in the Northeast face additional challenges compared to those applied more extensively in the Gulf of Mexico and the Mid-Atlantic (Woods Hole Group, 2017).

The goal of the New Hampshire living shoreline site suitability assessment (L3SA) is to identify sites (at the finest resolution possible given data availability) that may be suitable for specific living shoreline approaches in order to address erosion issues along the New Hampshire tidal shoreline. Borrowing from geospatial living shoreline site suitability modelling approaches conducted in other states and regions (see Appendix II), the L3SA integrates hydrodynamic, geophysical, ecological and sociopolitical characteristics of the state's tidal shoreline and also attempts to incorporate characteristics unique to the Northeast such as a short growing season, effects of ice, nor'easters and a large tidal range (Woods Hole Group, 2017). The L3SA assigns a suitability index number (on a scale of 1 to 6) to each point along the shoreline spaced 10 feet apart; an index number of 6 indicates that the site is "highly suitable for living shorelines with no structural components," and an index number of 1 indicates that the site "may be suitable for living shorelines with very significant hybrid components and/or site modification."

Eighty-two percent of the New Hampshire tidal shoreline received biophysical suitability index numbers between 4 and 6, suggesting that the majority of the New Hampshire tidal shoreline may be suitable for no stabilization action, low impact management or nature-based stabilization. The results also suggest certain areas that may be suitable for hybrid shoreline stabilization approaches that may involve additional site modification, and identify currently armored segments where replacement or softening of armoring with nature-based components may be an option. The sociopolitical feasibility assessment provides additional context about each site that may influence project feasibility or approach.

The L3SA is intended to be a screening tool used for planning purposes only and sites of interest should be further evaluated with a site-specific survey. The L3SA results are intended to inform a range of end-users including New Hampshire Department of Environmental Services (NHDES) Wetlands permitters, municipal conservation commission members, other regulatory agency staff, NHCP technical assistance providers, grant managers, engineers, consultants, landscape architects, nonprofits, and owners of land/property along the New Hampshire tidal shoreline as they consider appropriate stabilization actions for eroding shorelines.

1.0 Introduction and background

Coastal shoreline erosion is primarily a natural process driven by geologic and hydrodynamic factors that provide a valuable sediment source for New Hampshire's beaches and salt marshes (Strafford Rockingham Regional Council 1978). Erosion can be exacerbated by human influences like nearshore development and recreation. In extreme circumstances erosion can threaten public and private property, emergency vehicle routes, and other coastal infrastructure (U.S. Global Change Research Program 2016). There is limited local historic data available to quantify short-term and long-term estuarine and outer coast shoreline change in New Hampshire. A study along the outer coast of northern New England found that although this region exhibits a long-term net shoreline change rate of 0.1m of accretion per year, 41% of transects showed 0.2m of erosion per year (Hapke et al. 2011). In 1978, the Strafford Rockingham Regional Council made an attempt to document local erosional hotspots and discussed major drivers of erosion along stretches of tidal shoreline. The assessment identified ice, decreased sedimentation from eelgrass loss and dams upstream, ebb currents and waves, and scouring due to tides as the primary drivers of estuarine erosion and pointed to longshore transport, erosion of unconsolidated glacial deposits, nor'easters, and storm surges as the primary drivers of erosion along the open coast.

In an attempt to better understand erosional trends in New Hampshire beaches, a 2017 study of beach volumetric change found that the large southern beaches including Hampton Beach and Seabrook Beach show net seaward movement or accretion; the smaller northern beaches including Plaice Cove, the southern portion of Bass Beach, Rye Beach show a net landward movement or erosion; and while North Beach, the northern portion of Bass Beach, Foss Beach and Wallis Sands showed mixed results of accretion and erosion, they showed net volumetric losses (Olson and Chormann 2017). The results of the 2017 study are being supplemented with data from volunteer-based beach and dune profiling efforts that began in early 2017. Although the beach profiling data record is still too short to explain long-term trends, pre- and post-storm data showed that most beaches and dunes eroded significantly after Winter Storm Riley in March 2018, and that recovery was occurring to varying degrees (Eberhardt et al. 2018). Long-term coastal beach erosion, as driven by sea-level rise and storms, is projected to continue, with one study indicating that the shoreline is likely to erode inland at rates of at least 3.3 feet (1 m) per year among 30% of sandy beaches along the U.S. Atlantic coast (Gutierrez et al. 2014). In order to estimate bank and marsh erosion rates along sheltered coastlines in New Hampshire (Norton 2017), an attempt was made to delineate the shoreline and conduct a point-based change analysis of the entire estuarine shoreline; however, because of data limitations, this approach was abandoned (Appendix III). Some insights about projected estuarine shoreline change can be gleaned from the Sea Level Affecting Marshes Model (SLAMM) results which suggest that with 6.6 feet of sea level rise by 2100, 240 out of 6,040 existing acres of salt marsh are likely to be lost in the next decade and by 2100, less than 300 acres of currently existing salt marshes may remain (New Hampshire Fish and Game Department 2014).

In addition to natural erosion, the effects of development and nutrient loading are placing significant stress on the Great Bay and Hampton-Seabrook estuaries, which are both showing declining trends in water quality and habitat extent (Piscataqua Region Estuaries Partnership 2017). Between the early 1900s and 2010, an estimated 431 acres of salt marsh area were lost in the Great Bay Estuary, and 614 acres were lost in the Hampton-Seabrook Estuary (Piscataqua Region Estuaries Partnership 2010). Loss of salt marsh results not only in loss of habitat, pollutant attenuation capacity and carbon storage (Davis et al. 2015; Gittman et al. 2016; Piehler and Smyth 2011), but also in more exposed shorelines vulnerable to erosion (New Hampshire Fish and Game Department 2015). These trends are likely to continue given that development in this region is expected to increase over subsequent decades (U.S. Environmental Protection Agency 2009).

A common coastal landowner response to land loss from both natural and human-caused erosion is to construct shoreline protection structures such as rip rap, seawalls and revetments. A recent inventory of New Hampshire's tidal shoreline protection structures showed that approximately 12% of New Hampshire's tidal shoreline is armored by some type of engineered structure (Blondin 2016). An analysis of NHDES Wetlands Bureau permit applications related to tidal shoreline stabilization suggests that demand for permits is increasing, with 157 permits issued in the 1980s compared to 564 permits issued in the 2000s (Blondin 2016a). With rising seas and intensifying storm surges, this increasing demand for traditional shoreline stabilization will likely continue (Field, Dayer, and Elphick 2017). However, traditional armored shoreline structures have been shown to impede salt marsh migration, negatively impact shoreline stability, habitat condition and other ecosystem services, and potentially fail during major storms if built poorly or not maintained (Thieler and Young 1991; Gittman et al. 2014; Sutton-Grier, Work, and Bamford 2015; Smith et al. 2017).

Living shoreline alternatives to traditional shoreline protection structures may reduce unintended consequences of controlling for erosion. Under appropriate conditions, living shoreline installations absorb wave energy (Manis, Garvis, Jachec and Walters 2014) which reduces scour, sediment resuspension and erosion (Polk and Eulie 2018) while supporting natural movement and distribution of sediments (Meyer, Townsend, and Thayer 1997) and providing habitat for native species as well as pollutant attenuation and improved carbon storage (Davis et al. 2015; Gittman et al. 2016; Piehler and Smyth 2011). For the purposes of the L3SA, a "living shoreline" means a management practice that provides erosion control benefits, protects, restores or enhances natural shoreline habitat, and maintains coastal processes through the strategic placement of plants, stone, sand fill and other structural organic materials, maintaining the continuity of the natural land-water interface while providing habitat value and protecting against coastal hazards (RSA 482-A; Env-Wt 600 DRAFT). Living shoreline projects consist of a wide range of specific approaches and range from regrading and replanting a bank to building a fringe salt marsh with a stabilizing sill to replenishing a beach or creating protective dunes (Woods Hole Group 2017).

Recognizing the need to protect and enhance the resilience of coastal community shorelines, the New Hampshire Department of Environmental Services Coastal Program (NHCP) and its partners are advancing the practice of living shorelines as an erosion control strategy that works with nature. Coastal New Hampshire does not have a long history of living shoreline implementation and evaluation and although permitting is shifting to favor living shorelines (RSA 482-A; Env-Wt 600 DRAFT), the process is untested (Woods Hole Group 2017). Additionally, because of unique conditions in the Northeast such as a short growing season, ice, nor'easters and a large tidal range, living shoreline projects in the Northeast face additional challenges compared to those applied more extensively in the Gulf of Mexico and the

Mid-Atlantic (Woods Hole Group 2017). However, New Hampshire has a longer history of successful nature-based bank stabilization in freshwater riverine ecosystems and guidance and lessons learned from those projects may prove useful for siting and designing living shorelines in New Hampshire's tidal regimes (Schiff, MacBroom, and Bonin 2007). One important step toward better understanding how living shoreline projects might work in New Hampshire is to identify the appropriate physical and social conditions and sites where projects could be successful, in order to inform landowners who may be considering stabilization projects and enable decision makers to approve suitable proposals.

1.1 The NH living shoreline site suitability assessment (L3SA)

The goal of the New Hampshire living shoreline site suitability assessment (L3SA) is to identify sites (at the finest resolution possible given data availability) that may be suitable for specific living shoreline approaches in order to address erosion issues along the New Hampshire tidal shoreline. Building on geospatial living shoreline site suitability modelling approaches conducted in other states and regions (see Appendix II), the L3SA integrates hydrodynamic, geophysical, ecological and sociopolitical characteristics of New Hampshire's tidal shoreline and also attempts to incorporate characteristics unique to the northeast such as a short growing season, effects of ice, nor'easters and a large tidal range (Woods Hole Group, 2017). The L3SA assigns a suitability index number on a scale of 1 to 6 to points along the shoreline spaced 10 feet apart; an index number of 6 indicates that the site is "highly suitable for living shorelines with no structural components," and an index number of 1 indicates that the site "may be suitable for living shorelines with very significant hybrid components and/or site modification."

The objective of the L3SA is to identify sites on the tidal shoreline that are:

- Suitable for employing soft stabilization living shorelines (eg., vegetative restoration).
- Suitable for employing hybrid stabilization living shorelines (eg., fringe marsh restoration with a structural sill).
- Best left alone (no action needed) either because they are stable systems or should be allowed to erode and provide a sediment source.
- Need to be significantly modified for a living shoreline approach and/or combined with more hybrid components.
- Currently armored but suitable for armor removal and replacement with a living shoreline.

The L3SA is intended to be a screening tool only and not a site assessment or prioritization tool. While it helps identify sites that could benefit from erosion control, it is not intended to be used for flood risk reduction/property protection purposes. It is not intended to be used to justify modifying the shoreline. An engineers' site assessment is always recommended before moving forward with a living shoreline strategy.

The L3SA is intended to be used in the following ways by the identified end-users:

- NHDES Wetlands Bureau permitters, municipal conservation commission members and other regulatory agency staff to evaluate proposed shoreline stabilization projects and to inform conversations with applicants about potential living shoreline approaches at specific sites.

- NHCP technical assistance providers and grant managers to decide where to allocate resources for shoreline stabilization.
- Engineers, consultants and landscape architects to inform conversations with prospective or active clients about suitable living shoreline options as specific sites.
- Public and conservation landowners such as The Nature Conservancy, New Hampshire (TNC NH), land trusts and other government agencies to understand suitable living shoreline approaches at eroding sites.
- Private property owners to learn about their site and identify potential living shoreline approaches at eroding sites.
- Researchers to acquire baseline site suitability data for monitoring and other research.

1.2 Study area and unit of analysis

The L3SA was conducted along the New Hampshire tidal shoreline including but not limited to tidally-influenced waters along the Atlantic Coast, Great Bay, the Piscataqua River, Portsmouth Harbor, the Squamscott River, the Bellamy River, the Lamprey River, the Oyster River, the Cocheco River, the Salmon-Falls River, the Winnicut River and intertidal marshes. The L3SA includes the 17 New Hampshire Coastal Zone communities: Dover, Durham, Greenland, Exeter, Hampton, Hampton Falls, Madbury, New Castle, Newfields, Newington, Newmarket, North Hampton, Portsmouth, Rollinsford, Rye, Seabrook and Stratham.

The analytical units of the L3SA are points spaced 10 feet apart along the Mean Higher High Water line derived from LiDAR (see Appendix IV). All relevant site suitability and feasibility data was aggregated to each MHHW point.

2.0 Methods/approach

2.1 Applicability of other living shoreline suitability studies to NH

Living shoreline site suitability assessments conducted in other geographic areas along the U.S. eastern seaboard and Gulf of Mexico (Appendix II) were reviewed. These assessments were developed using GIS-based site suitability models. The model developed for Maine's Casco Bay (Slovinsky et al. 2017 ongoing) proved most comparable and transferable to New Hampshire's shoreline conditions.

Most of the assessments' stated goals related to informing erosion control and shoreline stabilization projects. While the assessments conducted for Worcester County, Maryland (Berman and Rudnicky 2008) and Mobile Bay, Alabama (Boyd et al. 2016) used high-quality, field-verified erosion data, others, including the assessments in Long Island Sound, Connecticut (Zylberman et al. 2015), measured shoreline change using the Digital Shoreline Analysis System (DSAS), while Slovinsky et al. (2017) in Casco Bay, Maine and Mitsova et al. (2016) in Southeast Florida used erosion proxies such as fetch, boat wakes and wave heights. Since New Hampshire did not have erosion data for the estuarine shoreline, different options for erosion analysis were evaluated (Norton 2017) and attempted. Ultimately, the use of erosion proxies was deemed to be the most feasible approach given staff capacity and data availability for the New Hampshire shoreline (Appendix II).

The outputs varied across assessments: Slovinsky et al. (2017) in Casco Bay, Maine and Dobbs et al. (2016) in Sarasota County, Florida produced numerical outputs spanning a range of suitability numbers while other assessment outputs (Berman and Rudnicky 2008; Boyd et al. 2016; Zylberman et al. 2015) produced ranges of prescriptive strategies to address erosion. These output approaches informed New Hampshire's decision to produce numerical outputs linked but not explicitly tied to potential living shoreline strategies.

2.2 Conceptual models

In consultation with the project team and technical team and informed by the assessments conducted in other states, conceptual models were developed to inform the L3SA in New Hampshire. The conceptual biophysical suitability model (Figure 1) synthesized ecological, geophysical and hydrodynamic data inputs. The values of each input dataset were categorized and each category was assigned a score. Then, weights were assigned to indicate relative importance of data inputs to living shoreline suitability. A weighted overlay equation (see Section 2.3) was used to calculate the suitability index numbers which range from 1 to 6; with 1 representing possible suitability for hybrid living shoreline approaches with very significant structural components and/or site modification and 6 representing high suitability for living shoreline approaches with no structural components and no site modification.

The sociopolitical feasibility model (Figure 2) did not include numerical scoring or weighting due to the subjective and overlapping nature of some of the data inputs. However, datasets were compiled that represent some measures of likelihood of demand for stabilization, owner capacity/interest, vulnerability of a project to sea-level rise, regulatory considerations, and ecological values assigned by stakeholders to sites along the shoreline.

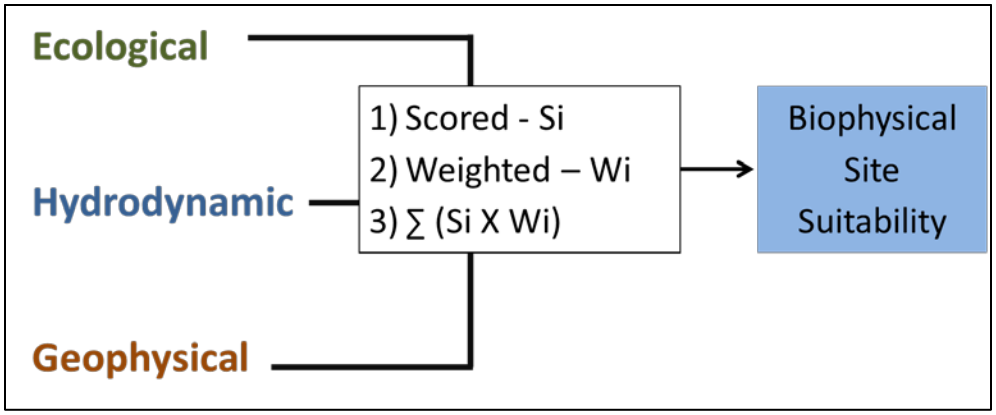


Figure 1. Conceptual model for living shoreline biophysical site suitability in New Hampshire

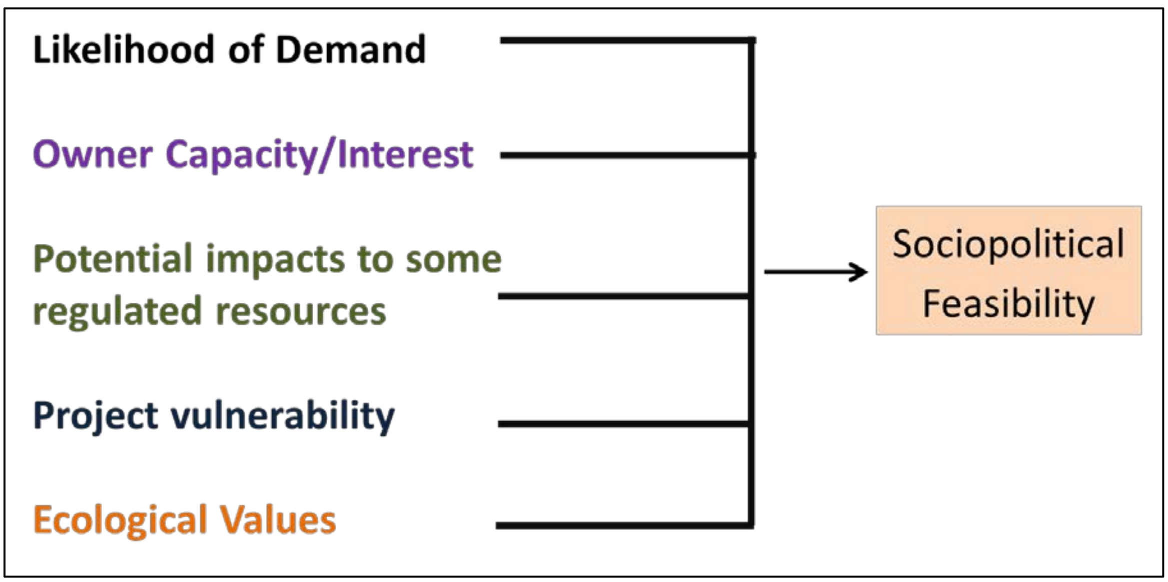


Figure 2. Conceptual model for living shoreline sociopolitical feasibility in New Hampshire

2.3 Biophysical suitability model

The analytical units of the biophysical suitability model are points spaced 10 feet apart (MHHW points). All input datasets were aggregated to these points based on rules specific to each dataset. The weighted overlay used in the biophysical suitability model was based on the following equation (Equation 1).

$$SI_i = (2A_i + 2B_i + C_i + D_i + E_i + F_i + G_i + 2H_i + 3I_i + 2J_i + K_i + 2L_i + 3M_i + 4N_i + O_i + 4P_i + 3Q_i) / (34-X_i)$$

Where:

i is MHHW point
SI is suitability index number
A is scored northeast fetch (proxy for storm effects)
B is scored northwest fetch (proxy for ice effects)
C is scored tidal crossing proximity (proxy for high velocity areas)
D is scored current velocity in terms of impacts on shoreline edge (proxy for scouring effects)
E is scored current velocity in terms of sediment transport (proxy for scouring effects)
F is scored distance from federal navigation channels (proxy for boat wakes which is in turn a proxy for erosion)
G is scored aspect (proxy for sunlight exposure)
H is scored distance from eelgrass beds (proxy for wave attenuation in sheltered coastlines)
I is scored landward shoretype
J is scored seaward shoretype
K is scored secondary seaward shoretype
L is scored future salt marsh potential
M is scored engineered shoreline structure presence
N is scored steep bank presence
O is scored beach erosion condition
P is scored seaward slope (proxy for wave energy)
Q is scored soils erodibility
X is the sum of weights for the input scores without data (sum weight when A, B, C, D, E, F, G, H, J, K, L, M, N, O, P, or Q = 0)

Equation 1. Equation used to calculate living shoreline biophysical suitability index numbers for MHHW points in New Hampshire

2.4 Sociopolitical feasibility model

The base unit of the sociopolitical feasibility model was the MHHW line split into points spaced 10 feet apart. All input datasets were aggregated to these points based on rules specific to each dataset. Sociopolitical datasets were not assigned a numeric score or weight due to the subjective and overlapping nature of some of the data inputs.

