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**Expanding the use of natural and nature-based infrastructure to enhance coastal resiliency: Forecast and hind-cast load reductions from Living shoreline BMPs : Project Report (Year 2 of 3)**

Marcia Berman  
*Virginia Institute of Marine Science*

Pamela Mason  
*Virginia Institute of Marine Science*

Tamia Rudnicki  
*Virginia Institute of Marine Science*

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## Expanding the use of natural and nature-based infrastructure to enhance coastal resiliency

A report to the Virginia Coastal Zone Management Program, Department of Environmental Quality and NOAA

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Prepared by: Center for Coastal Resources Management

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January 2020

Expanding the use of natural and nature-based  
infrastructure to enhance coastal resiliency:  
Forecast and hind-cast load reductions from Living  
Shoreline BMPs  
Project Report (Year 2 of 3)

Submitted to the Virginia Coastal Zone Management Program,  
Department of Environmental Quality

Marcia Berman, Pamela Mason, Tamia Rudnicki  
Center for Coastal Resources Management  
Virginia Institute of Marine Science  
William and Mary  
Gloucester Point, Virginia 23061

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## Introduction

The vulnerability of coastal communities and the growing risks to coastal infrastructure continue largely due to past and ongoing patterns of development in high risk areas. This project is focused on increasing the use of natural and nature-based features (NNBFs) to increase resilience of coastal communities to flooding caused by extreme weather events. This project has proposed two efforts to increase understanding of NNBFs; 1) describe the current status, and 2) quantify role of NNBF creation/ restoration for water quality benefits in support of coastal resilience. The products of the 3-year project are intended to support informed coastal management decision-making regarding two concerns associated with NNBFs:

- The natural capital of coastal communities is generally declining, and is projected to decline at an accelerating rate due to sea level rise and current land use practices.
- The use of NNBFs to sustain or increase resilience in coastal communities is restricted by the many competing needs for limited local resources.

In year one, the project addressed the potential loss of natural capital by identifying site suitability for natural capital as coastal protection. Specifically, year one enhanced the capabilities of the Shoreline Management Model (SMM) developed by the Center for Coastal Resources Management (CCRM) at the Virginia Institute of Marine Science (VIMS). These improvements incorporated shorelines which were hardened into the predictive model and streamlined the output to a more user friendly classification. The more robust model (v5.0) was applied to the entire coastal zone of Virginia and used to identify 1) where creation of new natural capital can offer protection to vulnerable shorelines and 2) where existing natural capital currently provides sufficient protection, and may be lost if traditional shoreline protection structures are put in place. The model results were posted to the CCRM Comprehensive Coastal Resource Management Portals (<https://www.vims.edu/ccrm/ccrmp/index.php>) and to ADAPTVA (<http://www.adaptva.org/index.html>).

The focus of this year has been to address the value of nature based features from the perspective of the co-benefits they provide. Specifically, the project is focused on how the creation of nature-based features such as living shorelines garner nutrient reduction credits that can be applied to assist local governments in meeting their TMDL nutrient reduction requirements. The analysis applies the Chesapeake Bay Program (CBP) approved process for crediting nature based solutions to areas where such treatment options could be incorporated into efforts focused on coastal resilience and shoreline protection. The Shoreline Management Model was modified again to enable and support the analysis proposed for the second year of this project. The latest version (v.5.1) was used to assess where living shorelines are appropriate along natural/unmanaged shoreline or previously hardened shorelines and where, if implemented according to the model output, would meet the CBP criteria for TMDL credits.

While communities continue to gain insight into the general understanding of actions that can lower risks and increase resilience, financial and people resources required to undertake those

actions are limited. In the face of competing interests, one solution to accelerating the pace of building resilience is to find ways to address multiple needs with each action. Therefore, the co-benefits of building resilience through nature-based features offer an opportunity for communities to acquire nutrient reduction benefits from carefully planned projects.

## Approach

The SMM (V5.1) delineates where living shoreline treatments are suitable erosion control methods based on current shoreline conditions, as well as where more traditional erosion control structures would work best (i.e. navigationally limited areas where living shorelines are not feasible). The SMM uses decision tree logic for arriving at a recommended shoreline management approach. These decision trees depict logic pathways that reflect the scientific literature and best professional judgement with regards to shoreline management options, and have been heavily vetted over many years of on the ground site reviews in the field. More information on the development of the model is available (Berman et al., 2018) and diagrams are included in Appendix 1.

This model has been run for nearly all of the coastal zone of Virginia. The model identifies different classes of living shoreline, or traditional alternatives that should provide protection along both natural (no erosion control adaptations in place) and modified shorelines (e.g. those existing structures such as bulkheads or revetments). A glossary and description of these classes is found in Appendix 2.

This project focused on the potential for the past and future implementation of nature and natural-based features, and specifically on the use of tidal vegetated marsh for erosion protection and the co-benefit of water quality improvement. Using vegetated marsh alone, or in combination with a channelward protective structure, are approaches that meet Commonwealth’s definition of living shorelines which are codified as the preferred practice for erosion control. In the SMM output, marsh creation is included in two of the shoreline best management practices; “non-structural living shorelines” or “plant marsh with sill” (Table 1).

**Table 1 List of classes for on the ground best practices in SMM v5.1. \* denotes classes that meet criteria for load reduction credits**

| <b>Shoreline Best Management Practices (V5.1)</b>            |
|--|
|  |
| Non-structural living shoreline*                             |
| Plant marsh with sill*                                       |
| Maintain beach or offshore breakwater with beach nourishment |
| Groin field with beach nourishment                           |
| Revetment  |
| Revetment/Bulkhead Toe Revetment                             |

The Chesapeake Bay Program (CBP) uses loading estimates to quantify expected amounts of nutrients (nitrogen and phosphorus) or sediment loads to water from specific land uses or point sources and makes adjustments based on an estimate of the effectiveness of a best management practice (BMP). BMP Expert Panels are convened to develop the BMP effectiveness estimates and the Water Quality Goal Implementation Team (WQGIT) is responsible for approving the loading rate reductions, and percentage adjustments to these rates, used in the Chesapeake Bay Watershed Model (CBWM). The CBP empaneled a group of shoreline science and management experts to provide a recommendation on nutrient and sediment load reduction efficiencies provided by shoreline management practices. The expert panel process has been codified by the CBP to include generation of a recommendation report and subsequent review, and approval, by the pertinent workgroups and Teams. The panel provided a recommendation based on a scientific literature review and best professional judgement.

Four different protocols are defined for shoreline BMPS:

Protocol 1, “Prevented Sediment” provides an annual mass sediment reduction credit for qualifying shoreline management practices that prevent tidal shoreline erosion that would otherwise be delivered to nearshore/downstream waters. The pollutant loads are reduced for sand content and bank instability (based on the state’s assessment).

Protocol 2, “Credit for Denitrification” provides an annual mass nitrogen reduction credit for qualifying shoreline management practices that include vegetation.

Protocol 3, “Credit for Sedimentation” protocol provides an annual mass sediment and phosphorus reduction credit for qualifying shoreline management practices that include vegetation.

