Sea–Level Rise Vulnerability Assessment Tools and Resources

A Guide for Florida's Local Governments

Florida Coastal Management Program

DEPARTMENT OF ENVIRONMENTAL PROTECTION FLORIDA

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

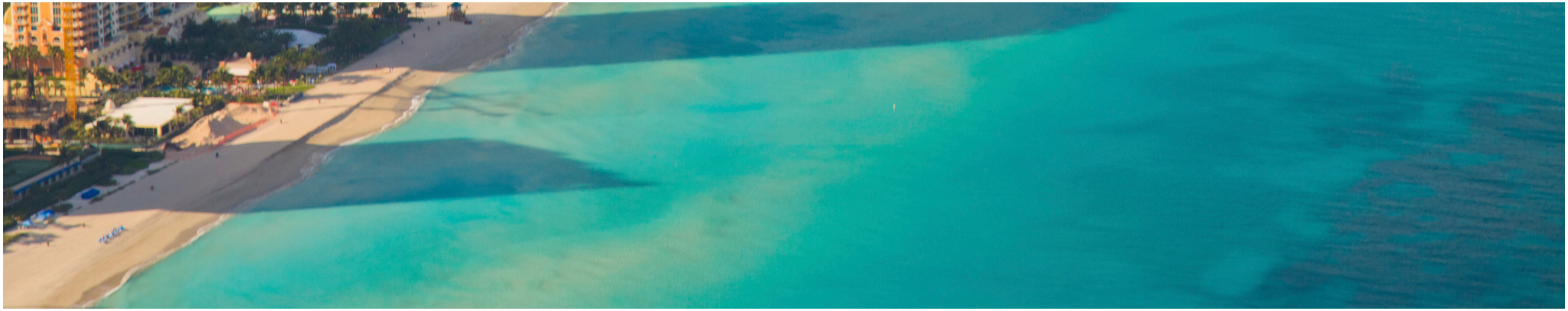

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Table of Contents

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Executive Summary

This guidebook provides guidance for approaching, developing, and completing sea-level rise risk and vulnerability analyses and scenarios and for incorporating the appropriate process and process outputs into local planning efforts.

Projected sea-level rise impacts threaten to increase the vulnerability of Florida's coastal man-made and environmental assets. These assets, already subject to tropical storm inundation, extreme high tides, and storm surge, may experience greater likelihood of flooding as sea-levels rise. Adapting to and mitigating sea-level rise impacts may become part of a community's adaptation measures that can be incorporated into all levels of a community's hazard mitigation and land use planning decisions. One of the first major steps that a community can take toward adaptation and mitigation is a *vulnerability analysis*. Many such tools currently exist to measure a community's potential future vulnerability to coastal flooding.

Section 163.3177(6)(g)(10), F.S., provides local governments the option to "…develop an adaptation action area designation for those low-lying coastal zones that are experiencing coastal flooding due to extreme high tides and storm surge and are vulnerable to the impacts of rising sea level." Section 163.3178 (2)(f)1, F.S., was recently amended and requires that communities "…include development and redevelopment principles, strategies, and engineering solutions that reduce the flood risk in coastal areas which results from high-tide events, storm surge, flash floods, stormwater runoff, and the related impacts of sea-level rise." Florida Department of Economic Opportunity (DEO), in partnership with the National Oceanic Atmospheric Administration (NOAA), Department of Environmental Protection (DEP), the Florida Coastal Management Office (FCMO), and the Florida Division of Emergency Management (DEM), are working together on the Community Resiliency Initiative, which provides guidance on the integration of coastal adaptation measures into existing local planning, policy, and budgeting mechanisms, such as comprehensive plans, mitigation strategies, economic development plans, special area management plans, and post-disaster redevelopment plans, as applicable.

This guidebook has been prepared to support initiative goals to offer local governments in the State of Florida guidance on evaluating sea-level rise vulnerability assessment tools for adaptation planning.

Chapter 1 provides an introduction and overview of the guidebook and describes the major activities and steps that comprise sea-level rise adaptation planning.

Chapter 2 defines the four main types of tools that are available to help local governments conduct a sea-level rise vulnerability analysis as well as the steps that could be taken when selecting the right tool to use.

Chapter 3 describes how sea-level rise vulnerability analysis tool outputs can be incorporated into other local planning efforts.

Chapter 4 identifies other adaptation planning resources available to local governments.

Appendix A provides an inventory of sea-level rise vulnerability analysis tools. A profile has been developed for each tool that describes the tool and identifies how it is relevant to the adaptation planning process. An inventory matrix is also included to allow readers to easily compare the tools to each other.

Appendix B includes a comparison report that describes how the tools found in the Appendix A inventory can be incorporated into each of eight local planning efforts. A short crosswalk document is also provided to summarize how each tool relates to the specific needs of each of the local planning efforts.

Appendix C includes a recommendations report that highlights a selection of tools from the Appendix A inventory which provide some of the most accessible features within their tool/resource group. The discussion is geared toward local governments who are newly approaching their vulnerability assessment options.

Appendix D includes user narratives which provide scenarios that define a user and the type of sea-level rise vulnerability analysis to be completed, describe the functionality required of the tool to be used in each case, and identify a vulnerability assessment tool that would be appropriate to select.

This guidebook is intended to serve as a resource for local governments to use when deciding how to address sea-level rise in the day-to-day planning considerations of our coastal communities.

Chapter 1:

Planning for Adaptation

This chapter provides an overview of the sea-level rise adaptation planning process. It describes the major activities and steps that comprise adaptation planning and discusses the relationship between a vulnerability assessment and the various planning activities.

Communities that are subject to sea-level rise may experience an increase in coastal hazard vulnerability. Impacts to communities may include:

- Increased flooding and drainage problems,
- Destruction of natural resource habitats,
- Higher storm surge,
- Increased evacuation areas and evacuation time frames,
- Increased shoreline erosion,
- Saltwater intrusion into surface and groundwater, and
- Loss of infrastructure and existing development.

Adaptation to sea-level rise represents concrete steps a community takes to become more resilient to the impacts of rising seas over a period of time. The purpose of this guidebook is to provide the information necessary for local governments in Florida to select the appropriate vulnerability analysis tools to support local sea-level rise adaptation planning efforts. It also provides information on how the tools can be integrated into other local planning efforts and identifies additional resources available for adaptation planning. This chapter provides information for local community leaders, planners, and resource managers about the basic considerations of sea-level rise adaptation planning.

Appendices A and B describe additional detailed information on the tools available to facilitate multi-sector sea-level rise adaptation planning, descriptions of the utility and role of the tools in relevant components of the adaptation planning process, as well as specific examples of how the tools can be integrated into other local planning efforts.

Components of an Adaptation Planning Process

Sea-level rise adaptation planning seeks to reduce the negative impacts of potential sea-level rise by reducing exposure, promoting resilience, and accommodating adaptation of ecosystems, species, communities, and infrastructure to changing conditions. Whether a community is starting a new adaptation planning process for the first time or updating existing plans – it is important to understand how and when a vulnerability analysis fits into the overall adaptation planning process. Figure 1, below, illustrates the key steps of adaptation planning.

Figure 1: Adaptation Planning Process

Figure 2: Adaptation Plan Overview

Sea-Level Rise Adaptation Plans

Main and Supporting Components

1. **Context**
   - 1.1. Assemble a Steering Committee
   - 1.2. Identify Opportunities for Community Participation
   - 1.3. Describe the Planning Context
   - 1.4. Set Guiding Principles + Motivations
2. **Vulnerability Assessment**
   - 2.1. Conduct an Exposure Analysis
   - 2.2. Conduct an Impact Analysis
   - 2.3. Assess Adaptive Capacity
3. **Adaptation Strategies**
   - 3.1. Assign Focus Areas
   - 3.2. Identify Adaptation Strategies
   - 3.3. Prioritize Adaptation Needs
4. **Implementation Strategies**
   - 4.1. Survey Funding Options
   - 4.2. Integrate into Existing Plans
   - 4.3. Create a Schedule of Activities
   - 4.4. Monitor and Evaluate

As described in this section, a sea-level rise adaptation plan includes 4 major activities (components) and 14 steps (subcomponents) (see Figure 2). The subcomponents which support and can be supported by the sea-level rise vulnerability analysis tools are outlined below. However, it is important to note that the adaptation planning process does not have to be a linear process. For example, some communities may choose to consider how they might implement possible strategies first (i.e., identify funding streams that are available which may require or promote the development of a plan). This in turn may drive the focus of the adaptation planning process and have a significant influence on the tools/resources and approaches that are selected in order to conform to the predetermined strategy (e.g., funding might be available for transportation improvements – so, a community might use a FDOT or FHWA product for related assessments).