2.5 Developing input datasets

2.5.1 Unit of analysis

The MHHW line was selected as the dataset to represent NH's tidal shoreline. This line was derived from 2011 6.5-foot LiDAR data and was generated by NH GRANIT in 2017 based on elevation zones that varied depending on the geography of the shoreline. Table 1 represents the different elevations used to generate the MHHW line in bays, rivers, oceans and embayments. The MHHW line was divided into 185,964 points spaced 10 feet apart from each other which form the analytical units for the L3SA. All datasets were aggregated to these points based on rules specific to each dataset (Appendix V).

Table 1. Elevations used to generate the MHHW line in bays, rivers, oceans and embayments (AECOM 2013)

Scenario	Zone			
	Bay	River	Ocean	Embayment
MHHW Elevation (NAVD88)	3.60	4.20	4.40	4.40

2.5.2 Erosion assessment

Since the focus of the L3SA is to address erosion issues, a priority data input included estimates of erosion or shoreline change along the tidal shoreline. However, while an assessment of historic beach shoreline change was completed in 2017 (Olson and Chormann 2017), New Hampshire lacked comprehensive geospatial erosion rates for the majority of the tidal shoreline. To inform the L3SA, a review was conducted of methods and feasibility for estimating marsh and bank erosion throughout the New Hampshire tidal shoreline (Norton 2017). The review recommended conducting a shoreline delineation and point-based change analysis of the entire estuarine shoreline. Appendix III describes the attempted delineation and point-based change analysis of the New Hampshire tidal shoreline and the justification for the decision to abandon this approach due to low quality of historic data in favor of the alternative recommendation to use erosion proxies.

2.5.3 Selecting and processing input datasets

L3SA input datasets represented ecological, hydrodynamic, geophysical and sociopolitical characteristics of the shoreline (Appendix IV). Datasets were selected based on their quality, resolution, comprehensiveness of their coverage of the tidal shoreline, date published, and expert input from the project and technical teams based on relevance to living shoreline site suitability.

Ecological datasets included habitat type, aspect (as a proxy for sun exposure), eelgrass extent (as a proxy for wave attenuation in sheltered coastlines), and the potential for favorable conditions for marsh migration. Hydrodynamic datasets included northwest fetch (as a proxy for ice shoving), northeast fetch (as a proxy for storm impacts), current velocities at both shoreline edge (as a proxy for scouring effects and likelihood of sediment resuspension), tidal crossings (as a proxy for high velocity water flow), and proximity to federal navigation channels (as a proxy for erosion risk from boat wakes). Geophysical datasets included presence of engineered shoreline stabilization structures, steep banks, seaward slope, soils erodibility and volumetric change in beaches. Dataset sources are listed in Appendix IV.

Sociopolitical datasets represented ecological values (using geospatial footprints of areas prioritized by conservation plans); owner interest/capacity (sites that were suggested for living shoreline projects by NHCP's partners, publicly owned sites and publicly accessible sites); potential impacts to certain regulated resources (historic eelgrass bed extent, shellfish bed extent, aquaculture site extents); likelihood of demand for stabilization (presence of trails and/or impervious cover, and a 2050 impervious cover buildout scenario); and project vulnerability (proximity of existing impervious cover to inundation extent of a 2-foot, sea-level rise scenario). The sociopolitical feasibility model did not include numerical scoring or weighting due to the subjective and overlapping nature of some of the data inputs. These datasets were thus treated separately from the biophysical model and represent feasibility not suitability. Dataset sources are listed in Appendix IV.

Some biophysical datasets (such as tidal crossings, current velocities, soils erodibility, shoreline structure inventory) and most of the sociopolitical datasets were already available for use in the L3SA. A few datasets were generated specifically for the L3SA (northeast fetch and northwest fetch) or processed further and re-interpreted (habitat type, steep banks, seaward slope, aspect, volumetric change in beaches) Information on how these datasets were generated and/or processed further can be found in Appendix IV.

2.5.4 Aggregating input datasets to the MHHW points

Each dataset was aggregated to the MHHW points based on rules specific to the dataset (Appendix V). For example, habitat types as delineated by the Environmental Sensitivity Index (NOAA Office of Response and Restoration 2016) were aggregated to their closest MHHW points through a Spatial Join (ArcToolbox, ESRI ArcGIS). Eelgrass beds were aggregated to the MHHW points by measuring the distance from each MHHW point to the closest eelgrass bed using the Near tool (ArcToolbox, ESRI). Most shoreline structures did not directly overlap with the MHHW points; consequently, the mode of aggregation for shoreline structures was to measure their distance to the closest MHHW point using the Near tool. Apart from Spatial Join and the Near tool, other GIS tools used for data aggregation included the Euclidean Distance tool and Extract Values to Points tool (for raster inputs). For more information on how each dataset was aggregated to the MHHW points, see Appendix V.

2.6 Scoring and weighting biophysical input datasets

The values of each input dataset were categorized based on living shoreline suitability thresholds informed by literature, other models reviewed, and expert input from the NH technical team (Miller 2015; Appendix II). For a given input dataset, each category was assigned a score ranging from 1 to 6 (Appendix VI) with 1 representing likelihood of suitability for hybrid living shoreline approaches with very significant structural components and/or site modifications and 6 representing high suitability for living shoreline approaches with no structural components. Sample Python and Visual Basic (VB) scripts for scoring are included in Appendix VIII.

Biophysical datasets were assigned weights based on their relative contribution to living shoreline site suitability as determined by the technical team and other stakeholder input sessions (Appendix VII). Input dataset weights are shown in Equation 1 and more details about the weighting methodology are available in Appendix VII. For sample Python and Visual Basic scripts used to assign weights, refer to Appendix VIII.

2.7 Suitability index with and without shoreline structures

The suitability index numbers were calculated using a weighted overlay equation that multiplies the score of each input dataset by the weight of its importance, sums the products, and then divides that sum by the sum of the weights for a final suitability index number between 1 and 6. A score of 0 for a particular input dataset at a specific MHHW point indicates no data available for that MHHW point and that data input is omitted from the suitability equation at that MHHW point. For each MHHW point, the “N18_No_datasets_missing” attribute sums the number of input datasets missing at a given point and further interpretation (“N18_Data_Quality”) enables the user to determine whether the MHHW point has adequate or minimal data (Appendix IX).

The model was run for two scenarios: suitability with shoreline structures and suitability without shoreline structures – the latter makes the simplistic assumption that no shoreline structures exist in order to inform users who may be interested in installing a living shoreline after removing a structure. Shoreline structures were assigned scores based on the type of structure (Appendix VI) and sites that are proximate to shoreline structures received lower suitability scores. The “Without Structures” scenario assumes a suitability score of 6 for the shoreline structure input at every MHHW point. The “Without Structures” scenario does not indicate the feasibility of removing the structure. VB scripts for the equations used to calculate the suitability index numbers for each of the two scenarios can be found in Appendix VIII.

2.8 Iteration and field check

Several changes were made to the model design based on feedback received in technical team and external stakeholder review meetings. Dataset input scores and weights were adjusted based on preliminary results for the Atlantic Coast and estuarine areas. Several stakeholders suggested including stormwater runoff and sub watershed drainage areas as data inputs, however, a suitable existing dataset did not exist to satisfy this recommendation. Experts also recommended replacing the tree canopy dataset which lacked accuracy with a calculated measure of aspect. The aspect dataset was developed and was used to replace tree canopy as a measure of exposure to sunlight.

A qualitative field check was conducted in January and February 2019. The goal of the field check was to understand whether or not the suitability index numbers represented on the ground conditions, so that the limitations of the L3SA could be clearly communicated to its end users. At 45 publicly accessible sites, GPS points were collected and photographs were taken of the entire shoreline profile (upland, shoreline, intertidal, tidal). Suitability index numbers were assigned to each site based on a visual site assessment. The suitability index numbers assigned to the photo were compared with the suitability index numbers generated by the model. Based on these visual observations and comparisons, the limitations of the L3SA were deduced and are described in detail in Section 4.0.

2.9 Quality assurance quality control

Each step of the GIS workflow was reviewed to correct any issues and identify inconsistencies. A review of the methods used to process and aggregate the datasets to the MHHW points resulted in several small adjustments to the data processing approaches. Fifty random MHHW points were chosen and the With and Without Structure Suitability Index numbers were recalculated for each point using an Excel-based workflow with identical results. Suitability Index numbers were determined to be calculated accurately.

2.10 Role of project team, technical team, and additional stakeholders

The project team defined the research questions, management goals and information needs of the L3SA. The project team met four times to review the progress of the L3SA and to ensure that it was relevant and useful for its target end-users.

The technical team provided expertise on data sources, scoring, weighting and reviewing draft results. The scores were developed based on interviews conducted individually with each technical team member in spring 2018. Technical team members were assigned datasets that aligned with their expertise, and were also given the opportunity to weigh in on scoring the other datasets. Where suggested scores differed among technical team members, discrepancies were recorded and a decision was made using literature and additional discussion. Weights for the model were assigned on the basis of the results of a sticky dot exercise conducted with technical team members in summer 2018. The sticky dot exercise was followed by a discussion to reflect on the results and resolve conflicts. “Draft weights” from the sticky dot exercise were employed for the first run of the model. Based on model results and further technical team review meetings, these weights were adjusted to ensure that the results closely aligned with on-the-ground conditions.

Following several iterations of the model run, two technical team meetings were conducted in fall 2018: one focused on the Atlantic Coast, and the other focused on the Great Bay and Hampton-Seabrook Estuaries. The goal of these meetings was to review the results and identify ways to improve the accuracy of the model. As a result of these meetings, some input datasets were added, replaced or removed; weights and scores were adjusted; and some of the results were re-framed. Two additional meetings were also convened: one with consultants/engineers, and a second with regulatory agency staff in order to understand what other information they needed in order to feel confident using this model.

3.0 Results

3.1 Interpreting the living shoreline site suitability index

The L3SA produced the following outputs:

I. The biophysical suitability model yielded a set of attributes and a suitability index number for a point on each 10-foot shoreline segment. The biophysical suitability model produced results for two scenarios:

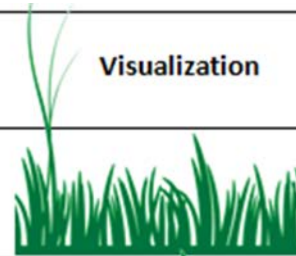
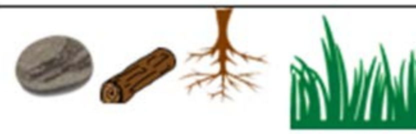
1) With Structures (existing condition): The site suitability results produced for this scenario should be used as a starting point for making decisions about living shoreline siting in areas under existing conditions, including areas proximate to armored shorelines.

2) Without Structures (hypothetical condition): The site suitability results produced for this scenario should be used as a starting point to evaluate whether a living shoreline approach might be an acceptable replacement for an existing engineered shoreline structure. It is important to note that no analysis was conducted to evaluate the feasibility of removing any existing shoreline structures, and further site-based assessment would be needed to understand if structure replacement is a feasible option (See Section 4.0 for more information about study uncertainty and limitations).

The suitability index numbers for the biophysical model range from 1 to 6. An index number 6 indicates that a site is highly suitable for living shorelines with no structural components. An index number 1 indicates that a site may be suitable for living shorelines with very significant hybrid components and/or site modification. Structural components could include materials such as rocks, coir logs, root wads, shells, and other biodegradable geotextile materials such as coir matting (NOAA 2015; Woods Hole Group 2017). Hybrid living shorelines could include a vegetated berm, a structural sill, an engineered core, or added habitat value to an existing hardened structure (NOAA 2015). Site modification could include limbing or cutting trees, grading a bank, and adding fill to create land-water continuity (Woods Hole Group, 2017). Certain types of site modifications are regulated by the NHDES Wetlands Bureau and Shoreland Bureau. Table 2 shows how to interpret the living shoreline suitability index numbers.

II. The sociopolitical feasibility assessment resulted in an attribute table that aggregated information on ecological values, owner capacity and interest, regulatory considerations, likelihood of demand for stabilization, and sea-level-rise vulnerability for a point along each 10-foot shoreline segment. No index numbers were produced for the sociopolitical feasibility assessment.

Table 2. Legend for interpreting the biophysical suitability index numbers.

Suitability Index Number	Living Shoreline suitability	Structural components	Visualization
6	Highly suitable for living shorelines	None	
5	Suitable for living shorelines	None to Minimal	
4	Suitable for living shoreline hybrid solutions	Minimal	
3	Suitable for living shoreline hybrid solutions	Moderate	
2	May be suitable for living shorelines with hybrid components and/or significant. site modification	Significant	
1	May be suitable for living shorelines with very significant hybrid components and/or site modification	Very significant	

3.2 Biophysical suitability results

In general, sheltered shorelines including those in Great Bay and the Hampton-Seabrook Estuary show suitability index numbers that are higher than suitability numbers for exposed, high energy shorelines along the Atlantic Coast. The lowest suitability index numbers occurred in developed areas along the Portsmouth section of the Piscataqua River and the Dover section of the Cocheco River. Figure 3 depicts biophysical suitability index numbers (With Structures scenario) across the study area.

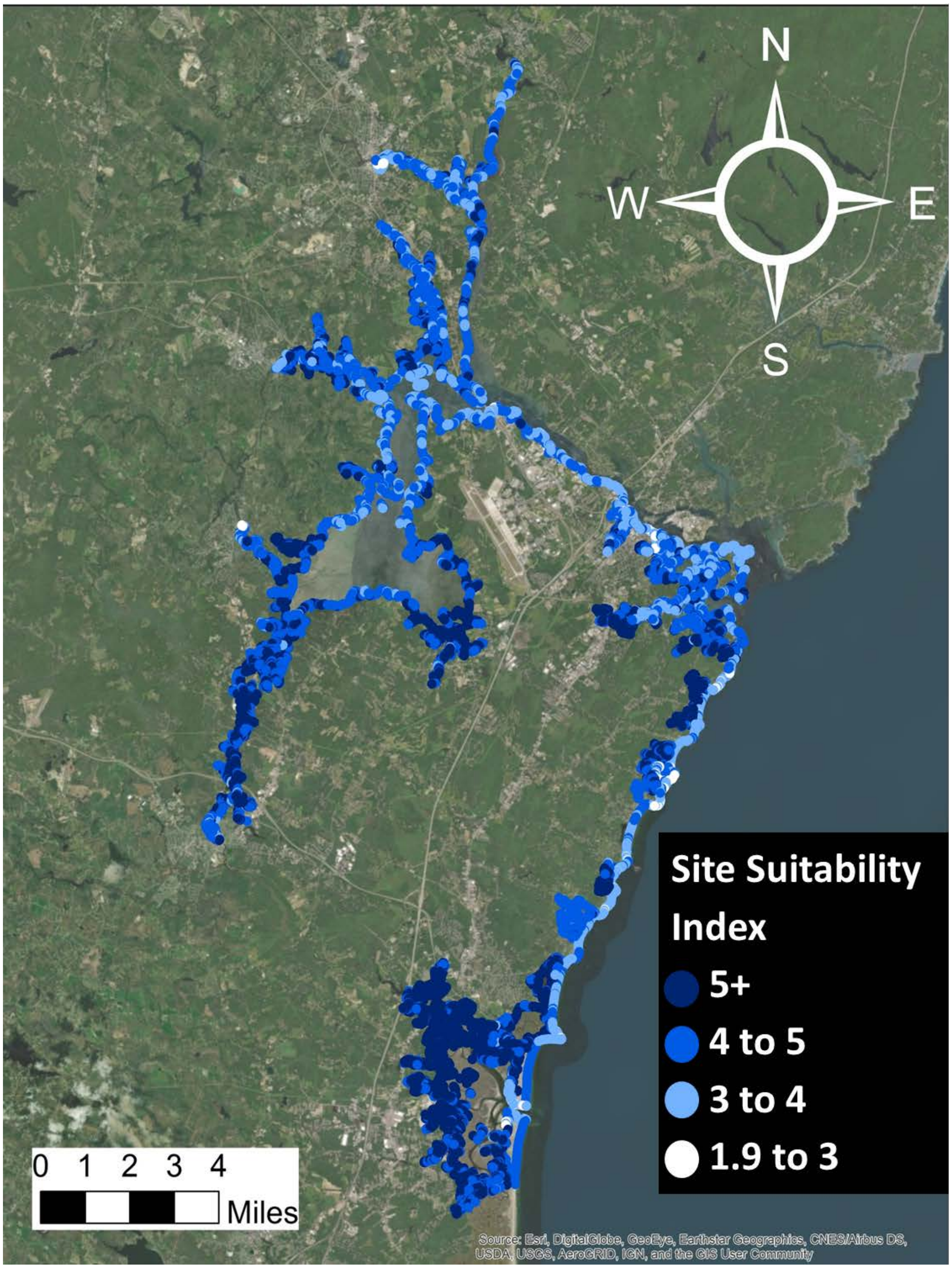


Figure 3. Geospatial distribution of suitability index numbers across New Hampshire tidal shoreline

3.2.1 With structures:

For the "With structures" scenario, the lowest suitability index number along the tidal shoreline is 1.9 and the highest suitability index number is 5.7. The sites with the lowest suitability index numbers are located along the armored sections of Rye Harbor State Park; however, the suitability index numbers for this area were calculated based on minimal data (8 datasets had missing values for this site; Section 2.7).