Protocol 4 “Credit for Marsh Redfield Ratio” provides one-time nutrient reduction credit for qualifying shoreline management practices that include vegetation.

A “Default Rate” provides an annual mass sediment and nutrient reduction credit for qualifying shoreline management practices.

Accounting for load reductions for Protocol 1 based on a GIS model is problematic as it would require detailed and precise bank elevation data and mean value for annual shoreline retreat. This data is not currently available. As such, protocol 1 load reductions are identified as site specific and are currently determined on a project by project basis. However, for calculating load reductions for existing and non-conforming practices, the approved BMP assigns values to nitrogen, phosphorus and sediment reductions based on linear feet. (CBP, 2017). Pollution load reductions under protocols 2 and 3 are credited annually. Recommendations call for a review to verify the BMP is still functioning as intended. Pollution load reductions under protocol 4 are a one-time nutrient reduction credit for practices that include vegetation.

Table 2 shows the approved CBP protocols for nitrogen, phosphorous and sediment reductions of shoreline management BMPs. Nutrient load reduction benefits were attributed to those potential living shoreline sites that included vegetative practices - the creation of marsh.

**Table 2. Summary of CBP protocols for nitrogen, phosphorus and sediment reductions of shoreline management BMPs**

| <b>Protocol</b>                        | <b>Submitted Unit</b>  | <b>Total Nitrogen<br/>(lbs per unit)</b> | <b>Total Phosphorus<br/>(lbs per unit)</b> | <b>Total Suspended Sediment<br/>(lbs per unit)</b> |
|--|------------------------|--|--|--|
| Prevented Sediment                     | Linear Feet            | Project-Specific*                        | Project-Specific*                          | Project-Specific                                   |
| Denitrification                        | Acres of re-vegetation | 85                                       | NA   | NA   |
| Sedimentation                          | Acres of re-vegetation | NA                                       | 5.289                                      | 6,959  |
| Redfield Ratio                         | Acres of re-vegetation | 6.83                                     | 0.3  | NA   |
| Non-conforming/<br>Existing Practices* | Linear Feet            | MD= 0.04756<br>VA = 0.01218              | MD= 0.03362<br>VA = 0.00861                | MD= 164<br>VA = 42                                 |

The geospatial analysis uses the ESRI® software ArcMAP for computation and output. The model’s output of location and extent of shoreline management recommendations is geospatially represented as a line along the shoreline. We selected the recommendations for non-structural living shoreline and plant marsh with sill only and converted that shoreline to a polygon by multiplying the alongshore dimension by a constant marsh width of eight (8) feet. With a greater than 50% reduction in wave energy and height (Knutsen et. al., 1982), this width is consistent with the minimal recommended width for marsh creation for erosion abatement. It is also specified as the minimum vegetated marsh area to qualify for the Virginia [Living Shoreline Group 2 General Permit](#) for “Certain Living Shoreline Treatments Involving Submerged Lands, Tidal Wetlands Or Coastal Primary Sand Dunes And Beaches”. The modeled marsh width is considered to be a minimum recommended width for erosion control, but creation of marshes with greater areal extent would qualify for great load reductions accordingly. The newly computed areas (or polygons in ArcMap) represent the location and minimal amount of vegetation which may be created along that shoreline to reduce erosion.

The analysis was run on shoreline currently unmanaged (i.e. no shoreline armoring present) and shorelines currently defended with structures such as bulkheads and revetments. The analysis excluded shorelines where marsh grass was already present as the criteria considers credit only for new marsh creation. However, it is possible to create additional marsh, which can qualify for load reduction credits if the qualifying criteria are met.

The approach applied in this project is to calculate the CBP approved nutrient load reductions

for nitrogen, phosphorous and sediment (Table 2) for potential created marsh areas generated through the spatial analysis. The analysis is for two time frames:

- forecasting – looking forward to all possible shoreline where the SMM assigns living shoreline suitability;
- back-casting – for all shoreline hardened between 2009 and 2018 where the CCRM permit database identified the suitability for a living shoreline.

Each potential living shoreline treatment option that includes vegetation is assessed to quantify its added value potential as a TMDL credit to satisfy pollution reduction requirements that must be met by the CBP signatories. The potential credits were calculated for each Tidewater locality and for 8-digit HUC units.

## Results

### Computing Future Nutrient Reduction Credits from Potential NNBF BMPs

We computed the location and amount of qualifying living shoreline BMPs appropriate for erosion control along the shoreline for each locality. The potential load reduction credits to be achieved if all these BMPs are to be implemented and credited was also calculated. For shorelines currently unmanaged, more than 760 acres of tidal marsh could potentially be created for erosion abatement across all tidewater localities analyzed (Note: King and Queen and King William counties had no data available for the analysis). Combining all potential nutrient reduction credits analyzed across all localities, Virginia's Tidewater communities could reduce the nitrogen load reduction requirement by 69,907 pounds of nitrogen. An additional 278 acres of marsh could be created along shorelines that have already been defended. This would add an additional 25,499 pounds of nitrogen as credit for a total of 95,406. Across Tidewater the credits applied for phosphorous reductions would equal 4,255 pounds with an additional 1,552 pounds (total = 5,8070 for hardened shorelines that convert to NNBF).

The total reduction goals for Virginia for nitrogen and phosphorus (2009 loads – 2025 targets) are about 15.5 and 2.3 million pounds, respectively. Implementation of living shorelines would provide a contribution to the total goals of approximately 0.65 and 0.26 percent respectively. However, it would be most relevant to consider the potential percentage of load reduction relative to the Agriculture and Urban sectors, considering that Wastewater, Forest and Non-tidal water and Reserve sectors are not targets for living shorelines as a BMP practice. The load reductions for those sectors are 8.6 and 2 million pounds with percent reduction from LS of 1.1 and 0.29, respectively.

The load reduction calculations for living shoreline implementation are conservative. Not all of the Virginia localities have been mapped with a SMM recommendation (specifically King and Queen, King William) and certain shoreline settings do not have a shoreline management approach recommendation. Some highly developed, high physical risk or special resource



landscapes such as: marinas and canals, infrastructure within 50 feet of the shoreline, along small spit features and in the vicinity of SAV, are excluded from provision of a specific recommendation even though a living shoreline may be feasible in some of these areas. The modeled living shorelines have the minimum 8-foot width called for in the Group 2 general permit, but for best performance and in practice, most are much wider. Finally, we did not include breakwaters which commonly include some vegetated area within the project.

The values computed for each locality represent the potential nutrient reduction credits available if vegetative alternatives are put in place everywhere possible. The actual credits will need to be evaluated on a project by project basis. Appendix 3 reports the rates for each locality (A = Currently Unmanaged Shoreline; B = Currently Defended Shoreline). Considering the benefit of vegetated BMP practices to TMDL credits per hydrologic unit, Appendix 3C and 3D also report data for the fifteen (15) different 8-digit hydrologic units within the coastal zone of Virginia.

