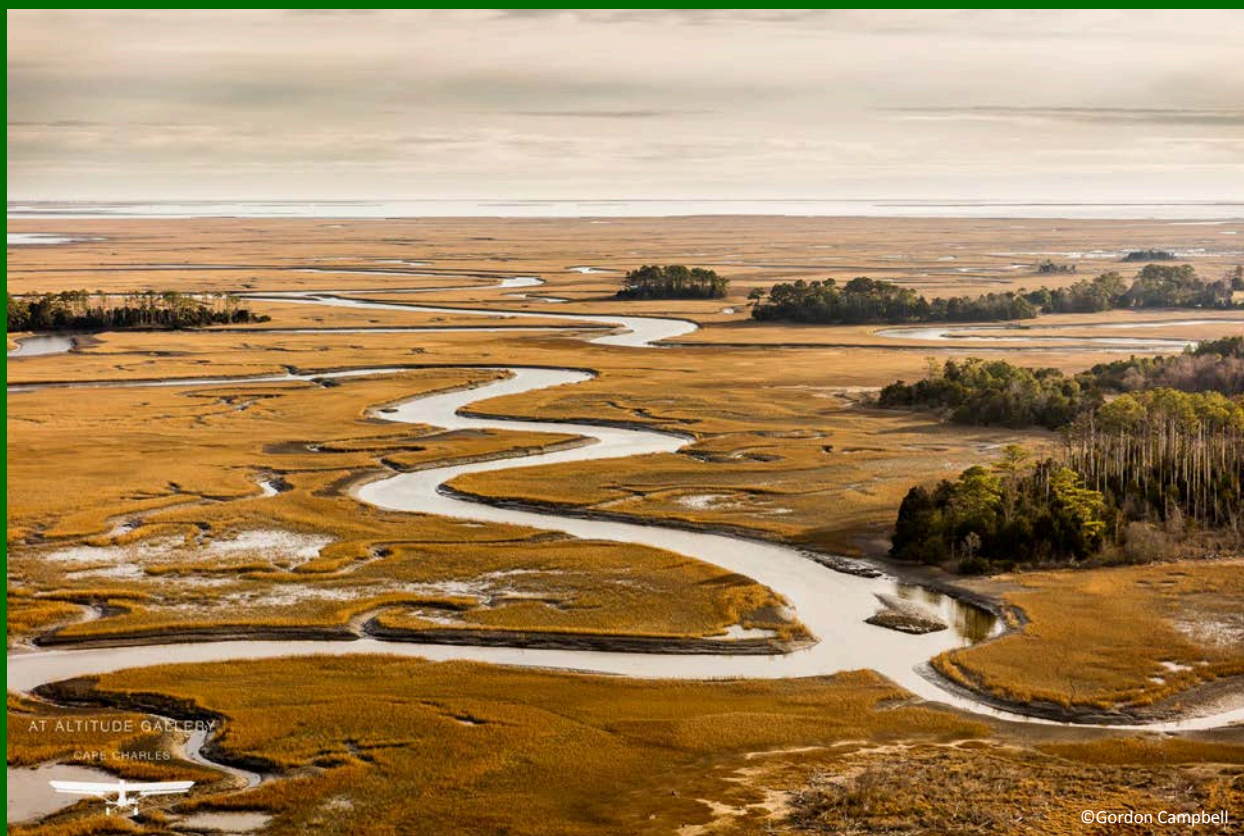


Virginia Eastern Shore Coastal Resilience Mapping & Decision Support Tool

Training Manual Version 4.0 (February 2018)



*A project funded by the
Department of Interior
Hurricane Sandy
Coastal Resilience Fund*



Cover Photo:

Aerial view of the seaside, near Red Bank, Virginia.

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Following Page Photo:

Fowling Point, Hog Island Bay

Photograph ©2015 Gordon Campbell/At Altitude Photography

Virginia Eastern Shore *Coastal Resilience Tool*

Training Manual, Version 4.0 (February 2018)

With input from the Community Leader Workshop held in November 2014, the customized Virginia Eastern Shore *Coastal Resilience* online mapping and decision support tool for visualizing and assessing regional vulnerability to storm surge, sea-level rise, and changes in coastal habitats can be found at maps.coastalresilience.org/virginia. Please visit the project webpage for more information at coastalresilience.org/virginia.



Coastal Resilience is a decision support tool that incorporates the best available science and local data to enable communities to visualize the risks imposed by sea-level rise and storm surge on the people, economy, and coastal habitats of the Eastern Shore and identify nature-based solutions for enhancing resilience and reducing risks where possible.

This training manual for the Coastal Resilience tool provides Exercises & Skills to practice real-world problem solving. Hints & Tips for using the tool and a glossary of terms are also included. The tool contains web mapping applications, or "apps." Each one is intended to address a specific coastal issue to inform conservation, mitigation, and/or adaptation planning. Fact Sheets provide additional information about the locally-sourced data and models that were used to generate each app.

Please read the [Legal Disclosure](#) carefully for more information about the proper use of the Virginia Eastern Shore Coastal Resilience tool.

Please contact us with your questions and input: vacoastalresilience@tnc.org

maps.coastalresilience.org/virginia

Virginia Eastern Shore Coastal Resilience Tool
Training Manual- Version 4.0

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Part One: Basic Navigation

Exercise A. Getting there

- Start by going to the Virginia Eastern Shore Coastal Resilience project website:
<http://coastalresilience.org/project/virginia-eastern-shore/>
 - Scroll down the page to learn more about the Coastal Resilience work going on in the region.
 - In the upper right hand corner of the header banner, click **Mapping Portal** to launch the Coastal Resilience mapping tool (or enter URL: <http://maps.coastalresilience.org>).
- In the left panel, click on **United States**, then scroll down and click on **Virginia**. Scroll down in the popup and click **Open map** button to open the mapping tool.

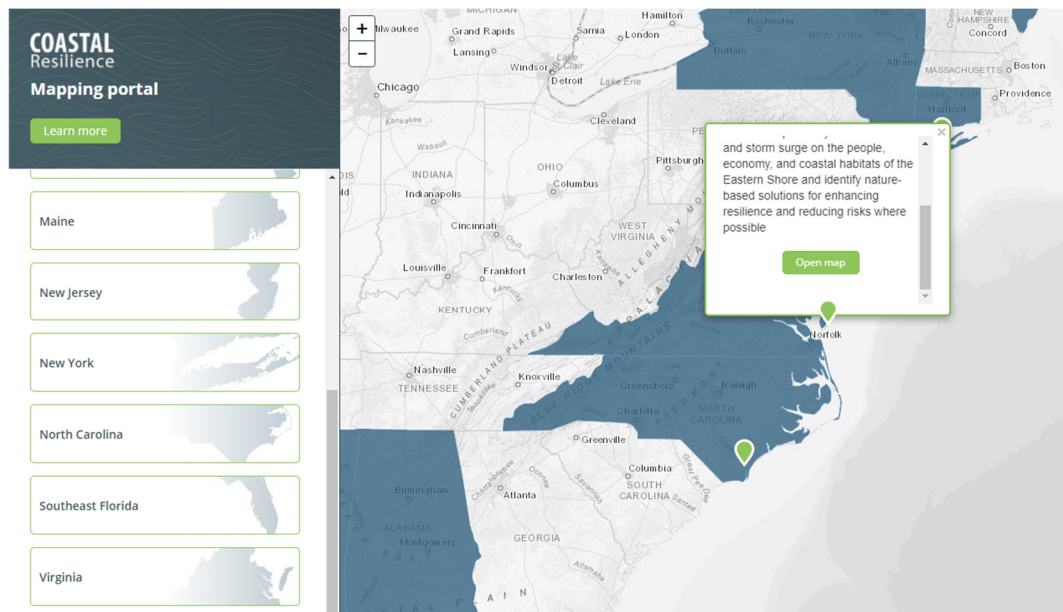


Figure 1. Accessing the Virginia map at maps.coastalresilience.org/virginia

Exercise B. Basic orientation to framework and apps

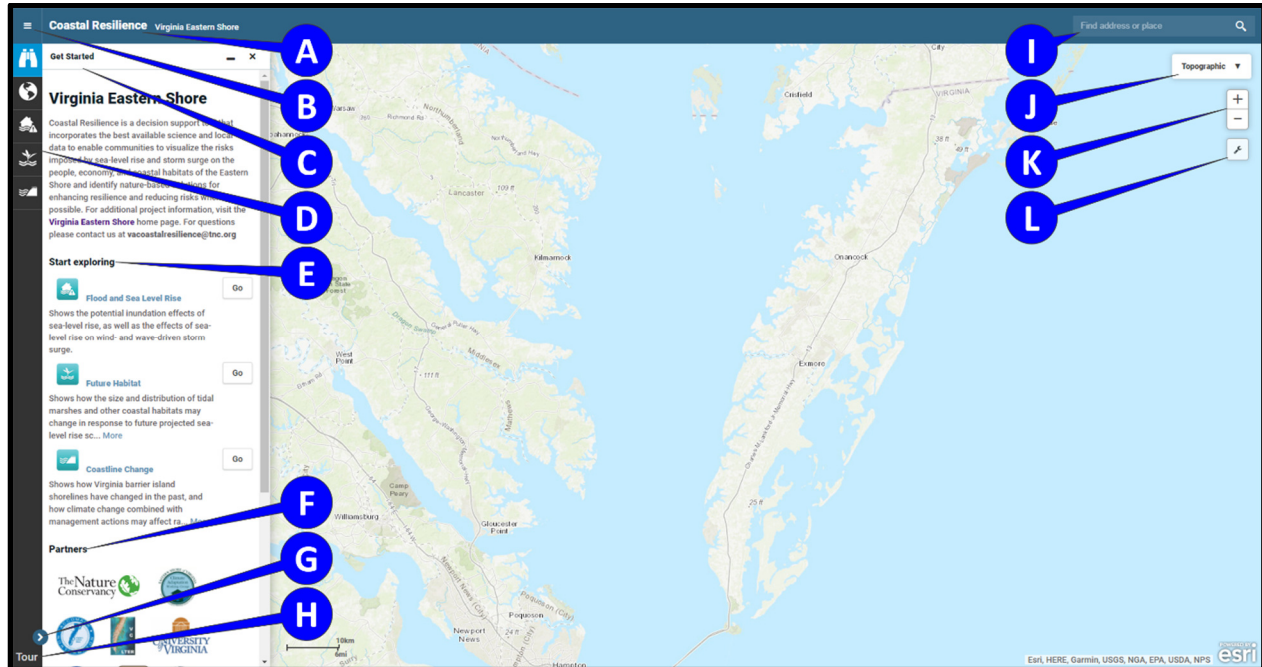


Figure 2. Orientation to the framework

- A. Clicking on **Coastal Resilience** will open a dropdown menu with links to The Nature Conservancy's home page, a legal disclosure, and other Coastal Resilience tool regions.
- B. This is a hamburger menu for exploring external links outside of the mapping tool.
- C. **Get Started:** This is the start menu that provides an introduction to the mapping application, specific links to apps in the left sidebar, and also partner and collaborator logos. Each item below the heading **Start exploring** contains a web mapping application, or "app."
- D. These are the Coastal Resilience tool apps. They are intended to address a specific coastal issue to inform conservation, mitigation, and/or adaptation planning. Click on a symbol to open an app. You can have multiple apps running at the same time when you use the minimize "_" option for an active app. Minimize (the icon will stay blue) and open other apps to view additional data and information. Minimize will leave data on the map, but close the app interface. If you do not minimize, apps and their data remain active until the "x" is clicked either in the app window or next to the app name on the left sidebar (the "x" is only present in the sidebar when the sidebar is expanded and more than one app is open). Use the close "x" to remove data from the map.
- E. These are quick links to the Coastal Resilience tool apps. Click on **Go** to open an app.
- F. Under **Partners** you can find organizations that partnered with The Nature Conservancy for the development of the Coastal Resilience tool.
- G. This arrow collapses and expands the app names to allow for a larger map area.
- H. Click **Tour** for an introduction to the map interface. Click on each number for feature information and close this window when finished.
- I. Go to the **Find address or place** search window in the top right corner of the map to find and zoom to a particular area on the map:
 - a. Start typing in your point of interest and you will get a list of available selections from a global address database.

- b. Choose the correct location from the dropdown menu.
 - c. Close the search window by clicking on the **X** icon.
- J. Click **Topographic** in upper right-hand corner and select the **Imagery** basemap option. Note that other base maps are available here as well.
- K. Click the **plus sign [+]** button to zoom in and the **minus sign [-]** button to zoom out. Note that you can hold down the Shift key and left-click to draw a zoom box.
- L. This button opens the **Tools** menu. It includes the following options:
 - a. The **Measure** option allows you to measure a distance. Select the tool, then click on a point on the map. You can create several segments; when you are done you need to double-click to display the measurement. You can also measure an area by clicking on the first point again when finished creating a shape. Click the **Clear** button to close this tool.
 - b. **Zoom to Extent** will zoom to the full extent of the Eastern Shore of Virginia.
 - c. **Create Map** allows you to print the current extent and selected layers or save the map as an Adobe Portable Document Format (PDF).
 - d. Click on **Save & Share** to generate a link to the current map, which can be copied and shared with colleagues.

Apps in the Toolbox



Regional Planning

The [Regional Planning](#) app includes supporting infrastructure, ecological, socioeconomic, and other data important for resilience and adaptation planning. These layers may be used in combination with the other apps to identify and assess vulnerability and potential solutions for specific locations and resources.



Flood and Sea Level Rise

The [Flood and Sea Level Rise](#) app allows users to view the potential future risk of inundation and flooding due to sea-level rise (SLR) and storm surge on towns, homes, properties, and critical built infrastructure like roads and utilities, as well as coastal habitats. This information helps support planning and decision-making related to hazard mitigation, emergency services, storm water management, land use and conservation.



Future Habitat

The [Future Habitat](#) app allows users to examine how coastal habitats, like salt marsh or freshwater tidal wetlands, may change and migrate inland over time under different sea-level rise scenarios. This information is useful when developing land acquisition, species management, shoreline management, or restoration plans.



Coastline Change

The [Coastline Change](#) app's [Historical Data](#) module and [Future Scenarios](#) module collectively serve to demonstrate the dynamic nature of barrier islands over time. These modules provide planners and managers with overall trends in shoreline change in response to climate change, useful context for understanding the barrier islands as they evolve in the future.



Living Shoreline Explorer

The [Living Shoreline Explorer](#) app shows suitability for living shorelines, along with a marsh vulnerability index. Planners, managers, and property owners can use this app to visualize erosion and inundation risk to shorelines and recommendations for nature-based shoreline stabilization. This information helps support shoreline management, hazard mitigation planning, and restoration plans.



Part Two: Flood & Sea Level Rise App

Assessing Vulnerability of Property and Infrastructure to Sea-Level Rise and Storm Surge

How to use the Tool: Basic Inundation

- Click on the **Flood & Sea Level Rise** app on the left or the **Go** button for the app in the **Get Started** menu.
- Click on the **Select a Hazard** dropdown menu and select **Basic Inundation**.
 - Click on the **Report** button (📄) next to the **Select a Region** dropdown for details on the underlying data.
 - Click on the **Data** button (📄) next to the **Select a Region** dropdown to download the geospatial data for this region.
- Select a **Climate Year** and **Sea Level Rise** scenario from the slider bars to view the predicted impact of sea-level rise in a selected year.
 - Click on the **?** icon for more information on each set of options. Click on the **X** to close the information window for **Climate Year**. Click outside of the pop-up to close the information window for **Sea Level Rise**.
 - Opacity (or transparency) of the layers in this app can be adjusted by using the **Opacity** slider.

Exercise A. Characterizing the risk of sea-level rise in Onancock.

- ★ **Exercise A Scenario:** *You are the owner of a charter boat company in Onancock. You depend on the town to maintain a functioning marina to support your business. In what **Climate Year** is the Wharf and Marina first inundated under each **Sea Level Rise** scenario? In which **Climate Year** would your livelihood as a charter boat owner be at risk in a business-as-usual scenario? If the town considered protecting the existing marina by raising it in response to predicted SLR, how high should it be raised to remain useful in 2065?*
- ★ **Exercise A Planning Outcome:** *Identify properties and infrastructure in Onancock that are critical for water access and predicted to become inundated in the future under different scenarios of SLR.*

- Select the **Flood & Sea Level Rise** app and its **Basic Inundation** option. Go to the **Find address or place** search window on the top right corner of the screen and type **Onancock, VA** and hit **Enter** or click the search result that comes up, then click the **X** to close the search result window.
 - Zoom in or out to adjust extent by clicking on the **plus sign [+]** or the **minus sign [-]** on the upper left or by using the mouse wheel.
 - **Pan:** hold the left mouse button down and move the mouse in the direction you want to pan.
 - Feel free to change the background from **Topographic** to **Imagery** if you find it helps to navigate.
- Navigate to the Onancock Wharf and Marina.
 - Select various combinations of **Climate Year** and **Sea Level Rise** to view the predicted impact of SLR in a selected year.
 - Adjust **Opacity** as necessary to visualize flooding from SLR.



Question 1-A: In what Climate Year is the Wharf and Marina first inundated under each Sea Level Rise scenario? At which Climate Year would your livelihood as a charter boat owner be at risk in a business-as-usual scenario?

- Using the Legend, identify the maximum inundation predicted for each **Climate Year** and **Sea Level Rise** scenario at the Onancock Wharf and Marina.