Figure 4. Example shoreline segment with suitability index numbers 3.4 - 3.6 | Hampton, NH

Figure 5. Example shoreline segment with suitability index numbers 4.5 - 4.8 | Rye, NH

The sites with the highest suitability index numbers include a small vegetated buffer strip along Great Bay near the Newington/Greenland town border, some shoreline segments along the Great Bay National Wildlife Refuge, marshes along Campbell Lane in New Castle, as well as sites along Meadow Pond in Hampton and along the back marshes of Hampton-Seabrook Estuary (Figure 3). More than 80% of the shoreline received a suitability index number greater than 4. Table 3 shows the distribution of index numbers for the "With structures" scenario by percentage of shoreline.

Figure 6. Example shoreline segment with suitability index numbers 2.7 - 3.2 | Dover, NH

Figure 7. Example shoreline segment with suitability index number of 5 | Newmarket, NH

3.2.2 Without structures:

For the "Without structures" scenario, the lowest suitability index number along the tidal shoreline is 2.6 and the highest suitability index number is 5.7. The highest and lowest index numbers were located at the same sites as the highest and lowest index numbers in the "With structures" scenario. The greatest difference in index number for a shoreline point between the two scenarios was 0.8. Table 3 shows the distribution of index numbers for the "Without structures" scenario by percentage of shoreline.

Table 3. Distribution of biophysical suitability index numbers along the New Hampshire tidal shoreline, as of March 2019

Suitability Index Number	With Structures (# MHHW points)	With Structures %	Without Structures (# MHHW points)	Without Structures %
5 to 6	73,810	39.7%	79,930	43.0%
4 to 5	79,732	42.9%	80,306	43.2%
3 to 4	30,252	16.3%	25,401	13.7%
2 to 3	2,121	1.1%	327	0.1%
Between 1-2	49	0%	0	0%
TOTAL	185,964	100%	185,964	100%

3.3 Sociopolitical feasibility results

The sociopolitical feasibility assessment produced an attribute table that aggregates information about likelihood of demand for stabilization, ecological values, owner capacity and interest, regulatory considerations, and sea-level-rise vulnerability for a point along each 10-foot shoreline segment. The attributes are not assigned scores, and therefore must be interpreted qualitatively. Table 4 shows the proportions of the shoreline that have a selection of characteristics that suggest higher feasibility for a living shoreline project.

Table 4. Selection of results from sociopolitical feasibility assessment, as of March 2019.

Feasibility Characteristic	Shoreline points (#)	% of shoreline
MHHW shoreline with two feet of SLR that will overlap with existing impervious cover, indicating upland development vulnerable to sea-level rise	13,587 out of 303,479 points*	4.5 %

>500 feet from eelgrass, shellfish, and aquaculture resources, indicating possibility of lower regulatory barriers	161,562 out of 185,964 points	86.9 %
Land under conservation/public ownership, indicating potential interest in living shoreline approach	70,187 out of 185,964 points	66.2%
Where >60% of the 100,000 sq ft area around the shoreline point is likely to be developed by 2050, indicating possible future desire for shoreline protection	5,418 out of 185,964 points	2.9%
High ecological value (identified in all 3: Wildlife Action Plan, Coastal Land Conservation Plan, and Water Resources Conservation Plan), indicating need to preserve the ecological functions of the site	85,378 out of 185,964 points	45.9%
Within 100 feet of a trail or impervious cover, indicating possible demand for shoreline protection	42,402 out of 185,964 points	22.8%
Publicly accessible, indicating possible accessibility for construction equipment	252 out of 185,964 points	0.01%

*The projected new 2050 MHHW shoreline with 2 feet of sea level rise has an additional number of points spaced 10 feet apart because of an increase in length of the exposed shoreline as the water encroaches landward. This increase in length is especially significant in bays and embayments.

3.4 Where to access the data and other materials

The biophysical suitability and the sociopolitical feasibility datasets can be downloaded via NH GRANIT and accessed via web on ArcGIS Online and on the NH Coastal Viewer. The attributes of each feature class can be interpreted using Appendices IX and X. If the feature class is converted into a shapefile, the name of the attribute will be truncated; however, the first three characters (Eg., N19, S19, W19) preceding the attribute name may be used to match the name of the truncated attribute on the shapefile to its corresponding interpretation in Appendices IX and X.

Upon request, NHCP will produce a property profile with tailored suitability results for a specific site. See Appendix XI for a sample property profile and information on who to contact if a property profile is desired.

4.0 Limitations and uncertainties

This section outlines the limitations and uncertainties of the L3SA, and identifies important considerations when applying the outputs of the L3SA to certain shoreline management decisions. Individuals who use the data understand that the NHDES, NHCP, and State of New Hampshire are not responsible for any inaccuracies or assumptions made with this dataset. It is recommended that the user read the metadata in its entirety before using the data (available through NH GRANIT). NHDES is not responsible for the use or interpretation of this information, or for any inaccuracies in the biophysical or sociopolitical assessments. All information is subject to verification. The information provided in the shapefile is not guaranteed to be complete. The data provided may be used in combination with other sources for decision making, but should not be used for enforcement decisions within NHDES or legal decisions that occur outside the purview of NHDES. This data should be used for planning, management and educational purposes only. Individuals who use this data also agree to use proper citation when displaying the data in other presentations or publications, or when using the data for other studies (see page ii for recommended citation).

The L3SA is intended to be a screening decision-support tool and does not replace an on-site assessment. The L3SA is not a comprehensive prioritization of living shoreline project sites – while it identifies areas that may be more suitable than others for living shoreline approaches, it is not an ordered hierarchy of site suitability from best to worst. The L3SA does not identify sites where living shorelines could be used to provide flood mitigation benefits – it focuses on potential for erosion control. The L3SA results should not be used to justify modifying the shoreline.

The L3SA used best available datasets that have varying resolutions and in some cases a lack of data coverage along the tidal shoreline. The proportional division employed to calculate the site suitability index numbers ensured points were not penalized for a lack of data inputs; however points lacking data inputs may reflect less accurate suitability results. A data quality attribute (N18_Data_Quality) was calculated for each point to show the count of data inputs missing (N18_No_datasets_missing) for each point as well as the percentage of weight values (N18_Percent_weights_missing) missing for each point (See Appendix IX).

4.1 Dataset limitations

The NHCP makes this data available with the understanding that the data is not guaranteed to be complete or accurate. Many of the datasets were developed by other agencies and information about data sources, resolutions, and other limitations is available directly from those data sources (listed in Appendix IV). Special caution should be exercised when considering the following attributes:

- **Habitat type (Landward shoretype/seaward shoretype):** Does not take into account small segments of marsh and other habitat features with <10 meter extents.

- **Future salt marsh**: identifies certain sites as a potential marsh migration area even though site verification shows that there is no marsh nearby or the site is too steep to allow for marsh migration. This limitation is likely due to the resolution and inaccuracies of National Wetlands Inventory (NWI) data which was used as an input for the SLAMM model.
- **Aspect (Sunlight Exposure):** Aspect is used as a proxy for sunlight exposure in the biophysical model, but aspect is only one of the determinants of the exposure of a site to sunlight. Other factors like tree canopy, man-made structures, etc. are not represented by this model, but should be taken into account for determining site suitability.
- **Fetch (NW and NE):** Fetch distances may be inaccurate in sheltered coastlines along the Atlantic Coast, especially within the Hampton-Seabrook Estuary.
- **Seaward slopes:** A variety of data sources and bathymetric contours were used to calculate the seaward slope. Information about the contour used is provided in the attribute table for each point (Appendix IX) and should be taken into consideration.
- **Suitability Index:** Index numbers do not fully account for interactions between the datasets and variability in resolution across datasets.

4.2 Using the L3SA at complex, vulnerable and armored sites

It is recommended that end-users of the L3SA consider several important limitations when determining site suitability for shoreline segments that have multiple habitat types, are vulnerable to sea level rise, or might involve installing new armoring and removing existing armoring:

4.2.1 Complex sites with multiple habitats and living shoreline approaches

Many sites have two or more shoreline types (i.e., a beach seaward of a dune or a salt marsh seaward of a bank). The model attempts to address this by identifying the landward shoretype and seaward shoretype. The model also detects the presence of a steep bank within 100 feet of the MHHW points. However, the suitability index output represents collective suitability at the site and does not provide independent suitability information based on shoretype. As a result, the end-user will have to explore the results and use additional information to understand whether the shoreline segment is suitable for a living shoreline approach at one or more of its shoretypes.

4.2.2 Sea-level rise, flooding and long-term planning

Living shoreline projects are typically intended to help control erosion and maintain intact or resilient habitats, but most often they will do little to alleviate flooding from sea-level rise and storms and in some cases may be vulnerable to sea-level rise and storms. A site might be more feasible for a living shoreline if conditions will allow salt marsh to migrate and persist over time at the site. A site may be less feasible for a living shoreline if sea-level rise is expected to inundate developed areas nearby. The model considers sea-level rise effects on a site through the marsh migration dataset (future salt marsh) in the biophysical model, and through the dataset representing impervious cover proximity to a 2-foot sea level rise extent in the sociopolitical model. Living shorelines and other stabilization projects should take into account sea-level rise on a site-by-site basis using best available guidance such as the ones developed by the New Hampshire Coastal Risk and Hazards Commission (2016).

4.2.3 Armoring

The model is not intended to provide justification for modifying the shoreline. A "low" suitability index number does not indicate that a site should be armored; it only indicates that more modification may be necessary (such as bank grading or filling) for a living shoreline project to be effective.

4.2.4 Removing Existing Armoring

The "Without Structures" scenario is intended to provide suitability information if the structures had never existed in the first place. It is important to note that no analysis was conducted to evaluate the feasibility of removing any existing shoreline structures, and further site-based assessment would be needed to understand if structure replacement is a feasible option, especially when property protection is of concern.

5.0 Discussion

According to the L3SA, 82% of the New Hampshire tidal shoreline received suitability index numbers between 4 and 6, suggesting that the vast majority of New Hampshire tidal shoreline may be suitable for no stabilization action, low-impact management, or nature-based stabilization. According to Blondin (2016a), 88% of New Hampshire tidal shoreline is currently not stabilized by an engineered shoreline protection structure, and given the undeveloped state of much of the New Hampshire tidal shoreline, the costs associated with engineered stabilization projects and permitting, relatively few landowners are actively pursuing tidal shoreline stabilization. Landowners interested in stabilizing their shorelines tend to choose riprap over living shorelines as their preferred approach because it is an approach traditionally used by contractors and it is perceived to be more effective and durable than living shorelines (Scyphers, Picou, and Powers 2014). However, given the likelihood that sea-level rise will exacerbate erosive trends, demand for shoreline stabilization is likely to increase as shoreline landowners grow increasingly concerned about visible and potentially hazardous erosion. By identifying the suitability of New Hampshire shorelines for nature-based stabilization, the L3SA presents important information for motivated landowners and decision-makers as they design and implement new stabilization projects or fortify existing structures. Successful pilot living shoreline projects, industry training and additional outreach to decision makers and landowners are needed to further advance living shorelines in coastal New Hampshire.

Any landowner considering managing shoreline erosion should first evaluate the option of doing nothing and/or moving at-risk assets away from the shoreline. Best available science suggests that sea-level rise will cause moderate to significant changes to shoreline composition and increase flood risk along the shoreline within the 21st Century and beyond (NH Coastal Risks and Hazards Commission 2016; New Hampshire Fish and Game Department 2014). In many cases, the most cost-effective and conservation-minded approach to dealing with erosion may be to allow the shoreline to erode, which can provide important sediments sources for salt marshes and beaches and enable salt marshes to migrate inland with sea-level rise. The sociopolitical feasibility analysis can provide some additional context about when the option of leaving a shoreline alone should be considered. Just over 45 percent of MHHW points are within areas designated as conservation priorities due to their ecological value (New Hampshire Fish and Game Department 2015; Zankel et al. 2006; Steckler et al. 2016). Depending on conservation management goals for these priority sites, leaving the shoreline alone or conducting low impact management may be a viable and effective option.

In low-lying areas, especially along the back marshes of the Hampton-Seabrook Estuary, MHHW points scored high in biophysical living shoreline suitability (greater than 4), but the sociopolitical feasibility analysis showed that some impervious surfaces immediately upland of the MHHW points will be inundated with 2 feet of sea-level rise which may occur as soon as 2050. Any shoreline stabilization (hard or soft) may temporarily address erosion but will not address the most pressing coastal hazard of high tide and storm-based flooding in these neighborhoods. In many cases these landowners also lack the option of moving assets upland away from erosion and flood risks due to small lot sizes. Some researchers have suggested neighborhood and landscape-scale concepts to address flooding and erosion in these areas such as back-barrier vegetated berms (Kirshen et al. 2018), but these options would likely be costly, face permitting obstacles and require significant multi-landowner coordination to mitigate any flooding without negatively influencing neighboring lots.

At shoreline segments that received high suitability numbers (4 to 6) and with motivated landowners, a variety of nature-based approaches may be feasible from low impact land management to a nature-based project with some hybrid components. A beach site might benefit from beach nourishment or a dune creation project while a low-energy mudflat or marsh site might benefit from natural marsh plantings with a coir sill, and an upland bank site might benefit from active understory enhancement and plantings.

At shoreline segments that received lower suitability numbers (1.7 to 4), are not currently armored, and have a motivated landowner, a potential living shoreline design could incorporate varying degrees of site modification and more hybrid components such as significant slope regrading and a rock sill. For sites with lower suitability numbers that are currently armored, a user could reference the site's biophysical suitability number using the "Without Structures" scenario. Depending on the landowner's goals, an appropriate expert could evaluate whether removing armoring and replacing with a living shoreline is a feasible option that might reduce scour and enhance ecological values. Alternatively, an increasing number of examples exist showcasing how to add functional habitats to engineered structures including adding breaks or openings in rip rap to maintain aquatic passage, incorporating marine-safe concrete or reef balls, fortifying seawalls with vegetated dunes, and maintaining wetlands and/or upland riparian buffers adjacent to existing structures (NOAA 2015).

In all cases, the appropriate shoreline management strategy can be informed by not just the biophysical suitability number, but will also depend on a variety of site-specific sociopolitical and biophysical factors such as landowner goals, soil and habitat type (i.e., exposed beach vs. sheltered intertidal), fetch, and seaward and shoreward slopes, among others. Details about some of these factors may be obtained from the L3SA attribute table for a shoreline site (Appendix IX and X) while other important information will need to be obtained from the landowner and a site visit. Some conceptual living shoreline designs for specific sites may be obtained from the Living Shorelines in New England: State of the Practice report (Woods Hole Group 2017).

6.0 Technical comments and reflections

This section identifies gaps and areas for future information development to improve our ability to determine living shoreline site suitability. This section summarizes reflections about how the model addresses erosion but not flooding, questions about site suitability approaches, and datasets that, if developed, would improve future iterations of the model.

6.1 Erosion versus flood protection

The L3SA attempts to identify sites that may be suitable for specific living shoreline approaches in order to address erosion issues along New Hampshire's tidal shoreline. "Erosion control" refers to the use of practices to contain soil particles and to prevent them from being displaced or washed down slopes by rainfall or run-off (RSA 482-A; Env-Wt 100 DRAFT). Living shorelines can be considered a set of structural erosion control practices (Woods Hole Group 2017). Flood mitigation refers to actions taken to reduce or eliminate risk to human life and property before a flood occurs and to foster resilience after a flood and can be structural (eg., flood proofing, elevation) or nonstructural (eg., planning and zoning, education for risk awareness, and insurance) (Cigler 2017). Erosion control might be effective for reducing the likelihood of flooding over the long-term because it preserves space and topographic relief to enable water storage; however, controlling erosion will not mitigate flooding in the short-term in most cases. The results of the L3SA should not be used to site living shoreline projects with the goal of reducing imminent flooding. Figure 4 developed by the U.S. Army Corps of Engineers: Engineer Research and Development Center (2018) explains the modes of flood risk management where erosion control is a strategy that is implemented at the site-specific scale (smaller areas) and only helps with reducing flood risk over time while flood mitigation strategies operate on a landscape scale (larger areas) and are more likely to reduce imminent flood risk (U.S. Army Corps of Engineers: Engineer Research and Development Center 2018).