1. Context. For the first part of an adaptation planning process, communities are encouraged to consider factors typical of all planning exercises, with a focus on how each factor relates to sea-level rise adaptation. This includes a survey of existing geographic, social, infrastructural, and environmental conditions. It also entails the creation of principles (e.g., goals, objectives, and policies) to guide the planning process, which are distinct from prioritized needs set during the Adaptation Strategies Analysis phase.

Context refers to the preparatory activities taken by the planning team and the community to increase their understanding of the planning issue at hand and to unite and fortify their efforts addressing the issue.

1.1 Assemble a Steering Committee. In order to write a sea-level rise adaptation plan that reflects the expertise and interests of the community's local stakeholders, a steering committee can be assembled. Steering committees have the ability to enhance all ensuing activities in the adaptation planning process.

1.2 Identify Opportunities for Community Participation. Within this sub-component, the planning team is encouraged to identify opportunities for community participation to discuss the resources created during the Vulnerability Assessment, Adaptation Strategies, and Implementation Strategies components.

1.3 Set Guiding Principles and Motivations. By deciding on guiding principles and motivations, the community can establish its compass for navigating through the following components. The principles and motivations are one of the plan's most inter-active sub-components and may be recalled to assist decision-making activities in the second, third, and fourth components.

1.4 Describe the Planning Context. Describing the planning context offers an opportunity to analyze prior adaptation planning efforts that may have occurred within or near the community, information gaps related to adaptation planning, the available human capacity (such as coastal scientists and land-use planners), and the outside resources needed to conduct the locally desired planning effort. Essentially, this sub-component provides a chance to assess the scope of work and the resources applicable to the adaptation planning process.

2. Vulnerability Assessment. The Vulnerability Assessment represents the second component in the sea-level rise adaptation planning process and consists of measuring the impact of sea-level rise and identifying the people, infrastructure, and land uses that may be affected. Vulnerability is often used interchangeably with risk when measuring hazard impacts.

The **Vulnerability Assessment** draws from the Risk Assessment framework described in the Code of Federal Regulations (Title 44 CFR 201.6(c)(2)), which measures the hazard exposures a community is likely to experience and the sensitivities—e.g., populations and land uses—that may be exposed to the identified hazards.

2.1 Conduct an Exposure Analysis. An exposure analysis utilizes a sea-level rise projection to answer the question "where" based on two choices – when (what horizon) and how much (which scenario). The "where" will depend on which computer model is used (e.g., SLAMM, ADCIRC, etc.) to produce the sea-level rise projection. The analysis can depict which areas in the community are likely to be susceptible to the chosen sea-level rise scenario on a map.

2.2 Conduct an Impact (Sensitivity) Analysis. Conducting an impact (sensitivity) analysis helps the community to identify natural resources, structures, populations, and other entities located in areas that are at risk to the sea-level rise scenario projected during the Exposure Analysis.

2.3 Assess Adaptive Capacities. This sub-component encourages the community to measure the degree to which it is equipped to adapt to sea-level rise through the existence of policies, structures, finances, and human resources that can assist, or already are assisting, adaption to potential changes.

3. Adaptation Strategies. Adaptation Strategies represent the third component in the adaptation planning process and are in effect a set of responses to the findings from the Vulnerability Assessment. Adaptation strategies are often classified according to their status as Protection, Accommodation, and Retreat (PAR) strategies. There are also a set of supporting activities that assist the development of the strategies themselves, which are described in this component. This component also identifies how adaptation strategies can be prioritized for each focus area and then applied through PAR and No Regrets interventions.

Adaptation Strategies refer to the toolkit of responses that communities can take to adapt to sea-level rise as well as the steps taken to decide which adaptation strategies are the best fit based on the needs of individual communities.

3.1 Assign Focus Areas. With the assistance of the steering committee and community stakeholders, the planning team may assign focus areas. This sub-component responds to the sensitive entities identified in the vulnerability assessment and assigns community preferences to areas that will receive the majority of adaptation strategy attention.

3.2 Identify Adaptation Strategies by Focus Area. The four main types of strategies a community may use to adapt to sea-level rise are:

- Protection – Hard and soft structurally defensive measures to mitigate the impacts of rising seas (e.g., seawalls, bulkheads, rip-rap, and living shorelines).
- Accommodation – Physical design alterations allowing a structure or land use to remain in place (e.g., floodable development, floating structures, and bio-swales).
- Managed Retreat – Relocation of existing development/limitation of future development (e.g., rolling easements, transfer of development rights, and design for dis-assembly).
- No Regrets – Comprehensive and targeted strategies, such as incorporating sea-level rise scenarios into other plans and enhancing sea-level rise outreach.

3.3 Prioritize Adaptation Needs. This sub-component recommends that the planning team assess the relative merits and costs of each adaptation strategy within a given focus area in order to prioritize the preferred adaptation strategy. This may be accomplished through a benefit-cost alternatives analysis, stakeholder feedback, or even new output from a tool utilized during the Vulnerability Assessment.

4. Implementation Strategies. Once a set of adaptation strategies has been developed and analyzed, it is recommended that communities prepare for the supporting activities that can facilitate adaptation activities to be successfully undertaken. This includes locating, preparing for, and applying for potential funding opportunities; creating a schedule of adaptation actions for the future; and addressing monitoring and evaluation needs.

Implementation Strategies encourage communities to look into available funding for adaptation activities, describe which groups will complete which tasks, and create mechanisms to evaluate how the adaptation plan strategies are being accomplished.

4.1 Survey Funding Options. A survey of funding options includes a systematic review of all known funding sources as well as inquiry into new funding opportunities that may facilitate a successful implementation strategy.

4.2 Integrate into Existing Plans. In order to integrate the components of the sea-level rise adaptation plan into other plans, the planning team is encouraged to: identify all relevant documents, assess documents for potential inclusion points, and (if applicable) initiate collaboration with the responsible party to ensure that the applicable sea-level rise objective can be included at the time of the next update.

4.3 Create a Schedule of Adaptation Activities and Actors. Creating a schedule will provide an impetus to the actions to be completed and assign the staff responsible for each action. This sub-component can serve to program different types of adaptation activities according to their prioritized need (see sub-component 3.2 above) and, in pairing with funding opportunities, generate a concise and easy-to-follow plan.

4.4 Monitor and Evaluate. Monitoring and Evaluation extends throughout the horizon of the plan's implementation, which could extend decades. The ability to communicate the guiding goals of the plan across generations of implementing actors is essential. This is done through a Monitoring and Evaluation plan that uses consistent language, such as "indicators" that can be tracked throughout the implementation horizon and rated as to successfulness by different implementing actors.

Relationship of the Vulnerability Assessment to other Components

Conducting a vulnerability assessment is a key analytical step in adaptation planning since it identifies assets, both ecological and community infrastructure assets, which may be impacted by sea-level rise. In addition to assessing assets' potential sources of vulnerability, a vulnerability assessment also considers the likelihood and consequences of potential sea-level rise impacts. This assessment will help pinpoint a community's vulnerable assets and the resulting community needs as well as help identify actions that can be implemented to address them.

Context

Defining the planning context sets the stage for the vulnerability assessment and, as such, is the most important part of the adaptation planning process. Engaging steering committee and community stakeholders allows a community to set guiding principles and motivations of the assessment and planning process early on as well as ensures that the process meets a community's needs. This will have a significant impact on the tools, resources, approaches, and planning horizons that are utilized to conduct a community vulnerability assessment, and it will also have a direct relationship to the feedback that is provided once the draft assessment has been completed.

Adaptation Strategies

Adaptation strategies are the responses that communities take to adapt to sea-level rise and are based on the needs of each individual community. Once a community's vulnerability and risk has been determined, adaptation strategies can be selected in response to the specific needs of a community that were identified. A vulnerability assessment provides the scientific basis for adaptation strategies and it can be used to gain public buy-in since stakeholders often determine how the vulnerability assessment is carried out. Due to the predictive nature of vulnerability assessments, there is a degree of uncertainty in the results. Understanding and accounting for this uncertainty when considering management actions is an important aspect of adaptation planning.

Implementation Strategies

Implementation strategies are the steps a community takes to incorporate adaptation strategies into existing planning, budgeting, and staffing mechanisms. Even before the vulnerability analysis is conducted, communities may consider possible implementation strategies based on available capacities, existing implementation schedules, or available funding sources. Communities must be able to support and implement adaptation activities in order to successfully reduce the negative impacts of potential sea-level rise that were identified during a vulnerability assessment.