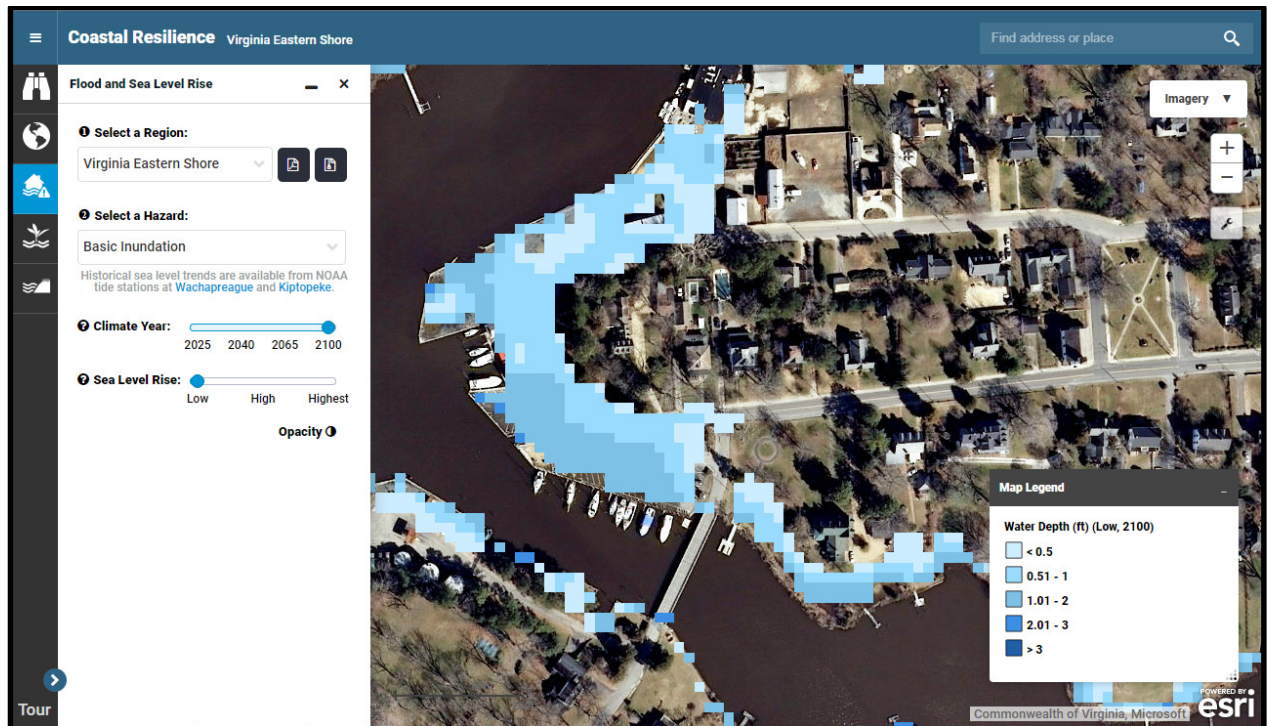


Figure 3. Example of what your screen should look like prior to Question 2-A.





Question 2-A: If the town considered protecting the existing marina by raising it in response to predicted SLR, how high should it be raised to remain useful in 2065 under each SLR scenario?



On Your Own:

Question 3-A: Using the Regional Planning app, find other nearby public water access sites that may be inundated in the future under various SLR scenarios.

How to use the Tool: Storm Surge

- If it is not already active, click on the **Flood & Sea Level Rise** app on the left or the **Go** button for the app in the **Get Started** menu.
- Click on the **Select a Hazard** dropdown menu and select **Storm Surge**.
 - Click on the **Report** button () next to the **Select a Region** dropdown for details on the underlying data.
 - Click on the **Data** button () next to the **Select a Region** dropdown to download the geospatial data for this region.
- Note the option to **Display hazard as** Surge Depth or Economic Loss.
- Select a **Climate Year** and **Storm Type** scenario from the slider bars to view the predicted impact of storm surge in a selected year.
 - Click the **?** icon for more information on each set of options. Click on the **X** to close the information window for **Climate Year**. Click outside of the pop-up to close the other information windows.
 - The Surge Depth datasets may be displayed as water depth, absolute difference (i.e., depth difference between current and predicted water levels), or percent difference (i.e., percent increase or decrease in water level elevation).
 - Note that the **Storm Type** options include an option to view surge from Nor'Ida, a 2009 nor'easter which was used to validate the data in this app. This is the default selection when loading the app.
 - You can view the Storm track(s) of modeled storms which provided data for this app. You can also view tidal range data to better understand the risks posed by storm surge during different tidal cycles.
 - Opacity (or transparency) of the layers in this app can be adjusted by using the **Opacity** slider.

Exercise B. Characterizing the risks due to flooding and inundation from future storm surge in Cape Charles.

- ★ **Exercise B Scenario:** *Your family has lived in Cape Charles for generations. You have seen hurricanes and nor'easters over the years, but you have heard that the frequency of these storms may increase. You pay for flood insurance even though your property is far from the water, near the town's Central Park. What is the Flood Hazard Area for the neighborhoods near Central Park? In what **Climate Year** is this Flood Hazard Area flooded regularly by low intensity storms? What is the maximum economic loss predicted for properties around Central Park for a medium intensity storm in **Climate Year** 2065?*
- ★ **Exercise B Planning Outcomes:** *(1) Identify 0.2-pct Flood Hazard Zones in Cape Charles that are at risk for flooding under various scenarios of SLR combined with storm surge and local conditions; (2) Identify potential estimated economic losses under different scenarios of SLR combined with storm surge.*

- Select the **Flood & Sea Level Rise** app and its **Storm Surge** option. Go to the **Find address or place** search window and type **Cape Charles, VA** and hit **Enter** or click the search result that comes up, then click the **X** to close the search result window.
- Navigate to the Cape Charles Central Park (change the basemap to Topographic if needed).

- Open the **Regional Planning** app (🌐) and select **Virginia** and **Coastal Management**. Select **Flood Hazard Areas (2014)**.

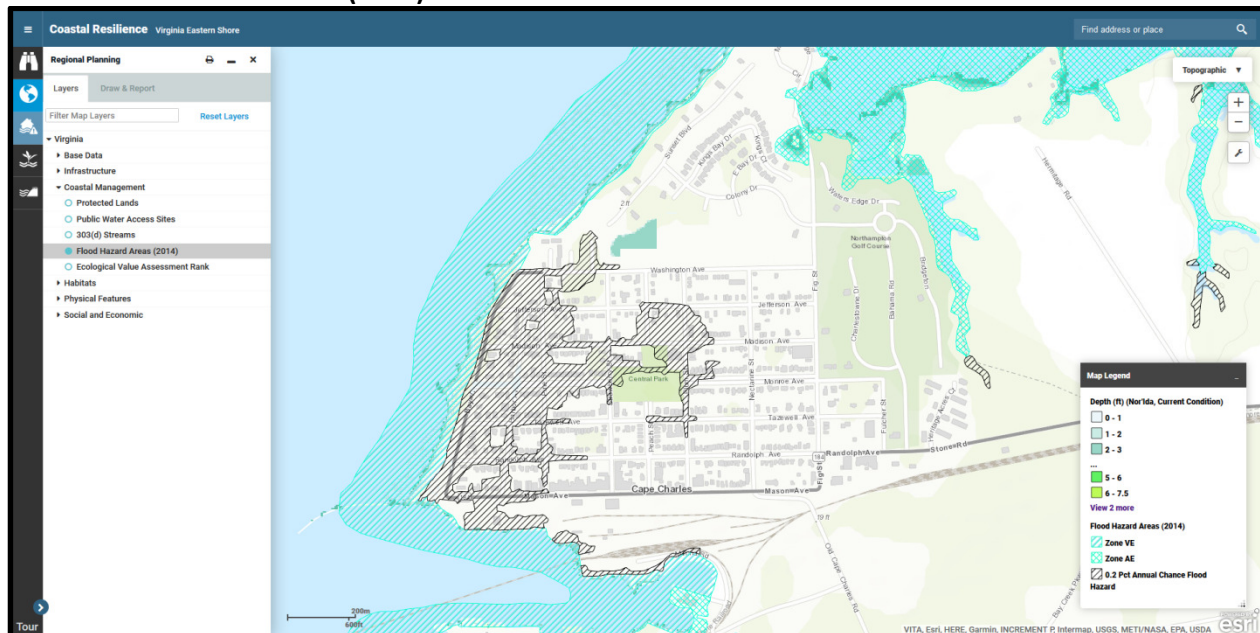


Figure 4. Example of what your screen should look like prior to Question 1-B.



Question 1-B: What is the Flood Hazard Area for the neighborhoods near Central Park?

- Click on the **Flood & Sea Level Rise** app to return to its menu.
- Under **Storm Type**, slide the bar to **Low Intensity** and compare **Climate Year** scenarios for **Current**, **2040**, and **2065**.



Question 2-B: In what Climate Year do the neighborhoods near Central Park begin to flood under a low intensity storm?

- Change the hazard displayed from Surge Depth to **Economic Loss**.
- Under **Storm Type**, slide the bar to **Medium Intensity** and the **Climate Year** to **2065**.



Question 3-B: What is the maximum economic loss for the area around Central Park for a medium intensity storm in Climate Year 2065?



On Your Own:

Question 4-B: Compare future Climate Year and Storm Type combinations. How might the current 0.2 Percent Annual Chance Flood Hazard zone change based on predicted flooding by Low and Medium Intensity storms? What do you think will happen to flood insurance rates as a result?

TECHNICAL SKILLS COMPLETED

- ☐ Ability to assess risk and vulnerability to specific places or infrastructure due to a range of flooding scenarios based on SLR inundation only or SLR plus storm surge scenarios.
- ☐ Ability to evaluate the relative impact SLR has on storm surge.
- ☐ Ability to evaluate potential future economic losses due to different scenarios of SLR plus storm surge.
- ☐ Ability to consider hazard mitigation actions that may reduce risk of flooding to specific areas based on planning horizons.

Implementation:

- ☐ You can now use the Flood & Sea Level Rise app to help guide stakeholder workshops or conversations around community socio-economic vulnerability to permanent inundation among a range of projected sea-level rise scenarios along with the potential impacts of sea-level rise on storm surge. For example, the Onancock Wharf and Marina is vulnerable to increased inundation under future SLR scenarios.
- ☐ You can now create a meaningful map that can help clearly communicate to decision-makers and stakeholders that the impacts of sea-level rise on storm surge are not uniform and vary based on place. For example, SLR may have a greater impact along water bodies that are more confined (e.g., Machipongo River, Chincoteague Bay).
- ☐ You can use the understanding of flood risk that you have gained to help make the case for adaptation recommendations like infrastructure or evacuation route relocation or future base flood elevation requirements, to help make your community more resilient.



Part Three: Future Habitat App

Identifying and Planning for Areas of Future Marsh Migration

How to use the Tool: Future Habitat

- Click on the **Future Habitat** app on the left or the **Go** button for the app in the **Get Started** menu.
 - There are three tabs within the **Future Habitat** app: **Choose Parameters**, **Results & Chart**, and **Compare & Chart**. The first tab, **Choose Parameters**, allows you to select various scenarios that affect habitat change. The **Results & Chart** tab shows tabulated data for quantities of habitat types for the chosen SLR scenario. The **Compare & Chart** tab will compare the quantities of habitat types in the chosen future scenario to current quantities. **Compare & Chart** only works if a future **Scenario Year** is selected.
 - Note that this app includes a very large dataset and may take several seconds to load each time its parameters and the zoom level are changed.
 - Click on the **Learn More** link to view a fact sheet regarding this app.
- Select a **Scenario Year** and **SLR Scenario** from the slider bars to view the predicted impact of sea-level rise on habitat types in a selected year.
 - Note that the **SLR Scenario** slider bar is inactive when the **Scenario Year** is set to **Current**.
 - Click on the ? icon for more information regarding the **SLR Scenario** data.
 - Use the **Filter Results by Habitat(s) of Interest** checkboxes to show only salt marsh and/or other wetlands.
 - The results presented by this app may be focused on a specific area using the options below **Filter Results by a User Defined Area**. The **Click to Draw an Area** button allows you to click at least three points to choose an area of interest (double-click the last point to close the shape). The app will now only show data within this area. Use the **Zoom to Selection** button to zoom to this area. The **Clear Filters** button will remove the area defined by the user and return to the full dataset. Note that this will also reset the **Filter Results by Habitat(s) of Interest** options.
 - Opacity (or transparency) of the layers in this app can be adjusted by using the **Layer Properties** slider.
 - The current geospatial data (either the full dataset or data for an area defined by the user) can be downloaded using the **Download Data** button.
 - The methods used to develop this app can be viewed by clicking the **View Methodology** button.

Exercise A. Future Habitat for Marsh Retreat at a Regional Scale

- ★ **Exercise A Scenario:** *You are part of a volunteer organization that promotes the preservation of salt marsh. What are the predicted changes in the amount of marsh habitat in 2025?*
- ★ **Exercise A Planning Outcome:** *Identify general regional trends in marsh habitat distribution and extent under different future SLR scenarios for Virginia's Eastern Shore.*

- Click on the **Future Habitat** app.

- Compare various **Scenario Year** and **Sea-Level Rise Scenario** combinations by sliding the bars to visualize where habitat types may change due to SLR.
- Click on the **Compare & Chart** tab to compare the modeled changes in habitat type quantities to current values.



Question 1-A: What are the predicted changes in the amount of salt marsh acreage in 2025 for each Sea Level Rise Scenario?

Exercise B: Future Habitat Changes in Wachapreague

- ★ **Exercise B Scenario:** *You are a town planner for Wachapreague. The town is proud of its scenic waterfront. However, you know that this area is vulnerable to SLR and associated habitat change. What habitat changes can be expected for Wachapreague between now and 2100 in a business-as-usual scenario? What areas of the town are most susceptible to habitat change as a result of SLR and what kinds of nature-based solutions could be implemented to reduce risks? Are there scenarios in which the surrounding area may change substantially, including loss of access routes, despite adaptation by the town?*
- ★ **Exercise B Planning Outcome:** *Identify areas of potential future marsh retreat within currently developed areas that should be the focus of adaptation actions.*

- Click on the **Future Habitat** app. Go to the **Find address or place** search window and type **Wachapreague, VA** and hit **Enter** or click the search result that comes up, then click the **X** to close the search result window.
- Compare various **Scenario Year** and **Sea-Level Rise Scenario** combinations by sliding the bars to visualize where habitat types may change due to SLR.

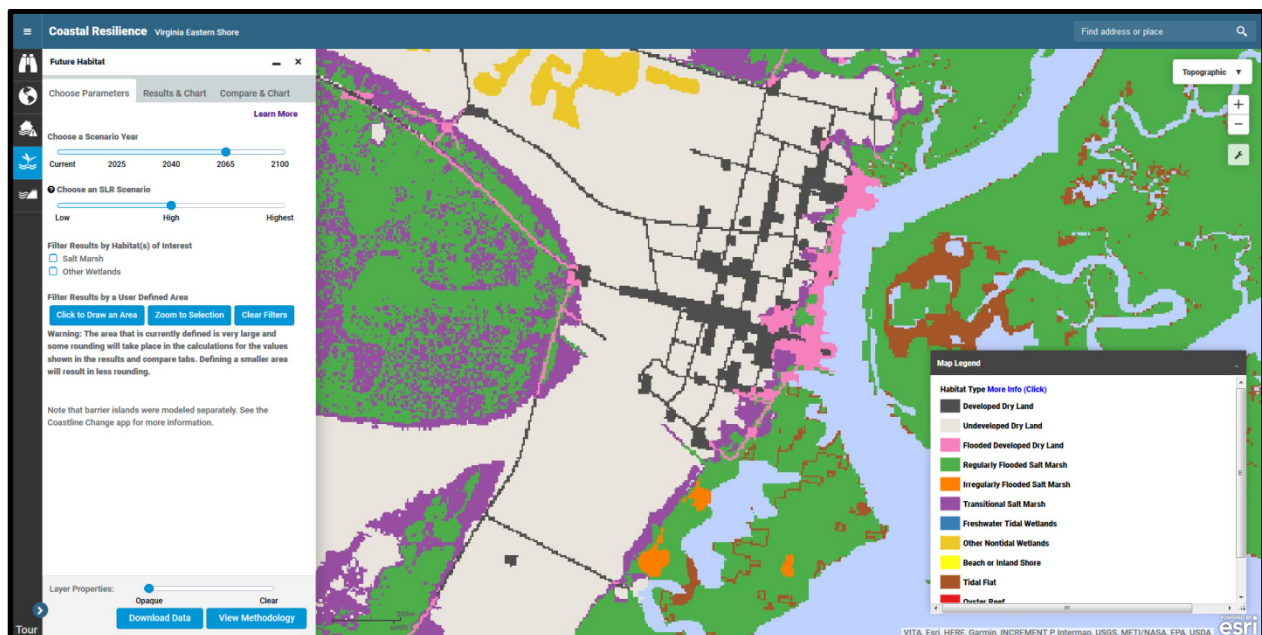


Figure 6. Example of what your screen should look like prior to Question 1-B.



Question 1-B: What habitat changes can be expected for Wachapreague between now and 2100 in a business-as-usual scenario?

- Using the slider bars and the Legend, identify the areas of Wachapreague that may experience habitat change first and the types of habitat predicted to replace **Undeveloped Dry Land**.



Question 2-B: What areas of the town are most susceptible to habitat change as a result of SLR? What kinds of nature-based solutions (e.g., marsh enhancement, seagrass beds, oyster reefs) could be implemented to reduce risks?

- Click on the **Regional Planning** app and select **Virginia** and **Base Data**. Select **Town Boundaries**. This will appear as a dark gray line around the town (you may choose to adjust the opacity of the Habitat Change app to better see it).
- Using the slider bars and the Legend, identify areas around Wachapreague which may experience significant habitat change, affecting access and infrastructure in the town.