The sociopolitical assessment informs the feasibility of siting a living shoreline project under sea-level rise conditions. The approach identifies areas where the "new shoreline" or MHHW line (given 2 feet of sea level rise by 2050) would inundate currently developed areas (based on impervious cover). At sites where the new shoreline inundates impervious cover by 2050, flooding is likely to be the priority concern of the property owner. While a living shoreline may be an effective strategy for maintaining land area at the site over the long-term, it is unlikely to be an effective approach for addressing flooding of developed areas. Other flood risk reduction strategies should be explored (Federal Emergency Management Agency 2018).

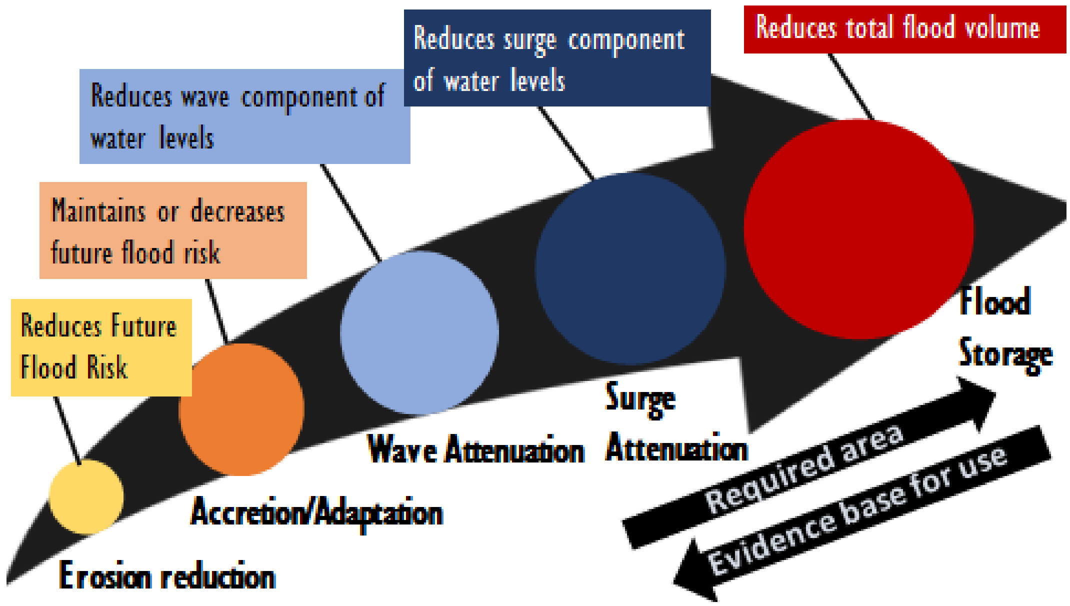


Figure 8. Modes of flood risk management: erosion reduction and flood mitigation (U.S. Army Corps of Engineers: Engineer Research and Development Center 2018)

6.2 Conceptual questions about suitability approaches

Several questions were considered throughout the development of the suitability model approach. In some cases, the literature did not sufficiently answer these questions for the New Hampshire shoreline, and expert opinion was taken into account in developing, scoring, and weighting the input datasets. Answers to the following questions would improve a future living shoreline site suitability model for New Hampshire:

- What factors significantly contribute to erosion along the New Hampshire shoreline? How do their effects vary along estuarine versus open coastlines?
- What are the shoreline change rates for the New Hampshire estuarine and open coastlines?
- What determines where ice is more likely to be formed, where ice is more likely to be shoved against the shoreline, and where ice needling effects are most likely to occur?
- Do eelgrass beds have a significant effect on wave attenuation in areas with a large tidal range? At what distance does their wave attenuation effect become significant?
- What factors should be used to determine the feasibility of removing an armored structure and replacing it with a living shoreline?
- What is the maximum distance from an engineered shoreline structure where erosional effects due to the presence of the structure can impact adjacent habitats?
- At what distance does erosion from boat wakes become significant?
- What factors should be used to determine when a shoreline is best left alone to erode?
- What factors influence landowners/shoreline property owners to protect their shoreline either through armoring or living shoreline stabilization?

- What combination of factors should be used to decide which living shoreline strategies suggested by the Living Shorelines in New England: State of the Practice report (Woods Hole Group 2017) are most applicable for a given site?

6.3 Data recommendations

The site suitability model should be updated as new data becomes available. During technical team meetings, a number of datasets were identified as important inputs for the living shoreline site suitability model; however, this project lacked capacity and resources to create some of these datasets. The following is a list of datasets to include in future iterations of the model:

Tree canopy: A high-resolution tree canopy dataset based on LiDAR point cloud interpretation would help identify shoreline segments that receive less sunlight thus inhibiting the growth of vegetation. This information could guide management decisions such as limbing shady tree branches.
Who to contact for generating this dataset: Fay Rubin and David Justice, NH GRANIT

Wave run-up: A geospatial dataset representing wave-run up would help identify structures that are likely to be overtopped and dunes that are eroding due to wave action. This information is integral for informing the design of a living shoreline project in open coastlines.
Who to contact for generating this dataset: Tom Lippmann, UNH Center for Coastal and Ocean Mapping.

Wave refraction: Integrating results from a wave refraction model would help identify sites where longshore drift is likely to occur thus providing information about sediment transport and beach erosion. Currently, the model uses bathymetry as a proxy for wave energy; however, wave refraction data would provide better information about the strength and speed of a breaking wave.
Who to contact for generating this dataset: Tom Lippmann, UNH Center for Coastal and Ocean Mapping.

Shoreline change for estuaries: While the Digital Shoreline Analysis System (DSAS) quantifies shoreline change for open coastlines with a linear geometry, it does not provide reliable information on shoreline change in estuarine shorelines with a complex geometry. A robust methodology to digitize shoreline change in New Hampshire's estuaries (keeping in mind the limitations of historic aerial imagery resolution) needs to be developed to calculate shoreline change.
Who to contact for generating this dataset: Neil Olson and Rick Chormann, New Hampshire Geological Survey; Larry Ward, UNH Center for Coastal and Ocean Mapping; J.P. Walsh, University of Rhode Island Coastal Resources Center.

Sediment circulation/sediment cells: Delineating sediment cells could provide a better understanding of coastline erosion and the sediment budget of potential living shoreline sites. This could be especially helpful for prioritizing beach nourishment sites.

Who to contact for generating this dataset: Larry Ward, UNH Center for Coastal and Ocean Mapping; Tom Ballestero, UNH Stormwater Center.

Drainage features generated by stormwater runoff: Currently, the model represents shoreline erosion from the seaward side but not the landward side. This does not provide a comprehensive picture of erosion given the possibility of stormwater runoff originating upland and eroding coastal banks by forming gullies. The project leads initially attempted to include curve numbers generated using land cover and soil hydrologic groups as inputs (US Department of Agriculture and Natural Resources Conservation Service, 1986); however, this did not adequately capture stormwater runoff in urbanized areas, and was therefore removed from the model. A better approach would be to use the ArcGIS Hydrology toolset to generate flow accumulation streamlines for delineating drainage features that could form due to runoff. This would be useful for designing living shoreline projects in such a way that they will not be undermined.
Who to contact for generating this dataset: UNH Stormwater Center.

Boat wakes: Currently, the model uses proximity to federal navigation channels as a proxy for boat wake activity which in turn serves as a proxy for erosion. However, a better approach would be to use a hydrodynamic model for boat wakes. A review of data needs and information on a prototype boat wake model can be found here (Bilkovic et al. 2017).
Who to contact for generating this dataset: Donna Marie Bilkovic, Virginia Institute of Marine Sciences; Tom Lippmann, UNH Center for Coastal and Ocean Mapping.

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Appendix

I. Definitions

Biophysical Suitability: Biophysical suitability is the suitability of a site for a living shoreline based on the hydrodynamic, geophysical and ecological factors of the site. Biophysical suitability does not take into consideration social or political factors that influence the site.

Biophysical Suitability Model: The biophysical suitability model is the GIS-based model that predicts biophysical suitability of a site for a living shoreline based on the hydrodynamic, geophysical and ecological factors of the site.

Ecological factors: Ecological factors are those that represent or affect habitat conditions at a particular site.

Geophysical factors: Geophysical factors are those that represent or affect the geologic form of the landscape at a particular site.

Hydrodynamic factors: Hydrodynamic factors are those that represent or affect the movement of water at a particular site.

Living Shoreline: "Living shoreline" means a management practice that provides erosion control benefits, protects, restores or enhances natural shoreline habitat, and maintains coastal processes through the strategic placement of plants, stone, sand fill and other structural organic materials, maintaining the continuity of the natural land-water interface while providing habitat value and protecting against coastal hazards (RSA 482-A; Env-Wt 600 DRAFT). For more information, refer to the Living Shoreline in New England: State of the Practice report (Woods Hole Group, 2017).

NH Living Shoreline Site Suitability Assessment (L3SA): The NH L3SA is an effort to analyze site suitability and feasibility for living shorelines in tidal New Hampshire through a biophysical model, a sociopolitical feasibility assessment and a sea level rise vulnerability analysis.

Scoring the L3SA datasets: Scoring is a process where the values of each input dataset were categorized based on living shoreline suitability thresholds informed by literature, other models reviewed and expert input from the New Hampshire technical team. Each category was assigned a number (score) from 1 to 6 in order to normalize all the input datasets so that they can be compared on the same scale.

Shoreline Structures: These shoreline structures are built with the intention of minimizing the effects of ocean waves, currents, and sand movement in order to stabilize and protect the shoreline or provide calm water areas for boats. These structures are artificial and often made of concrete, rock or timber (Blondin, 2016). For more information, refer to the New Hampshire Shoreline Structure Inventory report (Blondin, 2016).

Site modification: Site modification indicates the degree to which the site needs to be altered in order to implement a living shoreline project. Site modification could include but is not restricted to bank grading, tree removal and limbing, and filling.

Sociopolitical Feasibility: Sociopolitical feasibility is a measure of how feasible living shoreline project implementation might be at a given site based on social and political conditions at the site.

Structural components: Materials besides plantings that contribute to added stability of a living shoreline such as rocks, coir logs, root wads, shells and other biodegradable geotextile materials such as coir matting (NOAA, 2015; Woods Hole Group, 2017).

Suitability Index Number: Suitability index number is a cumulative score representing the suitability of a site for a living shoreline approach. A suitability index number 6 indicates that a site is highly suitable for living shorelines with no site modification or structural components, while a suitability index number 1 indicates that a site may be suitable for living shorelines with very significant hybrid components and/or site modification.

Suitability Index: Suitability Index refers to the set of suitability index numbers (ranging from 1—6)

Weighting the L3SA datasets: Weighting is a process where numbers (weights) were assigned to each input dataset based on how important the dataset was for determining site suitability. Weights were informed by living shoreline suitability literature, other models reviewed and expert input from the New Hampshire technical team.

II. Review of L3SAs conducted in other areas: summary table

Table 5. Summary table reviewing assessments conducted in other study areas along the US eastern seaboard and Gulf of Mexico.

	Worcester County, Maryland (Berman and Rudnicky, Virginia Institute of Marine Sciences 2008)	**Long Island Sound, Connecticut (Zylberman et al., University of CT, 2015)**	**Casco Bay, Maine- DRAFT (Slovinsky et al., Maine Geological Survey, 2017 ongoing)**	**Pamlico Sound, North Carolina (Carey et al., East Carolina University, 2013)**	**Mobile Bay, Alabama (Boyd et al., Geological Survey of Alabama and Mississippi State University, 2016)**	**Southeast Florida (Mitsova et al., Florida Atlantic University, 2016)**	**Sarasota County, Florida (Dobbs et al., University of Florida, 2016)**
Goals	Preferred alternatives to erosion control.	Erosion control	Stabilization of bluffs, adaptability to open beaches, stabilization of developed land.	Focus on "what percent of shorelines is suitable for ___" as opposed to "where are the suitable sites"?	Improved restoration decisions for shoreline erosion protection.	Attenuate wave action, mitigate erosional forces, and reduce storm damage	increase the different forms of coastal protection used throughout Sarasota County, Florida
Questions it answers	Is LS an appropriate alternative to erosion control?	• Which sites are suitable? • How much of the shoreline is suitable?	What are some sites that already have natural shorelines or characteristics of natural shorelines which will then make it more likely to support living shorelines?	• How much of the shoreline is suitable for employing soft stabilization living shorelines techniques for shoreline stabilization? • How much of the shoreline is suitable for employing hybrid stabilization living shorelines techniques for shoreline stabilization?	How to maximize ecosystem services while performing erosion control?	(1) understanding of the shoreline properties (2) developing an algorithm for exposure as a determinant of the shoreline vulnerability to natural and man-made disturbances (3) understanding of feasibility and ease of implementation issues when all other favorable environmental factors are present (4) Assess the feasibility of the generic model to a range of shoreline types, including developed, undeveloped, and protected.	The GIS model identifies coastlines that are 1) most suitable for living shoreline treatment, 2) most suitable for a hybrid solution, or 3) not suitable for living shorelines
Scale	1:12,000	3 feet resolution	1 point represents a 100 ft.	Unclear but focuses on 145.68 kilometers of shoreline to represent the rest of the APES.	1:24,000 **Unit:** m	Unclear. (outputs were in the form of points spaced 100 m apart)	Unclear, raster cell size of all datasets = 10
Inputs	**Conditions suitable for soft stabilization** • Fetch: o low (0-1.0 mile) o moderate (1.0-5.0 miles) o high (> 5.0 miles) • Beach presence o Present o absent • Bank Condition: o high: observed erosion o low: no observed erosion o undercut: bank toe • Bathymetry: o 1m contour > 10m from shoreline • Marsh presence: o Present o absent **Conditions suitable for hybrid stabilization** • Fetch:	• Beach o Present o Absent • Marsh o Present within 25 feet of MHW o Absent within 25 feet of MHW • Bathymetry: o 1-m contour > 30m from the shoreline • Erosion: o Low (4 feet per year) o Moderate (2-4 feet per year) o High (>4 feet per year) • Fetch: o Low (0-1.0 miles) o Moderate (1.0-5.0 miles) o High (>5.0 miles)	• Shoreline was MHHW line (50 ft inland, 100 ft seaward) • Annualized Weighted Fetch o <=0.5miles (Very Low=8) o >0.5 and <=1 mile (Low=6) o >1 and <=3 miles (Moderate=2) o >3 and <=5 miles (High=1) o >5 miles (Very High=0) • Nearshore Bathymetry (10m contour, 30 ft resolution) o Shallower than 3 ft within 100 feet of MHW line (Shallow=6) o Deeper than 3 feet within 100ft of MHW line (Deep = 0) • Landward Shoreline Type o Wetlands, swamps, marshes, banks=6 o Beaches and scarps=5 o Sheltered hard shorelines, rip rap=3 o Expanded shorelines, rip rap=1 • Seaward Shoreline Type o Marshes and flats=6 o Beaches, dunes and flats=5 o Lower energy channels=3 o Higher energy channels=1 o Ledge or man-made lands=0	• Fetch • Boat traffic o within 1 mile • Bathymetry • Marsh (NC wetlands inventory) o within 10 ft of a pre-existing marsh • SAV o within 1000 ft of an SAV bed • Shoreline polyline created by USGS (fetch and bathy criteria not mentioned, probably same as VIMS or MD erosion potential?)	**New version** • Riparian Land Use/Land cover • Bathymetry – 1m contour o Deep (<10m of shoreline) o Shallow (>10m of shoreline) • Marsh o Marsh present o Marsh island o No • Bank height o 0-5ft o 5-30ft o >30ft o >60ft • Canal (yes or No) • SandSpit (Yes or No) • Forestshl o Yes if RiparianLU=Forested o Yes if wide tree fringe (>100 feet) • Erosion control structures	**Shoreline Properties** • Shoreline Type and Erodibility (ESI recategorized) o Natural and erodible o Unnatural and erodible o Armored but permeable (riprap etc) o Armored with wall/impermeable **Exposure** • Avg nearshore slope (10m from pt seaward: bathy; 10 m from point landward: DEM) o <5% (Very low=1) o 5-7% (Low=2) o 7-8% (Moderate=3) o 9-10% (High=4) o >10% (Very High =5) • Fetch o Very low: <0.25 mi o Low: 0.25-0.5 mi o Medium: 0.5mi-1.0 mi o High: 1-3mi	• Bathymetry (nearshore slope) o 0-3%= 3 (most suitable) o 3-6%= 2 o 6-10%= 1 o >10%=0 • Land Use o High intensity urban areas= 3 o Low intensity urban areas= 2 o Rural= 1 • Land Values (value of land per acre from US census bureau) o $ 0-75,000 =1 o $ 75,000-250,000=2 o 250,000-15,000,000= 3 • Population (people/acre) o 9-175= 3 o 3-9= 2 o 1-3=1 o 0-1= 0 • Sensitive Shorelines (ESI)