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Chapter 2:

Sea-Level Rise Vulnerability Analysis Tools[1]

This chapter identifies the types of tools available to conduct a sea-level rise vulnerability analysis. It also outlines the steps a community can take to select the most appropriate tool that suits the local capacity, risk, and needs as well as other factors for consideration during tool selection.

Types of Tools

There are four main types of tools available to assist local governments conducting a sea-level rise vulnerability analysis to support local sea-level rise adaptation planning efforts. These four types of tools include: visualization tools, modeling tools, decision support tools, and databases of resources.

Visualization Tools can be used to create simulations and graphics of current and potential future conditions. These tools often perform analyses but generally require less user input and customization than other analytical tools. Often, they do not have the ability to run customized analyses with local data. These tools are generally easy to use and do not require specific software or hardware. Visualization tools are often used to support the Opportunities for Community Participation, Guiding Principles and Motivations, Planning Context, and Exposure Analysis components of adaptation planning.

Visualization tools can often be used to support Opportunities for Community Participation. These tools create visualizations of potential future conditions which can be used to help produce salience, engage public interest, and build awareness.

A community can set Guiding Principles and Motivations to direct the adaptation planning process based on the information provided by visualization tools. Visualization tools illustrate the potential impacts of sea-level rise on a community and describe a community's risk and vulnerability. These tools can be utilized to galvanize stakeholder support. By seeing the general projected inundation within their community, participants may be motivated to set more specific goals (e.g., "Ensure the protection of the community's environmental assets.").

The Planning Context can also be defined using information provided by visualization tools. By displaying the amount of risk to which a community is vulnerable as well as the potential losses that could be experienced due to sea-level rise, these tools will describe existing conditions and vulnerabilities that must be addressed by the adaptation planning process.

Visualization tools can also be used to conduct an Exposure Analysis. These tools often display or map different increments of sea-level and show where inundation areas will occur. This information can help a community visualize future conditions and potential vulnerable areas.

Modeling Tools are computer software programs or GIS add-ins that can calculate future coastal flood scenarios and visualize current and potential future conditions of geophysical, biological, and/or socioeconomic processes in a map-based, tabular, or graphic format. These tools are generally the most technically challenging to use and often require GIS software and appropriate hardware, technical expertise, and training. Modeling tools also generally require local data on the process being investigated. These tools are often used to support the Planning Context, Exposure Analysis, Impact Analysis, and Adaptive Capacity components of adaptation planning.

[1] The guidance offered in this section is modeled after the *Tools for Climate Adaptation Planning: A guide for selecting tools to assist with ecosystem-based climate planning* published by NatureServe in 2013.

Modeling tools, like visualization tools, can provide information that can be used to define the Planning Context. By showing the amount of risk to which a community is vulnerable as well as the potential impacts or losses that could be experienced due to sea-level rise, these tools will describe existing conditions and vulnerabilities that must be addressed by the adaptation planning process.

Modeling tools can also be used to conduct an Exposure Analysis. These tools can identify which areas in a community will be vulnerable to future sea-level rise, helping to visualize future conditions and potential inundation areas.

Additionally, modeling tools can be used to complete an Impact Analysis to estimate the extent to which community assets (man-made and environmental) will be impaired. The tools can identify which populations, infrastructure, resources, and other assets will be impacted as well as estimate the degree of impairment. A simple type of analysis used by some tools, called the bathtub approach, adds projected change in sea-level rise to the current sea level in order to give an estimate of projected sea level. Other tools may rely on a modified bathtub approach, which attempts to account for local and regional variability and hydrological connectivity, whereas more sophisticated tools will use models that take into account the effects of bathymetry, tides, storm surge, etc.

This type of tool can also offer insight into an asset's ability to accommodate or adjust to future flooding which can help a community assess Adaptive Capacity. Similarly, some modeling tools may be able to measure the entire community's ability to adjust to or accommodate future flooding.

Decision Support Tools help develop scenarios of future conditions resulting from potential sea-level rise and management decisions. These tools can integrate outputs from various tools, such as models, to help develop "what if" scenarios and investigate a wide variety of management outcomes. Decision support tools generally require at least a moderate degree of technical capacity such as GIS expertise. These tools are often used to support the Opportunities for Community Participation, Guiding Principles and Motivations, Impact Analysis, Adaptive Capacity, Focus Areas, and Adaptive Needs components of adaptation planning.

Decision support tools can often be used to support Opportunities for Community Participation. These tools are used to develop scenarios of future conditions which can be used to help engage public interest and build awareness by increasing saliency to stakeholders.

Decision support tools can also help a community set Guiding Principles and Motivations to direct the adaptation planning process. By developing scenarios of future conditions, these tools allow a community to compare different scenarios of sea-level rise, adaptation strategies, as well as potential outcomes.

An Impact Analysis can be conducted using decision support tools. The tools can be used to identify the populations, infrastructure, resources, and other assets that will be impacted by future sea-level rise and estimate the degree of damage under different sea-level rise projections as well as under different adaptation action scenarios.

The Adaptive Capacity of a community can also be assessed using some decision support tools. Tools can either provide information on the ability of assets in a community to accommodate future sea-level rise or measure the entire community's ability to adjust to sea-level rise in terms of the different forms of available capital.

Decision support tools can be used to assign Focus Areas in a community. Since these tools depict scenarios of future conditions, they can be used to help identify the areas which are most vulnerable to future sea-level rise and therefore have the greatest need for adaptation strategies to be implemented.

Some decision support tools are also capable of performing benefit-cost analysis and other value assets which can be used to determine the efficacy of proposed adaptation strategies. As such, these tools can be used to help prioritize the Adaptive Needs of a community.

Databases of Resources provide information on available sea-level rise vulnerability analysis tools, case studies, and other information relevant to adaptation planning. These databases often provide information on the available visualization, modeling, and decision support tools identified in this guidebook as well as information that can be used to support adaptation decision making. These databases are often used to support the Planning Context component of adaptation planning.

Databases of Resources are largely used to describe the Planning Context. Many of these resources offer case studies and examples of adaptation strategies and policies being implemented in other communities as well as information on tools and resources available to support local adaptation planning. Other databases provide access to data that are relevant to sea-level rise adaptation or can be used to describe existing conditions in a community.

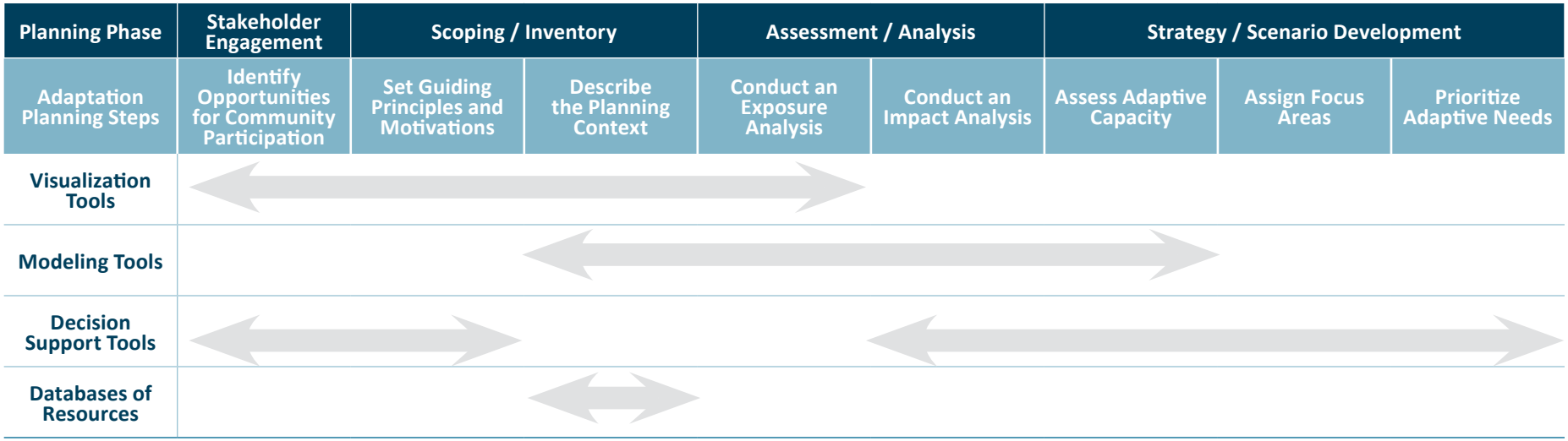
Where the Tools Fit within the Adaptation Planning Process

A key characteristic of the tools is how they assist in the adaptation planning process. Different tools perform different functions and are useful at different steps in the planning process (also described in the previous section—Types of Tools). Figure 3, below, illustrates the generalized planning phases as well as the specific adaptation planning steps during which each type of tool is generally useful. Keep in mind that these designations are based on the most common applications of each tool type, and they do not necessarily exclude a tool from being utilized during different steps of the adaptation planning process.