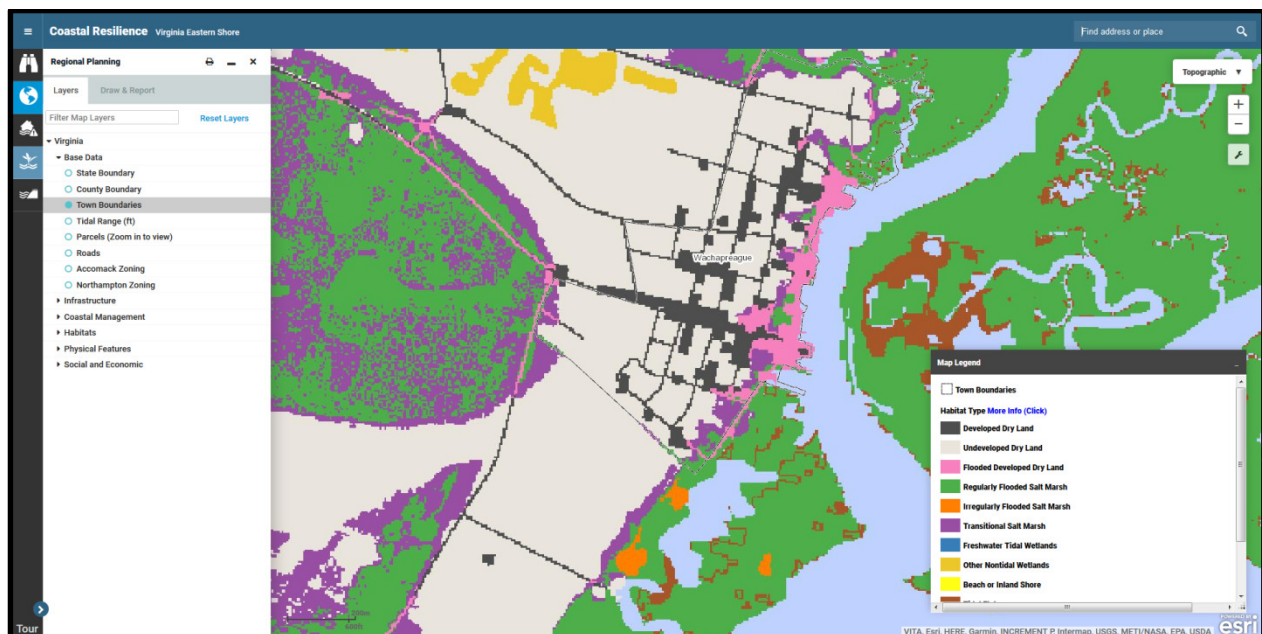


Figure 7. Example of what your screen should look like prior to Question 3-B.



Question 3-B: Are there scenarios in which the surrounding area may change substantially, including loss of access routes, despite adaptation by the town?



On Your Own:

Question 4-B: Using the Click to Draw an Area button, trace a general outline of the Wachapreague town boundaries. How does the acreage of Undeveloped Dry Land change between Scenario Years under the High SLR Scenario? How many acres of Developed Dry Land are at risk by Scenario Year 2100 under various SLR Scenario options?

TECHNICAL SKILLS COMPLETED

- ☐ Ability to identify places where habitats, particularly salt marsh, may change in the future due to sea-level rise.
- ☐ Ability to identify areas that are currently undeveloped dry land but that could become salt marsh under future sea-level rise scenarios.
- ☐ Ability to consider a range of planning options that would allow marshes to migrate naturally.

Implementation:

- ☐ You can use the Future Habitat app to more effectively communicate to decision-makers and stakeholders that coastal habitats will respond dynamically to sea-level rise.
- ☐ You have a better understanding that, although existing tidal marshes could be lost due to sea-level rise in the future, the landscape has high capacity for marsh migration on the mainland at the regional scale. The ability for marsh migration to occur unimpeded on the mainland will ultimately depend on shoreline management and land use decisions. With this information, you can begin to work with private landowners, resource management entities, and localities to identify open spaces or parcels where accommodating inland marsh migration is a viable management approach.
- ☐ You can use the “Save and Share” feature to work collaboratively with colleagues to get input on an analysis or create a map to help make the case for a project proposal.



Part Four: Coastline Change App

Understanding Past and Future Changes to the Seaside Barrier Islands

How to use the Tool: Coastline Change

- Click on the **Coastline Change** app on the left or the **Go** button for the app in the **Get Started** menu.
- There are two modules within the **Future Habitat** app: **View Historical Data** and **View Future Scenarios**. Click on **Explain Each Choice** for each dataset to see a description of the options listed below. Click **Learn More** to view a fact sheet for each module.
 - **View Historical Data** allows you to view historical shorelines of Virginia Eastern Shore barrier islands. Available data ranges from the 1850s to 2014. Under **Display Historic Shorelines**, these shorelines may be displayed using the **Slider** or by selecting **Multiple** shorelines at once. Under **Select Data Type**, the **Change Rate** option allows for selecting **Long Term** or **Short Term** change rates for Virginia Eastern Shore barrier island shorelines, indicating either seaward movement (accretion) or landward movement (erosion). Individual transects may be selected to view location-specific change rates.
 - **View Future Scenarios** allows you to view the effects of various combinations of **Sea Level Rise Scenario**, **Wave Climate Change Scenario**, and **Nourishment Scenario** on the **Rate of Change Difference** for Virginia Eastern Shore shorelines. In the graph, the **Rate of Change Difference** represents the average difference (in meters per year over a 50-year time frame) in the rate of shoreline change between current conditions and a modeled scenario. Note that zooming is disabled for this module.

Exercise A: Historical Shoreline Change Data for Virginia's Barrier Islands

- ★ **Exercise A Scenario:** *You and a group of friends regularly visit Virginia's barrier islands for kayaking and fishing. Over the years, you have noticed that the islands change constantly, some growing, some receding. What do historical shoreline data tell us about the overall **Long Term** and **Short Term** change rates for the Virginia barrier island chain? What percentage of barrier island transects are experiencing **Seaward Movement** and **Landward Movement** in each of the **Change Rate Types**?*
- ★ **Exercise A Planning Outcome:** *Gain understanding of historic long- and short-term rates of shoreline change at the scale of individual barrier islands and for the regional Virginia barrier island chain.*

- Click on the **Coastline Change** app.
- Select **View Historical Data**.
- Under **Select Shoreline Year**, click **Play** to watch the change in historical shorelines from the 1850s to 2014. Click **Stop** to stop on a particular year and end the animation.
- Under **Select Data Type**, click on **Change Rate** to view the shoreline change rate calculated from historical shorelines. Under **Show Change Rate Type**, select **Long Term** and then **Short Term** change rates and look at the differences in the graph.

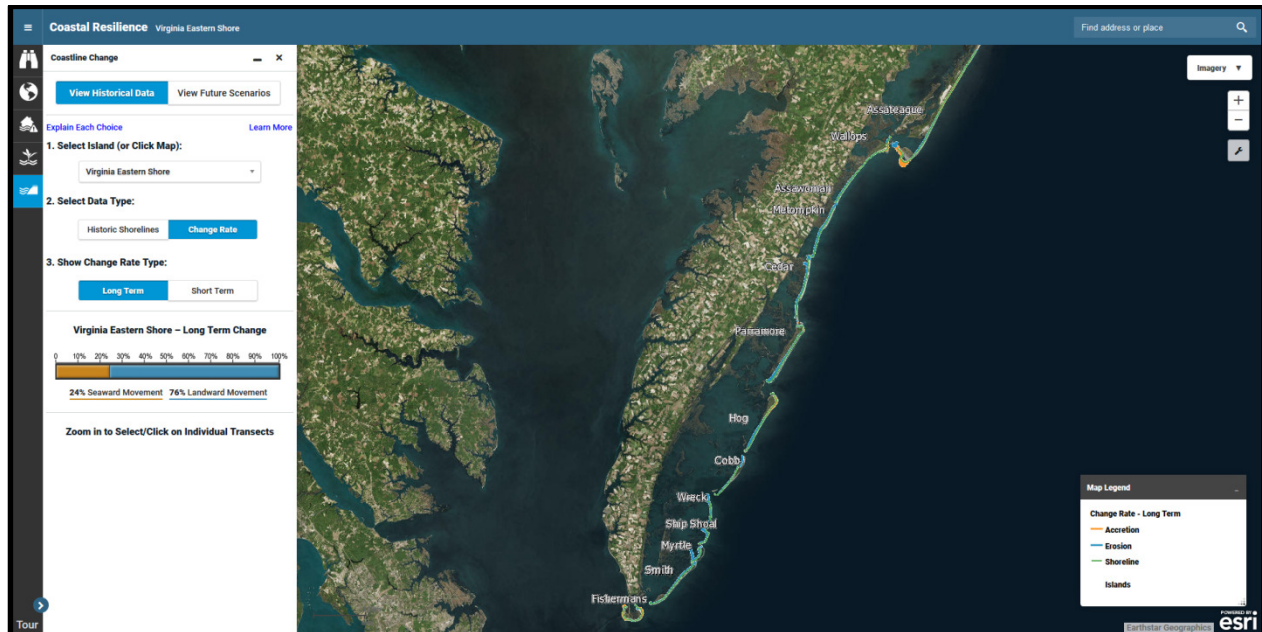


Figure 8. Example of what your screen should look like prior to Question 1-A.



Question 1-A: What do historical shoreline data tell us about the overall Long Term and Short Term change rates for the Virginia barrier island chain?

- Select one of the Virginia barrier islands in the **Select Island** dropdown. The map will zoom in to your selection.
- Click on a few transects on the map to view change rate information about each transect. Note that the length of each transect is proportional to the change rate.
- Compare the **Long Term** and **Short Term** change rates for various transects on the island.
- Compare the **Long Term Change** and **Short Term Change** values shown as a percentage of island transects. For example, the **Long Term Change Rate** for Hog Island is 41% **Seaward Movement**.



Question 2-A: What percent of this barrier island is experiencing Seaward Movement and Landward Movement in each of the Change Rate Types?



On Your Own:

Question 3-A: Where is the Short Term rate of change the greatest for both erosion and accretion on the island you selected? Hint: Look for very long transect lines.

Exercise B: Future Scenarios of Barrier Island Evolution

- ★ **Exercise B Scenario:** *You and your family visit Chincoteague Island every year on vacation for birding, surfing, and hiking. One of your favorite locations for these activities is Assateague Island. You have heard that there are plans to relocate current beach access routes farther to the north. What is the predicted **Rate of Change Difference** estimate for the south end of Assateague Island under various SLR and wave climate change scenarios? What effect does beach nourishment on Wallops Island have on the same Assateague Island **Rate of Change Difference** estimates?*
- ★ **Exercise B Planning Outcome:** *Understand the extent to which relative sea-level rise, changes in wave climate, and beach nourishment activities may change and influence the evolution of the Virginia barrier island chain.*

- Click on the **Coastline Change** app and the **View Future Scenarios** option.
- Note that the data presented in this app represent a modeled, hypothetical shoreline and do not represent the actual individual islands illustrated on the base map.
- Find the general location of Assateague Island on the map.
- Select and compare the various combinations of **Sea Level Rise Scenario** and **Wave Climate Change Scenario** options. Note that the bar graph changes with the various combinations of data. These values and those in the legend refer to the difference in rate of change from a baseline. The baseline is future change under current climate conditions where relative sea level rises at the rate of 3 mm per year, the wave climate is consistent with the best-known present wave climate, and no nourishment occurs at any location.

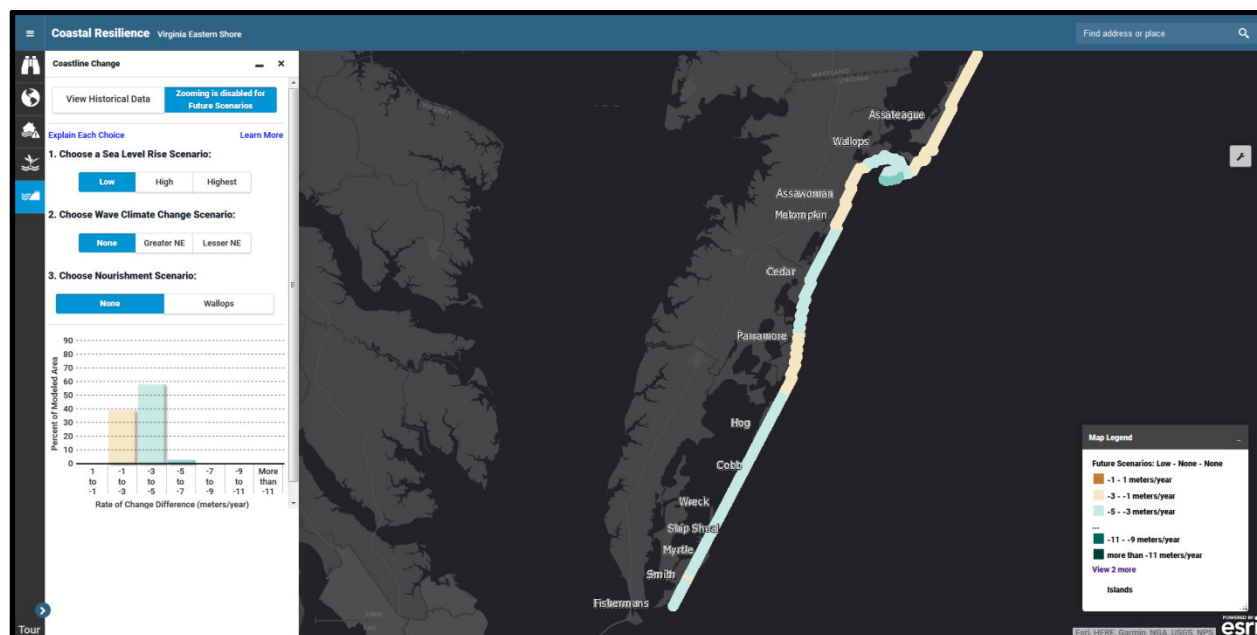


Figure 9. Example of what your screen should look like prior to Question 1-B.



Question 1-B: What is the predicted Rate of Change Difference estimate for the south end of Assateague Island under various SLR and wave climate change scenarios?

- Select and compare the various combinations of **Sea Level Rise Scenario**, **Wave Climate Change Scenario**, and **Nourishment Scenario** options.
 - **NOTE:** *Wallops Island was modeled as a zone where beach nourishment may occur in the future since it has been implemented in the recent past. The modeled projections should in no way indicate an endorsement of beach nourishment as a management option, on Wallops or elsewhere in the region.*



Question 2-B: What effect would beach nourishment on Wallops Island have on Assateague Island Rate of Change Difference estimates?



On Your Own:

Question 3-B: Based on the data presented in the View Future Scenarios dataset, would moving the current Assateague Island beach access routes farther north be an appropriate adaptation strategy?

TECHNICAL SKILLS COMPLETED

- ☐ Ability to view various historic shoreline positions along with rates and direction of barrier island movement for all of the Eastern Shore barrier islands.
- ☐ Understanding of how sea-level rise, potential wave climate shifts, and nourishment scenarios may affect future changes to barrier island shorelines.

Implementation:

- ☐ Organizations and agencies who manage barrier islands, research scientists, and local governments may use the Future Scenarios module in the Coastline Change app to explore different regional climate and nourishment scenarios in order to better anticipate and manage shoreline changes in the future.
- ☐ Suggested conclusions of the Future Scenarios modules outputs:
 - ☐ The Coastline Change app demonstrates that the Virginia Barrier Island chain is highly dynamic and dependent on the interaction of local and regional processes.
 - ☐ On a regional scale, the results suggest that relative sea-level rise is the dominant factor in causing more erosion or less accretion along the barrier island chain.
 - ☐ Nourishment activities are suggested to have a more limited and local effect on the barrier island chain than expected.
- ☐ The information from Future Scenarios is a springboard for additional inquiry and modeling efforts regarding potential local coastline change in the future.

Part Five: Living Shoreline Explorer App

Understanding Marsh Vulnerability and Living Shoreline Suitability Types



How to use the Tool: Living Shoreline Explorer

- Click on the **Living Shoreline Explorer** app on the left. There are two options within the **Living Shoreline Explorer** app: **Living Shoreline Suitability Types** and **Marsh Vulnerability Index**.
 - The first option, **Living Shoreline Suitability Types**, displays shoreline categorized as suitable for marsh vegetation enhancement, suitable for marsh vegetation enhancement with hard structure (e.g., oyster reef), or unsuitable for living shoreline. You can zoom in to select a shoreline segment and obtain more details.
 - The **Marsh Vulnerability Index option** displays either the **Overall Vulnerability** or **Individual Variables** used to determine marsh vulnerability to erosion and inundation. The individual variables are wave exposure, storm surge, sea level rise, boat activity, marsh buffer width, marsh vegetation height, marsh elevation and marsh slope.

Exercise A: Living Shoreline Suitability Types

- ★ **Exercise A Scenario:** *Accomack County is updating their comprehensive plan and they want to incorporate nature-based solutions to protect existing properties and infrastructure from erosion and inundation in the Upshur Neck area. The county decided to use the Coastal Resilience tool Living Shoreline Explorer App as a screening tool to initially identify areas that would be suitable for marsh vegetation enhancement or marsh vegetation with structure (e.g. oyster reefs). Where are these areas located?*
- ★ **Exercise A Planning Outcome:** *Identify areas that are suitable for nature-based shoreline stabilization solutions.*

- Click on the **Living Shoreline Explorer** app.
- Go to the **Find address or place** search window on the top right corner of the screen and type **Quinby, VA** and click the first search result that comes up, then click the **X** to close the search result window.
- Zoom out and pan the map so the area of Upshur Neck south of Quinby is visible.