	o low (0-1 ml) – moderate (1-5ml) • Bank condition: o high: observed erosion o low: no observed erosion o undercut: bank toe erosion • Bathymetry: o Shallow (1m contour>10meter from shoreline) • Beach presence: o yes or no • Marsh presence: o yes (>15 feet deep) o no • Tree Canopy: o yes or no		• Average upland relief (within 50ft of MHW) o 0-5ft (=6) o 10-20ft (=3) o 5-10 ft (=5) o >20 ft (=1) • Average upland slope (within 50 ft of MHW) o 0-3% (=6) o 16-30% (=2) o 4-9% (=5) o >30% (=1) o 10-15% (=4) • Shoreline Aspect o Southeast to Southwest facing = 1; Oher aspects=0 • Habitat considerations (presence or absence of special mapped habitat types within 100 ft of MHW) o Eelgrass (=2) o Shellfish (=2) o Tidal wading and waterfowl (=2)		• Defended (Yes if structures present) • Exposure (Fetch) o Low (0-0.5 mile) o Moderate (0.5-2 mile) o High (>2 mile) • Roads/Permanent Structures (Obstacles that prevent bank grading) • Beach and Wide Beach o Yes or No • Tributary o Tidal creek if fetch >2 miles	o Unbounded • Wave height (m) o 0-20 percentile (1) o 20-40 percentile (2) o 40-60 percentile (3) o 60-80 percentile (4) o 80-100 percentile (5) • Boat wakes o No Wake zones (1) o Medium boat wake exposure (3) o High boat wake exposure (5) • Storm surge category 5 (later used category 3 data) o No storm surge (1) o No storm surge (2) o <2m (3) o 2-3m (4) o >3m (5) • Distance to inlet (proxy for tidal influence, overall circulation patterns, observed boat traffic) o No tidal influence (1) o Tidal influence <=3 miles (5) **Feasibility** • Presence of habitat (seagrass/ESI sensitive plant communities) o Presence of nearshore and upland habitat (1) o No habitat (5) • Land Use • Ownership	ESI assigned most sensitivity to shorelines with high wave energy, low biological productivity. o 3=Most sensitive o 2= less sensitive o 1=least sensitive • Shoreline Habitat (Land cover dataset) o Isolated freshwater marsh, marshes, salt marshes = 3 o All other land cover types capable of growing vegetation and near the shoreline =2 o Remaining and upland =0 • Tree Canopy (National Land cover database) o 0-33%=3 o 33-66%=2 o 66-100%=1 • Wave Energy o Bayou, lagoon, slough, tidal creek, and canal= low wave energy =3 o Inlet, pass, waterway, and basin = medium wave energy = 2 o Gulf, channel, and bay= highest wave energy = 1 o freshwater lakes and detention ponds = 0 • Shoreline (400m buffer of county boundary)
How it measures erosion	The MD Shoreline Inventory delineates the condition of the bank observed in the field. Bank condition is classified as high erosion (unstable), low erosion (stable), and undercutting (erosion at the bank toe).	DSAS Shoreline Change Analysis	Fetch In future: mapping 1.4m contour of beaches and comparing year to year to estimate shoreline change.	It doesn't directly incorporate erosion into suitability model.	Contracted with USGS to develop an erosion layer.	Exposure Index -avg exposure under wind and wave conditions -impact of category 3 hurricane	Erosion is not considered directly
Outputs	• Suitable for soft stabilization • Suitable for hybrid options o marsh planting or marsh toe revetment o marsh planting or sill o marsh toe revetment o riparian modifications o sill • Not suitable for LS	• Marsh enhancement o Low fetch o Low erosion o Shallow bathymetry o presence of marsh • Beach enhancement o Low fetch o Low erosion o Shallow bathymetry o presence of beach • marsh with structures o Moderate-high fetch	• 0-13 (likely highly unsuitable) • 14-20 (likely unsuitable) • 21-27 (Possibly suitable) • 28-35 (Likely suitable) 36-44 (Likely highly suitable) Maine looked at overall suitability and not necessarily different approaches (later examined using a decision making tool)	**Suitable/Unsuitable** • Southwest (225˚) Fetch Suitability for Soft Stabilization Living Shoreline. • Southwest (225˚) Fetch Suitability for Hybrid Stabilization Living Shoreline. • North-northeast (10˚) Fetch Suitability for Soft Stabilization Living Shoreline. • North-northeast (10˚) Fetch Suitability for Hybrid Stabilization Living Shoreline. • Nearshore Depth Suitability for Soft Stabilization Living Shoreline. • Nearshore Depth Suitability for Hybrid Stabilization Living Shoreline.	**Shoreline BMP** • No Action Needed • Maintain/Enhance/Create Marsh • Maintain Beach or Offshore Breakwaters • Plant Marsh With Sill • Revetment • Area of Special Concern **Upland BMP** • Area of Special Concern	**1) Specific strategies** • Soft, with vegetation and potentially sediment only • Hybrid, with harder features • Enhancement, with harder features and vegetation • Enhancement, with vegetation only • Hybrid, with harder features • Soft, with vegetation only	**0- Least Suitable** **1** **2** **3- Most Suitable**

		o Low-high erosion o Shallow bathymetry o Presence of marsh • Offshore breakwaters. o Moderate-high fetch o Low-high erosion o Shallow bathymetry o Presence of beach		• Boat Traffic Suitability for Living Shorelines. • Preexisting Marsh Suitability for Living Shoreline. • Submerged Aquatic Vegetation Suitability for Living Shoreline. **Suitability Score 1-6** • Unweighted Suitability Index for Soft Stabilization Living Shoreline. • Unweighted Suitability Index for Hybrid Stabilization Living Shoreline. **Suitability Score in 6 ranges (23-38; 38-47; 48-57; 58-71; 72-85; 86-100)** • Weighted Suitability Index for Soft Stabilization LS • Weighted Suitability Index for Hybrid Stabilization LS.	• Land Use Management • Maintain/Enhance/Restore Riparian Buffer • No action needed.	• None, water depth>3 ft, slope>1:10 **2) Exposure score overlaid on each shoreline type** Maps were symbolized with ESI shoreline types, and each type was assigned a shoreline stabilization strategy.	
Method (weighted or unweighted?)	• Datasets were queried for suitability. • 6 combinations yield suitability for soft stabilization. • 39 combinations yielded suitability for hybrid stabilization	Unweighted	Datasets were added to estimate cumulative suitability.	Unweighted and weighted	Start with shoreline shapefile, populate with attributes representing each input. Weighted overlay	Composite scoring with weights from expert elicitation	Unweighted and Weighted overlay: multiply value of each parameter by weight of its importance, sum results together
Suitability (binary or range?)	Based on combinations.	Binary	Range	Binary, suitability score, suitability range		Exposure index range→Sorted into high/medium/low→matched to specific strategies in the above table	
Model audience	Management level LSSSM is intended to advise regulatory or management action.	Coastal engineers, decision-makers, and waterfront property owners that considers shoreline armoring alternatives.					
Assumption	• Some action will occur to prevent erosion • Soft stabilization is always preferred over hard structural control				• All the shoreline is unstable.		• Does not consider shoreline protection structures, erosion history, sea level rise, and tidal ranges. • Assigning the value of "0" to areas of "No Data" largely impacted and perhaps skewed the results. • Land use and shoreline habitat cancelled each other out. • Streams and rivers should have received a classification of "3" not "0" based on lower wave energy. • As areas of "0" should represent segments that are entirely unsuitable, the ranges of the tree canopy should have been divided in to quarters instead of thirds.

III. Erosion assessment

Based on a recommendation from the review of methods to assess bank and marsh erosion conducted by NHCP staff (Norton, 2017), an attempt was made to delineate the shoreline for two erosion hotspots (Fox Point and Adam's Point) identified in the shoreline change assessment conducted by Strafford Rockingham Regional Council (1978). Historic and current aerial imagery was used to delineate the shoreline based on the wet/dry line in non-vegetated areas and the vegetated/non-vegetated line in marshy areas. However, shoreline delineation was inconsistent, the historic aerial imagery varied in resolution and lacked documentation of the imagery's tide stage, and shadows cast by tree canopy often obscured the location of the wet/dry line. Technical team members reviewed the preliminary product and agreed that the shoreline delineation approach lacked the rigor needed to create a consistent shoreline change comparison. The aerial imagery datasets reviewed are listed in Table 6.

Table 6. Aerial imagery reviewed including year, source and their corresponding resolutions

Year	Source	Resolution
1962	Complex Systems Research Center, University of New Hampshire	3-ft
1974	Complex Systems Research Center, University of New Hampshire	3-ft
1998	Complex Systems Research Center, University of New Hampshire	3.2-ft
2003	U.S. Department of Agriculture, Farm Services Agency, Aerial Photography Field Office	3.2-ft
2005	NH Department of Transportation	1-ft
2009	U.S. Department of Agriculture, Farm Services Agency, Aerial Photography Field Office	3.2-ft
2010/2011	NH Department of Transportation	1-ft

2013	Piscataqua Region Estuaries Partnership	1-ft
2015	U.S. Geological Survey	1-ft

IV. List of input datasets

Table 7. Input datasets used for the L3SA including name of dataset, reason for using, source, resolution, date updated, justification for using, and information on additional processing.

Name of dataset	Reason for using	Source	Date last updated	Resolution	Why this was chosen	Why others weren't used	Additional processing
Unit of Analysis							
Shoreline (Mean Higher High Water)	Unit of analysis. All the datasets are aggregated to this point	AECOM/ GRANIT (LiDAR derived)	Derived from 2011 LiDAR, generated by NH GRANIT in 2017.	6.5-ft; for the suitability model, MHHW line was split into points 10 feet apart which serves as the resolution for the model.	Most objective and consistent delineation of the shoreline. It was also directly comparable to our sea level rise datasets since those datasets were also generated from the same LiDAR source.	Other shorelines such as the ESI shoreline were considered; however, the dataset we ultimately used was more region-specific. We also attempted to draw the shoreline using aerial imagery but the wet/dry line delineation was not objective.	All other datasets were aggregated to these points using a number of processing steps (see Appendix V).
Ecological							
Landward Shoretype, Seaward Shoretype, Seaward Extra Information	To characterize habitat type	Environmental Sensitivity Index, NOAA Office of Response and Restoration	2016	The ESI maps features that are >=10m	We conducted an interview with Dr. Nancy Kinner, Director of the Coastal Response Research Center at UNH who expressed confidence in using the dataset as a qualitative shoretype indicator, and knew enough about the process to generate the dataset to confirm that it had been vetted by local data users. Also, ESI was unique because it differentiates between landward and seaward serotypes, and delineates vegetated banks as a distinct habitat type.	➢ SLAMM doesn't differentiate between landward shoretype, seaward shoretype, and does not have as many categories as ESI. ➢ The National Wetlands Inventory (NWI) 2017 dataset was not used because it was at too high a resolution for this analysis (1:24,000 and 1: 25,000).	➢ Deleted all attributes that pertained to man-made structures (in order to not replicate shoreline structure inventory). ➢ Replaced Landward Shoretype with "Dunes" where applicable because ESI does not delineate dunes. See Appendix V for more information.
Dunes (integrated into landward shoretype- see above row)	ESI does not capture dunes	Eberhardt, A. (University of New Hampshire), Burdick, D. (University of New Hampshire). Hampton-Seabrook Estuary Restoration Compendium. Sand dune habitat within the Hampton-Seabrook Estuary was delineated and digitized from 2003 Emerge aerial photography for NH (obtained from NH GRANIT) and 2005 aerial photography for MA obtained from MASS GIS). Data for NH were corrected by field survey.	2008 with 2018 update (a few other prominent dune features were digitized by NHCP staff for this model's purposes)	Not available	This was the only digitized dune shapefile available.	This was the only digitized dune shapefile available.	Further processing includes integration of dunes into Landward Shoretype (see above row)

Name of dataset	Reason for using	Source	Date last updated	Resolution	Why this was chosen	Why others weren't used	Additional processing
Aspect	Proxy for shade/identifying sunlit slopes	USGS LiDAR	2011	3-ft	Aspect was derived from the highest resolution most recently updated LiDAR available.	There are several LiDAR datasets out there; however, this dataset is the highest resolution out of all the rest. The following is a documentation of the other LiDAR datasets that were considered and their resolution. National Elevation Dataset - NH Extract - 2011- DEM – 30 ft National Elevation Dataset - NH Extract - 2011- Hillshade - 30 ft LiDAR - Coastal NH - 2011 - 2Meter DEM – 6 ft (resampled to 2.5 ft for the coast) LiDAR - Coastal NH - 2011 - Hillshade – 6 ft (resampled to 2.5 ft for the coast) DEM available for download on GRANIT – 100 ft Regional LiDAR DEM (Found through Image Services) – 2.5 ft but mosaic of many different sources. The coastal LiDAR component of that mosaic was 6ft so this was RULED OUT (see table here for the composition of this mosaic)	LiDAR was further processed to generate aspect using the "Aspect" tool in ArcToolbox, but the resulting Aspect dataset was not processed any further.
Marsh migration in 2050 under highest SLR (approx 2 ft SLR by 2050)	To identify future favorable environments for salt marsh	"SLAMM_Status" geodatabase: SLAMM analysis by New Hampshire Fish and Game	2015	2m horizontal, 15 cm vertical accuracy	We used 2050 as our time horizon keeping in mind average mortgage lifespan. This dataset was designed for identifying shoreline segments that could be preserved as-is, to allow marshes to migrate, because they already have connectivity. Areas that will get "squeezed" or inundated, could also be identified from the same geodatabase. (Note: "salt marsh persistent" actually means that a site could be suitable for a salt marsh in 2050 even if salt marsh is not currently present) Mention that this used NWI and not always correct everywhere. To do an accuracy check, confirm that ESI also identifies this as salt marsh.	The Restoration Opportunities layer would have been useful for identifying areas of potential future marsh migration *IF connectivity is restored.	
Eelgrass extent	Proxy for wave attenuation	UNH CCOM; Dr. Frederick Short (Research Professor of Natural Resources), UNH	2015	Information unavailable	The 2015 eelgrass extent was used since that was the most updated extent when the model was run.	The 2015 eelgrass extent could be replaced by the latest extent for the next model run.	

Name of dataset	Reason for using	Source	Date last updated	Resolution	Why this was chosen	Why others weren't used	Additional processing
					Hydrodynamic		
Tidal Crossings	To identify areas that might be scoured by high velocity flow of water	New Hampshire Coastal Program Tidal Crossing Assessment	2018	Varying resolutions	Most updated and QAQC'ed dataset.	An intersection of roads with NHD flowlines could have been used, but this dataset is the modified and ground verified version of the NHD-derived dataset.	
Current velocities (Maximum flood current at spring tide)	Proxy for ice formation and scour	Dr. Tom Lippmann (nearshore oceanographer at UNH CCOM)	2018	100-ft	This is the only dataset for current velocities in coastal NH.	There is a Gulf of Maine-wide current velocities dataset out there; however the resolution does not match the data needs of this model.	
Northwest Fetch (292 degree direction)	Proxy for ice shoving	USGS Fetch tool -Wind direction data from the Isles of Shoals buoy (National Buoy Data Center). -Shoreline shapefile from the ESI dataset (with an additional distance added to make up for discrepancy between MHHW points and ESI shoreline)	2017	10-ft	No other dataset that represents ice formation on a regional scale. The 292 degree direction was chosen because it was the predominant wind direction.	We used a 10ft resolution dataset because lack of processing speeds did not allow us to generate a higher res dataset.	The wind direction data and ESI shoreline shapefile were used as inputs for the USGS Fetch Tool. More information on how fetch was generated using these two inputs can be found here.
Northeast Fetch (90 degree direction)	Proxy for storms	USGS Fetch tool -Wind direction data was input as a default 90 degrees (without analysis) -Shoreline shapefile from the ESI dataset (with an additional distance added to make up for discrepancy between MHHW points and ESI shoreline)	2017	10-ft	The 90-degree direction was chosen although it was not the dominant wind direction. Although the 22-degree direction was the dominant wind direction, we felt that the exposure depicted by this direction did not match the actual damage by storms. Also, some of the technical team members pointed out that regardless of wind direction, most storm waves hit the coast from a perpendicular direction.	We used a 10ft resolution dataset because lack of processing speeds did not allow us to generate a higher resolution dataset. We didn't use storm surge data because they did not represent the *exposure* from wind-driven waves. Also, the storm surge data depicts flooding *extent* and not *exposure*.	The wind direction data and ESI shoreline shapefile were used as inputs for the USGS Fetch Tool. More information on how fetch was generated using these two inputs can be found here.
Likelihood of boat wake activity (Distance from federal navigation channels)	Proxy for erosion	Federal Navigation Channels from USACE	Information unavailable	3-ft	A number of other data sources were tested out but this presented the most objective, region-specific data source that fit the resolution of this model.	The recreational boater route density/water trails/recreational boater activities datasets from the Northeast Ocean Planning data portal did not match our resolution needs (~1000ft). Also takes into account non-motorized boat activity, which does not result in significant erosion. A buffer distance to access sites (data from NH Office of Energy and Planning, 2012) was also attempted but the technical team recommended a different approach because this would include non-motorized boat activity which in reality, doesn't contribute much to boat wakes.	

Name of dataset	Reason for using	Source	Date last updated	Resolution	Why this was chosen	Why others weren't used	Additional processing
				Geophysical			
Bathymetry (slope between MHHW points and the 0ft contour or the -1ft contour or the -2 ft contour depending on what data is available for each region)	Seaward slope	Great Bay - NHDES/UNH-CCOM-JHC	2015-2016	3-ft	There was no "one" comprehensive dataset for bathymetry. Different datasets were pieced together from different sources based on resolution, when it was updated, and the comprehensiveness of the coverage that it provided.	Woods Hole/USGS produced a 3-arc second DEM (~200ft) for the entire Gulf of Maine, however the resolution and coverage was not suitable for the model.	A number of steps were taken for further data processing in order to generate the seaward slope using contours. First, the contours were extracted from the raster DEMs using the "Raster to Contour" tool in ArcToolbox. Then, the slope was calculated using the rise over run equation. See Appendix V for more information.
		Little Bay - NHDES/UNH-CCOM-JHC	2013	3-ft			
		Hampton- Seabrook LiDAR Mosaic – compiled by Lippmann Lab (Kate von Krussentiern) using USACE and USGS data	USCACE: 2010, 2011, 2014; USGS:2011 , 2014	All resampled to 32-ft			
		Piscataqua river -NOAA NGS LiDAR	2008	3-ft			
		Atlantic Coast – USACE	2010, 2014	6-ft (2010), 3-ft (2014)			
		AECOM/ GRANIT (LiDAR derived)	2016	6-ft (GRANIT resampled to 3-ft)			
Shoreline Structure Inventory	Treated as a negative influence on adjacent shoreline (within 50ft for GBE and SHE and within 100ft for Atl Coast) To evaluate potential for removal	NHDES Coastal Program	2015	1:1500	High resolution, ground-truthed digitized version of shoreline structures.	ESI documents shoreline structures but does not categorize them beyond "Sheltered/Exposed man-made structures" whereas the inventory identifies walls, revetments, rip rap, groins as distinct entities.	
Soils Erodibility	Measure of erosion	USDA NRCS	Unknown	100-ft, ~30m	This dataset evaluates soils erodibility on the basis of raindrop impact and runoff potential and is calculated using the Universal Soil Loss Equation (USLE). Data ranges from 0 -0.64 with 0.64 being more erodible.	One of many datasets to represent the cause of erosion. Other datasets, if better, could be incorporated into the model during its next scheduled run.	
Beach Volumetric Change	Measure of erosion	LiDAR beach erosion study (Olson and Chormann, 2017)	2017	3.3-ft	This is the only analysis that directly measures erosion/accretion in a beach setting.	This is the only analysis that directly measures erosion/accretion in a beach setting. Beach shoreline change could not be quantified using DSAS because of extensive hardening of shorelines.	The geospatial footprint to represent the results of this analysis was manually created. See Appendix V for more information.