The sector or sectors for which a tool is appropriate is another key characteristic. Many tools have the ability to address issues in different sectors and can therefore be useful if a multi-sector planning approach is being taken. The sectors used in the inventory of tools and resources found in Appendix A are based on those used by the U.S. Global Change Research Program. The five sector designations include:

1. Natural Resources (including ecosystems, coastal zones, and water resources)
2. Agriculture (working land classifications)
3. Built Environment (including urban, public health, and telecommunications infrastructure)
4. Transportation (including all human transport systems and pipelines)
5. Energy (including energy production and conveyance infrastructure)

Figure 3: Tools and the Adaptation Planning Process



Selecting the Right Tool

Selecting the right tool can be a challenging task. It is best to take a systematic approach to selecting a tool in order to make the decision process easier and more straightforward. The general process that can be used to select a tool is as follows:

1. Characterize Planning Questions

Start by considering the goals of the local adaptation planning process. Determine what information is needed for planning and the specific planning questions that need to be answered. Considerations include the following:

1. What sectors (e.g., natural resources, built environment) do you need to address?
2. What issues (e.g., at risk human populations, critical habitats, critical species) do you need to address?
3. Are your questions broad in scope (e.g., general questions about potential vulnerability) or fairly specific (e.g., predicted range shift for an individual species)?
4. What geographic scale(s) are you concerned with (e.g., regional, for an individual protected area, for an individual municipality)?
5. What temporal scale(s) are you concerned with (e.g., do you need to assess immediate or long-term impacts)?
6. Are your questions primarily at a "planning scale" (e.g., need to identify general areas that may be impacted, are suitable for activities, etc.) or do you need results than help determine optimal actions at specific sites?
7. Do you need to understand the interactions of multiple stressors (e.g., climate change and development)?

Information to help answer these questions can be found in the sea-level rise vulnerability analysis tool inventory found in Appendix A.

2. Identify Tool Functions Needed

Determine the general functions you want the tool to perform and where in the planning process you will use the tool.

Tool functions can be broadly categorized as:

1. Visualization Tools
2. Modeling Tools
3. Decision Support Tools
4. Databases of Resources

Steps in the adaptation planning process where tools might be useful are:

1. Identify Opportunities for Community Participation
2. Set Guiding Principles and Motivations
3. Describe the Planning Context
4. Conduct an Exposure Analysis
5. Conduct an Impact Analysis
6. Assess Adaptive Capacity
7. Assign Focus Areas
8. Prioritize Adaptive Needs

Information to help address these considerations can be found in the sea-level rise vulnerability analysis tool inventory found in Appendix A.

3. Research Available Tools

Learn about available tools, starting with the tool profiles and inventory matrix found in Appendix A to see if any tools seem to provide the functionality your local adaptation planning process requires and outputs that would help address your planning questions. Considerations include the following:

1. How well do your desired functionality and outputs align with the tool's functionality and outputs?
2. Does the tool work in/for your issues and sectors of interest?
3. Does the tool work for your location?
4. Does the tool work at the needed geographic and temporal scales?
5. Can the tool be customized to fit your project needs if it does not do so currently? How difficult/expensive would that be, if so?

4. Assess Data and Topical Expertise Needed

Once you have identified a tool that may suit your needs, determine the data inputs, information, and topical expertise needed to use it. Considerations include the following:

1. What datasets, information, and topical expertise are needed?
2. Are the datasets and information accessible and in a usable format (e.g., spreadsheets, GIS files, hard copy reports)?
3. Are the data sets and information at the appropriate spatial and temporal scales?
4. How reliable are the available datasets and information (e.g., from a trusted source, collected recently enough)? Are they precise and accurate enough?
5. How feasible is it to obtain datasets and information that are not currently available? If collecting new data and information is being considered, what are the costs and how much time is needed?
6. Are topical and local experts available to provide information for and advise on tool use?

Information to help answer these questions can be found in the sea-level rise vulnerability analysis tool inventory found in Appendix A.

5. Assess Available Capacity

In addition to considering the availability of data, consider the availability of human and technical resources for using tools. Considerations include the following:

1. Are there training resources available?
2. Can you provide sufficient time for project personnel to get trained in the use of the tool and actually use it?
3. Do you have the financial resources for any needed personnel training, hardware, and software?

Information to help address these considerations can be found in the sea-level rise vulnerability analysis tool inventory found in Appendix A.

Alternative Tool Selection Methods

In addition to following the systematic approach outlined above, communities can also use one of the following alternative methods when selecting the best tool to conduct a sea-level rise vulnerability assessment:

Interactive Approach

A group of stakeholders can sit down together and review each of the available tools and resources identified in the sea-level rise vulnerability analysis tool inventory found in Appendix A. This approach will allow the group to learn when and where each of the tools can be applied as well as determine the tools' usability for their community. An interactive approach allows stakeholders to engage in discussion, provide feedback on the fly, and work together in a collaborative setting. In order for this approach to be successful, the stakeholder group must be willing to sit down and meet for an extended length of time. It is also important that group members are willing to collaborate and work together when selecting a tool.

Homework Approach

Stakeholders can work alone on their own time to explore the available tools and resources identified in the sea-level rise vulnerability analysis tool inventory found in Appendix A. The stakeholders can then report back to the group and vote on their preferred tool in a "fish bowl" planning framework. The homework approach allows stakeholders to interact with their peers and discuss best practices and options after they have become more familiar with the alternatives individually. This approach will be better suited for stakeholder groups that have limited meeting time available, but group members must be highly motivated to spend the time necessary researching the available tools on their own time.

Leader/Contractor Approach

One person, either a hired contractor or internal stakeholder group member, can be responsible for conducting research on the available tools and resources identified in the sea-level rise vulnerability analysis tool inventory found in Appendix A. This individual will also be responsible for carrying out the sea-level rise vulnerability assessment using the tool he or she felt was best suited to meet the community's needs. After completing the assessment, the leader or contractor will then report back to the stakeholder group with the methodology used and the analysis findings. The leader or contractor will then incorporate any comments and feedback received into the final assessment. In order for this approach to be successful, a community should either have a person who is familiar with sea-level rise adaptation planning and the available vulnerability assessments tools serve as the leader or have enough funding to hire a contractor who has the necessary expertise.

Combination Approach

A community may also choose to use a combination of all the identified alternative approaches in order to tailor the process to best meet the unique needs and conditions in the community.

Other Considerations

When selecting a tool, the level of detail in the data output is dependent on location-specific data used within the tool's database and/or the precision of required input data. The more detail-specific the input data is, the more reliable the output data produced by the selected tool will be. If a community is looking for generalized sea-level rise information to use for strictly visual purposes or in larger scale planning initiatives, then a tool with a broader, less exact data methodology would be appropriate for use, such as CanVis or the USACE Sea Level Change Curve Calculator. If a community is looking for site-specific sea-level rise information for a certain location to determine more precise calculations or to support smaller scale planning processes, then a tool with a more detailed, defined data methodology would be appropriate, such as SLAMM or Hazus-MH. The more specific the sea-level rise data on which planning decisions are based is, the more reliable and defendable land use decisions will be.

With the recently signed Senate Bill 1094 "Perils of Flood Hazard," Section 163.3178 (2)(f)1, F.S., requires communities to "include development and redevelopment principles, strategies, and engineering solutions that reduce the flood risk in coastal areas which results from high-tide events, storm surge, flash floods, stormwater runoff, and related impacts of sea-level rise." There is also a legal mandate that basic decisions about building locations, development intensity, and by what means development occurs should be based on the character of the land (e.g., sea-level rise vulnerability) and that the projected availability of infrastructure and services be the principals by which land use planning decisions impact mitigation and adaptation. Local governments have the ability to determine the most appropriate use of land which can be based on vulnerability and/or susceptibility. "Planning decisions are legislative, subject to the most deferential standards of judicial review", *Martin County v. Yusem*, 690 So.2d 1288, 1295 (Fla. 1997). Local and regional agencies should use appropriate judgment to guide development and avoid extending or rebuilding roads, water and sewer lines, and other infrastructure into projected vulnerable areas. Planning tools and processes for cities and counties are required to "[l]imit public expenditures that subsidize development in coastal high-hazard areas." §163.3177 (6)(g)6, Fla. Stat., 2014.