A cautionary note comes from the CBP expert panel report regarding the forecasting of load reduction credits attributable to all shoreline identified as suitable for vegetated practices. The load reduction values may provide a perverse incentive for shoreline management along shorelines where erosion protection is not warranted. A perverse incentive is an incentive that has an unintended and undesirable result which is contrary to the intentions of its designers. Perverse incentives are a type of negative unintended consequence. From an ecosystem perspective, shoreline management even in the form of preferred natural and nature-based practices, still result in environmental consequences, most notably the prevention of sediment inputs into the waterways. While sediment prevention is an intended consequence from a water quality perspective, the loss of available material necessary for wetland and beach resilience can adversely impact the provision of erosion abatement, flood risk reduction and habitat services. The panel addressed this concern by including a set of qualifying conditions. The qualifying conditions establish living shoreline (nonstructural, hybrid marsh with sill, hybrid beach/dune with breakwater) as the first option when the site is experiencing erosion. The second option is for a revetment or breakwater where a living shoreline is not feasible, and finally bulkhead or seawall where certain land use limitations necessitate the approach (CBP 2017). Nevertheless, given the concern for erosion and the current rate at which erosion control practices are applied for (660/ year), the projection of water quality benefits from vegetated practices provides rationale for their implementation as a preferred practice.

### Computing Potential Nutrient Reduction Credits Lost Due to Past Shoreline BMP Decisions

This study also analyzed credits which may have been available to local governments had NNBFs been installed instead of traditional erosion abatement structures. In order to backcast the potential load reductions for existing and non-conforming shoreline practices, permits applications for the years 2009-2018 were reviewed for all the coastal localities in Virginia (CCRM 2019). As the CBP model has already accounted for landuse and BMPs activities up through 2008, we selected those actions that could have received load reduction credits

starting in 2009 to presently available data. The analysis called for an extraction of all sites where a traditional bulkhead or revetment was permitted but a non-structural living shoreline or a hybrid marsh planting with sill was recommended through the SMM. The total linear footage of shoreline along which marsh creation was possible was estimated by the project lengths reported in the permit application (n=306,234 linear feet of shoreline). Table 3 reports the values by locality.

Using the same method above to estimate the amount of marsh that could have been created at each site, the project length was multiplied by a minimal marsh width of 8 feet to calculate the area of possible marsh creation along the shoreline (n=56.24 acres of marsh).

Since the Chesapeake Bay Program's guidance does allow for credits for existing and non-conforming practices such as bulkheads and revetments, the load reduction values for these conventional shoreline practices were calculated using the approved removal rates for these practices. We also calculated the potential load reductions if the projects had been living shorelines. For the Protocol 1 calculation for the living shorelines backcasting, we used the same sediment removal rate as for the non-conforming/ existing and the approved removal rates of 0.00029 pounds of total nitrogen per pound of total suspended solids and 0.000205 pounds of total phosphorus per pound of total suspended solids. Table 4 shows the totals for all conventional hardening approaches with both the "approved" rates for non-conforming/ existing practices and the possible rates if those practices had been living shorelines as identified in the SMM. This is the load reduction the locality lost because NNBFs were not used where appropriate for erosion control abatement, and the number of sites where this occurred. Using the load reduction numbers from Table 1, we projected the potential amount of nutrient reduction credits available to the locality had the preferred NNBF management practice been installed. The importance of this figure is to re-emphasize the co-benefits and value of encouraging the use of NNBFs for erosion control.

Furthermore, while much of tidal shore permitting decisions are made at the local level, the implications for water quality benefits are not necessarily well communicated to decision making boards. Year three of this project plan includes communication to these local units to help build awareness of the co-benefits of NNBFs.

**Table 3. Linear feet of conventional structures permitted along shoreline suitable for vegetated practices (Non-structural living shoreline and Plant marsh with sill)**

| <b>Locality</b>         | <b>LF Approved</b> |
|-------------------------|--------------------|
| <i>Accomack</i>         | <i>12533</i>       |
| <i>Charles City</i>     | <i>897</i>         |
| <i>Chesapeake</i>       | <i>6483</i>        |
| <i>Chesterfield</i>     | <i>500</i>         |
| <i>Colonial Heights</i> | <i>26</i>          |
| <i>Essex</i>            | <i>3225</i>        |
| <i>Fairfax</i>          | <i>357</i>         |
| <i>Gloucester</i>       | <i>15244</i>       |
| <i>Hampton</i>          | <i>6607</i>        |
| <i>Henrico</i>          | <i>168</i>         |
| <i>Hopewell</i>         | <i>165</i>         |
| <i>Isle of Wight</i>    | <i>1906</i>        |
| <i>James City</i>       | <i>2617</i>        |
| <i>King George</i>      | <i>1490</i>        |
| <i>Lancaster</i>        | <i>31212</i>       |
| <i>Mathews</i>          | <i>13525</i>       |
| <i>Middlesex</i>        | <i>23093</i>       |
| <i>New Kent</i>         | <i>2540</i>        |
| <i>Newport News</i>     | <i>1082</i>        |
| <i>Norfolk</i>          | <i>19885</i>       |
| <i>Northampton</i>      | <i>2537</i>        |
| <i>Northumberland</i>   | <i>64893</i>       |
| <i>Poquoson</i>         | <i>2813</i>        |
| <i>Portsmouth</i>       | <i>4101</i>        |
| <i>Prince George</i>    | <i>251</i>         |
| <i>Richmond County</i>  | <i>1524</i>        |
| <i>Spotsylvania</i>     | <i>325</i>         |
| <i>Stafford</i>         | <i>729</i>         |
| <i>Suffolk</i>          | <i>4159</i>        |
| <i>Virginia Beach</i>   | <i>55124</i>       |
| <i>Westmoreland</i>     | <i>16332</i>       |
| <i>York</i>             | <i>9891</i>        |
| <b>Total</b>            | <b>306234</b>      |

| <b>Protocol</b>                           | <b>Unit of measure</b> | <b>Total N<br/>Removal (lbs)</b> | <b>Total P<br/>Removal (lbs)</b> | <b>Total SS<br/>Removal (lbs)</b> |
|---|------------------------|----------------------------------|----------------------------------|-----------------------------------|
| <b>1. Prevented Sediment</b>              | 306,234 linear feet    | 373                              | 2637                             | 12,861,828                        |
| <b>2. Denitrification</b>                 | 56.24 acres            | 4,780                            | NA                               | NA                                |
| <b>3. Sedimentation</b>                   | 56.24 acres            | NA                               | 297                              | 391,374                           |
| <b>4. Marsh Redfield Ratio</b>            | 56.24 acres            | 384                              | 17                               | NA                                |
| <b>TOTAL Nutrient Credits</b>             |                        | 5,537                            | 2,951                            | 391,374                           |
| <b>Non-conforming /Existing Practices</b> | 306,234 linear feet    | 3,729                            | 2637                             | 12,861,828                        |
| <b>Difference</b>                         |                        | <b>1,808</b>                     | <b>314</b>                       | <b>391,374</b>                    |

**Table 4. Potential nutrient reduction credit lost from permitted activities 2009-2018**

## Summary

The implementation of shoreline BMPs can result in significant nutrient and sediment load reduction and in support of Virginia's efforts to achieve the pollutant reductions required by the Bay Total Maximum Daily Load (TMDL). Where property owners are seeking to manage their shoreline to reduce or prevent erosion, they have a range of management options including living shorelines and conventional hardening. Virginia has established public policy to identify living shoreline as the preferred practice and the CBP has approved a pollution load reduction rate for shoreline management practices. While all shoreline management practices may be eligible for load reduction credits, the CBP BMP requires that an eligible site be experiencing current erosions, and use a natural or nature-based vegetative practice unless demonstrated to be infeasible. The BMP load reduction rates for conventional practices are smaller than living shoreline practices because they lack the additional load reduction attributed to the creation of marsh. As such, the co-benefit of water quality improvement, and opportunity for credits, provides additional rationale for the preference of NNBF shoreline management approaches over conventional hardening techniques.