Name of dataset	Reason for using	Source	Date last updated	Resolution	Why this was chosen	Why others weren't used	Additional processing
Bank slope	To identify steep banks (slope > 30 degrees) which would in turn help us understand degree of modification/grading that might be needed at the upland for a living shoreline project	USGS LiDAR	2011	3.3-ft	See "Aspect" and "Landward Shoretype".	See "Aspect" and "Landward Shoretype".	See Appendix V for more information on how this dataset was processed.
		ESI Banks delineation	2016	The ESI maps features that are >=10m			
Sociopolitical							
Ecological Values	To acknowledge and take into consideration the ecological values that stakeholders assign to a site.	Wildlife Action Plan	2015	1:5000	These were the only plans that had geospatial footprints associated with them.	The conservation and public lands layers could have also been included, but it has been used separately in the sociopolitical feasibility assessment.	N/A
		Coastal Conservation Plan	2006				
		Water Resource Conservation plan	2016				
Suggested Living Shoreline Sites	To document sites where there is motivation for a living shoreline project	Solicited from partners/stakeholders	2018	N/A- manually placed dots	This is currently the easiest way we could document motivation.	This dataset could be added to through a more formal site solicitation process or by conducting a survey of landowners in the Seacoast.	N/A
Shoreline Access Sites	public education potential, construction accessibility	Compiled by New Hampshire Office of Energy and Planning, with input from New Hampshire Department of Fish and Game and the regional planning commissions of the state.	2012	1:24,000	Only dataset publicly available that documents shoreline access sites	Only dataset publicly available that documents shoreline access sites	N/A
Eelgrass extent 1996	to represent regulatory concern about not impacting current and historic eelgrass beds.	UNH CCOM; Dr. Frederick Short (Research Professor of Natural Resources), UNH	1996	Unknown	Represents largest eelgrass extent in history.	We wanted to use a dataset that represent greatest eelgrass coverage in case water quality improves in Great Bay. Some of the permitters said that they review projects based on largest historical extent even if those beds aren't currently present.	N/A
Shellfish beds	to represent regulatory concern about not impacting shellfish beds.	Shellfish field observation (NHDES),	2013	Unknown	These were the only datasets that we could find that map natural and restored shellfish beds.	These were the only datasets that we could find that map natural and restored shellfish beds. Some earlier versions exist for the restored beds, but we decided to use the most current version.	N/A
		UNH (Ray Grizzle), Shellfish restoration sites (TNC and UNH)	2017	Unknown			

Name of dataset	Reason for using	Source	Date last updated	Resolution	Why this was chosen	Why others weren't used	Additional processing
Aquaculture sites	to represent regulatory concern about not impacting aquaculture resources	NH Department of Environmental Services (NHDES)	5/13/2015	Unknown	This was the only dataset we could find that document licensed aquaculture sites.	This was the only dataset we could find that document licensed aquaculture sites.	N/A
Trails	To anticipate demand for stabilization	NH Office of Energy and Planning and NH Fish and Game Department	2016	Unknown	This was the only dataset we could find that maps NH's recreational trails.	This was the only dataset we could find that maps NH's recreational trails.	N/A
Conservation/Public Lands	To represent level of motivation/capacity/interest for living shoreline projects	The development of this data layer was initiated in the early 1990's as a collaboration between the Society for the Protection of NH Forests (SPNHF), the NH Office of Strategic Initiatives (OSI), and the Earth Systems Research Center at the University of New Hampshire (ESRC).	June 2018	1:24,000	Most comprehensive dataset identifying conservation and public lands.	Parcel data could have been used however this dataset was specifically developed for conservation purposes and uses parcel data as one of the inputs.	N/A
Impervious cover	To represent demand for stabilization and to understand project vulnerability.	Earth Systems Research Center, University of New Hampshire	2015	1:2,000 or greater (1 ft)	Highest resolution impervious cover dataset	This was the latest updated, highest resolution impervious cover dataset available	N/A
Buildout Scenarios for Impervious Cover under "Linear" development scenario by 2050	To represent demand for stabilization	Earth Systems Research Center, University of New Hampshire (Alexandra Thorn)	2017	100-ft	Currently, this was the most comprehensive buildout scenario dataset available. The planning commissions only had pieces of buildouts for some towns but didn't have anything comprehensive for the entire coast.	The Linear Scenario was selected over "Backyard" and "Community" because it assumed a medium value placed on ecosystem services and a population distribution in-between dispersed and concentrated, which the project team felt was most representative of seacoast NH.	N/A
Sea Level Rise 2050 High Emissions Scenario (2 feet)	To assess project vulnerability	AECOM/ GRANIT (LiDAR derived)	Derived from 2011 NH coastal LiDAR	6.5-ft; split into points 10-ft apart.	The 2050 time horizon matched the life span of the average homeowners' mortgage and most design life spans of projects.	This is the most region-specific SLR dataset available. We chose the 2050 high emissions scenario because the recent NCA4 suggested that sea level rise might be more than we expected.	Converted Raster to Vector and then generated points from the lines (See Appendix V)

V. Aggregation of datasets to MHHW points

Table 8. Methods used to aggregate L3SA input datasets to the MHHW points.

Dataset	Method of aggregation
	Ecological
Landward Shoretype, Seaward Shoretype, Seaward Extra Info Dunes	• Conducted a Spatial Join with the MHHW points as the Target Feature and the ESI lines as the Join feature, and selected "Closest" as the match option. • The "Near" tool was run to quantify the distance between the MHHW point (input feature) and its closest dune (near feature). • If a dune feature was present within a distance of 400 feet of the MHHW points (some features were added or removed manually based on the specific shoreline environment), the Landward Shoretype attribute was replaced with "Dune". • If a shoreline structure was present, the Landward Shoretype was re-classified as "None" and the shoreline structure dataset was given precedence.
Aspect	• Converted Aspect Raster to Points. • Conducted a Spatial Join with the MHHW points as the Target Feature and the Aspect points as the Join feature, selected "Closest" as the match option, and entered "3 feet" in "Search Radius".
Marsh migration in 2050 under highest SLR (approx 2-ft SLR by 2050)	• Conducted a Spatial Join with the MHHW points as the Target Feature and the salt marsh polygons as the Join feature, selected "Intersect" as the match option. • Used the attribute "STATUS 2M" to join.
Eelgrass proximity	• The "Near" tool was run to quantify the distance between the MHHW point (input feature) and its closest eelgrass bed (near feature).
	Hydrodynamic
Tidal Crossings	• Conducted a Spatial Join with the MHHW points as the Target Feature and the tidal crossing points as the Join feature, selected "Intersect" as the match option, and entered "50 feet" as the Search Radius.
Current velocities (Maximum flood current at spring tide)	• Conducted a Spatial Join with the MHHW points as the Target Feature and the current velocity points as the Join feature, selected "Closest" as

<table>
<tr><td></td><td>the match option and “200 feet” as the Search Radius.
• Manually went and set all the MHHW points beyond the coverage of the current velocities dataset to “Null” using the selection tool and field calculator.</td></tr>
<tr><td>Northwest Fetch (292 degree direction)</td><td>• Converted fetch raster to vector polygons (each polygon was 10 X 10 ft just like the raster grid).
• Ran the “Near” tool to quantify the distance between the Fetch polygons (input feature) and nearest MHHW point (near feature).
• Added the near distance to the fetch distance to get a new fetch.
• Conducted a Spatial Join with the MHHW points as the Target Feature and the fetch polygons as the Join feature, selected “Closest” as the match option.</td></tr>
<tr><td>Northeast Fetch (90 degree direction)</td><td>• Converted fetch raster to vector polygons (each polygon was 10 X 10 ft just like the raster grid)
• Ran the “Near” tool to quantify the distance between the Fetch polygon (input feature) and nearest MHHW point (near feature).
• Added the near distance to the fetch distance to get a new fetch.
• Conducted a Spatial Join with the MHHW points as the Target Feature and the fetch polygons as the Join feature, selected “Closest” as the match option.</td></tr>
<tr><td>Likelihood of boat wake activity (Distance from federal navigation channels)</td><td>• Ran the “Euclidean Distance” tool with Federal Navigation Channels as the Input feature.
• Ran the “Extract Values to Points” tool with the MHHW points as the “Input Point Features” and the Euclidean Distance Raster as the “Input Raster”.</td></tr>
<tr><td colspan="2">Geophysical</td></tr>
<tr><td>Seaward Slope</td><td>Ran the “Near” tool to quantify the distance between the MHHW point (input feature) and either the 0-ft bathymetric contours or the minus -1 foot bathymetric contour or the -2 foot bathymetric contour (near features). The Near Tool allowed all 3 contours to be entered in the “near features” section. Then, the elevation of the MHHW point was divided by the distance using a simple rise over run equation to get the slope. This value was then converted into degrees.</td></tr>
</table>

Shoreline Structure Inventory	Conducted a Spatial Join with the MHHW points as the Target Feature and the tidal crossing points as the Join feature, selected "Intersect" as the match option, and entered "100 feet" as the Search Radius for the Atlantic Coast and "50 feet" as the Search Radius for Great Bay Estuary.
Soils Erodibility	Conducted a Spatial Join with the MHHW points as the Target Feature and the slope points as the Join feature, selected "Closest" as the match option, and entered "10 feet" in "Search Radius".
Beach Volumetric Change	Using an aerial background layer, all the points along each beach was assigned their condition using a manual approach. This was because of the lack of a comprehensive beach shapefile to conduct a Spatial Overlay (the beaches delineated by the NWI did not cover all the beaches analyzed in the volumetric change assessment). • Hampton and Seabrook beaches showed gains in both the volumetric analysis and the DSAS analysis. (Accretion) • Plaice, Bass Beach 1, Rye Beach and Unnamed beach showed losses in both the volumetric analysis and the DSAS analysis. (Erosion) • North Beach, Bass Beach 2, Foss beach and Wallis Sands had mixed results, all showing total volumetric losses and a mix of accretion and erosion for some time period in the DSAS analysis. (Potentially stable)
Bank Slope	• Converted slope raster to slope points • Extracted slope points within 100 feet of the MHHW points. • Queried for all slopes greater than 30 degrees. • Extracted those points as a separate dataset. • Aggregated the points to the attribute table, aggregated each steep slope point to the closest MHHW point as long as they're within 100 feet of each other, also added an attribute specifying the distance. If > 100 foot, it comes out as null.
Sociopolitical	
Ecological Values	• Used Pete Steckler's One-Stop Dataset for Land Protection Transaction Grants' Screening. • Queried for each type, created a separate layer out of each type (for eg., separate layer for "Core Areas", separate layer for "Supporting Areas" (doing a single Spatial Join with just the

	OneStop dataset would not have been effective as this dataset has overlapping features). • Conducted a Spatial Join to join each layer to its intersecting MHHW point.
Suggested Living Shoreline Sites	Conducted a Spatial Join with the MHHW points as the Target Feature and the suggested points as the Join feature, selected "Closest" as the match option, and entered "730 feet" in "Search Radius" (based on a "Near" analysis keeping the suggested points as the Input feature and the MHHW points as the Target Feature and reviewing the near distances).
Shoreline Access Sites	Conducted a Spatial Join with the MHHW points as the Target Feature and the access sites as the Join feature, selected "Closest" as the match option, and entered "50 feet" in "Search Radius".
Eelgrass extent 1996	Ran the "Near" tool to quantify the distance between the MHHW point (input feature) and the closest eelgrass bed (near feature).
Shellfish beds	Ran the "Near" tool to quantify the distance between the MHHW point (input feature) and the closest shellfish bed feature (near feature).
Aquaculture sites	Conducted a Spatial Join with the MHHW points as the Target Feature and the access sites as the Join feature, selected "Closest" as the match option and "1000 feet" as the search distance.
Trails	Conducted a Spatial Join with the MHHW points as the Target Feature and the trails as the Join feature, selected "Closest" as the match option and "100 feet" as the search distance.
Conservation/Public Lands	Conducted a Spatial Join with the MHHW points as the Target Feature and Conservation/Public Lands as the Join feature, selected "Within a distance of" as the match option and "100 feet" as the search distance. Joins were conducted to match each code to its description using the accompanying Excel metadata spreadsheet for this dataset.
Impervious Cover	Clipped the Impervious Cover dataset to within a 1,000-foot buffer of the MHHW points (because of the large size of this dataset). Ran the "Near" tool to quantify the distance between the MHHW point (input feature) and the closest impervious cover feature (near feature) within 100 feet.
Buildout Scenarios	Used the "Extract Values to Points" tool with the MHHW points as the Input point feature and the

	Buildout raster as the Input Raster and checked the box for interpolation of values.
Sea Level Rise	• Used the 2-foot SLR polygon generated by GRANIT, used the “Dissolve” tool to combine all the polygons into one big polygon, broke the polygon up into lines using “Feature to Lines”, generated points along the lines using “Generate Points Along Lines” and setting the spacing to “10 feet”. • This became the “new shoreline in 2050 with 2 feet of sea-level rise.” • Conducted a spatial overlay using Select by Location where the Target Feature was the SLR point layer and the Source Layer was the impervious cover dataset. All the points from the SLR layer that intersected with the impervious cover dataset got assigned “Vulnerable” in the corresponding vulnerability attribute.

VI. Scores assigned to each dataset

Note: All scores were assigned based on technical team expert opinion and consultation with the literature.

Table 9. Scores assigned to datasets used in the biophysical model and justification for the scores assigned.

Name of dataset	Name of scoring attribute	Attribute values	Score (1-6)	Reasoning
		Ecological		
Landward Shoretype,	S1_Landward_Shoretype_Score	2A: Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay)	2	Scored based on expert opinions. In general, pre-existing vegetation, sheltered areas, and habitat got higher suitability scores.
		3A: Fine to Medium Grained Sand Beaches	5	
		4: Coarse Grained Sand Beaches	4	
		5: Mixed Sand and Gravel Beaches	3	
		8A: Sheltered, Impermeable, Rocky Shores	2	
		9B: Vegetated Low Banks	5	
		10A: Salt and Brackish Water Marshes	6	
		10B: Freshwater Marshes	6	
		10C: Swamps	6	
		10D: Scrub and Shrub Wetlands	6	
		Dunes	6	
Seaward Shoretype,	S2_Seaward_Shoretype_Score	2A: Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay)	2	
		3A: Fine to Medium Grained Sand Beaches	5	
		4: Coarse Grained Sand Beaches	4	
		5: Mixed Sand and Gravel Beaches	3	
		7: Exposed Tidal Flats	2	
		8A: Sheltered, Impermeable, Rocky Shores	2	
		8A: Sheltered Scarps (Bedrock/Mud/Clay)	4	
		9A: Sheltered Tidal Flats	5	
		9B: Vegetated Low Banks	5	

Seaward Extra Information	S3_Seaward_Extra_Info_Score	2A: Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay)	2	
		3A: Fine to Medium Grained Sand Beaches	5	
		4: Coarse Grained Sand Beaches	4	
		5: Mixed Sand and Gravel Beaches	3	
		7: Exposed Tidal Flats	2	
		8A: Sheltered, Impermeable, Rocky Shores	2	
		9A: Sheltered Tidal Flats	5	
Aspect	S4_Aspect_SunExposure_Score	Flat (-1)	4.5 (More info)	Since Southern and Western faces tend to be warmer, the scores were set by incrementing the number gradually across the compass rosette. For instance, treating SSW as a maximum chance (using 3-6 with 6 being highest). Flat got a score of 4.5 because it's a neutral aspect.
		North (0-22.5)	3	
		Northeast (22.5-67.5)	3	
		East (67.5-112.5)	4	
		Southeast (112.5-157.5)	5	
		South (157.5-202.5)	6	
		Southwest (202.5-247.5)	6	
		West (247.5-292.5)	5	
		Northwest (292.5-337.5)	4	
		North (337.5-360)	3	
Marsh migration in 2050 under highest SLR (approx 2 foot SLR by 2050)	S6_Future_Salt_Marsh_Score	Salt Marsh lost	0.5	Salt marsh lost got 0.5 only so it doesn't get counted as a zero because zero is for no data. Areas where there is persistence or potential for marshes both got high suitability scores because we are equally interested in both areas.
		Salt Marsh persistent	6	
		Salt Marsh potential	6	
Eelgrass proximity	S5_Eelgrass_Proximity_Score	**0-1000 feet**	**2—5**	Used 1,000 feet as cut off because analysis proves that mean distance of eelgrass bed to shoreline is 1129 feet (0.1 mile). Also, Carey et al., (2013), used 1,000 feet in Pamlico Sound L3SA (Appendix II). For salt marshes in Great Bay, eelgrass is not so important for site suitability. In the Squamscott river, it may be more important for site suitability. Coves have potential for LS when eelgrass is present >1,000 feet got a score of 1 because wave attenuation benefits of eelgrass are not felt at this distance.
		Eelgrass in Great Bay	2	
		Eelgrass in Squamscott	4	
		Eelgrass in sheltered areas	5	
		>1000 feet	**1**	