Chapter 3:

Other Local Planning Efforts

This chapter describes how sea-level rise vulnerability analysis tools can be used by a community to support additional local planning efforts.

Sea-level rise vulnerability analysis tools, and their associated analyses, can also be incorporated into other local planning efforts. These local planning efforts include the following: local comprehensive plan, local mitigation strategy, special area management plan, economic development plan, post-disaster redevelopment plan, capital improvements plan, stormwater management plan, and historic preservation plan.

Local Comprehensive Plan

All of Florida's counties and municipalities are required to adopt local comprehensive plans that guide future growth and development. Local comprehensive plans establish policies that are intended to guide a community's day-to-day land use decisions and capital facilities expenditures. These policies have a major impact on whether people and property are exposed to natural hazards as well as the extent to which they are vulnerable to injury and damage. The sea-level rise vulnerability analysis tools can be used to facilitate public engagement, understand the planning contact, inform future land uses and various plan elements (i.e., natural resources, transportation), and inform plan goals and policies. As such, they assist communities to fulfill the statutory requirement to make the coastal element "based on studies, surveys, and data…and contain…an analysis of the environmental, socioeconomic, and fiscal impact of development…[and outline] principles for hazard mitigation" (§163.3178(2), Fla. Stat., 2014).

Local Mitigation Strategy

In Florida, a local mitigation strategy (LMS) is often a multi-jurisdictional plan developed collaboratively at the county level to reduce and/or eliminate the risks associated with natural and man-made disasters. The LMS identifies existing and potential hazards and proposes actions that would mitigate losses caused by those hazards. By identifying these vulnerabilities and proposing solutions for them, communities are able to prevent losses to lives and property. The sea-level rise vulnerability analysis tools can be used to facilitate public engagement, understand the planning context, inform the hazard risk assessment, and inform mitigation strategy priorities. This will be important if a community wants to incorporate sea-level rise as a hazard in the LMS since Title 44 CFR §201.6 directs local governments to include: "A risk assessment [with a] description of the type, location, and extent of all natural hazards that can affect the jurisdiction, [including] types and numbers of existing and future buildings, infrastructure, and critical facilities located in hazard areas; an estimate of the potential dollar losses to vulnerable structures; [and] a general description of land uses and development trends within the community."

Special Area Management Plan

A special area management plan (SAMP) is a comprehensive plan providing for natural resource protection and reasonable coastal-dependent economic growth containing a detailed and comprehensive statement of policies, standards, and criteria to guide public and private uses of lands and waters as well as mechanisms for timely implementation in specific geographic areas within the coastal zone. SAMPs provide for increased specificity in protecting natural resources, reasonable coastal-dependent economic growth, and improved protection of life and property in hazardous areas, including those areas likely to be affected by sea-level rise, as well as improved predictability in government decision making. The sea-level rise vulnerability analysis tools can be used to inform management area boundaries. A key SAMP enabled by state statute is the Adaptation Action Area, which is "a designation…which identifies one or more areas that experience coastal flooding due to extreme high tides and storm surge, and that are vulnerable to the related impacts of rising sea levels for the purpose of prioritizing funding for infrastructure needs and adaptation planning." (§163.3164(1), Fla. Stat., 2014).

Economic Development Plan

An economic development plan provides a comprehensive overview of the economy, sets policy direction for economic growth, and identifies strategies, programs, and projects to improve the local economy. These policies and strategies can guide future investment and economic growth or activities to areas that are safe and that have reduced exposure to hazard risks. The sea-level rise vulnerability analysis tools can be used to identify vulnerable infrastructure and assets, inform infrastructure investment and reinvestment and economic redevelopment initiative priorities, identify and incentivize a less vulnerable growth center, and identify impacts to major employers and industries. In order to integrate sea-level rise assessment, a community may wish to pair the analysis of future economic development investments with a projection of sea-level rise.

Post-Disaster Redevelopment Plan

A post-disaster redevelopment plan (PDRP) is encouraged for all communities. A PDRP identifies policies, operational strategies, and roles and responsibilities for implementation that will guide decisions that affect long-term recovery and redevelopment of a community after a disaster. PDRPs emphasize seizing opportunities for hazard mitigation and community improvement consistent with the goals of the local comprehensive plan and with full participation of the citizens. The sea-level rise vulnerability analysis tools can be used to inform policies for post-disaster development and redevelopment and inform post-disaster restoration project, armoring, and coastal protection project priorities. This will assist emergency managers to promote transformative resilience, or the ability to build back stronger than before, in the event of coastal flooding. Rather than "No-Regrets" strategies that may be implemented in the present, PDRPs can utilize sea-level rise projections to direct where future development should be limited.

Capital Improvements Plan

A capital improvements plan (CIP) guides the scheduling of spending on public improvements, such as capital projects and equipment purchases. A CIP can serve as an important mechanism for guiding future investments and improvements away from identified hazard areas. The sea-level rise vulnerability analysis tools can be used to inform infrastructure investment and reinvestment priorities, inform armoring or coastal protection project priorities, and incentivize less vulnerable growth areas. As the schedule for amenities protecting the health and welfare of community members, it is essential the CIP react to the influence of sea-level rise vulnerability assessment, programming large infrastructure away from the scope of coastal flooding.

Stormwater Management Plan

A stormwater management plan is designed to address flooding associated with stormwater runoff. A stormwater management plan is typically focused on design and construction measures that are intended to reduce the impact of more frequently occurring minor urban flooding. The sea-level rise vulnerability analysis tools can be used to inform policies for stormwater management infrastructure design. A community looking to integrate sea-level rise vulnerability assessment into a stormwater management plan will need to evaluate environmental changes that could be brought about by sea-level rise and impacts of flood hazards when combined with sea-level rise.

Historic Preservation Plan

A historic preservation plan is intended to preserve historic structures or districts within a community. An often overlooked aspect of the historic preservation plan is the assessment of buildings and sites located in areas subject to natural hazards and the identification of ways to reduce future damages. The sea-level rise vulnerability analysis tools can be used to identify vulnerable historic structures, neighborhoods, and/or districts. Because historic properties take many forms – sculptures, open space, buildings, archeological sites, etc. – a detailed mapping of property locations, with a good exposure analysis that incorporates multiple types of flooding, is essential.

More detailed summaries of how the sea-level rise vulnerability analysis tools can be integrated into these other local planning efforts can be found in Appendix B.

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Chapter 4:

Other Adaptation Planning Resources

This chapter identifies additional available resources that a community can review for more information on sea-level rise and adaptation options.

At the national, regional, and state level, there are a number of resources that may be useful to communities who are interested in learning more about the potential for sea-level rise and available adaptation options. The following is a list of resource recommendations:

Climate Change and Sea-Level Rise in Florida—The Florida Oceans and Coastal Council published a 2010 update concerning the potential effects of climate change on Florida's coastal resources. This short primer provides a scientifically-based discussion of both historically observed and future projected sea-level rise, with an emphasis on sea-level rise effects across different coastal categories.

How Countries, States, and Florida Address Sea-Level Rise: A compendium of climate adaptation research—This Florida Department of Economic Opportunity Community Resiliency Initiative publication identifies national, state, and local adaptation projects.

Incorporating Sea Level Change Scenarios at the Local Level—This NOAA publication outlines eight steps to help communities calculate sea level change scenarios and communicate impacts. It is a "low-tech" companion document for a NOAA technical publication that assesses technical considerations for use of geospatial data in sea level change mapping and assessment.

Planning Time Frames for Coastal Hazards and Sea-Level Rise—This report provides guidance for the Florida Department of Economic Opportunity's Community Resilience Initiative to assist coastal communities who wish to integrate adaptation planning for future sea-level rise into their comprehensive, hazard mitigation, and post-disaster redevelopment planning.

Sea Level Changes in the Southeastern United States—This 2011 publication by Dr. Gary Mitchum of the University of South Florida's College of Marine Science presents a scientific overview of past, present, and future sea-level rise. Written with the non-scientist in mind, Dr. Mitchum's paper is highly accessible, informative, and relevant to Florida's coastal communities.

Sea-Level Rise Adaptation Options for Local Governments—This presentation, prepared by Dr. Robert Deyle of Florida State University's Department of Urban and Regional Planning, delivers an overview of sea-level rise challenges facing local governments and available adaptation resources.

Tools for Coastal Climate Adaptation Planning: A guide for selecting tools to assist with ecosystem-based climate planning—This guide provides the information necessary for coastal natural resource managers and community planners to select appropriate tools for their projects. The guide focuses on spatially-explicit solutions for climate-related planning.