Our analysis shows that future implementation of living shorelines at all suitable locations would result in 1,070 miles of living shoreline and the creation of 1,038 acres of tidal marsh. This area of marsh creation could, at least for some time into the future, improve the sustainability of tidal vegetated wetlands in the face of loss to rising seas. The load reductions anticipated from future marsh creation would be about 100,000 pounds nitrogen, 5800 pounds phosphorus annually, plus additional nutrient and sediment load reductions to be calculated on a project-specific basis. Additionally, back-casting the application of living shorelines to suitable locations where conventional hardening was used during the years

2009-2018 found 58 miles of eligible shoreline that would have minimally created 56.3 acres of tidal marsh. This would have also resulted in potential annual reduction of almost 2000 pounds of nitrogen, about 300 pounds of phosphorus and almost 400,000 pounds of sediment.

## References

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**APPENDIX 1. Shoreline Management Model (v5.1) Flow Diagrams**

SMM Flow Diagram for Undefined Shoreline

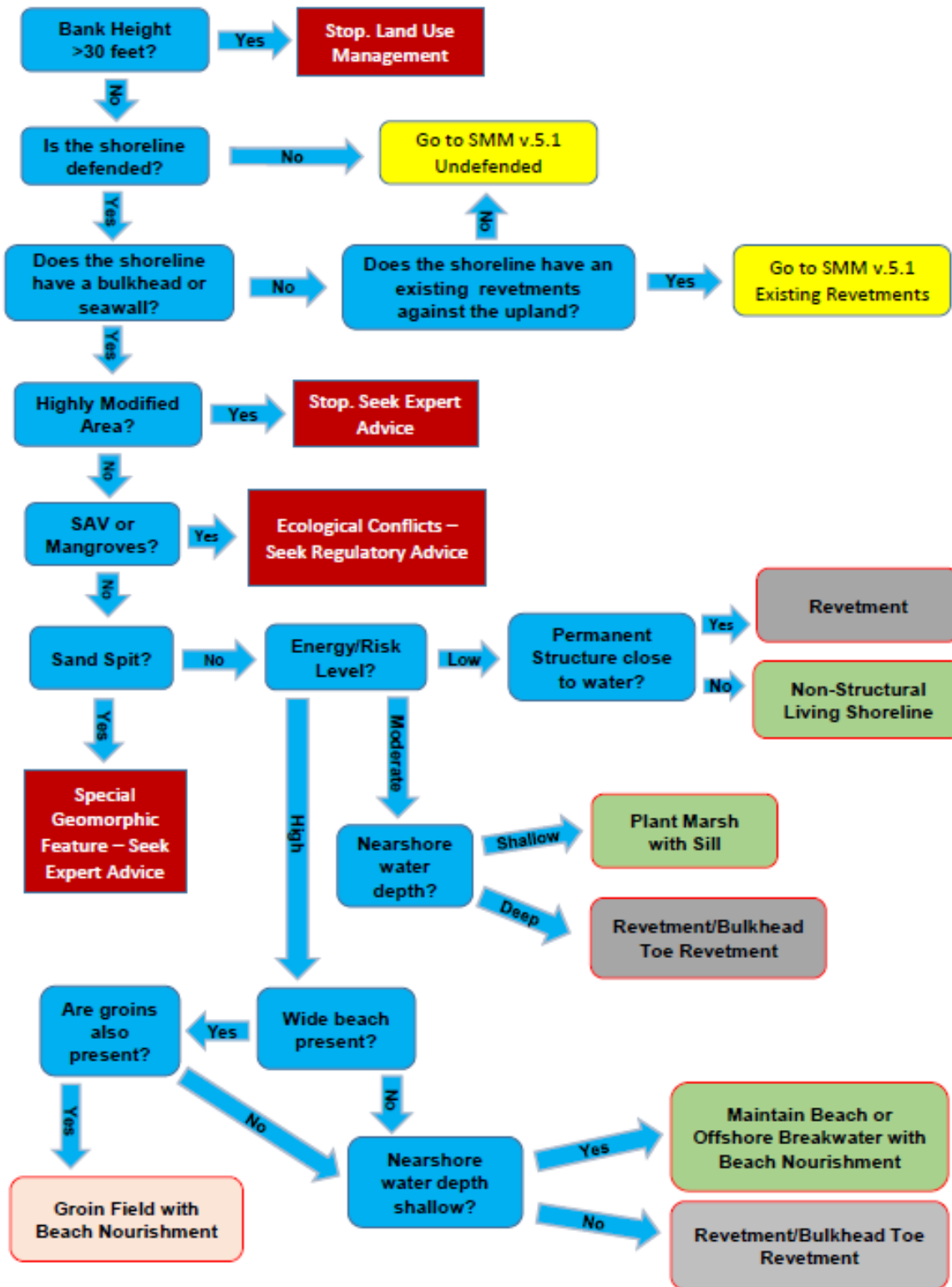
SMM Flow Diagram for Shoreline with existing Bulkheads

SMM Flow Diagram for Shoreline with existing Revetments

# Shoreline Management Model version 5.1 for Undefined Shoreline



# Shoreline Management Model version 5.1 for Shoreline with Existing Bulkheads





# Shoreline Management Model version 5.1 for Shoreline with Existing Revetments



**Appendix 2. Shoreline Management Model (V5.1)**  
Treatment Classes and Glossary

## **Shoreline Management Model version 5.1 - Preferred Shoreline Best Management Practices Glossary**

**Groin Field with Beach Nourishment:** Maintain existing wide beach between groins. Remove unnecessary structures at the backshore (e.g. bulkheads) and stabilize the bank with grading and riparian plants. Repair/replace existing groins, add beach nourishment and plant beach vegetation.

**Maintain Beach or Offshore Breakwater with Beach Nourishment:** If shoreline exceeds 200 feet in length, remove existing shoreline structure, add beach nourishment sand, consider offshore breakwaters or another type of wave attenuation device with beach nourishment; consider adding plantings to the nourished areas. When the shoreline length is less than 200 feet an offshore breakwater may not be practical. In this case, remove failed shoreline structures and repair or construct a revetment as far landward as possible. Consider shoreline enhancement such as creation of vegetated wetlands and/or riparian buffer and/or sandy beach/dune above and immediately channelward of the structure.