Hydrodynamic					
Tidal Crossings	S12_Tidal_Crossing_Score	Present within 50 feet		3	Having a tidal crossing does not preclude the possibility of a living shoreline because the living shoreline project can be designed taking high velocity flow into account. The absence of a tidal crossing, does however, reduce the chance of scouring due to high velocity flow, and reduces the likelihood of long term erosion.
		Absent within 50 feet		6	
Current velocities (m/s) (Maximum flood current at spring tide)	S10_Current_Edge_Impact_Score	**m/s**	**ft/s**		Scoring based on 2 ft/s is the critical shear stress i.e., the sand transport capacity. At current velocities > 2 ft/s, sediment transport takes place.
		0.000000 - 0.057000	0 - 0.18700787	6	
		0.057001 - 0.176000	0.18700787 - 0.57742782	6	
		0.176001 - 0.362000	0.57742782 - 1.187664	6	
		0.362001 - 0.669000	1.187664 - 2.1948819	4	
		0.669001 - 1.119000	2.1948819 - 3.6712598	3	
		1.119001 - 1.912000	3.6712598 - 6.2729659	1	
	S11_CurrentSedimentImpact_Score	0.000000 - 0.057000	0 - 0.18700787	6	
		0.057001 - 0.176000	0.18700787 - 0.57742782	6	
		0.176001 - 0.362000	0.57742782 - 1.187664	5	
		0.362001 - 0.669000	1.187664 - 2.1948819	4	
		0.669001 - 1.119000	2.1948819 - 3.6712598	2	
		1.119001 - 1.912000	3.6712598 - 6.2729659	1	
Northwest Fetch (292 degree direction)	S8_NW_Fetch_Ice_Proxy_Score	0 - 0.01mi		6	Longer fetch = more ice shoved against the shoreline. Negative fetch got the lowest score (0.5) but not a 0 because 0= No Data.
		0.01- 0.18mi		5	
		0.18 - 0.56 mi		4	
		0.56- 0.94 mi		4	
		0.94 -3 mi		4	
		> 3 mi		4	
		Negative (unbounded)		0.5	

Northeast Fetch (90 degree direction)	S9_NE_Fetch_Storm_Proxy_Score	0 - 0.5 mi	6	Longer fetch= greater the impact from storm waves. Negative fetch got the lowest score (0.5) but not a 0 because 0= No Data.
		0.5 -1 mi	5	
		1 -2 mi	4	
		2 -3 mi	3	
		3 -5 mi	2	
		>5 mi	1	
		Negative (unbounded)	0.5	
Likelihood of boat wake activity (Distance from federal navigation channels in feet)	S13_BoatWakeErosionProxy_Score	0- 2677 ft	1	Further from federal navigation channels, more suitability because less likelihood of boat wake impacts. Scoring categories were generated using ArcGIS' Natural Jenks function.
		2678- 5342 feet	2	
		5343- 8006 feet	3	
		8007- 10671 feet	4	
		10672- 13336 feet	5	
		13337- 21119 feet	6	
Geophysical				
Seaward Slope	S17_Seaward_Slope_Score	28-49 degrees	1	"Steep" slopes were considered to be slopes greater than 28 degrees and hence these slopes got the lowest score indicating that more site modification (such as fill) might be needed before setting up a living shoreline. "Flat" slopes were those that were less than 3 degrees and they got the highest scores because these areas would not need much site modification, and in case of a marsh restoration project, migration would be easily facilitated if the slope was flat.
		18-28 degrees	2	
		12-18 degrees	3	
		7-12 degrees	4	
		3- 7 degrees	5	
		0- 3 degrees	6	
Shoreline Structure Inventory	S7_Shoreline_Structures_Score	Berm	4	Jetty/Groin got the lowest scores because they have the most negative influence on erosion and least habitat benefits. Walls got the second lowest scores because in some cases, walls can exist in conjunction with marshes/dunes but they still inhibit inland migration. Riprap/revetment got the third lowest score because they provide some, if sparse, habitat value. Berms got the next lowest because they are not as vertically obstructive as the other structures.
		Jetty/Groin	1	
		Riprap/revetment	3	
		Wall	2	

Soils Erodibility	S14_Soils_Erodibility_Score	0.05 - 0.15	2	Lower the erodibility, less suitable because it likely is bedrock. Higher erodibility values might also make it less suitable because of top soil loss. Thus, the mid-values got the highest scores.
		0.15 - 0.23	4	
		0.23 - 0.31	5	
		0.31 - 0.41	4	
		0.41 - 0.48	3	
		0.48 - 0.64	2	
Beach Volumetric Change	S16_Beach_Erosion_Score	Erosion	5	Based on the results of the Beach Volumetric Change report, each beach was considered as a unit. We used long term trends analyzed by the report to associate each beach with its overall condition. Eroding and Accreting beaches got scores of 5 because instability could warrant more site modification for a living shoreline project to be successfully. Potentially stable beaches got high scores because of the likelihood of a project to succeed if the sediment is in place. • Hampton and Seabrook beaches showed gains in both the volumetric analysis and the DSAS analysis. (Accretion) • Plaice, Bass Beach 1, Rye Beach and Unnamed beach showed losses in both the volumetric analysis and the DSAS analysis. (Erosion) • North Beach, Bass Beach 2, Foss beach and Wallis Sands had mixed results, all showing total volumetric losses and a mix of accretion and erosion for some time period in the DSAS analysis. (Potentially stable)
		Accretion	5	
		Potentially stable	6	
Bank slope (degrees)	S15_Steep_Bank_Slope_Score	0 –30 degrees	6	A slope greater than 30 degrees (1:2) indicates the presence of a steep bank which would require a high degree of site modification; hence these steep banks got a score of 1.
		> 30 degrees	1	
Sociopolitical				
Sociopolitical datasets were not scored and sociopolitical data is intended to be interpreted in a qualitative way.				

VII. Weights assigned to each dataset

Note: All weights were assigned based on technical team expert opinion and consultation with the literature.

Table 10. Weights assigned to datasets used in the biophysical model and justification for the weights assigned.

Dataset	Name of weighting attribute	Weight	Justification for weight
	Ecological		
Landward Shoretype,	W1_Landward_Shoretype_Weight	3	Habitat type has a very high influence on site suitability. Pre-existing vegetation is an important determinant of suitability.
Seaward Shoretype,	W2_Seaward_Shoretype_Weight	2	
Seaward Extra Info	W3_Seaward_Extra_Info_Weight	1	
Aspect	W4_Aspect_SunExposure_Weight	1	Not all living shoreline strategies are vegetation dependent (such as beach nourishment), and aspect does not fully capture shading from trees.
Marsh migration in 2050 under highest SLR (approx 2 feet SLR by 2050)	W6_Future_Salt_Marsh_Weight	2	Future persistent salt marsh suggests high suitability for natural approaches in that area and any shoreline stabilization at the site should enable future migration.
Eelgrass proximity	W5_Eelgrass_Proximity_Weight	2	Wave attenuation benefits of eelgrass are limited due to the large tidal range.

Hydrodynamic			
Tidal Crossings	W12_Tidal_Crossing_Weight	1	The tidal crossing dataset does not specify tidal restrictions and the current velocity dataset also helps account for high velocity flow areas.
Current velocities (Maximum flood current at spring tide)	W10_Current_Edge_Impact_Weight	1	Although waves are generally considered to be the primary force impacting the design of coastal structures, currents also play an important role, particularly for living shorelines sites located near tidal inlets or along riverbanks. Currents have the capacity to uproot vegetation, scour the bank, and during storms can transport debris which increases the scour potential. In areas subject to freezing, currents can also transport blocks of ice, which similar to debris can scour the shoreline.
	W11_CurrentSedimentImpact_Weigh	1	
Northwest Fetch (292 degree direction)	W8_NW_Fetch_Ice_Proxy_Weight	2	Greater northwest fetch creates increased likelihood for ice to be shoved against the shoreline, contributing to erosion.

Northeast Fetch (90 degree direction)	W9_NE_Fetch_Storm_Proxy_Weight	2	Greater northeast fetch creates larger more powerful waves, lessening the likelihood of successful living shoreline establishment and stable sediment.
Likelihood of boat wake activity (Distance from federal navigation channels)	W13_BoatWakeErosionProxy_Weight	1	Boat wakes are only one of many indicators of wave energy/shoreline exposure and proximity to federal navigation channels is a coarse measure of boat wake impact.
Geophysical			
Bathymetry (Seaward Slope)	W17_Seaward_Slope_Weight	4	Nearshore slope is an important determinant of wave energy and erosion.
Shoreline Structure Inventory	W7_Shoreline_Structures_Weight	3	Shoreline structures have significant implications for the feasibility of a living shoreline approach in a particular area. They indicate a likelihood that erosion has occurred at the site.
Soils Erodibility	W14_Soils_Erodibility_Weight	3	Soils erodibility is an indicator of erosion at a site.
Beach Volumetric Change	W16_Beach_Erosion_Weight	1	Beach volumetric change was scored on a beach unit scale, resulting in a coarse unit of analysis.
Bank slope (degrees)	W15_Steep_Bank_Slope_Weight	4	Steep banks negatively affect

			suitability and indicate a need for hybrid stabilization measures and site modification such as bank regrading and vegetation removal.
Sociopolitical			
Sociopolitical datasets were not weighted and sociopolitical data is intended to be interpreted in a qualitative way.			

VIII. Sample Visual Basic (VB) and Python Scripts

Python scripts for scoring (to be plugged into field calculator)

Sample script for numeric attributes (replace with name of dataset being scored):

Code Block:

```
def S4_Aspect_SunExposure_Score(N4_Aspect_SunExposure_Dgrs):
  if (N4_Aspect_SunExposure_Dgrs >=0) and
(N4_Aspect_SunExposure_Dgrs <= 22.5):
    return 3
  elif (N4_Aspect_SunExposure_Dgrs> 22.5) and
(N4_Aspect_SunExposure_Dgrs<= 67.5):
    return 3
  elif (N4_Aspect_SunExposure_Dgrs> 67.5) and
(N4_Aspect_SunExposure_Dgrs<= 112.5):
    return 4
  elif (N4_Aspect_SunExposure_Dgrs> 112.5) and
(N4_Aspect_SunExposure_Dgrs<= 157.5):
    return 5
  elif (N4_Aspect_SunExposure_Dgrs> 157.5) and
(N4_Aspect_SunExposure_Dgrs<= 202.5):
    return 6
  elif (N4_Aspect_SunExposure_Dgrs> 202.5) and
(N4_Aspect_SunExposure_Dgrs<= 247.5):
    return 6
  elif (N4_Aspect_SunExposure_Dgrs> 247.5) and
(N4_Aspect_SunExposure_Dgrs<= 292.5):
    return 5
  elif (N4_Aspect_SunExposure_Dgrs> 292.5) and
(N4_Aspect_SunExposure_Dgrs<= 337.5):
    return 4
  elif (N4_Aspect_SunExposure_Dgrs> 337.5) and
(N4_Aspect_SunExposure_Dgrs<= 360):
    return 3
  elif (N4_Aspect_SunExposure_Dgrs==-1):
    return 4.5
  else:
    return 0
```

Expression: S4_Aspect_SunExposure_Score (!N4_Aspect_SunExposure_Dgrs!)

A score of 0 implies that there is no data at that site.

Sample script for non-numeric attributes (replace with name of dataset being scored):

Code Block:

```
def S7_Shoreline_Structures_Score (N7_Shoreline_Structures):
  if (N7_Shoreline_Structures =='Rip Rap/Revetment'):
    return 3
  elif (N7_Shoreline_Structures =='Wall'):
    return 2
  elif (N7_Shoreline_Structures =='Jetty/Groin'):
    return 1
  elif (N7_Shoreline_Structures =='Berm'):
    return 4
  else:
    return 6
```

Expression: S7_Shoreline_Structures_Score (!N7_Shoreline_Structures!)

For Yes/No attributes like the shoreline structure inventory, areas with no structures get a score of 6 (highest suitability). Here, 0 is not part of the score assignment.

Python scripts for weighting (to be plugged into field calculator)

Replace with name of dataset being weighted:

Code Block:

```
def W4_Aspect_SunExposure_Weight (S4_Aspect_SunExposure_Score):
  if (S4_Aspect_SunExposure_Score >=1) and
(S4_Aspect_SunExposure_Score <= 6):
    return 1
  else:
    return 0
```

Expression: W4_Aspect_SunExposure_Weight (!S4_Aspect_SunExposure_Score!)

If an attribute has a score of 0, it means that there is no data, and so it is also assigned a weight of 0. In this case, this attribute is neither a part of the numerator nor the denominator.

VB script for calculating the suitability index (to be plugged into field calculator)

VB script for the "With structures" scenario:

(([S9_NE_Fetch_Storm_Proxy_Score] * 2) + ([S8_NW_Fetch_Ice_Proxy_Score] * 2) + ([S5_Eelgrass_Proximity_Score] * 2) + ([S1_Landward_Shoretype_Score]* 3) + ([S2_Seaward_Shoretype_Score]* 2) + ([S3_Seaward_Extra_Info_Score]* 1) + ([S7_Shoreline_Structures_Score] * 3) + ([S15_Steep_Bank_Slope_Score] *4) + ([S12_Tidal_Crossing_Score] *1) + ([S10_Current_Edge_Impact_Score]* 1) + ([S11_CurrentSedimentImpact_Score]* 1) + ([S13_BoatWakeErosionPrxy_Score]* 1) + ([S16_Beach_Erosion_Score] * 1) + ([S17_Seaward_Slope_Score] * 4) + ([S14_Soils_Erodibility_Score] * 3)+ ([S6_Future_Salt_Marsh_Score] *2) + ([S4_Aspect_SunExposure_Score] *1)) / ([W9_NE_Fetch_Storm_Proxy_Weight] + [W8_NW_Fetch_Ice_Proxy_Weight] + [W5_Eelgrass_Proximity_Weight] + [W1_Landward_Shoretype_Weight] + [W2_Seaward_Shoretype_Weight] + [W3_Seaward_Extra_Info_Weight] + [W10_Current_Edge_Impact_Weight] + [W11_CurrentSedimentImpact_Weigh] + [W13_BoatWakeErosionPrxy_Weight] + [W16_Beach_Erosion_Weight] + [W17_Seaward_Slope_Weight] + [W14_Soils_Erodibility_Weight] + [W6_Future_Salt_Marsh_Weight] + [W4_Aspect_SunExposure_Weight] + [W15_Steep_Bank_Slope_Weight] + [W12_Tidal_Crossing_Weight] + [W7_Shoreline_Structures_Weight])

VB script for the “Without structures” scenario:

(([S9_NE_Fetch_Storm_Proxy_Score] * 2) + ([S8_NW_Fetch_Ice_Proxy_Score] * 2) + ([S5_Eelgrass_Proximity_Score] * 2) + ([S1_Landward_Shoretype_Score]* 3) + ([S2_Seaward_Shoretype_Score]* 2) + ([S3_Seaward_Extra_Info_Score]* 1) + (6* 3) + ([S15_Steep_Bank_Slope_Score] *4) + ([S12_Tidal_Crossing_Score] *1) + ([S10_Current_Edge_Impact_Score]* 1) + ([S11_CurrentSedimentImpact_Score]* 1) + ([S13_BoatWakeErosionPrxy_Score]* 1) + ([S16_Beach_Erosion_Score] * 1) + ([S17_Seaward_Slope_Score] * 4) + ([S14_Soils_Erodibility_Score] * 3)+ ([S6_Future_Salt_Marsh_Score] *2) + ([S4_Aspect_SunExposure_Score] *1)) / ([W9_NE_Fetch_Storm_Proxy_Weight] + [W8_NW_Fetch_Ice_Proxy_Weight] + [W5_Eelgrass_Proximity_Weight] + [W1_Landward_Shoretype_Weight] + [W2_Seaward_Shoretype_Weight] + [W3_Seaward_Extra_Info_Weight] + [W10_Current_Edge_Impact_Weight] + [W11_CurrentSedimentImpact_Weigh] + [W13_BoatWakeErosionPrxy_Weight] + [W16_Beach_Erosion_Weight] + [W17_Seaward_Slope_Weight] + [W14_Soils_Erodibility_Weight] + [W6_Future_Salt_Marsh_Weight] + [W4_Aspect_SunExposure_Weight] + [W15_Steep_Bank_Slope_Weight] + [W12_Tidal_Crossing_Weight] + [W7_Shoreline_Structures_Weight])

Python script for counting the number of attributes with no data (to be plugged into field calculator)

Attribute Name: N18_No_datasets_missing

Expression: FieldCount(!S8_NW_Fetch_Ice_Proxy_Score!, !S10_Current_Edge_Impact_Score!, !S11_CurrentSedimentImpact_Score!, !S5_Eelgrass_Proximity_Score!, !S1_Landward_Shoretype_Score!, !S2_Seaward_Shoretype_Score!, !S3_Seaward_Extra_Info_Score!, !S13_BoatWakeErosionPrxy_Score!, !S16_Beach_Erosion_Score!, !S14_Soils_Erodibility_Score!, !S7_Shoreline_Structures_Score!, !S6_Future_Salt_Marsh_Score!, !S9_NE_Fetch_Storm_Proxy_Score!, !S4_Aspect_SunExposure_Score!, !S12_Tidal_Crossing_Score!, !S15_Steep_Bank_Slope_Score!, !S17_Seaward_Slope_Score!)