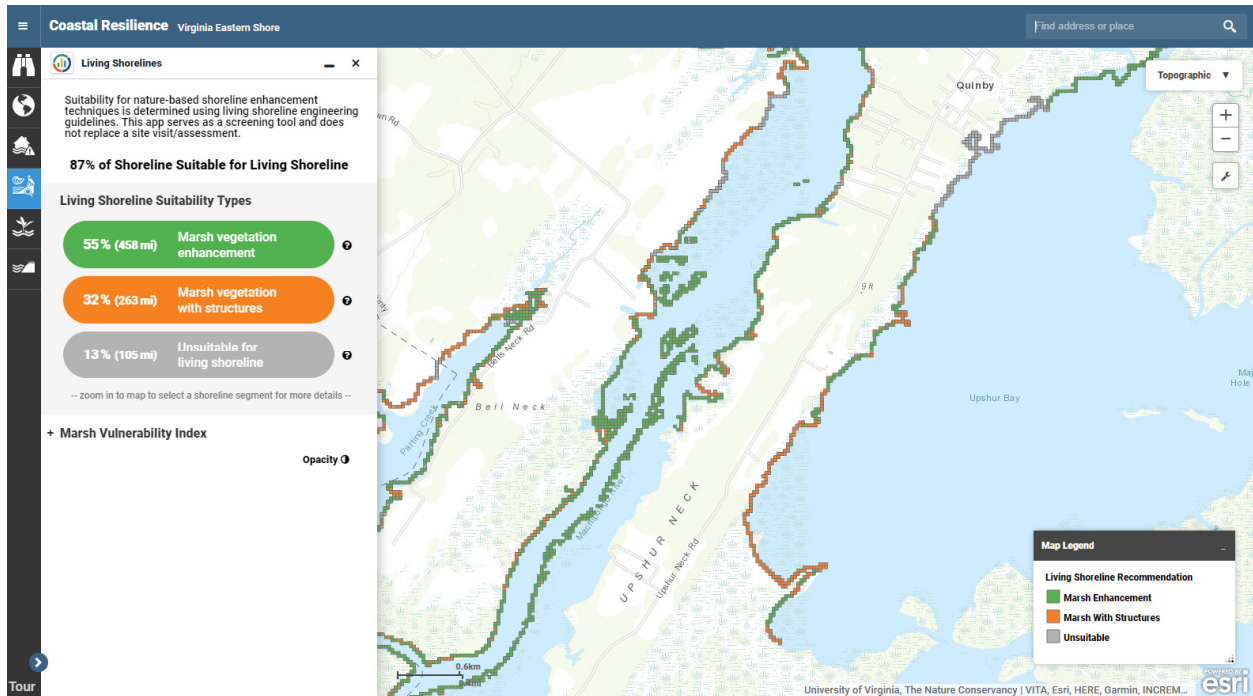


Figure 10. Example of what your screen should look like prior to Question 1-A.



➤ **Question 1-A: Identify the shorelines on Upshur Neck that are suitable for marsh vegetation enhancement or marsh vegetation enhancement with structure. Where are these areas located?**



On Your Own:

Zoom in enough to be able to click on a single (orange, green, or gray) cell and explore on your own the vulnerability of individual factors.

Exercise B: Marsh Vulnerability Index

- ★ **Exercise B Scenario:** *You are an ecology student, who needs to write a paper about the vulnerability of the marshes around Upshur Neck. You are using the tool to look into the overall marsh vulnerability as well as individual parameters contributing to marsh vulnerability. Where are the most vulnerable marshes located? How does vulnerability due to wave exposure vary along this section of the shoreline? How about vulnerability due to marsh elevation?*
- ★ **Exercise B Planning Outcome:** *Understanding marsh vulnerability overall as well as individual parameters vulnerability.*

- Keep the **Living Shoreline Explorer** app open and the map zoomed to Upshur Neck.
- Select **Marsh Vulnerability Index**.



Question 1-B: Where along the western shoreline of Upshur Bay is the marsh most vulnerable

- Select **Individual Variables**.
- In the Select a Variable box, examine the vulnerability scores of the various individual variables.



Question 1-C: Along the southwestern shoreline of Upshur Bay, where overall vulnerability is Very High, which individual variables are High or Very High?

TECHNICAL SKILLS COMPLETED

- ☐ Ability to view and determine living shoreline suitability for specific segments of shoreline.
- ☐ Ability to view and determine overall marsh vulnerability and vulnerability of individual variables.

Implementation:

- ☐ The Living Shoreline Explorer app can be used as a screening tool to assist planners, managers, and property owners in considering nature-based shoreline stabilization options, with the understanding that living shoreline design and placement is complex and requires a site visit for a final determination.

Answer Key

Flood & Sea Level Rise

Question 1-A: In what Climate Year is the Wharf and Marina first inundated under each Sea Level Rise scenario? At what point in time would your livelihood as a charter boat owner be at risk in a business-as-usual scenario?

Answer: Low = 2065; High = 2040; Highest = 2040. Depending on the experienced SLR and the severity of inundation that can be tolerated, your livelihood might be at risk as early as **Climate Year 2040**.

Question 2-A: If the town considered protecting the existing marina by raising it in response to predicted SLR, how high should it be raised to remain useful in 2065 under each SLR scenario?

Answer: Low: at least 0.5 ft in most locations; High: up to 2 ft in many areas; Highest: 2-3 ft.

Question 3-A: Using the Regional Planning app, find other nearby public water access sites that may be inundated in the future under various SLR scenarios.

Answer: There are several other nearby public water access sites that would experience inundation by 2065 or 2100, depending on the SLR scenario.

Question 1-B: What is the Flood Hazard Area for the neighborhoods near Central Park?

Answer: 0.2 Pct Annual Chance Flood Hazard

Question 2-B: In what Climate Year do the neighborhoods near Central Park begin to flood under a low intensity storm?

Answer: 2065

Question 3-B: What is the maximum economic loss for the area around Central Park for a medium intensity storm in Climate Year 2065?

Answer: \$5,000,000

Question 4-B: Compare future Climate Year and Storm Type combinations. How might the current 0.2 Percent Annual Chance Flood Hazard zone change based on predicted flooding by Low and Medium Intensity storms? What do you think will happen to flood insurance rates as a result?

Answer: If Low Intensity storms are predicted to regularly flood the current 0.2 Percent Annual Chance Flood Hazard zone in Cape Charles in 2065, this area could be reclassified as a different Flood Hazard Zone in the future. Flood insurance rates would likely be adjusted accordingly.

Future Habitat

Question 1-A: What are the predicted changes in the amount of salt marsh acreage in 2025 for each Sea Level Rise Scenario?

Answer: Regularly Flooded Salt Marsh
2025/Low = -38 acres; 2025/High = +171 acres; 2025/Highest = +1,234
Irregularly Flooded Salt Marsh
2025/Low = -616 acres; 2025/High = -1,155 acres; 2025/Highest = -2,230
Transitional Salt Marsh
2025/Low = --588 acres; 2025/High = -148 acres; 2025/Highest = +271

Note: clicking on **Salt Marsh** under **Filter Results by Habitat(s) of Interest** will narrow results to only salt marsh.

Question 1-B: What habitat changes can be expected for Wachapreague between now and 2100 in a business-as-usual scenario?

Answer: Salt marsh encroachment and conversion of **Developed Dry Land** to **Flooded Developed Dry Land**.

Question 2-B: What areas of the town are most susceptible to habitat change as a result of SLR? What kinds of nature-based solutions (e.g., marsh enhancement, seagrass beds, oyster reefs) could be implemented to reduce risks?

Answer: The waterfront and areas near creeks or streams (to the north and south). Enhancement of existing marshes or use of oyster castles may prevent marsh loss and migration into **Undeveloped Dry Land** and **Developed Dry Land** within the town.

Question 3-B: Are there scenarios in which the surrounding area may change substantially, including loss of access routes, despite adaptation by the town?

Answer: Yes. Beginning in 2065 under the **Low** or **High SLR Scenarios**, or as early as 2040 under the **Highest SLR Scenario**, low areas to the west, south, and north of the town begin to change from **Undeveloped Dry Land** to marsh habitats which may affect access or other aspects of the town's prosperity.

Question 4-B: Using the Click to Draw an Area button, trace a general outline of the Wachapreague town boundaries. How does the acreage of Undeveloped Dry Land change between Scenario Years under the High SLR Scenario? How many acres of Developed Dry Land are at risk by Scenario Year 2100 under various SLR Scenario options?

Answers:

Undeveloped Dry Land: 2025 = -2 acres; 2040 = -7 acres; 2065 = -24 acres; 2100 = -125 acres

Developed Dry Land: 2100/Low = 21 acres; 2100/High = 59 acres; 2100/Highest = 67 acres

Coastline Change

Question 1-A: What do historical shoreline data tell us about the overall Long Term and Short Term change rates for the Virginia barrier island chain?

Answer: The historical shoreline data indicate that the **Long Term** and **Short Term** change rates vary by island and may depend on a number of factors. Overall, the trend is landward movement (erosion) in both **Change Rate Types**.

Question 2-A: What percent of this barrier island is experiencing Seaward Movement and Landward Movement in each of the Change Rate Types?

Answers:

Assateague Island

Long Term = 54% Seaward/46% Landward; Short Term = 18% Seaward/82% Landward

Wallops Island

Long Term = 30% Seaward/70% Landward; Short Term = 30% Seaward/70% Landward

Assawoman Island

Long Term = 0% Seaward/100% Landward; Short Term = 0% Seaward/100% Landward

Metompkin Island

Long Term = 0% Seaward/100% Landward; Short Term = 34% Seaward/66% Landward

Cedar Island

Long Term = 1% Seaward/99% Landward; Short Term = 0% Seaward/100% Landward

Parramore Island

Long Term = 7% Seaward/93% Landward; Short Term = 0% Seaward/100% Landward

Hog Island

Long Term = 41% Seaward/59% Landward; Short Term = 19% Seaward/81% Landward

Cobb Island

Long Term = 0% Seaward/100% Landward; Short Term = 2% Seaward/98% Landward

Wreck Island

Long Term = 0% Seaward/100% Landward; Short Term = 46% Seaward/54% Landward

Ship Shoal Island

Long Term = 0% Seaward/100% Landward; Short Term = 20% Seaward/80% Landward

Myrtle Island

Long Term = 0% Seaward/100% Landward; Short Term = 0% Seaward/100% Landward

Smith Island

Long Term = 0% Seaward/100% Landward; Short Term = 0% Seaward/100% Landward

Fishermans Island

Long Term = 73% Seaward/27% Landward; Short Term = 61% Seaward/39% Landward

Question 3-A: Where is the Short Term rate of change the greatest for both erosion and accretion on the island you selected? Hint: Look for very long transect lines.

Answer: This will vary depending on the island selected. For example, Wreck Island is eroding most at its north end and accreting most at its south end.

Question 1-B: What is the predicted Rate of Change Difference estimate for the south end of Assateague Island under various SLR and wave climate change scenarios?

Answer: Low/(all **Wave Climate Change Scenarios**)= -7 to -5 meters/year
High/(all **Wave Climate Change Scenarios**) = -11 to -9 meters/year
Highest/(all **Wave Climate Change Scenarios**) = more than -11 meters/year

Question 2-B: What effect would beach nourishment on Wallops Island have on Assateague Island Rate of Change Difference estimates?

Answer: The **Rate of Change Difference** estimates of Assateague Island change very little in response to the Wallops Island **Nourishment Scenario**.

Question 3-B: Based on the data presented in the View Future Scenarios dataset, would moving the current Assateague Island beach access routes farther north be an appropriate adaptation strategy?

Answer: Based on the results presented in the **Coastline Change** app, the south end of Assateague Island will be subject to relatively high **Rates of Change Difference** when compared with areas to the north. Therefore, relocating current beach access routes further north would be an appropriate adaptation strategy.

Living Shoreline Explorer

Question 1-A: Identify the shorelines on Upshur Neck that are suitable for marsh vegetation enhancement or marsh vegetation enhancement with structure. Where are these areas located?

Answer: Most of the shoreline on the Machipongo River side is suitable, as well as the southern part of the Upshur Bay shoreline.

Question 1-B: Where along the western shoreline of Upshur Bay is the marsh most vulnerable?

Answer: Marshes along the southwestern portion of Upshur Bay are most vulnerable.

Question 1-C: Along the southwestern shoreline of Upshur Bay, where overall vulnerability is Very High, which individual variables are High or Very High?

Answer: Marsh vegetation height, marsh elevation, and storm surge all score high or very high in this area.



COASTAL RESILIENCE

COASTALRESILIENCE.ORG

Coastal Resilience is a program led by The Nature Conservancy to examine nature's role in reducing coastal flood risk. The program consists of an approach, a web mapping tool, and a network of practitioners around the world supporting hazard mitigation and climate adaptation planning.

APPROACH

The approach consists of four critical steps:



1. Assess Risk and Vulnerability to coastal flood hazards including current and future storms and sea level rise



2. Identify Solutions for reducing flood-related risk across social, economic and ecological systems



3. Take Action at priority conservation and restoration sites to help communities identify and implement nature-based risk reduction solutions



4. Measure Effectiveness to ensure that efforts to reduce flood risk while increasing community and ecosystem resilience are successful

Coastal Resilience projects around the U.S., encompassing 17 coastal states, in the Caribbean, across Mexico and Central America, and a global effort enable planners, government officials, and communities to develop risk reduction, restoration and resilience strategies.



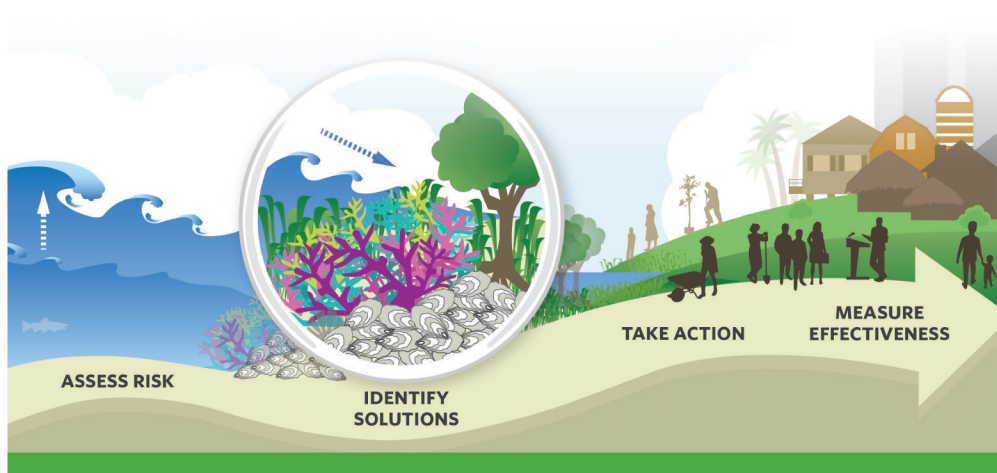
The program has trained and supported over 100 communities around the world on the uses and applications of Coastal Resilience, focusing on the identification of nature-based adaptation and risk mitigation solutions.

SOLUTIONS & ACTIONS

The best solutions may depend less on modern infrastructure, and more on rethinking how we value existing natural resources. By providing information on coastal hazards, socio-economics, habitats and ecosystems, Coastal Resilience explores nature-based solutions in:

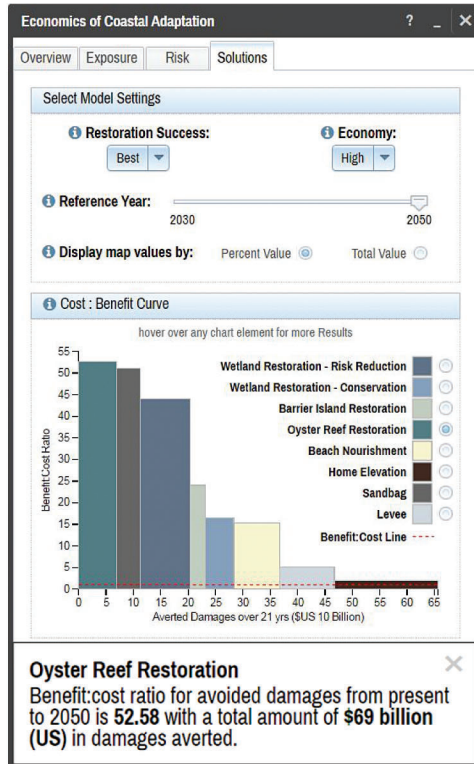
- protecting or restoring habitats as buffers to flooding in front of coastal communities
- developing hybrid approaches that link natural and built defense structures
- accommodating the landward movement of tidal marshes and mangroves as sea levels rise
- designing restored oyster and coral reefs as breakwaters that reduce wave height and power
- removing incentives to build in high-risk areas

The science of nature-based solutions in reducing coastal flood risk is growing rapidly; a Coastal Resilience communication and decision support tool examines when and where they are most effective.



MAPS & APPS

An innovative web-mapping tool consists of a data-viewing platform and web apps designed to engage key stakeholders and provide decision support.



The Coastal Resilience tool allows users to:

- view potential impacts of sea level rise, surge from storms and hurricanes, and inland flooding
- combine coastal habitat and exposure with socio-economic data to identify where habitat management may most reduce risks
- examine natural and built coastal defense strategies
- compare risk and vulnerability indicators across countries

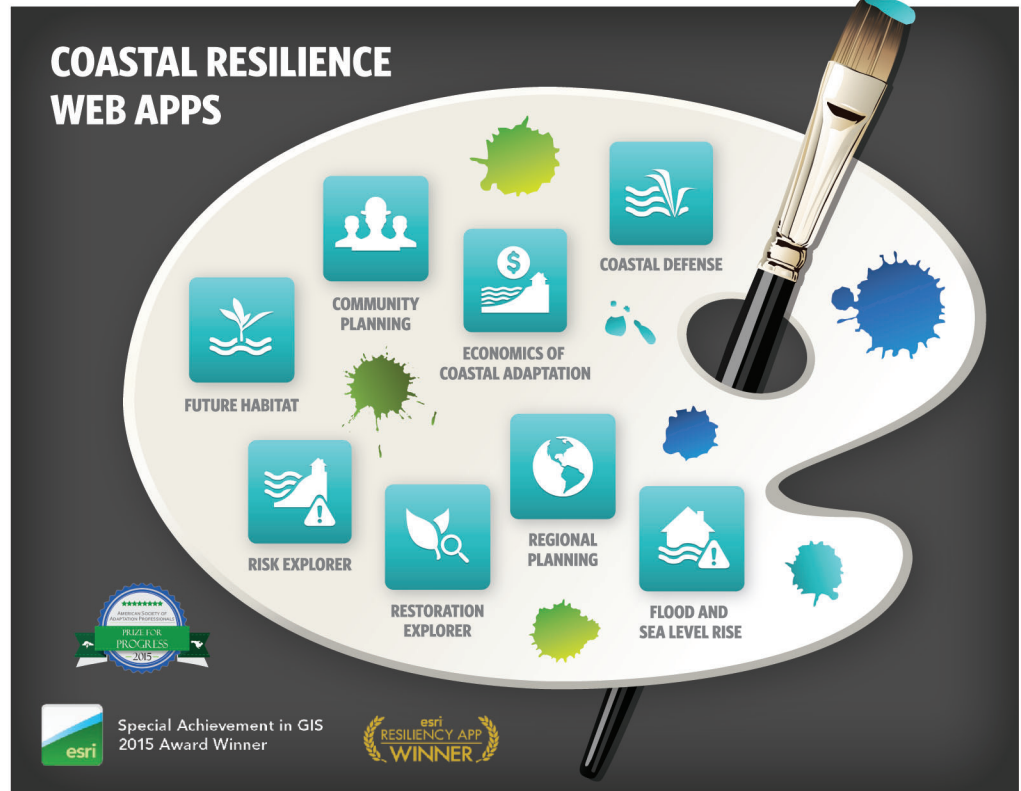


Web apps are customized to meet a specific need, whether a coastal management policy, post-storm disaster decision-making, community assessment, hazard mitigation plan or cost effectiveness evaluation.