**Non-Structural Living Shoreline:** Remove existing shoreline structure if present; grade bank if necessary and install a non-structural living shoreline which may include riparian buffer planting along the bank, and/or marsh plants, coir logs, or oyster reefs along the shoreline. Best choice for low energy environments.

**Plant Marsh with Sill:** In moderate energy environments a sill may be required to establish a living shoreline. Remove any existing shoreline structure if present and grade the bank if possible. Stabilize bank with riparian vegetation and plant a marsh with a sill. If the bank cannot be graded, repair existing shoreline structure with a minimal footprint and consider incorporating a marsh with a sill or some other shoreline enhancement (e.g. oyster castles).

**Revetment:** Remove existing failing or failed shoreline structure, if present. Construct new revetment as far landward as possible; grade the bank and plant vegetation buffers where possible. If grading is not possible, construct or repair existing revetment in the same alignment. A bulkhead should be considered only if previously present and the site is limited by navigation. Consider shoreline enhancement such as creation of vegetated wetlands and/or riparian buffer and/or sandy beach/dune above and immediately channelward of the structure. In high energy settings where shoreline extends more than 200 feet see option for **Offshore Breakwater with Beach Nourishment**.

**Revetment/Bulkhead Toe Revetment:** If grading is possible, remove the failed bulkhead and replace with a revetment landward of the current bulkhead. When grading not possible, (re)construct bulkhead in the same alignment and/or add a toe revetment. Consider a shoreline enhancement project such as creation of vegetated wetlands and/or riparian buffer and/or sandy beach/dune above and immediately channelward of the structure.

## Special Considerations

**Ecological Conflicts:** Management options for this shoreline may be limited by the presence of Submerged Aquatic Vegetation (SAV) or Mangroves (Florida and Gulf coast shorelines). For Virginia shorelines, seek advice from the Virginia Marine Resources Commission Habitat Management Division <http://www.mrc.virginia.gov/>. If you live in another state, seek advice from your local marine regulatory agency.

**Highly Modified Area:** Management options for this shoreline may be limited due to the presence of highly developed upland (e.g. commercial wharfs) or infrastructure directly adjacent to the shoreline (e.g. road) and will depend on the need for and limitations posed by navigation access and erosion control. Seek expert advice on the design of your project.

**Land Use Management:** Shorelines with tall banks greater than 30 feet limit possible solutions to address bank erosion. Forces other than tidal erosion, such as over-land runoff, upland development, and vegetation management are likely also having effect on bank conditions. Assessment of all factors and modifications to address causes for bank erosion are recommended. This may include changes to vegetation management, implementation of projects to address storm water, relocating buildings, utilities, and other infrastructure. All new construction should be located 100 feet or more from the top of bank. Actions may also include requesting zoning variances for relief from setback and other land use requirements or restrictions that may increase erosion risk. Seek expert advice to inform management options.

**No Action Needed:** No specific management actions are suitable for shoreline protection, e.g. boat ramps, undeveloped marsh, and barrier islands.

**Special Geomorphic Feature:** Maintain the natural condition of this shoreline to allow for unimpeded sediment movement and the corresponding response of wetlands, beach and/or dune. If primary structures are present and threatened, seek expert advice on the design of your project.