Code Block:

```
def FieldCount(S8_NW_Fetch_Ice_Proxy_Score,
S10_Current_Edge_Impact_Score, S11_CurrentSedimentImpact_Score,
S5_Eelgrass_Proximity_Score, S1_Landward_Shoretype_Score,
S2_Seaward_Shoretype_Score, S3_Seaward_Extra_Info_Score,
S13_BoatWakeErosionPrxy_Score, S16_Beach_Erosion_Score,
S14_Soils_Erodibility_Score, S7_Shoreline_Structures_Score,
S6_Future_Salt_Marsh_Score, S9_NE_Fetch_Storm_Proxy_Score,
S4_Aspect_SunExposure_Score, S12_Tidal_Crossing_Score,
S15_Steep_Bank_Slope_Score, S17_Seaward_Slope_Score):
 fields=[S8_NW_Fetch_Ice_Proxy_Score, S10_Current_Edge_Impact_Score,
S11_CurrentSedimentImpact_Score, S5_Eelgrass_Proximity_Score,
S1_Landward_Shoretype_Score, S2_Seaward_Shoretype_Score,
S3_Seaward_Extra_Info_Score, S13_BoatWakeErosionPrxy_Score,
S16_Beach_Erosion_Score, S14_Soils_Erodibility_Score,
S7_Shoreline_Structures_Score, S6_Future_Salt_Marsh_Score,
S9_NE_Fetch_Storm_Proxy_Score, S4_Aspect_SunExposure_Score,
S12_Tidal_Crossing_Score, S15_Steep_Bank_Slope_Score,
S17_Seaward_Slope_Score]
 return sum(f==0 for f in fields)
```

VB script for counting the % of weights missing (to be plugged into field calculator)

```
100 - ( (( [W9_NE_Fetch_Storm_Proxy_Weight] +
[W8_NW_Fetch_Ice_Proxy_Weight] + [W5_Eelgrass_Proximity_Weight] +
[W1_Landward_Shoretype_Weight] + [W2_Seaward_Shoretype_Weight] +
[W3_Seaward_Extra_Info_Weight] + [W10_Current_Edge_Impact_Weight]
+ [W11_CurrentSedimentImpact_Weigh] +
[W13_BoatWakeErosionPrxy_Weight] + [W16_Beach_Erosion_Weight] +
```

[W17_Seaward_Slope_Weight] + [W14_Soils_Erodibility_Weight] + [W6_Future_Salt_Marsh_Weight] + [W4_Aspect_SunExposure_Weight] + [W15_Steep_Bank_Slope_Weight] + [W12_Tidal_Crossing_Weight] + [W7_Shoreline_Structures_Weight])/ 34) * 100)

Python script for qualitatively assigning data quality (to be plugged into field calculator)

CodeBlock:

```
def N18_Data_Quality (N18_Percent_Weights_Missing):
  if (N18_Percent_Weights_Missing>=32):
    return "Minimal Data"
  else:
    return "Adequate Data"
```

Expression:

```
N18_Data_Quality ( !N18_Percent_Weights_Missing! )
```

IX. Biophysical suitability attribute table

Table 11. Details of attributes produced by the biophysical suitability model.

Attribute	Intention for using	Name	Range of Values	Units	Name of scoring attribute	Scoring range	Name of weighting attribute	Weight	Name of proximity attribute (Distance of MHHW points from attribute)
Landward Shoretype	Identification of banks, characterize habitat roughly landward of the MHHW points.	N1_Landward_Shoretype	10A: Salt and Brackish Water Marshes 10B: Freshwater Marshes 10C: Swamps 10D: Scrub and Shrub Wetlands 1A: Exposed, Rocky Shores 1B: Exposed, Solid Man-Made Structures 2A: Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay);\ 3A: Fine to Medium Grained Sand Beaches; 4: Coarse Grained Sand Beaches 5: Mixed Sand and Gravel Beaches 6A: Gravel Beaches 6B: Riprap 8A: Sheltered, Impermeable, Rocky Shores 8B: Sheltered, Solid Man-Made Structures 8C: Sheltered Riprap 9B: Vegetated Low Banks	N/A (qualitative)	S1_Landward_Shoretype_Score	1-6	W1_Landward_Shoretype_Weight	3	D1_Dune_Distance (if applicable)
Seaward Shoretype	Identification of marshes/mudflats and other seaward shoreline types; characterize habitat roughly seaward of the MHHW points.	N2_Seaward_Shoretype	1A: Exposed, Rocky Shores; 1B: Exposed, Solid Man-Made Structures; 2A: Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay); 3A: Fine to Medium Grained Sand Beaches; 4: Coarse Grained Sand Beaches; 5: Mixed Sand and Gravel Beaches; 6B: Riprap; 7: Exposed Tidal Flats; 8A: Sheltered Scarps (Bedrock/Mud/Clay); 8A: Sheltered, Impermeable, Rocky Shores; 8B: Sheltered, Solid Man-Made Structures; 8C: Sheltered Riprap; 9A: Sheltered Tidal Flats; 9B: Vegetated Low Banks	N/A (qualitative)	S2_Seaward_Shoretype_Score	1-6	W2_Seaward_Shoretype_Weight	2	N/A
Seaward Extra Info	Secondary (extra) seaward habitat information	N3_Seaward_Extra_Info	2A: Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay); 3A: Fine to Medium Grained Sand Beaches; 4: Coarse Grained Sand Beaches; 5: Mixed Sand and Gravel Beaches; 7: Exposed Tidal Flats;	N/A (qualitative)	S3_Seaward_Extra_Info_Score	1-6	W3_Seaward_Extra_Info_Weight	1	

			8A: Sheltered, Impermeable, Rocky Shores; 9A: Sheltered Tidal Flats						
Aspect	Proxy for shade/identifying sunlit slopes	N4_Aspect_SunExposure_Dgrs	-1 – 360	degrees	S4_Aspect_SunExposure_Score	1-6	W4_Aspect_SunExposure_Weight	1	D4_Aspect_SunExposure_Dist
Eelgrass proximity	Proxy for wave attenuation	N5_EelgrassProximityWaveBenefit	22 – 69,378	feet	S5_Eelgrass_Proximity_Score	1-6	W5_Eelgrass_Proximity_Weight	2	Is itself a proximity attribute.
Marsh migration in 2050 under highest SLR (approx 2 feet of SLR by 2050)	To identify future favorable environments for salt marsh	N6_Future_SaltMarsh2050_2ftSLR	Persistent= means persistent in 2050 under 2 feet of sea level rise Potential Lost	N/A (qualitative)	S6_Future_Salt_Marsh_Score	0.5 or 6	W6_Future_Salt_Marsh_Weight	2	N/A
Shoreline Structures	Treated as a negative influence on adjacent shoreline (within 50 feet for GBE and SHE and within 100 feet for Atl Coast) To evaluate potential for removal	N7_Shoreline_Structures	Wall Riprap/Revetment Jetty/Groin Berm	N/A (qualitative)	S7_Shoreline_Structures_Score	1-4	W7_Shoreline_Structures_Weight	2	D7_Shoreline_Structure_Distance
NW Fetch	Proxy for ice shoving. Distance wind blows over open water before reaching the MHHW point.	N8_NW_Fetch_Ice_Proxy_ft N8_NW_Fetch_Ice_Proxy_miles	0 to unbounded (infinity)	feet miles	S8_NW_Fetch_Ice_Proxy_Score	1-6	W8_NW_Fetch_Ice_Proxy_Weight	2	N/A
NE Fetch	Proxy for storm impacts	N9_NE_Fetch_Storm_Proxy_ft N9_ NE_Fetch_Storm_Proxy_miles	0 to unbounded (infinity)	feet miles	S9_NE_Fetch_Storm_Proxy_Score	1-6	W9_NE_Fetch_Storm_Proxy_Weight	2	N/A

Currents	Proxy for scour	N10_11_Current_Scour_Proxy	0 – 1.19	m/s	S10_Current_Edge_Impact_Score	1-6	W10_Current_Edge_Impact_Weight	1	N/A
					S11_CurrentSedimentImpact_Score	1-6	W11_CurrentSedimentImpact_Weigh	1	
Tidal Crossing	Proxy for high velocity flows	N12_TidalCrossingVelocity_prxy	Yes within 50 feet/Null	N/A (qualitative)	S12_Tidal_Crossing_Score	3 or 6	W12_Tidal_Crossing_Weight	1	N/A
Proximity to federal navigable channels	Proxy for boat wakes which is in turn a proxy for erosion	N13_Boat_Wakes_Erosion_Proxy	0 – 21,119	Feet (qualitative)	S13_BoatWakeErosionProxy_Score	1-6	W13_BoatWakeErosionProxy_Weight	2	Is itself a proximity attribute.
Soils erodibility	Measure of erosion calculated via the Universal Soils Loss Equation (USLE) based on raindrop impact and runoff potential of soil types	N14_Soils_Erodibility	0 – 0.64	N/A (this is a ratio)	S14_Soils_Erodibility_Score	1-6	W14_Soils_Erodibility_Weight	3	N/A
Bank slope	To identify steep banks (slope > 30 degrees)	N15_Steep_Bank_Slope	30 – 61	degrees	S15_Steep_Bank_Slope_Score	1 or 6	W15_Steep_Bank_Slope_Weight	4	D15_Steep_Bank_Distance
Beach Volumetric Change	Qualitative measure of whether a beach unit is eroding, accreting, or stable.	N16_Beach_Erosion	Accretion Erosion Potentially Stable	Meters/3 years	S16_Beach_Erosion_Score	1-6	W16_Beach_Erosion_Weight	1	N/A
Bathymetry	Seaward slope	N17_Seaward_Slope_Rise_Over_Run	0 – 11, 11293	Feet	S17_Seaward_Slope_Score	1-6	W17_Seaward_Slope_Weight	4	D17_SeawardSlope_Dist_toContou
		N17_Seaward_Slope_Degrees	0 – 90	Degrees					

		N17_Seaward_Slope_Radians	0 – 1.57	Radians					
		N17_Seaward_Slope_Contour_Used	0-ft contour from Atlantic Coast/HSE mosaic -1-ft contour Lippmann -2 -ft contour Lippmann 0-ft contour GRANIT Coastal LiDAR	N/A (qualitative)					
		N17_MHHW_Contour_Elevation	3.6—Bay; 4.2—River; 4.4—Ocean/Embayment	feet					
Adequacy of data	To indicate where the site suitability index might be lower than it should be because of insufficient data	N18_No_datasets_missing	1—10	Number of datasets	N/A	N/A	N/A	N/A	N/A
		N18_Precent_Weights_Missing	2.9 – 55.8	%					
		N18_Data_Quality	Adequate Data (2.9 – 32%) Minimal Data (32 – 55.8%)	N/A (qualitative)					
Suitability Index	To suggest the degree of site modification for a soft stabilization approach	N19_Suitability_Index	1.9 – 5.7 6= Highly suitable for living shorelines 5= Suitable for living shorelines 4= Suitable for living shoreline hybrid solutions 3= Suitable for living shoreline hybrid solutions 2= May be suitable for living shorelines with hybrid components and/or significant. site modification 1= May be suitable for living shorelines with more hybrid components and/or sig. site modification	N/A (this is a ratio)	N/A	N/A	N/A	N/A	N/A
Suitability Without Structures	To understand how other factors contribute to site suitability if shoreline structures were absent	N20_SuitabilityIndex_WO_Struct	2.6 – 5.7 6= Highly suitable for living shorelines 5= Suitable for living shorelines 4= Suitable for living shoreline hybrid solutions 3= Suitable for living shoreline hybrid solutions 2= May be suitable for living shorelines with hybrid components and/or significant. site modification 1= May be suitable for living shorelines with more hybrid components and/or sig. site modification	N/A (this is a ratio)	N/A	N/A	N/A	N/A	N/A

X. Sociopolitical feasibility attribute table

Table 12. Details of attributes produced by the sociopolitical feasibility assessment.

Attribute	Intention for using	Name	Range of Values	Units	Name of proximity attribute (Distance of MHHW points from feature)
Ecological Values	To acknowledge and take into consideration the ecological values that stakeholders assign to a site.	N1_Coastal_Conservation_Plan	Core Areas, Landscape Areas (more info here)	N/A	N/A
		N2_Wildlife_Action_Plan	Tier 1 = Habitats of Highest Relative Rank by Ecological Condition in New Hampshire Tier 2 = Habitats of Highest Relative Rank by Ecological Condition in Biological Region (more info here)		
		N3_Water_Resources_Flood	"WR: Flood" or Null (areas across the watershed with high flood storage capacities that reduce flood risks to downstream infrastructure, and natural areas that will accommodate sea level rise and salt marsh migration)		
		N4_Water_Resources_Public_wate	"WR: PWS" or Null (lands that safeguard surface and groundwater resources for human consumption)		
		N5_Water_Resources_Water_Qlty	"WR: WQ" or Null (riparian buffers that intercept stormwater runoff and at the same time maintain natural cover adjacent to surface waters, and riparian wetlands that are highly efficient at treating pollutants already in surface waters) More info here		
Suggested Living Shoreline Sites	To document sites where there is motivation for a living shoreline project.	N6_Suggested_Location_Name N7_Suggested_Location_Desc	Includes name and description of each site.	N/A	N/A
Shoreline Access Sites	public education potential, construction accessibility	N8_Access_Facility N9_Access_Site_Owner N10_Access_Type	Includes name and access type.	N/A	N/A since access sites were not precisely geo-located.
Eelgrass extent 1996	to represent regulatory concern about not impacting current and historic eelgrass beds.	N11_Proximity_to_1996Eelgrass	0 – 68,616	ft	Is itself a proximity attribute
Shellfish beds	to represent regulatory concern about not impacting shellfish beds.	N12_Proximity_To_Shellfish	0 – 26,723	ft	Is itself a proximity attribute

Aquaculture sites	to represent regulatory concern about not impacting aquaculture resources	N13_Proximity_To_Aquaculture_Site N14_Aquaculture_Site_Name N15_ Aquaculture_Species	53 – 49,121	ft	Is itself a proximity attribute
Trails	To anticipate demand for stabilization	N16_Trail_Name N17_Trail_Property_Name	Includes names of trails.	N/A	D14_Distance_to_trail
Conservation/Public Lands	To represent level of motivation/capacity/interest for living shoreline projects	N18_ConsPub_Land_Name N19_ConsPub_Primary_Type N20_ConsPub_Protection_Term N21_ConsPub_Agency_Type N22_ConsPub_Program N23_ConsPub_Management_Status	For more information, refer metadata for this dataset here. Attributes for this data set are provided in 'Cons_Document.doc'. In addition, please also see 'AttributeCodes.xls' for a listing of codes for fields with defined domains. These documents are available as part of the dataset download.	N/A	N/A since boundaries were not precisely geo-located.
Impervious cover	To represent demand for stabilization and to understand project vulnerability.	N24_Distance_to_Impervious	-1 (no impervious surface within a 100 ft) to 100	ft	N/A
Buildout Scenarios for Impervious Cover under “Linear” development scenario by 2050	To represent demand for stabilization	N25_Percent_development_by_2050	0 – 97 (shows projected percentage of development by 2050 within 10000 sq feet.)	%	N/A
Biophysical Suitability Index	To provide information about biophysical conditions.	N26_Biophysical_Suitability_Index	1.9 – 5.7	N/A	N/A
		N27_Biophysical_Suitability_Index_WO_Struct	2.6 – 5.7		
Sea Level Rise 2050 High Emissions Scenario (2 feet)	To assess vulnerability of development to sea level rise.	Inundation_development_2ft_SLR	Inundated or Null	N/A	N/A

XI. Sample living shoreline suitability property profile

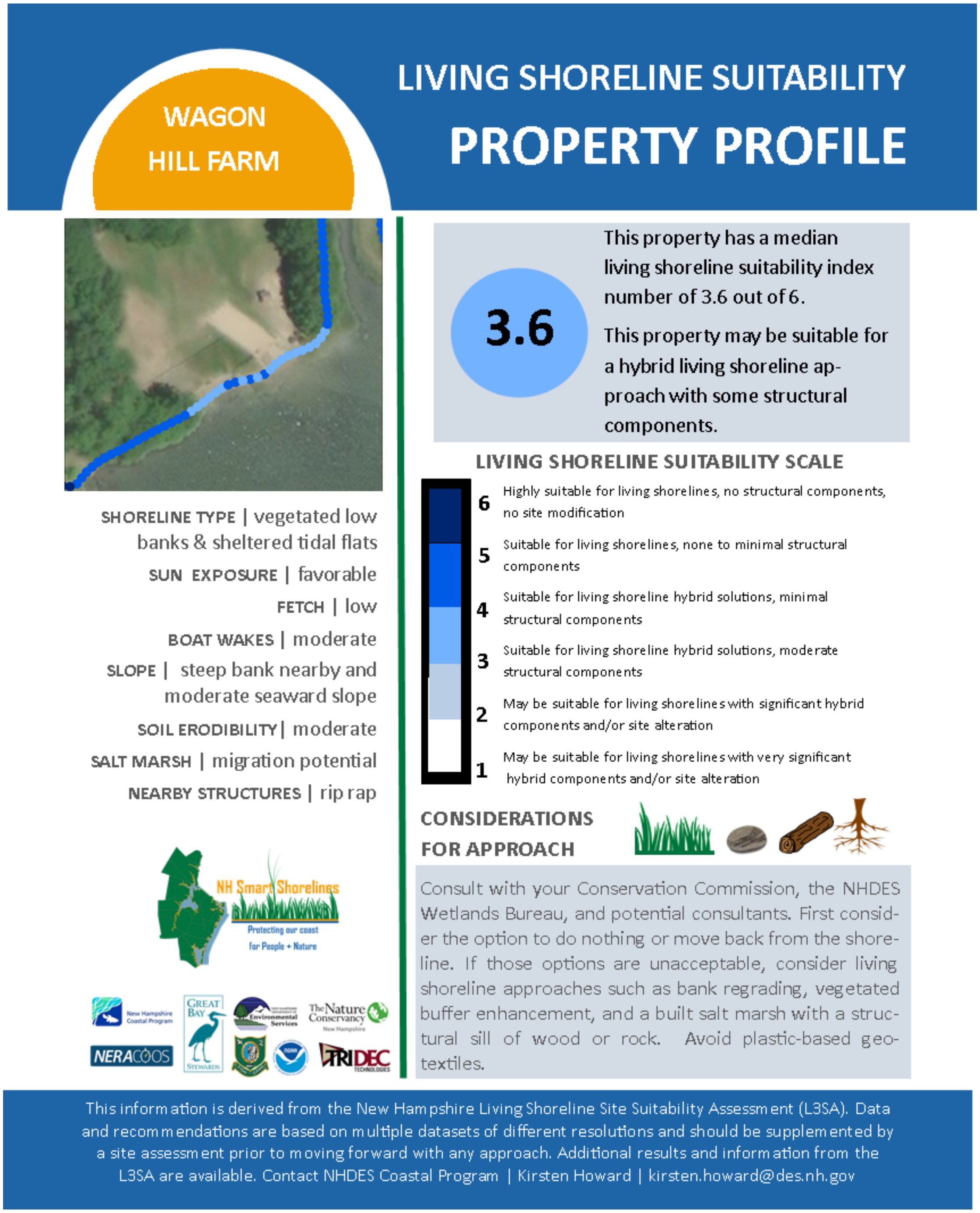

Figure 9. Sample property profile for Wagon Hill Farm, Durham, NH.

To get a tailored property profile for your site, contact:

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