Planning for Sea-Level Rise Legal Issues Facing Florida—This document includes three presentations by the state's leading experts on the legal ramifications of sea-level rise in Florida that identify potential challenges and appropriate local government responses.

Florida also has a number of sea-level rise adaptation planning processes completed and under development at the state, local, and regional levels. Notable projects include:

The City of Punta Gorda Adaptation Plan—The City of Punta Gorda completed a publicly-led adaptation planning process at the city-level to assess sea-level rise in its downtown area.

Lee County Climate Change Resiliency Strategy—Lee County followed up a 2010 Climate Change Vulnerability Assessment with the Climate Change Resiliency Strategy. This strategy includes approaches to mitigate and adapt to the effects of climate change while also positioning the county to take advantage of potential economic development opportunities associated with climate change.

Municipal Adaptation to Sea-Level Rise: City of Satellite Beach, Florida—In the fall of 2009, the City of Satellite Beach, Florida embarked on a project to assess municipal vulnerability to rising sea level and initiate the planning process to properly mitigate impacts.

The Southeast Florida Regional Climate Change Compact—The Southeast Florida Regional Climate Change Compact represents a joint commitment of Broward, Miami-Dade, Palm Beach, and Monroe Counties to partner in mitigating the causes and adapting to the consequences of climate change. The compact is the lead alliance that supports planning for "adaptation action areas," and is working to secure funding to further this effort.

Appendix A:

Inventory of Sea-Level Rise Adaptation Assessment Tools and Resources

Appendix A:

Inventory of Sea-Level Rise Adaptation Assessment Tools and Resources (cont.)

Introduction

This appendix provides a comprehensive inventory of sea-level rise vulnerability visualization tools, modeling tools, decision support tools, and databases of resources. As presented in greater detail in Chapter 2: Sea-Level Rise Vulnerability Analysis Tools, a visualization tool creates simulations and graphics of current and potential future conditions and processes. A modeling tool models current and potential future conditions of geophysical, biological, and/or socioeconomic processes. A decision support tool develops scenarios of future conditions resulting from the effects of potential sea-level rise and management decisions. A database of resources provides information on available vulnerability analysis tools, case studies, and other relevant information.

Each record in the inventory includes a one-page summary that contains snapshot information for local government stakeholders to use when considering which of these resources would be most useful for their community's needs. The sample profile found on pages A-4 and A-5 provides an overview of what information can be found in each of the summaries found in this appendix. Generally, each summary includes:

- The **Tool/Resource Name**;
- An overview that provides information about:
  - The *Tool/Resource Type* (visualization tool, modeling tool, decision support tool, or database of resources);
  - *Sectors* for which the tools is capable of processing data and creating output (natural resources, agriculture, built environment, transportation and/or energy);
  - *Relevant Adaptation Planning Process Phase(s)* to which the tool applies (Stakeholder Engagement, Scoping/ Inventory, Assessment/Analysis, Strategy/Scenario Development, and/or Implementation/Monitoring[1]);
  - *Geographic Scale* for which the tool/ resource can be applied;
  - *Cost* of the tool/resource;
  - *Data Inputs* required by the tool/resource;
  - *Website* where more details about the tool/ resource can be found; and,
  - *Developer/Sponsoring Agency* who was responsible for developing the tool/ resource.
- A brief general **Description** of the tool/ resource, including a discussion of the following criteria (where applicable):
  - Methodology;
  - Cost;
  - Transferability;
  - Precision;
  - Accuracy; and,
  - Capacity.
- **Examples of Use** documenting where the tool/ resource has been used or applied;
- A summary of best examples of **When and Where to Use** the tool/resource; and,
- **Images** of the tool/resource interface or the tools itself.

A summary table is provided on pages A-6 and A-7 to identify the relevant adaptation planning phases to which each tool/resource can be applied. Additionally, a detailed inventory matrix is included at the end of this appendix to allow readers to easily compare the tools to each other.

[1] Note: These are generalized phases of the planning process. To see how each phase relates to specific steps of the adaptation planning process refer to the "Where the Tools Fit within the Adaptation Planning Process" section in Chapter 2.

Name of Tool / Resource

Tool/Resource Type: *Visualization Tool / Modeling Tool / Decision Support Tool / Database of Resources*

Sector(s): *Sectors for which the tool is capable of processing data and creating output (Natural Resources, Agriculture, Built Environment, Transportation, and/or Energy)*

Relevant Adaptation Planning Process Phase(s): *Point at which tool may be involved in the adaptation planning process (Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development, and/or Implementation / Monitoring)*

Geographic Scale: *Geographical extent of analysis to which the tool can be applied*

Cost: *Cost of purchasing the tool (may be a range)*

Data Input(s): *Data requirements to use/run the tool*

Website: *URL where additional information about the tool can be found*

Developer/Sponsoring Agency: *Organization responsible for developing the tool*

Images

This section of the profile shows images of the tool in action, such as screen shots of the user interface and outputs

Description

This section of the profile provides an overall description of the tool, how it can be used, and how it relates to the sea-level rise adaptation planning process

Examples of Use

This section of the profile identifies examples of the tool/resource being used in communities

Examples for a small, medium, and large size jurisdiction are provided wherever possible

When & Where to Use

This section of the profile summarizes when and where a community can best use the tool and highlights how it applies to sea-level rise vulnerability analysis as well as its relationship to the adaptation planning process (i.e., public engagement, build awareness, visualization, vulnerability assessment, etc.)

Sea-Level Rise Vulnerability Tools/Resources Inventory Summary Table[2]

Tool/Resource Name	Stakeholder Engagement	Scoping / Inventory	Assessment / Analysis	Strategy / Scenario Development	Implementation / Monitoring
Visualization Tools					
CanVis	■		■		
Climate Central's Surging Seas	■	■	■		
FDOT Sea Level Scenario Sketch Planning Tool	■	■	■		
The Nature Conservancy Coastal Resilience Mapping Portal	■	■	■		
NOAA Coastal Change Analysis Program (C-CAP) Land Cover Atlas and Coastal Comparison Tool	■	■			
NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer	■	■	■		
NOAA Sea Level Trends		■	■		
Social Vulnerability Index (SoVI)		■	■		
USGS National Assessment of Coastal Vulnerability to Sea-Level Rise: Coastal Vulnerability Index (CVI)		■	■		
USGS Digital Shoreline Analysis System (DSAS)		■	■		
Modeling Tools					
ADvanced CIRCulation Model (ADCIRC)			■		
Hazus-MH			■		
Integrated Valuation of Environmental Services and Tradeoffs (InVEST)			■	■	
NatureServe Climate Change Vulnerability Index (CCVI)			■		
NOAA Wave Exposure Model (WEMo)			■		
Sea Levels Affecting Marshes Model (SLAMM)			■		
Simulator of Climate Change Risks and Adaptation Initiatives (SimCLIM)			■		
USACE Sea Level Change Curve Calculator		■	■		

[2] Note: This table identifies the relevant adaptation planning phases to which each tool/resource can be applied based on the most common applications of each tool/resource. Keep in mind that if a planning phase is not checked, it does not necessarily exclude the tool/resource from being utilized during that phase.

Sea-Level Rise Vulnerability Tools/Resources Inventory Summary Table Continue

Tool/Resource Name	Stakeholder Engagement	Scoping / Inventory	Assessment / Analysis	Strategy / Scenario Development	Implementation / Monitoring
Decision Support Tools					
Beach-*fx*		■		■	
Coastal Adaptation to Sea-Level Rise Tool (COAST)	■	■	■	■	
CommunityViz	■	■	■	■	
NatureServe Vista	■	■	■	■	
NOAA Inundation Analysis Tool		■	■		
U.S. DOT Vulnerability Assessment Scoring Tool (VAST)		■	■		
Databases of Resources					
Adaptation Database for Planning Tool (ADAPT)		■		■	
Climate Adaptation Knowledge Exchange (CAKE)		■		■	
Ecosystem-Based Management (EBM) Tools Network and Database		■			
FL DEP Map Direct Gateway		■			
Florida Natural Areas Inventory (FNAI)		■			
Georgetown Climate Center		■		■	
Geospatial Assessment Tool for Operations and Response (GATOR)		■			
U.S. Climate Resilience Toolkit	■	■		■	
weADAPT		■		■	