NETWORK

Coastal Resilience practitioners are collaborating with engineering firms, the reinsurance sector, aid groups and multi-national institutions to find viable nature-based solutions to climate change, for instance:

- guiding Connecticut's sea level rise policy
- developing a cooperative agreement with the U.S. Navy to actively manage strategic retreat of a naval base in Southern California
- assessing social-ecological vulnerability and prioritizing mangrove and coral reef restoration with the Red Cross in Grenada
- determining the costs and benefits of natural and built infrastructure with SwissRe in the Gulf of Mexico



Contact us at coastalresilience@tnc.org, discover the tool at maps.coastalresilience.org, and follow us @CoastResilience

PARTNERS INCLUDE:

International Federation of Red Cross and Red Crescent Societies

The Nature Conservancy
Protecting nature. Preserving life.

USGS
science for a changing world

Alliance Development Works

UNITED NATIONS UNIVERSITY
UNU-EHS
Institute for Environment and Human Security

natural capital PROJECT

ISR

AFPP

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Global Disaster Preparedness Center

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

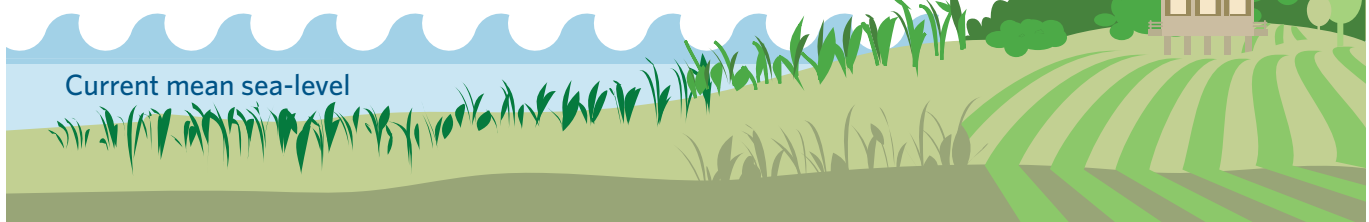
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Flood & Sea-Level Rise App: Storm Surge Fact Sheet

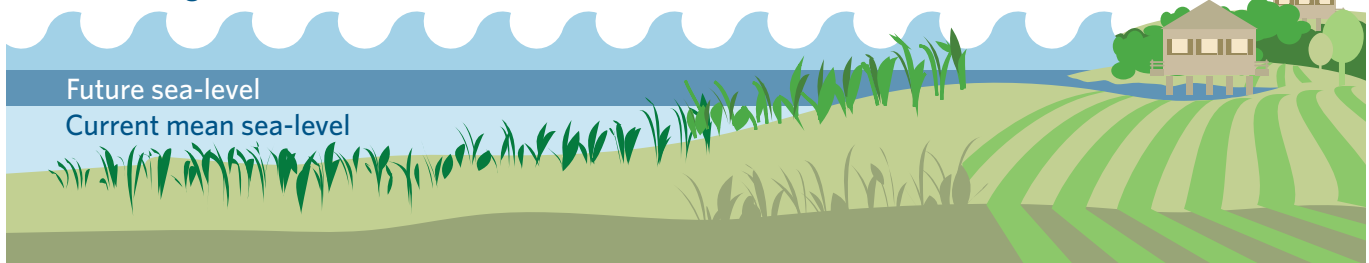
VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

Storm Surge: Current and Future Mean Sea-level

Storm surge



Storm surge



What is the Storm Surge part of the Flood & Sea Level Rise App?

The Storm Surge module in the Flood & Sea Level Rise app in the *Coastal Resilience* tool shows the potential effects of sea-level rise on wind- and wave-driven storm surge along Virginia's Eastern Shore. Both potential modeled depths and estimated economic losses due to projected storm surge are available in the app module.

Multiple theoretical hurricanes and one historic nor'easter were modeled in the app module. The theoretical storms were selected from the Federal Emergency Management Agency's (FEMA) Flood Insurance Study database. The selected storm scenarios include a variety of storm parameters and tracks to capture a range of potential surge conditions in areas of interest identified by community stakeholders. In addition, FEMA's Hazus model, a nationally standardized methodology that estimates potential economic losses due to flood hazards, was run with the storm surge model results.

Who should use it?

Planners and managers can use this app to visualize the potential future risk of storm surge in response to sea-level rise on towns, homes, property, and critical built infrastructure like roads and utilities, as well as coastal habitats. This information helps support planning and decision-making related to hazard mitigation, emergency services, storm water management, land use and conservation.

How does it work?

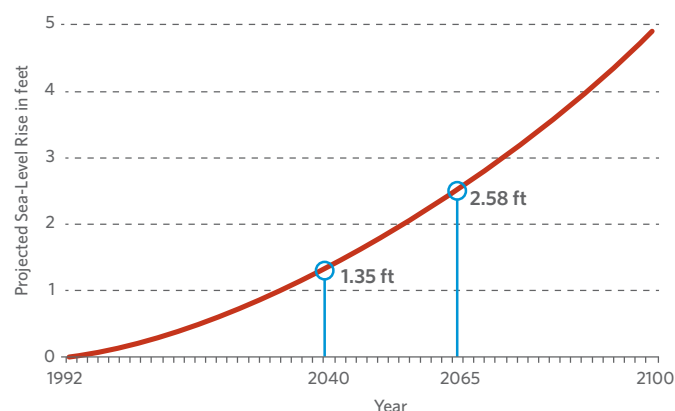
The app shows the potential maximum storm surge water depth and estimated economic losses for multiple modeled storms for three intensity categories and one historic storm defined, as follows:

- **Low Intensity** includes three Category 1 hurricanes with maximum winds of 80 mph.
- **Moderate Intensity** includes a combined total of six Category 1 and 2 hurricanes with maximum winds between 85 and 110 mph.

- **High Intensity** includes a combined total of seven Category 2 and 3 hurricanes with maximum winds between 95 and 115 mph.
- **Nor'Ida** shows the modeled storm surge generated by that particular storm, which occurred in 2009.

All storms were modeled for current (2015), 25-year (2040) and 50-year (2065) sea-level rise scenarios using the projected “high” sea-level rise curve based on the 2012 National Climate Assessment and corrected for local land subsidence by the Virginia Institute of Marine Science.

The sea-level rise scenarios selected to model with storm surge, (feet above baseline)



What are strengths and limitations?

The app demonstrates that surge does not respond uniformly in response to sea-level rise as commonly portrayed by simplistic “bath tub models”, but rather, is influenced by topography, bathymetry, and land cover in addition to sea-level rise. Simply stated, a given sea level rise will not affect all places equally. Users can see these differences in the app by clicking on the absolute difference (in feet) or percent difference options.

All the storm surge modeling was done based on mean tide level. Since the purpose of the app is to convey how wind- and wave-driven surge will be affected by rising sea levels, tides are not needed to evaluate the sensitivity of surge to sea level. The app allows users to visualize surge-only results and to view the local tidal amplitude for locations throughout the study area. Importantly, actual water levels may be higher or lower based on tidal conditions at the time of the surge. The modeled storms in the app do not have a probability of occurrence associated with them. However, subjectively speaking, a low-intensity storm has a higher probability of occurring in any given year than a high intensity storm. Also, the storms were randomly generated and, therefore, do not share the same track, which results in varying flooding potential for seaside versus bayside. Finally, uncertainties inherent in the economic loss estimates may result in significant differences between the modeled results and the actual economic losses following a specific flood event.

How is the app being used?

The Storm Surge module of the Flood & Sea Level Rise app is currently being used by Accomack-Northampton Planning District Commission to update the Eastern Shore Hazard Mitigation Plan.

Who developed it?

The Storm Surge module of the Flood & Sea Level Rise app was developed through a partnership between [The Nature Conservancy](#), [Arcadis](#) and the [Virginia Coast Reserve Long-Term Ecological Research Program](#) with input from local community stakeholders on Virginia’s Eastern Shore. Economic loss data were developed with guidance from the [FEMA Hazus team](#).

For general info about the Virginia Eastern Shore *Coastal Resilience* project: coastalresilience.org/virginia

To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: maps.coastalresilience.org/virginia/

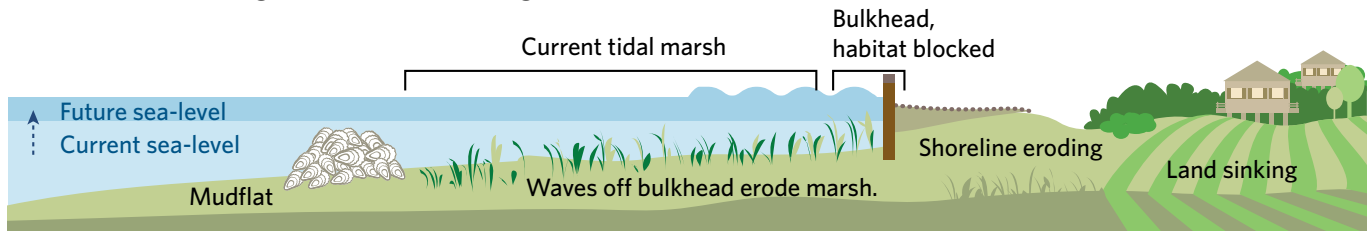
For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565



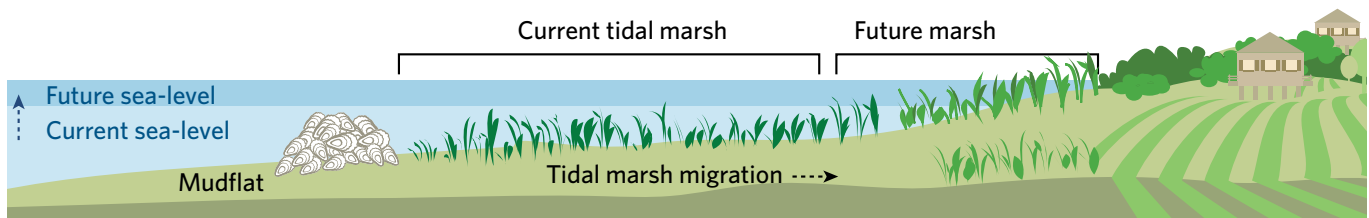
Future Habitat App Fact Sheet

VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

Future Habitat Changes: Landward Marsh Migration Scenarios



Tidal marsh migration blocked as sea-level rises.



Tidal marsh able to migrate landward as sea-level rises.

What is the Future Habitat App?

The Future Habitat app in the *Coastal Resilience* tool shows how the size and distribution of tidal marshes and other coastal habitats on the Virginia Eastern Shore may change in response to future projected sea-level rise scenarios. Tidal salt marshes connected to the mainland have the ability to migrate landward as sea-level rises. This depends on several factors including the elevation of the marsh, the rate of sediment accretion, the rate of sea-level rise, and existing barriers to migration in the landscape (e.g., bulkheads, roads).

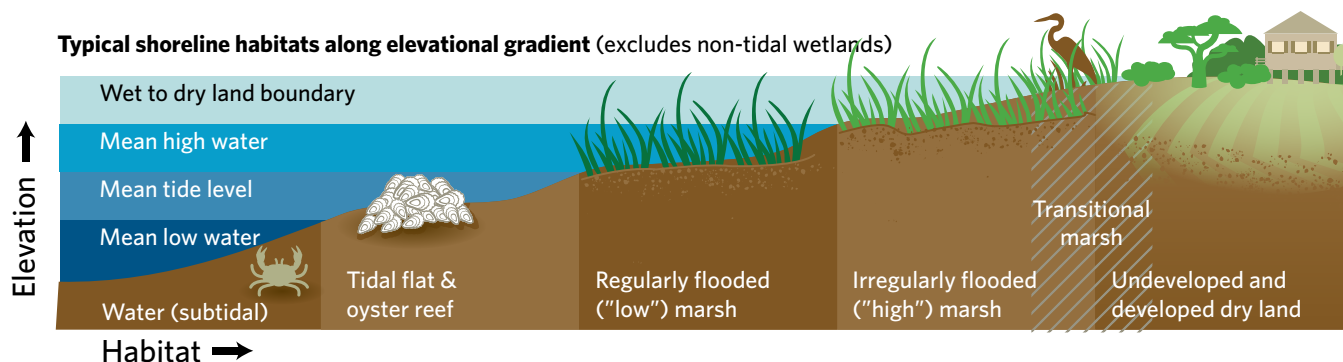
Who should use it?

Planners, managers and property owners can use this app to visualize general trends in the distribution and location of marsh habitat in response to sea-level rise. This information helps support shoreline management, hazard mitigation planning, land use planning and restoration plans. However, this app is not appropriate for local siting or permitting decisions without gathering more site-specific information.

How does it work?

The app displays results generated from the Sea Level Affecting Marshes Model (SLAMM) that incorporates elevation, land cover, and wetland extent with locally-derived empirical data on tides, accretion and erosion rates to predict where tidal marshes may migrate upland in response to changes in sea-level over time. Relative sea-level rise scenarios are based on the low, high and highest projections from the 2012 National Climate Assessment that have been adjusted for local land subsidence rates by the Virginia Institute of Marine Science. For each of the three sea-level rise curves, the model was run for the following years: 2025, 2040, 2065, and 2100.

In addition to visualizing various scenarios on a map, results can be filtered for a user-defined area using the "Click to Draw an Area" tool or by habitat types of interest. Charts and tables are generated to show both the percent and absolute change (acreage) in habitat types for selected relative sea-level rise scenarios compared to current condition.



What are the strengths and limitations?

Multiple sources of unquantified uncertainty exist in SLAMM results concerning the future rates of sea-level rise, as well as local rates of accretion. The Future Habitat app should be considered as a general representation of how tidal marshes may respond to sea-level rise, with the understanding that actual changes in coastal wetlands are complex and difficult to predict.

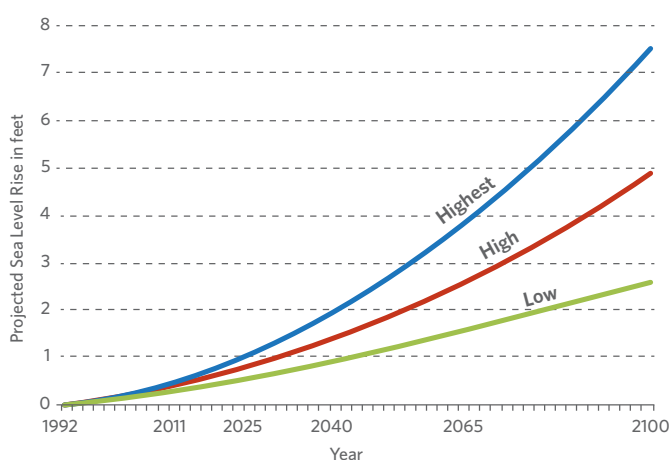
Further, SLAMM is designed to model mainland marsh migration that is driven largely by accretion of sediment, whereas barrier islands and back barrier marshes migrate in response to a more complex suite of geophysical processes. Therefore, SLAMM cannot reliably predict the future extent and location of barrier islands and back-barrier marshes. Consequently, Atlantic barrier islands and inlets are modeled separately and the results are presented in the future scenarios portion of the Coastline Change app.

How is the app being used?

The Future Habitat app is being used by natural resource managers on the Eastern Shore to target areas for conservation and restoration activities. In addition, the Accomack-Northampton Planning District Commission is providing information from the Future Habitat app to local planning commissions for updates to county comprehensive plans.

Relative Sea-Level Rise Projections Modeled in Future Habitat app (in feet) from 2011 baseline.

	2025	2040	2065	2100
Low	0.23	0.59	1.22	2.29
High	0.34	0.97	2.20	4.51
Highest	0.48	1.41	3.32	7.07



Who helped develop it?

The Future Habitat app was developed through a partnership between Warren-Pinnacle Consulting, Inc., the Virginia Coast Reserve Long-Term Ecological Research Program, the University of Southern Mississippi, and The Nature Conservancy.

For general info about the Virginia Eastern Shore *Coastal Resilience* project: coastalresilience.org/virginia

To access the Virginia Eastern Shore *Coastal Resilience* mapping portal: maps.coastalresilience.org/virginia/

For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565



Coastline Change App: Historical Data Fact Sheet

VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

Historical shoreline change along a Virginia Barrier Island



Illustration: © Vin Reed/Vin Design

What is the Historical Data module in the Coastline Change app?

Beaches and barrier islands are dynamic systems that move constantly in response to processes that erode, transport, and deposit sand. The Historical Data module of the Coastline Change app in the *Coastal Resilience* tool uses a robust dataset that covers 165 years of observed shoreline changes along the Virginia barrier islands (including Assateague Island), allowing users to explore how much and in which direction these shorelines have changed over this time period.

Who should use it?

Organizations and agencies who manage barrier islands, research scientists, local governments, and citizens who want to learn about the dynamic nature of Virginia's barrier islands may benefit from viewing the historical data that provides useful context for understanding the barrier islands as they continue to evolve in the future.

How does it work?