**Appendix 3. Potential Nutrient Reduction Loads from Living Shorelines  
Along Unmanaged and Defended Shorelines**

A. Estimated load reduction credits for created marsh along unmanaged shoreline by county

| Unmanaged Shoreline with Potential Living Shoreline BMP (SMM v.5.1)* - Estimated Nutrient Load Reduction: County Analysis |                 |                             |                           |                                |                                  |                        |  |  |
|---|-----------------|-----------------------------|---------------------------|--------------------------------|----------------------------------|------------------------|--|--|
| County/City   | Estimated Acres | Protocol 2: Denitrification | Protocol 3: Sedimentation |                                | Protocol 4: Marsh Redfield Ratio |                        | Sum of Total Nitrogen (lbs) <sup>1</sup> | Sum of Total Phosphorus (lbs) <sup>2</sup> |
|   |                 | Total Nitrogen (lbs)        | Total Phosphorus (lbs)    | Total Suspended Sediment (lbs) | Total Nitrogen (lbs)             | Total Phosphorus (lbs) |  |  |
| Accomack  | 31.049          | 2639.131                    | 164.216                   | 216067.167                     | 212.062                          | 9.315                  | 2851.192                                 | 173.531                                    |
| Alexandria  | 0.156           | 13.291                      | 0.827                     | 1088.158                       | 1.068                            | 0.047                  | 14.359                                   | 0.874                                      |
| Arlington   | 0.525           | 44.604                      | 2.775                     | 3651.785                       | 3.584                            | 0.157                  | 48.188                                   | 2.933                                      |
| Caroline  | 5.881           | 499.909                     | 31.106                    | 40927.812                      | 40.169                           | 1.764                  | 540.078                                  | 32.870                                     |
| Charles City  | 9.837           | 836.116                     | 52.026                    | 68453.297                      | 67.184                           | 2.951                  | 903.300                                  | 54.977                                     |
| Chesapeake  | 17.984          | 1528.630                    | 95.117                    | 125149.826                     | 122.830                          | 5.395                  | 1651.460                                 | 100.512                                    |
| Chesterfield  | 13.718          | 1165.993                    | 72.552                    | 95460.573                      | 93.691                           | 4.115                  | 1259.685                                 | 76.668                                     |
| City of Hopewell  | 3.087           | 262.366                     | 16.325                    | 21480.044                      | 21.082                           | 0.926                  | 283.448                                  | 17.251                                     |
| Colonial Heights  | 2.786           | 236.787                     | 14.734                    | 19385.875                      | 19.027                           | 0.836                  | 255.813                                  | 15.569                                     |
| Essex   | 16.017          | 1361.452                    | 84.714                    | 111462.863                     | 109.397                          | 4.805                  | 1470.849                                 | 89.519                                     |
| Fairfax   | 3.756           | 319.221                     | 19.863                    | 26134.805                      | 25.650                           | 1.127                  | 344.871                                  | 20.990                                     |
| Fredericksburg  | 2.485           | 211.231                     | 13.144                    | 17293.597                      | 16.973                           | 0.746                  | 228.204                                  | 13.889                                     |
| Gloucester  | 27.077          | 2301.580                    | 143.212                   | 188431.715                     | 184.939                          | 8.123                  | 2486.519                                 | 151.336                                    |
| Hampton   | 9.038           | 768.242                     | 47.803                    | 62896.435                      | 61.731                           | 2.711                  | 829.973                                  | 50.514                                     |
| Hanover   | 0.821           | 69.822                      | 4.345                     | 5716.343                       | 5.610                            | 0.246                  | 75.432                                   | 4.591                                      |
| Henrico   | 5.758           | 489.393                     | 30.452                    | 40066.867                      | 39.324                           | 1.727                  | 528.717                                  | 32.179                                     |
| Isle of Wight   | 14.253          | 1211.532                    | 75.386                    | 99188.865                      | 97.350                           | 4.276                  | 1308.883                                 | 79.662                                     |
| James City  | 16.176          | 1374.920                    | 85.552                    | 112565.545                     | 110.479                          | 4.853                  | 1485.399                                 | 90.405                                     |
| King George   | 21.878          | 1859.645                    | 115.714                   | 152250.218                     | 149.428                          | 6.563                  | 2009.073                                 | 122.277                                    |
| Lancaster   | 83.078          | 7061.643                    | 439.400                   | 578140.883                     | 567.424                          | 24.923                 | 7629.067                                 | 464.324                                    |
| Mathews   | 30.904          | 2626.840                    | 163.451                   | 215060.931                     | 211.074                          | 9.271                  | 2837.914                                 | 172.722                                    |
| Middlesex   | 44.508          | 3783.180                    | 235.403                   | 309731.166                     | 303.990                          | 13.352                 | 4087.170                                 | 248.755                                    |
| New Kent  | 5.701           | 484.598                     | 30.153                    | 39674.287                      | 38.939                           | 1.710                  | 523.536                                  | 31.864                                     |
| Newport News  | 7.799           | 662.884                     | 41.247                    | 54270.737                      | 53.265                           | 2.340                  | 716.149                                  | 43.587                                     |
| Norfolk   | 9.223           | 783.943                     | 48.780                    | 64181.842                      | 62.992                           | 2.767                  | 846.935                                  | 51.547                                     |
| Northampton   | 28.132          | 2391.222                    | 148.790                   | 195770.774                     | 192.142                          | 8.440                  | 2583.364                                 | 157.230                                    |
| Northumberland  | 155.057         | 13179.822                   | 820.095                   | 1079039.795                    | 1059.037                         | 46.517                 | 14238.860                                | 866.612                                    |
| Petersburg  | 0.237           | 20.139                      | 1.253                     | 1648.812                       | 1.618                            | 0.071                  | 21.758                                   | 1.324                                      |
| Poquoson  | 3.798           | 322.819                     | 20.087                    | 26429.348                      | 25.939                           | 1.139                  | 348.758                                  | 21.226                                     |
| Portsmouth  | 2.702           | 229.641                     | 14.289                    | 18800.883                      | 18.452                           | 0.810                  | 248.094                                  | 15.100                                     |
| Prince George   | 8.657           | 735.842                     | 45.787                    | 60243.824                      | 59.127                           | 2.597                  | 794.969                                  | 48.384                                     |
| Prince William  | 0.830           | 70.522                      | 4.388                     | 5773.647                       | 5.667                            | 0.249                  | 76.188                                   | 4.637                                      |
| Richmond  | 14.632          | 1243.756                    | 77.391                    | 101827.059                     | 99.939                           | 4.390                  | 1343.696                                 | 81.781                                     |
| Richmond (city)   | 3.062           | 260.309                     | 16.197                    | 21311.656                      | 20.917                           | 0.919                  | 281.226                                  | 17.116                                     |
| Spotsylvania  | 3.137           | 266.639                     | 16.591                    | 21829.922                      | 21.425                           | 0.941                  | 288.065                                  | 17.532                                     |
| Stafford  | 7.025           | 597.133                     | 37.156                    | 48887.646                      | 47.981                           | 2.108                  | 645.115                                  | 39.263                                     |
| Suffolk   | 13.687          | 1163.379                    | 72.390                    | 95246.555                      | 93.481                           | 4.106                  | 1256.860                                 | 76.496                                     |
| Surry   | 5.844           | 496.737                     | 30.909                    | 40668.157                      | 39.914                           | 1.753                  | 536.651                                  | 32.662                                     |
| Virginia Beach  | 51.712          | 4395.538                    | 273.506                   | 359865.311                     | 353.194                          | 15.514                 | 4748.733                                 | 289.020                                    |
| Westmoreland  | 54.730          | 4652.043                    | 289.467                   | 380865.460                     | 373.805                          | 16.419                 | 5025.848                                 | 305.885                                    |
| Williamsburg  | 0.476           | 40.428                      | 2.516                     | 3309.855                       | 3.248                            | 0.143                  | 43.676                                   | 2.658                                      |
| York  | 24.050          | 2044.213                    | 127.198                   | 167360.950                     | 164.259                          | 7.215                  | 2208.472                                 | 134.413                                    |
| TOTALS  | 761.260         | 64707.136                   | 4026.306                  | 5297611.290                    | 5199.409                         | 228.378                | 69906.545                                | 4254.685                                   |

\* Shoreline Management Model (SMM) version 5.1 living shoreline BMPs used for this project are Plant Marsh with Sill and Non-Structural Living Shoreline. Shoreline with these BMPs where excluded from analysis if tidal marsh is present or if the shoreline is adjacent to NWI Palustrine Forest (PFO) or Palustrine Scrub/shrub (PSS) polygons.

<sup>1</sup> Sum of Total Nitrogen = Protocol 2 Total Nitrogen + Protocol 4 Total Nitrogen

<sup>2</sup> Sum of Total Phosphorus = Protocol 3 Total Phosphorus + Protocol 4 Total Phosphorus