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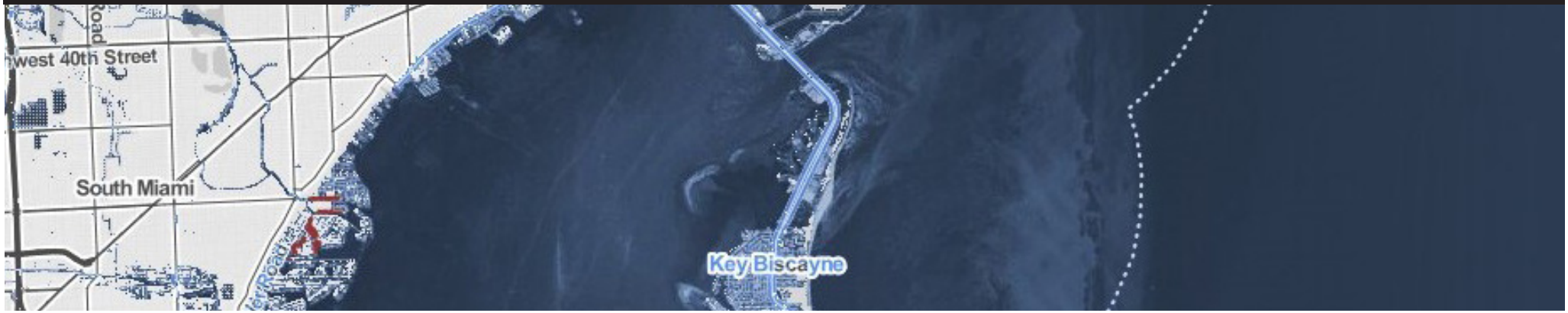
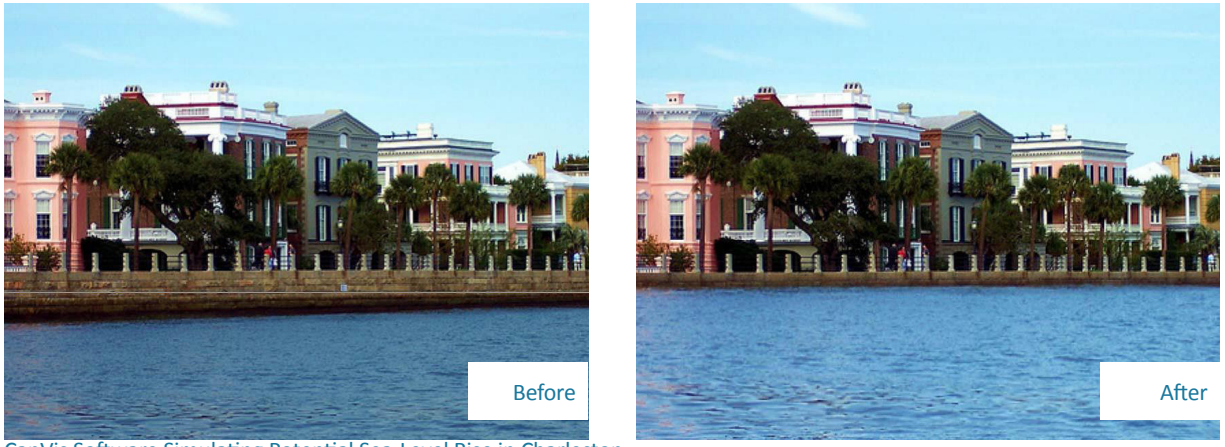
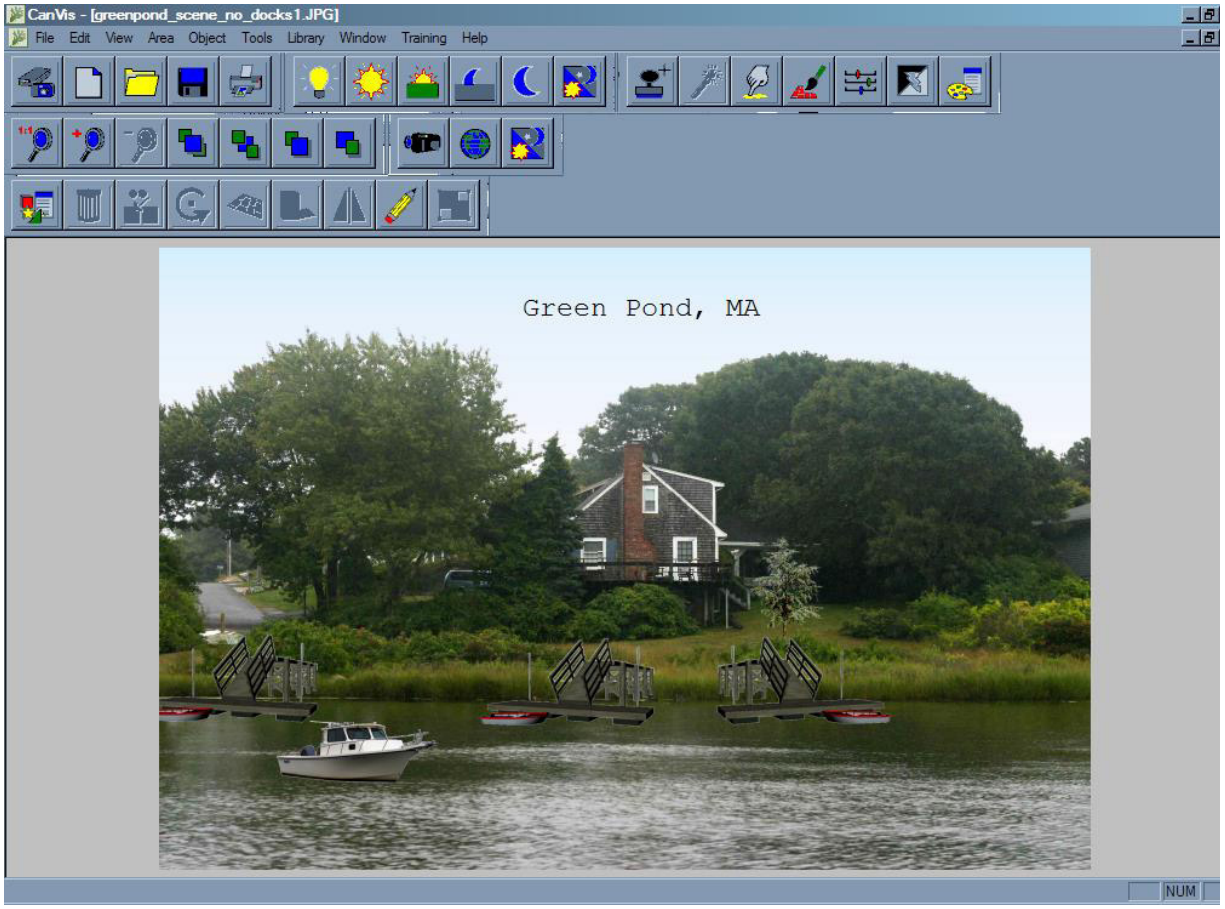
Visualization Tools



CanVis



CanVis Software Simulating Potential Sea-Level Rise in Charleston



Tool/Resource Type: **Visualization Tool (Software)**

Sector(s): **Natural Resources, Built Environment**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Assessment / Analysis**

Geographic Scale: **Determined by horizontal width and depth of view shown in digital photograph uploaded by user**

Cost: **Software Download = Free**

Data Input(s): **Digital photograph**

Website: **http://coast.noaa.gov/digitalcoast/tools/canvis**

Developer/Sponsoring Agency: **National Oceanic and Atmospheric Administration**

Description

CanVis is an image editing software that allows users to create photo-realistic simulations for visualizing potential impacts from sea-level rise. Users create visual simulations by duplicating elements (e.g., houses, boat docks) already in a digital photograph and adding an image of rising waters. The software allows elements to be resized, color-adjusted, and have shadows added to create realistic looking simulations. The software also allows text boxes to be added to photographs. To utilize, assistance by personnel with photo editing software experience is recommended.

The program includes a scale tool that is calibrated to an actual ruler and allows users to base relative measurements off a known object height. This allows users to depict inundation that is equal to a given water height, such as one foot, to simulate that amount of sea-level rise. The images of future conditions will only be accurate if the known object height that is used to scale the water level is precise. Careful measuring with the scale tool will also be required to generate a more accurate output image. Rather than providing actual data which can be used for sea-level rise adaptation, CanVis provides a visualization of possible future sea level conditions.

Limited expertise and effort are required to create a realistic image using CanVis, making it accessible to communities of all sizes. The basic features of this program can be learned in under 30 minutes by users with little or no photo-editing experience.