The Historical Data module in the Coastline Change app allows users to view two kinds of data: (1) the geographic location of past shorelines, and (2) the calculated change rates (in meters per year) for shorelines over short- and

longer-term time ranges. Users can explore the historical shorelines by playing an animation that illustrates sequential shoreline locations over the years for which data exist or by manually selecting multiple shorelines to display side by side.

Users can also view shoreline change rates at multiple spatial and temporal scales. Shoreline change was measured at transects spaced 50 meters apart and approximately perpendicular to the shoreline. **Long-term rates of change** are based on an analysis of all historic shorelines from the earliest to most recent dates. Sometimes, a change in the long-term trend is observed. Where this is the case, a **short-term rate of change** has been calculated from the time the change occurred to the most recent date available.

When viewing change rate data in the app, the percent seaward and landward movement is summarized at the scale of the entire Virginia Eastern Shore or of individual islands. Negative rates of change indicate **landward movement** of the shoreline (erosion) and positive rates of change indicate **seaward movement** (accretion). Shorelines can switch from landward to seaward movement, or vice versa, over time, leading to a short-term rate of change that may differ from the long-term rate.

Additional data about shoreline trends are available for individual transects on the islands, including the rate of change in meters per year, the time span of the earliest and latest date, and the number of shoreline positions measured to calculate the change rate.

What are strengths and limitations?

The historic shoreline data presented in the Coastline Change app are among the most comprehensive and long-term datasets describing shoreline change anywhere in the world, including 38 unique years of data spanning 1850-2014. However, it is important to recognize that quantifying shoreline positions is only a proxy for how coastal processes such as sea-level rise, storms and sediment dynamics impact barrier islands and cause them to move in space and time. While a good proxy for island movement—and a proxy used by many federal and state coastal management agencies—shoreline change rates do not provide correlations with, or information about, the coastal processes that produce the shape changes to islands over time.

In addition, there are sources of error in these data. Digitizing shorelines from paper maps may introduce more error into shoreline rate of change calculations

than digitizing shorelines from aerial photos because the on-ground survey techniques did not always use the same techniques or the same sea-level datum. Aerial photographs (or orthophotographs) provide actual imagery of a beach, but contain potential distortion error. Fortunately, the amount of error introduced into shoreline rate of change calculations by comparing different shorelines decreases as the amount of time between the earliest (oldest) recorded shoreline and latest (most recent) recorded shoreline increases.

Who developed it?

The database for the Historical Data module of the Coastline Change app was funded by National Science Foundation Research Opportunity Awards through the University of Virginia's Long-term Ecological Research Program and developed by a partnership between Randolph-Macon College and the University of Mary Washington. The app design and functionality was developed by a partnership among Randolph-Macon College, University of Mary Washington, The Nature Conservancy, NASA-Wallops Flight Facility, National Park Service Assateague Island National Seashore, U.S. Fish and Wildlife Service Chincoteague National Wildlife Refuge, the Accomack-Northampton Planning District Commission, and the Virginia Coast Reserve Long-Term Ecological Project.

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Coastline Change App: Historical Data Supplemental Information

VIRGINIA EASTERN SHORE COASTAL *RESILIENCE* TOOL

Coastline Change App: Historical Data Supplemental Information

VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

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Introduction

Shorelines are the intersection of land and sea and move constantly over sandy coastal environments such as beaches and barrier islands. Shorelines move (or migrate) in response to oceanographic and geologic processes that operate over a variety of time scales. On one end of the time spectrum, daily waves and the currents resulting from the change in tides move sediment (sand) that can make shorelines move. On the other end of the time spectrum, changes in sea level (rise or fall) and/or the supply of sand (increases or decreases) influence the direction and rate that shorelines move.

The current state of scientific knowledge does not enable a cause-and-effect analysis of shoreline movement (or migration). In other words, we can measure the rate at which shorelines move, but cannot conclusively explain “why?” they move. Consequently, coastal scientists, land managers and planners use the rates of shoreline movement (in meters or feet per year) as a proxy for (or representation of) the processes that erode, transport and deposit sand and to assess the mobility of beaches and barrier islands. In other words, measurements of the rate and direction of shoreline movement (i.e., migration) provide insight into the mobility of beaches and barrier islands and into the processes that are responsible for causing shorelines to move.

Description of Shoreline Change Database

The data used to calculate the rate and direction of shoreline movement over a particular time period come from a variety of sources. These sources include aerial photographs taken perpendicular to the land surface (orthophotographs), beach surveys on the ground using Global Positioning System (GPS) technology or other survey technology (e.g., beach profiles), historical maps and T-sheets (nautical charts), and, more recently, airborne Light Detection and Ranging (LiDAR) technology. Most scientists agree that the high water line (HWL), i.e., the boundary between the wet and dry parts of a beach, is the best representation of a shoreline. However, maps, T-sheets, and LiDAR can use other reference lines as the shoreline (e.g., mean high water [MHW]; mean low low water [MLLW], etc.). Fortunately, the amount of error introduced into shoreline rate of change calculations by comparing “different” reference shorelines decreases as the amount of time between the earliest (oldest) recorded shoreline and latest (most recent) recorded shoreline increases.

For the Virginia barrier islands south of Assateague Island, a subset of 38 individual (unique) years of partial or complete shorelines spanning the time period 1850-2014 was used for analyzing the rate of shoreline change. For Assateague Island, 34 shorelines spanning 1849-2014 were used. These shoreline data were developed “in-house” or came from well-known repositories of shoreline data, including the University of Virginia, the United States Geological Survey, and the National Park Service.

Shoreline Change Analysis

Shorelines from all sources were entered into sophisticated software programs such as Geographic Information Systems (GIS) software which position them accurately in space (on a map). An additional software program (Digital Shoreline Analysis System, [DSAS]) determined each shoreline's distance away from a baseline (in meters) at shore-perpendicular transects spaced 50 meters apart along the coast (Figure 1).

The transects are "cast" every 50 meters at right angles from the baseline which is situated offshore and approximately parallel to the shoreline. At each transect, the distance from the baseline to the intersection of each shoreline provides the data necessary to calculate a shoreline rate of change statistic and direction of movement (i.e., seaward or landward) using a linear regression (or best fit line) analysis (Figure 2).

Figure 1:

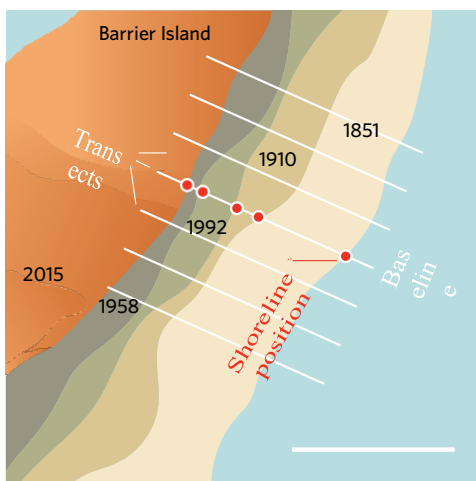
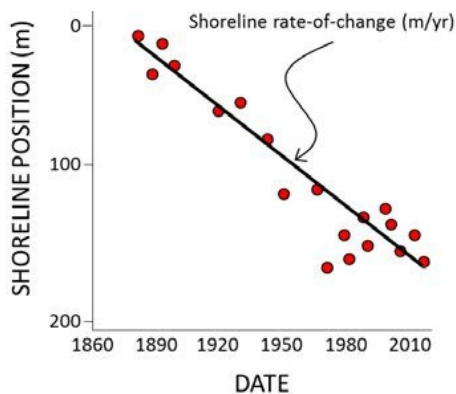


Figure 2:



While DSAS calculates shoreline rates of change, an additional program was used to calculate both rates of change, any short-term changes to long-term rates of change, and the direction of shoreline movement (and possible changes in direction).

This method, known as the Minimum Description Length (MDL), assesses the complexity of successively increasing functions that best fit the data against the accuracy of each function to determine if either one, two, or no changes in the long-term trend occurred:

$$MDL_k = MSE_k + \frac{\ln(N) \times K \times \sigma_p^2}{N}$$

Accuracy \longleftrightarrow Coplexity

WHERE...

MSE_k is mean squared error

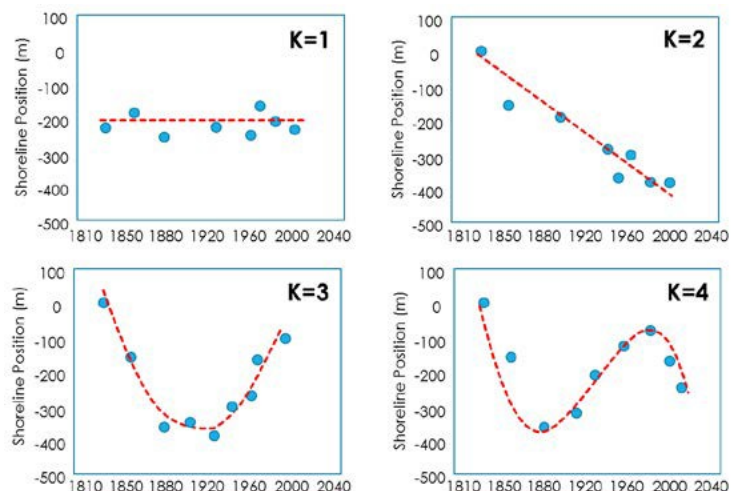
N is the number of positions

K is the number of parameters in the model

σ_p^2 is the given prior noise variance

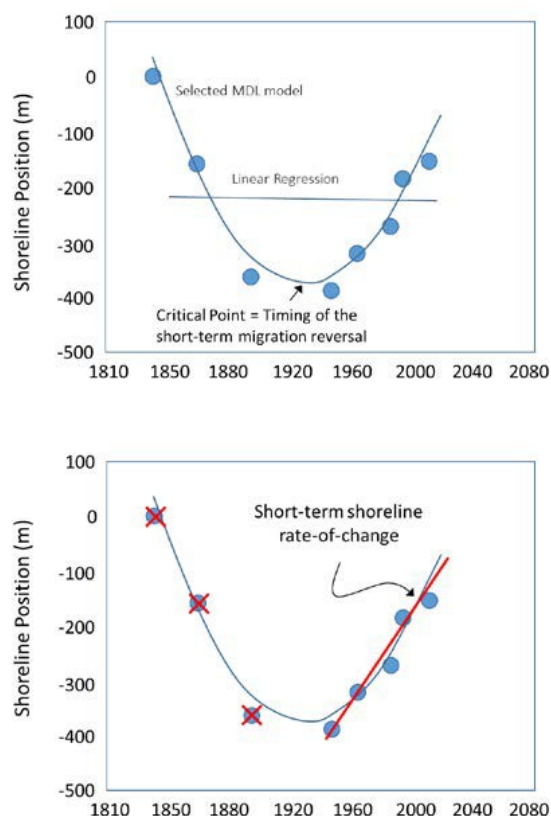
The minimum value of that analysis determines whether a constant (i.e., stable shoreline with no landward or seaward migration), linear (i.e., trend that does not change), quadratic (i.e., one short-term change in the long-term trend occurred) or cubic (i.e., two short-term changes in the long-term trend occurred) function best represents the historical shoreline migration history (Figure 3).

Figure 3:



If one short-term change occurred to the long-term trend, the MDL method uses a mathematical method to determine when the historical trend change occurred (called the critical point, which occurs when the first derivative of a function is equal to zero) and the rate-of-shoreline change after the shoreline migration reversal occurred (Figure 4). If two short-term changes have occurred to the long-term trend, only the shoreline position data of the most recent reversal were used to calculate a short-term linear regression rate of change.

Figure 4:



Using this approach, both long-term and shorter term change rates (when $K=3$ or 4) using linear regression are represented in the Coastline Change app for each individual transect along the Virginia barrier islands and Assateague Island. Additionally, the Coastline Change app provides info on the number of shoreline positions used in both the long- and short-term calculations as well as the earliest and latest date (time span) used to calculate the long-term trend.

Overall Conclusions from Historic Shoreline Database

The Virginia barrier islands constantly change in area (two dimensions) and volume (three dimensions) in response to sediment erosion, transportation and deposition resulting from coastal processes that affect the beach synergistically and operate over various temporal and spatial scales. These processes include sea-level changes, storm surges, storm waves, tidal inlet migration, tidal currents, and non-storm ("everyday") waves.

Shoreline movement along the Virginia barrier islands has had a complex history during the past 165 years. Individual islands have rotated clockwise and counter-clockwise, moved entirely landward or moved simultaneously both landward and seaward along their lengths. Furthermore, these patterns have changed over time. For example, most of the shorelines have had one or two short-term reversals in their longer-term trends. Preliminary analyses of these data show that nearly 91% of the Virginia barrier islands have experienced two changes in their long-term shoreline migration trend history, a little more than 6% of the shorelines have migrated linearly (monotonically or without a reversal) and only 1.5% have been stable. Of those shorelines that experienced a short-term trend reversal, the most recent change apparently occurred in the late 1880s toward landward migration. These data also show that an "arc of (perpetual) erosion" along the northern 35 km of the Virginia barrier islands (Wallops Island to Cedar Island) has apparently extended southward to Parramore Island during the past decade.

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Coastline Change App: Future Scenarios Fact Sheet

VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

What is the Future Scenarios module of the Coastline Change App?

The Future Scenarios module of the Coastline Change app in the *Coastal Resilience* tool provides results from a modeling effort that allows users to explore how climate change combined with management actions over a 50-year time frame may affect the rates of shoreline change along a simulated Virginia barrier island system. In exploring the Future Scenarios module of the app, you can compare a variety of possible climate change and management scenarios and learn about potential long-term, large-scale coastline and barrier island evolution resulting from these changes.

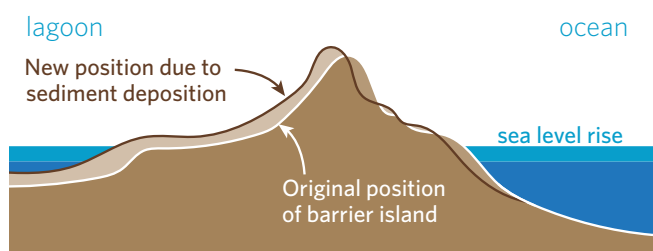
Who should use it?

Organizations and agencies who manage barrier islands, research scientists, and local governments may use the Future Scenarios module in the Coastline Change app to explore different regional climate and nourishment scenarios in order to better anticipate and manage shoreline changes in the future. This information should not be used to identify future shoreline changes for specific locations along the Virginia barrier islands, but rather should be a springboard for additional inquiry and modeling efforts regarding potential local coastline change in the future.

How does it work?

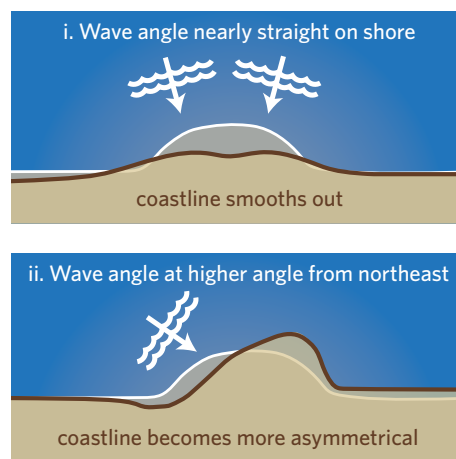
This app enables users to explore 36 different future scenarios of coastline change along a generalized Virginia barrier island system. The scenarios are based on three coastal processes that act alone or in combination to create a shift to the coastline via erosion or accretion of sediment:

- Relative sea-level rise
- Shifts in wave climate
- Beach nourishment



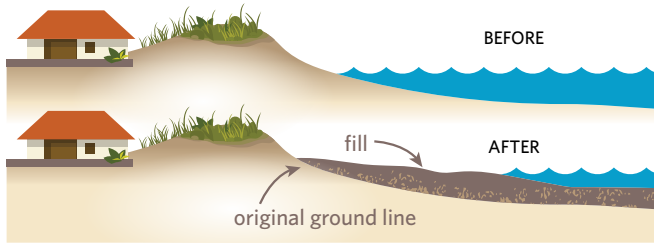
Landward migration of barrier island as sea level rises

▲ **Relative sea-level rise** occurs because of the expansion of oceans due to warming temperatures, the melting of land-based ice, and local rates of subsidence. Accelerated rates of sea-level rise can cause barrier islands to migrate toward the mainland, allowing them to maintain elevation as long as they can get enough sediment.



Shifting wave climate under (i) existing condition and (ii) changing climate scenario

▲ **Shifts in wave climate**, or the average distribution of wave characteristics over many years, affects patterns of coastline change rates. Wave climate includes a number of factors relevant to sediment transport including the angle waves are approaching from and the height of the waves. If storm frequency or intensity changes because of climate change, the influence of waves approaching from different directions may also change, affecting how sediments shift and therefore how coastlines evolve.



Barrier island beach profile before and after nourishment

↑ **Beach nourishment** is a management strategy implemented by people to prevent erosion and beach loss in an effort to stabilize or protect shorelines. Beach nourishment was modeled only for those areas where it has been undertaken in the past (Wallops only) or may be considered in the future (Assateague) based on stakeholder input, **but the selected nourishment scenarios should in no way indicate an endorsement of any management option, either in those areas or elsewhere in the region.**

In this app, you'll be able to explore the modeled effect—alone or combined—of three relative sea-level rise projections, three potential wave climate scenarios, and four beach nourishment scenarios, on the rate of coastline change. The results will show you, along a generalized coastline, whether these scenarios will lead to more erosion and less accretion or less erosion and more accretion along the modeled future shoreline than would be expected to occur in the future under current conditions.

What are the strengths and limitations?

Because of the uncertainty in the environmental variables affecting coastline change, coastal geomorphologists cannot make detailed predictions of where barrier islands will be or what shape they will have in the future. However, numerical modeling allows scientists to take an important step toward determining how certain physical processes may affect the future evolution of barrier islands and the coastline. Modeled future scenarios in the app of a simulated Virginia barrier island coastline are a leap forward in the field of coastal science. However, at this early stage, the results are not yet intended to support decisions but to serve as a springboard for new and additional research and modeling efforts. Lessons learned from this breakthrough model will provide opportunities for next steps in modeling possible coastline and island evolution and advancing the science of coastal geomorphology.