B. Estimated load reduction credits for created marsh along currently defended shorelines by county

| Defended Shoreline with Potential 278Living Shoreline BMP (SMM v.5.1)* - Estimated Nutrient Load Reduction: County Analysis |                 |                             |                           |                                |                                  |                        |  |  |
|---|-----------------|-----------------------------|---------------------------|--------------------------------|----------------------------------|------------------------|--|--|
| County/City   | Estimated Acres | Protocol 2: Denitrification | Protocol 3: Sedimentation |                                | Protocol 4: Marsh Redfield Ratio |                        | Sum of Total Nitrogen (lbs) <sup>1</sup> | Sum of Total Phosphorus (lbs) <sup>2</sup> |
|   |                 | Total Nitrogen (lbs)        | Total Phosphorus (lbs)    | Total Suspended Sediment (lbs) | Total Nitrogen (lbs)             | Total Phosphorus (lbs) |  |  |
| Accomack  | 5.792           | 492.342                     | 30.635                    | 40308.326                      | 39.561                           | 1.738                  | 531.903                                  | 32.373                                     |
| Alexandria  | 0.045           | 3.783                       | 0.235                     | 309.698                        | 0.304                            | 0.013                  | 4.087                                    | 0.249                                      |
| Arlington   | 0.262           | 22.286                      | 1.387                     | 1824.561                       | 1.791                            | 0.079                  | 24.077                                   | 1.465                                      |
| Caroline  | 0.352           | 29.914                      | 1.861                     | 2449.094                       | 2.404                            | 0.106                  | 32.318                                   | 1.967                                      |
| Charles City  | 1.849           | 157.129                     | 9.777                     | 12864.243                      | 12.626                           | 0.555                  | 169.755                                  | 10.332                                     |
| Chesapeake  | 9.398           | 798.794                     | 49.704                    | 65397.696                      | 64.185                           | 2.819                  | 862.979                                  | 52.523                                     |
| Chesterfield  | 1.022           | 86.879                      | 5.406                     | 7112.815                       | 6.981                            | 0.307                  | 93.860                                   | 5.713                                      |
| City of Hopewell  | 0.252           | 21.443                      | 1.334                     | 1755.547                       | 1.723                            | 0.076                  | 23.166                                   | 1.410                                      |
| Colonial Heights  | 0.046           | 3.952                       | 0.246                     | 323.539                        | 0.318                            | 0.014                  | 4.269                                    | 0.260                                      |
| Essex   | 4.308           | 366.174                     | 22.785                    | 29978.871                      | 29.423                           | 1.292                  | 395.597                                  | 24.077                                     |
| Fairfax   | 0.862           | 73.255                      | 4.558                     | 5997.446                       | 5.886                            | 0.259                  | 79.141                                   | 4.817                                      |
| Gloucester  | 8.011           | 680.919                     | 42.369                    | 55747.278                      | 54.714                           | 2.403                  | 735.633                                  | 44.772                                     |
| Hampton   | 12.403          | 1054.260                    | 65.600                    | 86312.920                      | 84.713                           | 3.721                  | 1138.973                                 | 69.321                                     |
| Henrico   | 0.662           | 56.287                      | 3.502                     | 4608.243                       | 4.523                            | 0.199                  | 60.810                                   | 3.701                                      |
| Isle of Wight   | 1.246           | 105.876                     | 6.588                     | 8668.104                       | 8.507                            | 0.374                  | 114.383                                  | 6.962                                      |
| James City  | 1.496           | 127.183                     | 7.914                     | 10412.550                      | 10.220                           | 0.449                  | 137.403                                  | 8.363                                      |
| King George   | 1.121           | 95.249                      | 5.927                     | 7798.076                       | 7.654                            | 0.336                  | 102.902                                  | 6.263                                      |
| Lancaster   | 35.105          | 2983.886                    | 185.668                   | 244292.478                     | 239.764                          | 10.531                 | 3223.650                                 | 196.199                                    |
| Mathews   | 9.447           | 803.002                     | 49.966                    | 65742.212                      | 64.524                           | 2.834                  | 867.525                                  | 52.800                                     |
| Middlesex   | 14.156          | 1203.231                    | 74.869                    | 98509.233                      | 96.683                           | 4.247                  | 1299.914                                 | 79.116                                     |
| New Kent  | 0.839           | 71.307                      | 4.437                     | 5837.946                       | 5.730                            | 0.252                  | 77.037                                   | 4.689                                      |
| Newport News  | 2.061           | 175.203                     | 10.902                    | 14343.984                      | 14.078                           | 0.618                  | 189.281                                  | 11.520                                     |
| Norfolk   | 22.223          | 1888.942                    | 117.537                   | 154648.779                     | 151.782                          | 6.667                  | 2040.724                                 | 124.203                                    |
| Northampton   | 0.933           | 79.297                      | 4.934                     | 6492.132                       | 6.372                            | 0.280                  | 85.669                                   | 5.214                                      |
| Northumberland  | 48.928          | 4158.894                    | 258.781                   | 340491.096                     | 334.179                          | 14.678                 | 4493.073                                 | 273.460                                    |
| Poquoson  | 4.796           | 407.625                     | 25.364                    | 33372.510                      | 32.754                           | 1.439                  | 440.379                                  | 26.803                                     |
| Portsmouth  | 5.710           | 485.375                     | 30.202                    | 39737.961                      | 39.001                           | 1.713                  | 524.377                                  | 31.915                                     |
| Prince George   | 1.605           | 136.423                     | 8.489                     | 11169.035                      | 10.962                           | 0.481                  | 147.385                                  | 8.970                                      |
| Prince William  | 0.139           | 11.838                      | 0.737                     | 969.221                        | 0.951                            | 0.042                  | 12.790                                   | 0.778                                      |
| Richmond  | 1.173           | 99.666                      | 6.202                     | 8159.699                       | 8.008                            | 0.352                  | 107.674                                  | 6.553                                      |
| Richmond (city)   | 0.387           | 32.892                      | 2.047                     | 2692.901                       | 2.643                            | 0.116                  | 35.535                                   | 2.163                                      |
| Spotsylvania  | 0.054           | 4.618                       | 0.287                     | 378.053                        | 0.371                            | 0.016                  | 4.989                                    | 0.304                                      |
| Stafford  | 0.263           | 22.378                      | 1.392                     | 1832.072                       | 1.798                            | 0.079                  | 24.176                                   | 1.471                                      |
| Suffolk   | 1.121           | 95.325                      | 5.931                     | 7804.298                       | 7.660                            | 0.336                  | 102.984                                  | 6.268                                      |
| Surry   | 1.001           | 85.109                      | 5.296                     | 6967.944                       | 6.839                            | 0.300                  | 91.948                                   | 5.596                                      |
| Virginia Beach  | 55.380          | 4707.299                    | 292.905                   | 385389.333                     | 378.245                          | 16.614                 | 5085.544                                 | 309.519                                    |
| Westmoreland  | 14.363          | 1220.855                    | 75.966                    | 99952.106                      | 98.099                           | 4.309                  | 1318.954                                 | 80.275                                     |
| York  | 8.863           | 753.328                     | 46.875                    | 61675.396                      | 60.532                           | 2.659                  | 813.860                                  | 49.534                                     |
| <b>TOTALS</b>   | <b>277.673</b>  | <b>23602.217</b>            | <b>1468.613</b>           | <b>1932327.395</b>             | <b>1896.508</b>                  | <b>83.302</b>          | <b>25498.725</b>                         | <b>1551.915</b>                            |

\* Shoreline Management Model (SMM) version 5.1 living shoreline BMPs used for this project are Plant Marsh with Sill and Non-Structural Living Shoreline. Shoreline with these BMPs were excluded from analysis if tidal marsh is present or if the shoreline is adjacent to NWI Palustrine Forest (PFO) or Palustrine Scrub/shrub (PSS) polygons.

<sup>1</sup> Sum of Total Nitrogen = Protocol 2 Total Nitrogen + Protocol 4 Total Nitrogen

<sup>2</sup> Sum of Total Phosphorus = Protocol 3 Total Phosphorus + Protocol 4 Total Phosphorus