Who developed it?

The Coastline Change app was developed through a partnership between a team of coastal geologists and geomorphologists from [University of North Carolina at Chapel Hill](#), [University of North Carolina Wilmington](#), [Duke University](#), and [Randolph-Macon College](#) (team that performed the modeling work) and staff from [The Nature Conservancy](#), [NASA-Wallops Flight Facility](#), the [U.S. Fish and Wildlife Service Chincoteague National Wildlife Refuge](#) and the [Accomack-Northampton Planning District Commission](#).

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Coastline Change App: Future Scenarios Supplemental Information

VIRGINIA EASTERN SHORE COASTAL *RESILIENCE* TOOL

Coastline Change App: Future Scenarios Supplemental Information

VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

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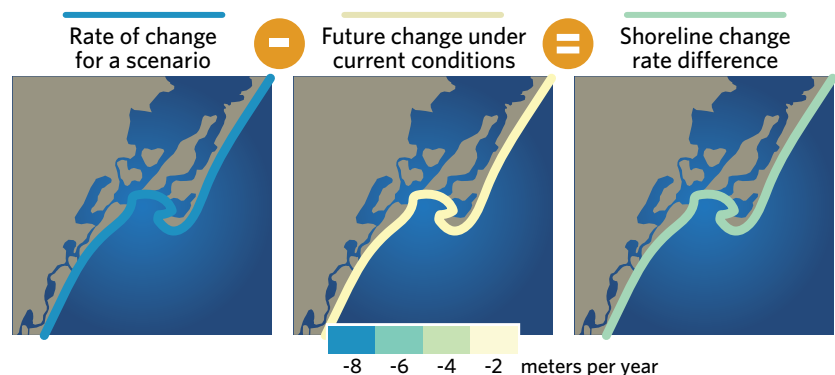
Jonathan Whitley, University of North Carolina Wilmington, Department of Earth and Ocean Science/Center for Marine Science

Overview

A first-of-its-kind model was used to make reasonable estimates of how shorelines might move in the future, along a model coastline that shares some key characteristics with the Virginia coast. To do this, the model extrapolates from the best scientific understanding about processes that contribute to shoreline movement; such as the effect of waves on erosion, transportation and deposition of sand. With more frequent and intense storms expected in the future, waves and currents—in combination with relative sea-level rise (RSLR)—are expected to strongly influence the way that shorelines move. One management strategy employed in response to these changes is the engineered rebuilding of shorelines using a process known as beach nourishment. Wallops Island is one example of a location with a history of using beach nourishment to counter the effects of coastal erosion.

By comparing the difference between the base case of shoreline movement and experimental future scenarios, this app helps identify climate and nourishment scenarios that are likely to cause shifts in the rates of shoreline change. The base case is defined as future change under current climate conditions where relative sea level rises at the rate of 3 mm per year, the wave climate is consistent with the best-known present wave climate, and no nourishment occurs at any location. The results are

presented as the *shoreline change rate difference* (SCRD). The shoreline change rate difference is the 50-year average difference in the rate of shoreline change between the base case and the experimental scenario (which includes a higher rate of RSLR and may include a shift in wave climate or beach nourishment).



Shoreline change rate difference calculation used in model

A negative SCRD indicates that the experimental scenario causes more erosion or less accretion relative to the base case, whereas a positive SCRD indicates that the scenario causes more accretion or less erosion relative to the base case. Although this information cannot be used to identify specific shoreline positions at future points in time, it does support the exploration of different regional climate and nourishment scenarios in order to better estimate and plan for the management of future shoreline changes.

The Selection of Scenarios

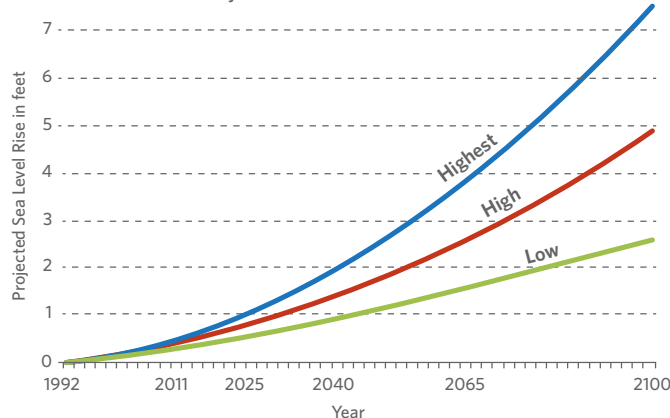
A scenario is a specific combination of potential climate and/or human management changes that might affect shoreline change rates. A total of 36 future scenarios were modeled for the app. These include different combinations of three sea-level rise scenarios, four wave climate scenarios, and three beach nourishment scenarios. The specifics of each scenario are described below.

Description	No. of Scenarios
Sea-Level Rise Only	3
Sea-Level Rise + Wave Climate Change	6
Nourishment + Sea-Level Rise	9
Nourishment + Sea-Level Rise + Wave Climate Change	18
Total	36

A. Relative sea-level rise: Relative sea-level rise scenarios are based on the customization for Virginia, developed by the Virginia Institute of Marine Science, of the 2012 National Climate Assessment. The three sea-level rise scenarios that were modeled were selected by stakeholders and are as follows:

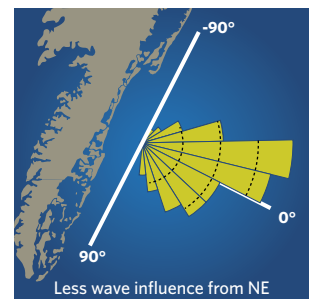
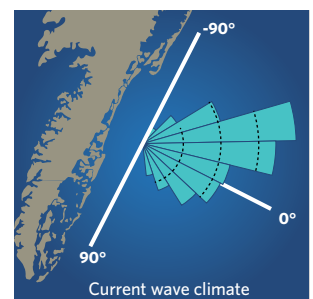
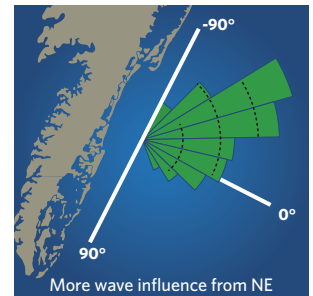
1. The “low” scenario is based on the Intergovernmental Panel on Climate Change 4th Assessment model using conservative assumptions about future greenhouse gas emission (the B1 scenario).
2. The “high” scenario is based on the upper end of projections from semi-empirical models using statistical relationships in global observations of sea level and air temperature. Generally, scientists currently see this as the most likely scenario.

Sea-Level Rise Projections used in Model



3. The “highest” scenario is based on estimated consequences from global warming combined with the maximum possible contribution from ice-sheet loss and glacial melting (a practical worst-case scenario based on current understanding).

B. Wave Climate: Climate change is likely to lead to increases in the frequency of the most intense hurricanes. In addition, the frequency and magnitude of winter storms is likely to shift in a changing climate. This will affect future patterns of coastal erosion and accretion by altering the prevailing wave climate (specifically wave heights and angles of approach). Although it is not clear how wave climate may change in the future, two potential future wave climates were considered to provide an understanding of how changes in storm intensity may alter patterns of shoreline change along the Virginia Eastern Shore. The modeled wave climates represent changes to the present wave climate that involve either a greater or lesser proportion of wave influence approaching from the northeast. The three wave climate scenarios modeled in the app are:



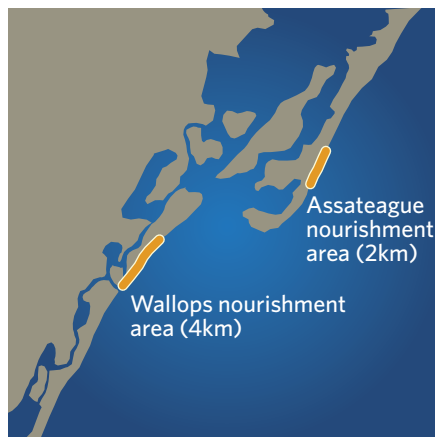
Wave climate angles of approach for three scenarios used in model

1. No change; present wave climate stays the same in future.
2. Shift to northeast by 15 degrees from present wave climate.
3. Shift to southeast by 15 degrees from present wave climate.

C. Beach Nourishment:

Based on stakeholder input, two zones corresponding roughly to sites on Assateague Island and Wallops Island were identified as areas where beach nourishment may take place in the future. To estimate the effects of nourishment, the model considered a 2 km stretch of beach as the nourishment zone for Assateague Island and a 4 km stretch for Wallops Island. The model assumes that (1) nourishment is done at just the right long-term rate to maintain the shoreline position, (2) the sand used for nourishment comes from far enough away that removing it doesn't affect the coastal response, and (3) nourishment will continue for the entire model run regardless of cost. These projections represent hypothetical future scenarios which are intended to enhance the stakeholders' understanding of the potential evolution of the coastline in response to climate change and management interventions. Beach nourishment was modeled only for those areas where it has been undertaken in the past (Wallops only) or may be considered in the future (Assateague).

However, the modeled projections should in no way indicate an endorsement of any management option, either in those areas or elsewhere in the region.



Suggested zones of existing or potential future beach nourishment used in model

levels on the ocean-side causing a channel to be cut in the seaward direction. Whether an inlet remains open depends on the volume of water flowing into and out of the inlet during the tidal flood and ebb cycles. This process is represented in the model, yet the temporal and spatial resolution of the model experiments do not allow for explicit predictions of where and when inlet openings could occur. At the beginning of each model experiment, the model starts with enough inlets so that the processes that keep inlets open are working at about the same magnitude as they currently do on the Virginia coast (note: the specific loca-

tions of initial inlets are generalized and don't correspond to the present-day inlet locations). At the end of each 50-year experiment, island height is measured at each shoreline location. Areas with critically low elevations at the end of the 50-year experiment, and which are in excess of the number of original open inlets, are deemed as coastal areas with enhanced potential for inlet opening.

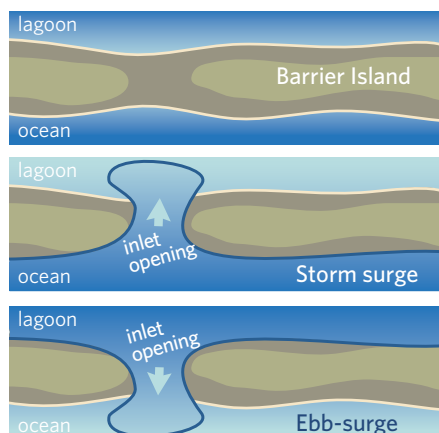
Major conclusions for each group of scenarios

The specific locations mentioned in the summaries below are referenced only for the purpose of discussion. The scenarios presented in the module were considered for the model coastline that shares some key characteristics with the Virginia coast, not for the actual Virginia coastline. Additional research will be necessary to confirm the summary statements for the specific locations mentioned below.

Potential Inlet Openings

Tidal inlets are openings in the shoreline connecting the ocean to bays, lagoons, or marshes. On low-lying barrier

islands, inlets may form during storms when storm surge overtops island dunes and erodes sediment from the top of the barrier island, effectively cutting a channel, or when water levels on the bay side of barrier islands become higher than water



Barrier island inlet formation process

Relative Sea-level Rise only

- In all scenarios, accelerated sea-level rise results in more erosion or less accretion compared to the base case scenario (which includes only 3 mm/yr relative sea-level rise). Some areas respond to sea-level rise more dramatically than other areas. For example, in the model, the south end of Assateague Island is more responsive to increased sea-level rise compared to its surroundings, while the Wallops Island area is less responsive to increased sea-level rise. These results indicate that future rates of shoreline change are likely to be sensitive to the rate of relative sea-level rise.
- The model does not indicate enhanced potential for inlets to open along the simulated coastline under the sea-level rise only scenarios.

Illustrations: © Vin Reed/Vin Design

Relative Sea-Level Rise + Wave Climate Change

- During both wave climate change scenarios, the southern end of Assateague Island is still affected more strongly by accelerated rates of sea-level rise compared to its surroundings.
- In contrast, the southern end of Assateague just north of Fishing Point may be affected less strongly by accelerated rates of sea-level rise compared to its surroundings. This effect is diminished when a lesser proportion of wave influence is from the northeast.
- The Wallops Island area is also affected less strongly by accelerated rates of sea-level rise compared to its surroundings. This effect is diminished when a greater proportion of wave influence is from the northeast.
- The model indicates the enhanced potential for inlets to open in the vicinity of southern Wallops Island when a greater proportion of wave influence is from the northeast at the highest sea-level rise rates.

Nourishment + Relative Sea-Level Rise

- Differences in shoreline change rates resulting from nourishment appear to be limited to within only a couple of kilometers of the nourishment area. This finding is surprising given that previous work suggests that effects of nourishment are often non-local.
- At higher sea-level rise rates, nourishment affects shoreline change rates more dramatically and farther away from the nourishment site than in low sea-level rise scenarios.
- The model does not indicate the enhanced potential for inlets to open along the simulated coastline under the nourishment plus sea-level rise scenarios.

Nourishment + Relative Sea-Level Rise + Wave Climate Change Conclusions

- **Relative sea-level rise is the dominant factor in causing more erosion or less accretion along the coastline.** Although sea-level rise may affect some parts of the coast more strongly than others, these results suggest that, with accelerated rates of sea-level rise, the whole coast will experience more erosion or less accretion, regardless of wave climate shifts.

- **Wave climate shifts affect patterns of erosion and accretion.** Generally speaking, a greater proportion of waves approaching from the northeast is predicted to result in lower rates of erosion near the southern part of Assateague Island and higher rates of erosion in the Wallops Island area. The converse is true for lesser proportions of waves approaching from the northeast. These findings have implications for rates of nourishment needed at each site to maintain a constant shoreline position.
- **Nourishment has a more limited alongshore effect than previously anticipated.** For this area, the nature of the wave climate relative to the shoreline limits alongshore effects of nourishment.
- **The model suggests that there is enhanced potential for inlets to open in the vicinity of southern Wallops and Assateague Islands** under various combinations of wave climate and beach nourishment scenarios at the high and highest sea-level rise rates.

Further Information

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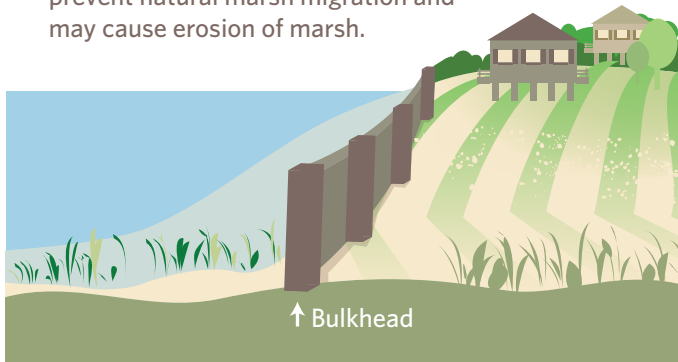
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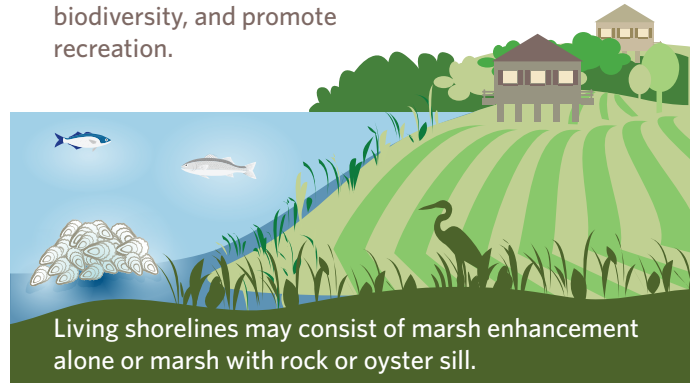
Living Shoreline Explorer App Fact Sheet

VIRGINIA EASTERN SHORE COASTAL RESILIENCE TOOL

Hard shoreline structures like bulkheads prevent natural marsh migration and may cause erosion of marsh.



Living shorelines improve water quality, provide fisheries habitat, increase biodiversity, and promote recreation.



What is the Living Shoreline Explorer app?

The Living Shoreline Explorer app in the Coastal Resilience tool shows recommendations for nature-based shoreline stabilization solutions on the Virginia Eastern Shore. Living shorelines seek to control erosion while maintaining ecosystem functions by buffering waves and preserving the connection between marine and terrestrial environments. Field study in Virginia's coastal bays suggests that marsh vegetation and constructed oyster reefs may offer effective and sustainable long-term shoreline stabilization. Measurements show that constructed oyster reefs are effective at dampening waves at low to moderate water levels while marsh vegetation dampens waves at higher water levels by as much as 91%.

Successful implementation of living shorelines depends on site-specific factors; thus, the Living Shoreline Explorer app also includes a marsh vulnerability assessment that illustrates shoreline risk to erosion and inundation based on several factors including wind wave and boat wake exposure, the elevation and shape of the marsh edge, marsh vegetation characteristics, current rate of sea level rise, and moderate intensity storm surge. This assessment illustrates which bio-geophysical variables are most influential and where physical change is most likely to occur.

Who should use it?

Planners, managers, and property owners can use this app to visualize erosion and inundation risk to shorelines and recommendations for nature-based shoreline stabilization. This information helps support shoreline management, hazard mitigation planning, and restoration plans. However, this app is not appropriate for local siting or permitting decisions without first conducting an in-depth site visit.

How does it work?

The app displays results generated from the Living Shoreline Explorer Model (LSEM) and the Marsh Vulnerability Index (MVI) model. The LSEM is a spatial modeling tool that considers conditions suitable for the use of soft and hybrid shoreline stabilization methods. The model also considers areas where nature-based solutions are not suitable and traditional hardened structures would be more appropriate. Soft stabilization involves treatments like marsh plantings (i.e., marsh enhancement); hybrid stabilization involves treatments like marsh enhancement with rock or oyster sill (i.e., marsh with structures). The LSEM considers five variables: wind wave and boat wake exposure, the elevation and shape of the marsh edge, and marsh vegetation characteristics.