C. Estimated load reduction credits for created marsh within unmanaged shoreline by 8-digit HUC

| Unmanaged Shoreline with Living Shoreline BMP (SMM v.5.1)* - Estimated Nutrient Load Reduction: HUC 8 Analysis |                                   |                              |                 |                               |                                 |   |                                  |                                 |   |   |
|--|-----------------------------------|------------------------------|-----------------|-------------------------------|---------------------------------|---|----------------------------------|---------------------------------|---|---|
| Hydrologic Unit Code - 8 Digit   | HUC 8 Name                        | Number of Shoreline Segments | Estimated Acres | Protocol 2: Denitrification   | Protocol 3: Sedimentation       |   | Protocol 4: Marsh Redfield Ratio |                                 | Sum of Total Nitrogen (lbs per acre) <sup>1</sup> | Sum of Total Phosphorus (lbs per acre) <sup>2</sup> |
|  |                                   |                              |                 | Total Nitrogen (lbs per acre) | Total Phosphorus (lbs per acre) | Total Suspended Sediment (lbs per acre) | Total Nitrogen (lbs per acre)    | Total Phosphorus (lbs per acre) |   |   |
| 02040303   | Chincoteague                      | 83                           | 3.353           | 285.005                       | 17.734                          | 23333.509                               | 22.901                           | 1.006                           | 307.906   | 18.740  |
| 02040304   | Eastern Lower Delmarva            | 94                           | 6.626           | 563.196                       | 35.044                          | 46109.150                               | 45.254                           | 1.988                           | 608.450   | 37.032  |
| 02070010   | Middle Potomac-Anacostia-Occoquan | 65                           | 4.879           | 414.673                       | 25.802                          | 33949.522                               | 33.320                           | 1.464                           | 447.993   | 27.266  |
| 02070011   | Lower Potomac                     | 2666                         | 124.990         | 10624.186                     | 661.074                         | 869808.354                              | 853.685                          | 37.497                          | 11477.871   | 698.571   |
| 02080102   | Great Wicomico-Piankatank         | 5091                         | 172.218         | 14638.543                     | 910.862                         | 1198466.128                             | 1176.250                         | 51.665                          | 15814.793   | 962.527   |
| 02080104   | Lower Rappahannock                | 3030                         | 160.996         | 13684.687                     | 851.510                         | 1120373.391                             | 1099.605                         | 48.299                          | 14784.292   | 899.808   |
| 02080106   | Pamunkey                          | 71                           | 5.156           | 438.291                       | 27.272                          | 35883.152                               | 35.218                           | 1.547                           | 473.509   | 28.819  |
| 02080107   | York                              | 462                          | 21.026          | 1787.214                      | 111.207                         | 146320.222                              | 143.608                          | 6.308                           | 1930.821  | 117.515   |
| 02080108   | Lynnhaven-Poquoson                | 1708                         | 57.983          | 4928.586                      | 306.674                         | 403506.236                              | 396.026                          | 17.395                          | 5324.612  | 324.069   |
| 02080110   | Tangier                           | 13                           | 0.583           | 49.591                        | 3.086                           | 4060.066                                | 3.985                            | 0.175                           | 53.576  | 3.261   |
| 02080111   | Pokomoke-Western Lower Delmarva   | 1339                         | 49.281          | 4188.875                      | 260.647                         | 342945.660                              | 336.588                          | 14.784                          | 4525.463  | 275.431   |
| 02080206   | Lower James                       | 1412                         | 80.956          | 6881.288                      | 428.178                         | 563375.117                              | 552.932                          | 24.287                          | 7434.220  | 452.465   |
| 02080207   | Appomattox                        | 105                          | 10.975          | 932.881                       | 58.047                          | 76375.489                               | 74.960                           | 3.293                           | 1007.840  | 61.340  |
| 02080208   | Hampton Roads                     | 1346                         | 47.811          | 4063.974                      | 252.875                         | 332719.978                              | 326.552                          | 14.343                          | 4390.527  | 267.218   |
| 03010205   | Albemarle                         | 263                          | 14.425          | 1226.146                      | 76.295                          | 100385.316                              | 98.524                           | 4.328                           | 1324.671  | 80.623  |

D. Estimated load reduction credits for created marsh along defended shoreline by 8-digit HUC

| Defended Shoreline with Living Shoreline BMP (SMM v.5.1)* - Estimated Nutrient Load Reduction: HUC 8 Analysis |                                   |                              |                 |                               |                                 |   |                                  |                                 |   |   |
|---|-----------------------------------|------------------------------|-----------------|-------------------------------|---------------------------------|---|----------------------------------|---------------------------------|---|---|
| Hydrologic Unit Code - 8 Digit  | HUC 8 Name                        | Number of Shoreline Segments | Estimated Acres | Protocol 2: Denitrification   | Protocol 3: Sedimentation       |   | Protocol 4: Marsh Redfield Ratio |                                 | Sum of Total Nitrogen (lbs per acre) <sup>1</sup> | Sum of Total Phosphorus (lbs per acre) <sup>2</sup> |
|   |                                   |                              |                 | Total Nitrogen (lbs per acre) | Total Phosphorus (lbs per acre) | Total Suspended Sediment (lbs per acre) | Total Nitrogen (lbs per acre)    | Total Phosphorus (lbs per acre) |   |   |
| 02040303  | Chincoteague                      | 90                           | 1.924           | 163.564                       | 10.178                          | 13391.051                               | 13.143                           | 0.577                           | 176.706   | 10.755  |
| 02040304  | Eastern Lower Delmarva            | 71                           | 1.417           | 120.414                       | 7.493                           | 9858.336                                | 9.676                            | 0.425                           | 130.089   | 7.918   |
| 02070010  | Middle Potomac-Anacostia-Occoquan | 38                           | 1.280           | 108.780                       | 6.769                           | 8905.919                                | 8.741                            | 0.384                           | 117.521   | 7.153   |
| 02070011  | Lower Potomac                     | 1192                         | 31.883          | 2710.029                      | 168.628                         | 221871.634                              | 217.759                          | 9.565                           | 2927.787  | 178.192   |
| 02080102  | Great Wicomico-Piankatank         | 2287                         | 61.902          | 5261.696                      | 327.401                         | 430778.156                              | 422.793                          | 18.571                          | 5684.489  | 345.972   |
| 02080104  | Lower Rappahannock                | 1270                         | 40.039          | 3403.289                      | 211.765                         | 278629.270                              | 273.464                          | 12.012                          | 3676.753  | 223.776   |
| 02080106  | Pamunkey                          | 12                           | 0.117           | 9.903                         | 0.616                           | 810.797                                 | 0.796                            | 0.035                           | 10.699  | 0.651   |
| 02080107  | York                              | 172                          | 4.409           | 374.744                       | 23.318                          | 30680.501                               | 30.112                           | 1.323                           | 404.856   | 24.641  |
| 02080108  | Lynnhaven-Poquoson                | 1964                         | 65.581          | 5574.343                      | 346.855                         | 456374.703                              | 447.915                          | 19.674                          | 6022.257  | 366.529   |
| 02080110  | Tangier                           | 6                            | 0.147           | 12.464                        | 0.776                           | 1020.437                                | 1.002                            | 0.044                           | 13.466  | 0.820   |
| 02080111  | Pokomoke-Western Lower Delmarva   | 178                          | 4.058           | 344.946                       | 21.464                          | 28240.912                               | 27.717                           | 1.217                           | 372.663   | 22.681  |
| 02080206  | Lower James                       | 341                          | 11.850          | 1007.267                      | 62.676                          | 82465.578                               | 80.937                           | 3.555                           | 1088.204  | 66.231  |
| 02080207  | Appomattox                        | 19                           | 0.469           | 39.898                        | 2.483                           | 3266.450                                | 3.206                            | 0.141                           | 43.104  | 2.623   |
| 02080208  | Hampton Roads                     | 1581                         | 48.011          | 4080.903                      | 253.928                         | 334105.964                              | 327.913                          | 14.403                          | 4408.816  | 268.331   |
| 03010205  | Albemarle                         | 128                          | 4.588           | 389.977                       | 24.266                          | 31927.687                               | 31.336                           | 1.376                           | 421.313   | 25.642  |