Illustrations: © Vin Reed/Vin Design

The MVI is a spatial modeling tool which determines the vulnerability of tidal salt marshes to erosion and inundation on the Virginia Eastern Shore. The MVI incorporates high resolution spatial data on eight tidal salt marsh erosion variables: wind wave and boat wake exposure, the elevation and shape of the marsh edge, marsh vegetation characteristics, current rate of sea level rise, and moderate intensity storm surge. Variables are assigned a risk value in the range of 1 to 5 in order of increasing vulnerability and combined via a simple spatial computation to reveal erosion and inundation vulnerability (Equation 1). High-risk shorelines have one, or a combination, of the following characteristics: high exposure to wind waves or boat activity, steep and high marsh platform, short or non-existent vegetation, narrow vegetation buffers, high storm surge impacts and rate of sea level rise.

$$MVI = \left[\frac{1}{8} (a * b * c * d * e * f * g * h) \right]^{\frac{1}{2}}$$

Equation 1. MVI equation, where, a = wave exposure, b = marsh elevation, c = marsh edge morphology (i.e., slope), d = vegetation height, e = vegetation buffer width, f = boat wake, g = storm surge, and h = relative sea level rise rate.

What are the strengths and limitations?

Any geospatial computation is dependent on the quality and type of data used. The Living Shoreline Explorer app uses high-resolution spatial data from a variety of sources at different resolutions. The results represent a simplified approach that can be used as a screening tool to assist planners, managers, and property owners in considering nature-based shoreline stabilization options, with the understanding that living shoreline design and placement is complex and requires a site visit for a final determination.

In addition, the MVI and LSEM are designed to predict vulnerability and offer solutions for tidal salt marshes in shallow estuarine environments; therefore, the Living Shoreline Explorer app cannot reliably model the deeper estuarine environment of the Chesapeake Bay or the ocean-facing shoreline of the barrier islands. Consequently, the Chesapeake Bay and Atlantic Ocean-facing shorelines are not represented.

How is the app being used?

The Living Shoreline Explorer app is being used by natural resource managers on the Eastern Shore to target areas for nature-based shoreline stabilization activities.

Who helped develop it?

The Living Shoreline Explorer app was developed through a partnership between The Nature Conservancy and the Virginia Coast Reserve Long-Term Ecological Research Program.

For general info about the Virginia Eastern Shore Coastal Resilience project: coastalresilience.org/virginia

To access the Virginia Eastern Shore Coastal Resilience mapping portal: maps.coastalresilience.org/virginia/

For questions, contact info, etc: Chris Bruce, GIS Manager | vacoastalresilience@tnc.org | (434) 951-0565






Virginia Eastern Shore Coastal Resilience Tool




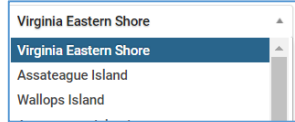



Training Manual, Version 4.0 (February 2018)

Glossary of Terms (alphabetical)


Locations where these terms occur are noted in [brackets]:

Flood & Sea Level Rise = [F&SLR] Future Habitat = [FH] Regional Planning = [RP] Coastline Change = [CC]
Living Shoreline Explorer = [LSE] Map Viewer = [Map Viewer]

Absolute Difference:	A measure in feet of the difference between current water levels and those during modeled storm events. [F&SLR]
Base Data:	A map layer which shows boundaries, parcels, and roads. [RP]
Basic Dark Gray:	A gray background map layer. [Map Viewer]
Basic Inundation:	A data source, which displays predicted sea-level rise for several sea-level rise scenarios and scenario years. [F&SLR]
Boat Activity:	Increased boat activity can lead to wakes which creates higher wave action along a coast, and can lead to higher erosion rates. [LSE]
Breakwater:	Breakwaters are artificial offshore structures built to protect harbors or shoreline from water waves. Breakwaters intercept longshore currents and tend to prevent beach erosion. These artificial structures also cut off the intertidal habitat between the water and marsh edge. [LSE]
Bulkheads:	Coastal bulkheads are most often referred to as seawalls, bulkheading, or revetments. These manmade structures are constructed along shorelines and can help reduce coastal erosion. [LSE]
Change Rate Type:	Includes both long- and short-term change rates for historical shorelines. Long-term change rates are calculated using all historic shoreline data from the earliest to the most recent dates for the selected area. Short-term change rates are calculated using historical shoreline data from the most recent change in the long-term rate to the most recent dates for the selected area. [CC]
Choose Parameters:	A tab, which allows you to select the Scenario Year and SLR Scenario, affecting the data displayed in the map viewer. [F&SLR]
Clear Filters:	Clicking this button () resets the visible data to its original state, removing drawn areas and other filters that narrow results. [FH]
Click to Draw an Area:	Clicking this button () allows you to draw an area of interest, which will exclude all other data. [FH]
Coastal Management:	A grouping of map layers that include public access sites, boat ramps, streams, flood hazard areas, protected lands, and Virginia Ecological Value Assessment. [RP]
Coastline Change App:	An app (), which shows historic and future changes in coastlines in response to predicted sea-level rise. [Map Viewer]

Compare & Chart:	A tab, which allows you to view changes between the current habitat area and the predicted condition. Note that data is only displayed if a future Scenario Year (e.g., 2025) is selected. [FH]
Create Map:	Accessible through the wrench icon in the upper right of the screen (). Create Map allows you to export the current view as a pdf. [Map Viewer] [RP]
Download data:	Clicking this button () or () within an app allows you to download a GIS file geodatabase. [FH]
Dropdown menu:	A vertical menu of options, like that shown to the right, which is opened by clicking on it. 
Economic Loss:	Estimated potential monetary impacts resulting from the selected storm surge scenario. [F&SLR]
Ecosystem:	A system of biological components (species) and physical components (geography and resources). [FH]
Erosion:	Degradation of features such as shorelines or structures, usually by the action of water or wind. [FH]
Explain Each Choice:	Clicking this text (Explain Each Choice) shows additional information regarding Coastline Change App options. Additional information may be hidden by clicking on the “Hide Explanations” text (Hide Explanations). [CC]
Filter Results by Habitat(s) of Interest:	A section, which allows you to reduce the data being displayed to only salt marsh or only “other wetlands”. [FH]
Flood & Sea Level Rise App:	An app (), which shows the predicted effects of sea-level rise and storm surge on the Eastern Shore of Virginia. Includes two datasets: Basic Inundation (focuses on the effects of sea-level rise) and Storm Surge (displays predictions for storm surge from hurricanes and tropical storms). [Map Viewer]
Future Habitat App:	An app (), which shows changes in habitat type in response to predicted sea-level rise. [Map Viewer]
Get Started:	Get started () provides a splash screen that allows you to access apps by clicking on the “Go” button. [Map Viewer]
Habitat:	The biological and physical settings in which species exist. Also, a map layer, which shows commercial shellfish aquaculture, public oyster grounds, and tidal marshes. [RP] [FH]
Hide Explanations:	Clicking this text (Hide Explanations) hides additional information. [CC]
Imagery:	Aerial imagery base map of the Virginia Eastern Shore. [Map Viewer]
Infrastructure:	A grouping of map layers that include schools, fire stations, roads vulnerable to sea level rise, and evacuations routes. [RP]
Inundation:	Flooding of upland areas. [FH]
Land Accretion:	Increase in elevation or area of land due to sediment deposition. [FH]


Learn More:

A graphic () in the upper left corner of an app window that links to the app fact sheet when clicked. [F&SLR, LSE]

Legend:

A window, which shows the list of active layers and their symbology. [Map Viewer]

Living Shoreline Explorer App:

An app (), which shows suitability for living shorelines, along with a marsh vulnerability index. [Map Viewer]

Marsh Buffer Width:

Wave energy dissipates with distance when a wave crosses a marsh. A narrow marsh may offer shoreline protection, however larger marshes will increase this protection. [LSE]

Marsh Elevation:

The elevation of the marsh edge (the height of the root and soil structures) affects flooding frequency and the likelihood of waves attacking the edge or spreading over the marsh structure. The mean rate of shoreline change is higher for higher marsh elevations. [LSE]

Marsh Slope:

On shorelines with gentle, more gradual slopes, the wave impacts are less and the gentle slope allows marsh grasses to migrate upslope as the sea level rises over time. Shorelines that have a greater, steeper slope tend to erode more dramatically and do not allow marsh grasses to migrate as sea levels rise over time. [LSE]

Marsh Vegetation Enhancement:

Wetland vegetation absorbs wave energy and helps to hold soil in place. On many low wave energy shorelines, vegetation can effectively protect against erosion. Marsh enhancement refers to techniques such as marsh plantings to enhance or restore existing marsh. This living shoreline type is recommended for locations with existing marsh that has low wave exposure and low to moderate marsh elevation and slope. [LSE]

Marsh Vegetation Height:

This is the overall height of the exposed vegetation on the marsh, measured from marsh soils to the top of the plant. Different species of plants will grow to different heights, taller plant structures can lead to more stable shorelines overtime. [LSE]


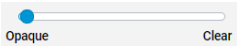


Marsh Vegetation with Structure:

On shorelines with moderate wave energy, vegetation alone may not be enough to curb shoreline erosion. Marsh with structures involves treatments like marsh enhancement with rock or oyster sill. In these settings, a low-profile sill parallel to shore provides an initial wave break, allowing the marsh vegetation to grow, further reducing waves and trapping sediment. This living shoreline type is recommended for locations which may or may not have existing marsh and which have low to moderate wave exposure and higher marsh elevation and slope. [LSE]

Marsh Vulnerability Index (MVI):


The marsh vulnerability index (MVI) shows the vulnerability of tidal salt marshes to erosion and inundation. The MVI incorporates high resolution spatial data on eight tidal salt marsh erosion variables: wind wave and boat wake exposure, the elevation and shape of the marsh edge, marsh vegetation characteristics, current rate of sea level rise,

and moderate intensity storm surge. These individual variables are assigned a risk value and then combined via a simple spatial computation to reveal an overall erosion and inundation vulnerability. High-risk shorelines have one, or a combination, of the following characteristics: high exposure to wind waves or boat activity, steep and high marsh platform, short or non-existent vegetation, narrow vegetation buffers, high storm surge impacts and rate of sea level rise. [LSE]


Measure:	Accessible through the wrench icon in the upper right of the screen (). Used to measure distance and area in various units. [Map Viewer]
Methodology:	A description of the methods used to develop data layers. [FH]
National Geographic:	A background map layer developed by National Geographic. [Map Viewer]
Nor'Ida:	A nor'easter that impacted the mid-Atlantic in November 2009. [F&SLR]
Nourishment:	The action of replenishing or restoring a beach with sand. [CC]
Ocean:	A background map layer developed by the National Oceanic and Atmospheric Administration. [Map Viewer]
Opacity:	The extent to which an image is not transparent. [RP]
Opaque:	The opposite of transparent. Appears in transparency slider bars (). [F&SLR] [FH]
Pan:	Moving the map by clicking, holding, and dragging the mouse. [Map Viewer]
Percent Difference:	A measure in percentage of the difference between current water levels and those during modeled storm events. [F&SLR]
Permalink:	A bookmark hyperlink to a map showing selected features. [Map Viewer]
Physical Features:	A map layer, which shows physical geography. [RP]
Regional Planning App:	An app (), which includes information appropriate for regional-scale planning, such as schools, roads, tidal range, protected lands, and wetlands. [Map Viewer]
Reset Layers:	Clicking this text (Reset Layers) clears all selected layers in the Regional Planning App. [RP]
Rate of Change: Difference:	The 50-year average difference in the rate of shoreline change (in meters per year) between the current conditions and a modeled scenario. Also known as the shoreline rate of change difference. [CC]
Results & Chart:	A tab, which allows you to view a pie chart and table explaining acreage of habitat types in the total dataset or a user-defined area for the selected Scenario Year and SLR Scenario. [FH]
Riprap:	Riprap are large stones or concrete pieces that are piled up to protect a shoreline from wave erosion. [LSE]
Save & Share:	Accessible through the wrench icon in the upper right of the screen (). Save and Share allows you to copy a link that saves the current state of the map and all active apps in order to share it with others. [Map Viewer]

Scenario Year:	The year for which predictions (sea level rise, storm surge, or habitat change) were calculated. [F&SLR] [FH]
Sea Level Rise (SLR):	The predicted increase in the elevation of sea water over time. [F&SLR] [FH] [RP] [CC] [LSE]
Shaded Relief:	A background layer, which shows elevation of uplands. [Map Viewer]
Social and Economic:	A map layer, which shows persons by age, area, and certain types of employment, as well as percent of mobile home housing units and 1% annual chance flood economic losses. [RP]
Storm Surge:	Increased water height due to storm dynamics. Also a data source. [F&SLR] [LSE]
Storm Tracks:	Paths taken by hurricanes and tropical storms which were used as the basis for modeling storm surge. [F&SLR]
Storm Type:	A dataset. Impacts from low Intensity storms were based on three theoretical Category 1 hurricanes with max winds of 80 miles per hour (mph). Impacts from Moderate Intensity storms were based on six theoretical Category 1 and 2 hurricanes with max winds of 85-110 mph. Impacts from High Intensity storms were based on seven Category 2 and 3 hurricanes with max winds of 95-115 mph. Impacts from Nor'Ida were based on the storm surge generated by that particular storm. Impacts from each of these Storm Types are shown for current conditions and two future Scenario Years. [F&SLR]
Streets:	A background map layer, which shows roadways. [Map Viewer]
Terrain:	A background map layer, which shows differences in terrain. [Map Viewer]
Tidal Range (ft):	Data regarding the typical variability in water level due to tides. [F&SLR] [RP]
Topographic:	A background map layer, which shows roads, waterways, elevation, forested land, and wetlands. [Map Viewer]
Tour:	Clicking this text (Tour) at the bottom left corner of the screen opens a quick reference for the parts of the <i>Coastal Resilience</i> tool map viewer. [Map Viewer]
Transect:	A line along which data is collected. [CC]
Water Depth (ft):	A measure of the predicted depth of water in feet due to storm surge. [F&SLR]
Wave Climate:	A term, which includes the predominant direction of wave influence on a system. [CC]
Wave Exposure:	The amount of wave activity that impacts a shoreline. Exposed shorelines tend to have greater wave exposure, and protected shorelines tend to have less exposure to waves that will cause erosion. [LSE]
View Methodology:	Clicking (View Methodology) within an app will load a document which explains the methods used to develop data for that app. [FH]
Zoom:	To change the scale of the map viewer. Click on the zoom in button (+) for a narrower view or the zoom out button (-) for a wider view. [Map Viewer]

Zoom to Extent:

Accessible through the wrench icon in the upper right of the screen () . Zoom to Extent returns the view to the entire Virginia Eastern Shore. [Map Viewer]

Zoom to Selection:

Clicking this button () will zoom to the area you draw using the Click to Draw an Area option. [FH]

Virginia Eastern Shore Coastal Resilience Tool
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Hints and Tips

1. The *Coastal Resilience* tool is web-based. Make sure your internet connection is working before use.
2. The *Coastal Resilience* tool can be used in most internet browsers, including Chrome, Internet Explorer, Firefox, and Safari. However, be sure your browser is up-to-date to avoid issues.
3. It is a good practice to reboot your device before using the tool to ensure that you have sufficient memory available to use it.
4. It may be helpful to periodically refresh the browser window (refresh button or F5 key) in which you are viewing the *Coastal Resilience* tool in order to prevent errors from occurring. Keep in mind that refreshing will return the *Coastal Resilience* tool to its starting condition.
5. If the *Coastal Resilience* tool really seems to be stuck, try clearing the local cache in your browser by pressing Control + F5 (you may want to press this several times to fully clear the system). On an Apple machine press Command + R. You can also close the browsing window or tab and open it again to fully refresh the site.
6. Another option to avoid issues caused by web browser history is to open the *Coastal Resilience* tool in a window which does not retain cookies or other browsing data. This is known by different names in different web browsers. For example:
 - Chrome: incognito window
 - Internet Explorer: InPrivate Browsing
 - Firefox and Safari: private browsing window
7. The *Coastal Resilience* tool is optimized to work on desktops and laptops, and may experience issues when open in a tablet or hand-held devices. Additionally, the *Coastal Resilience* tool map viewer may seem crowded when viewed on a laptop.
8. If a background map layer does not load (grey screen displayed), try choosing another layer or changing the zoom level. Some layers do not appear when zoomed in extensively.
9. For a quick run-down on the functions of the tool click on “Tour” at the bottom left corner of the screen – this will point to the different elements of the tool and give a short explanation of them.
10. When you open an app the icon changes color and appears like an app on your phone. When done using the app you can either use the close (‘x’) button in the upper right hand corner to remove it from being active, and remove its data from the map, or the minimize (‘_’) button to have it remain active and, therefore, keep data on the map. You can have multiple apps open – minimizing the apps helps maximize how much of the map is shown.

11. Likewise, the Map Legend can be minimized ('_'). To show the legend again, click on the plus button ('+') on the right side of the Map Legend header. The legend can also be dragged to a different location.
12. App data displays in the order in which you access it. For example, if you open the Flood & Sea Level Rise app first, then the Future Habitat app, future habitat data will be layered on top. For this reason, we recommend opening the Regional Planning app last if you wish to use it.
13. Clicking on data that appears on the map will open an Identify window showing the attributes of the data layer at that point. If the Identify box is too big and goes off the map then pan the map (click and hold mouse down, then drag) until you see the entire window. Note that the Identify window does not move.
14. You can also hold the Shift key down and click and hold the mouse to draw a box for zooming into a particular area. This may allow you to zoom to a level that is between those used by the zoom in and zoom out buttons.
15. Remember that the *Coastal Resilience* tool is a work in progress! If you find obvious errors, feel free to report them to vacoastalresilience@tnc.org.

Thank you very much for using the *Coastal Resilience* tool!

If you have any feedback, please submit it to vacoastalresilience@tnc.org