Examples of Use

Green Bay, WI (Pop. = 105,000)—created photorealistic visualizations of potential flooding impacts on shore-abutting residences along Lake Michigan. Visualizations were shared with residents of possible flooding scenarios caused by strong storms in order to raise awareness and increase further adaptation planning support.

Charleston, SC (Pop. = 128,000)—created a visualization of future sea-level rise by simulating 1.5 meters of sea-level rise relative to prized community landmarks which are characterized by historical, aesthetic, and economic importance in the tourism- driven region. By visualizing potential impacts to community landmarks, the City hoped to raise awareness of potential sea-level rise impacts and build community support for adaptation planning activities.

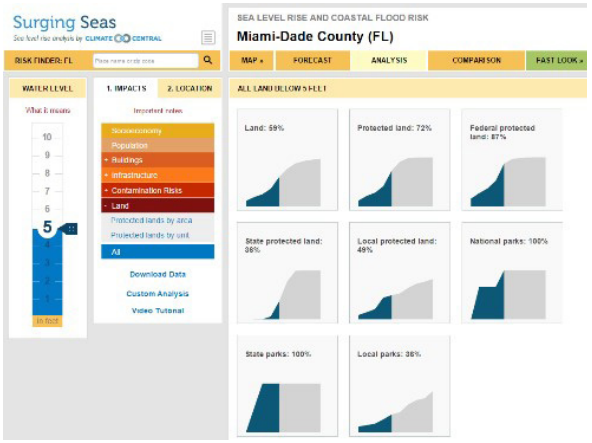
Seattle, WA (Pop. = 652,000)—created a visualization of future sea-level rise by making a before and after image of the Seattle Boardwalk. Mean projections indicate that Seattle will experience 7 inches of sea-level rise by 2050 and 24 inches by 2100. By visualizing potential impacts to community landmarks, the City hope to raise awareness of potential sea-level rise impacts and build community support for adaptation planning activities.

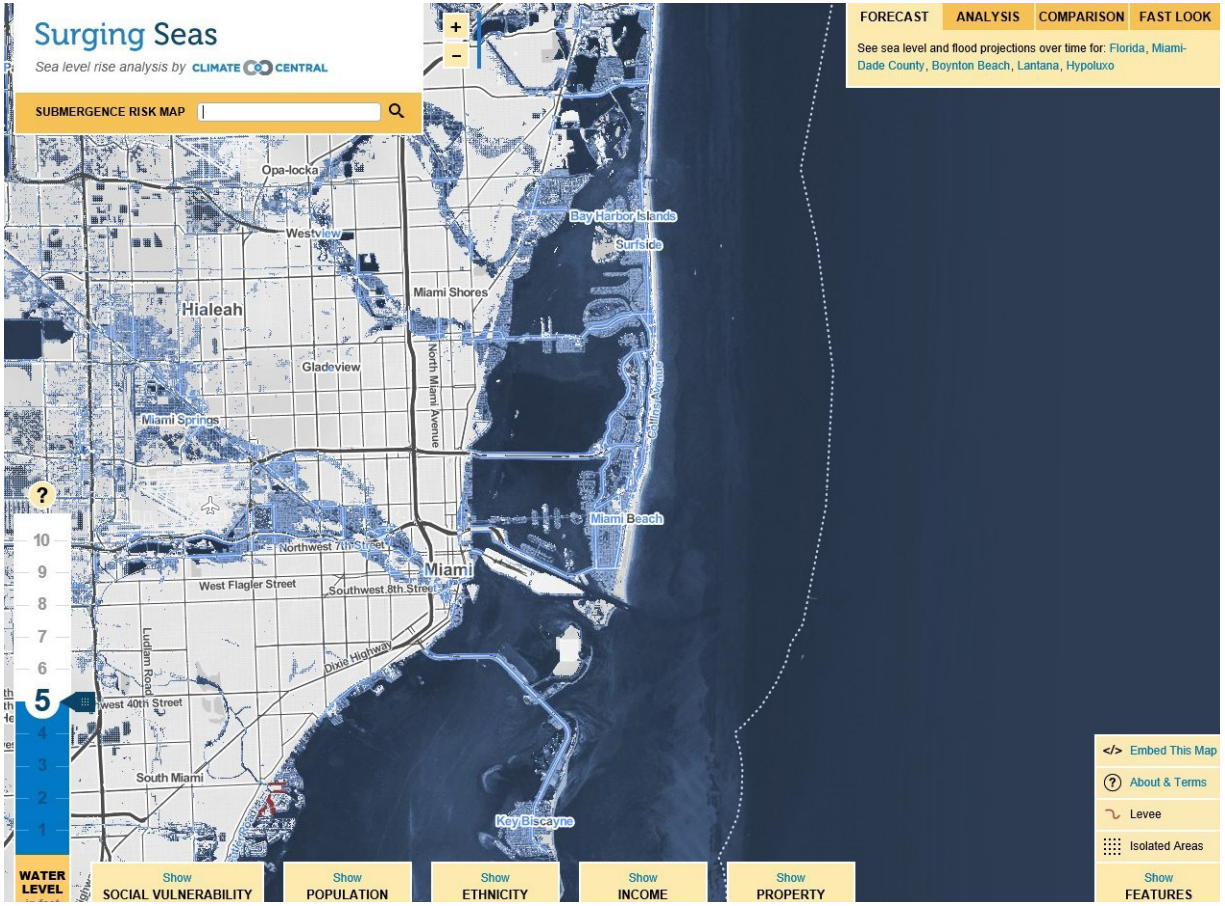
When & Where to Use

CanVis can be used to create visualizations of possible future conditions to help build awareness and facilitate public engagement during adaptation planning.

It may be applied to site-specific areas where digital photography near the waterfront exists.

Climate Central's Surging Seas





- Tool/Resource Type: **Visualization Tool (Online Mapper, Data Download)**
- Sector(s): **Natural Resources, Built Environment, Transportation**
- Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis**
- Geographic Scale: **Local, Regional, Statewide**
- Cost: **Online Map Viewer = Free; Data Download = Free**
- Data Input(s): **None**
- Website: **http://sealevel.climatecentral.org/**
- Developer/Sponsoring Agency: **Climate Central**

Description

Climate Central's Surging Seas analysis suite includes an interactive Risk Finder and Submergence Risk Map. The Risk Finder shows populations, infrastructure, and assets exposed to coastal flooding aggravated by different sea levels, as determined by the user (i.e., 1 to 10 feet of rise). The Submergence Risk Map is a tool that depicts sea-level rise scenarios. To utilize, assistance by personnel with Geographic Information Systems (GIS) experience is recommended.

The Risk Finder is a searchable data toolkit that allows users to explore vulnerability from zip code at the city, county, and state levels. It also provides the ability to compare risk across areas as well as the ability to analyze the likelihood of coastal flooding and sea level inundation occurring in the future by decade.

The Submergence Risk Map is a sea-level rise vulnerability assessment tool. This map is a web-based visualization tool that allows users to depict scenarios of sea-level rise for 1-foot height intervals from 1 to 10 feet above local high tide using an interactive slider. As the slider is moved, the map automatically updates to show what land would be covered or inundated by water and associated impact statistics (e.g., 21% of the population would be impacted). The tool also accounts for social vulnerability by identifying vulnerable communities and populations.

This tool is most useful for conducting a regional level exposure analysis; its use for informing site-specific decisions may be limited. Additionally, the tool does not incorporate physical modeling of storm surge or waves on top of sea-level rise, coastal erosion, or other coastal processes. Despite these limitations, Surging Seas is a good communications tool to help illustrate risk to others.

The data underlying the tool is available for download and the online tool can be used to generate interactive maps, tables, and figures, as well as risk timelines and other tools for assessing vulnerability to sea-level rise.

Examples of Use

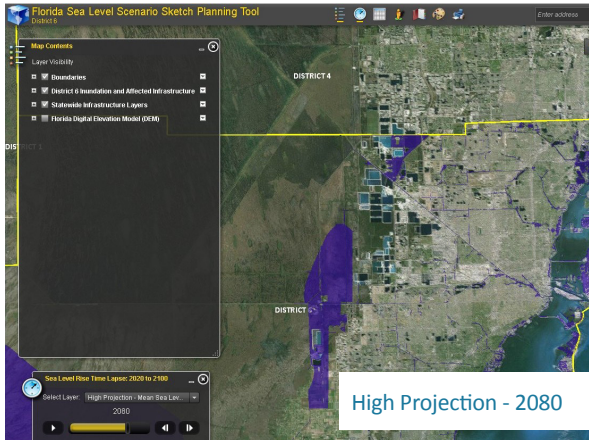
Benicia, CA (Pop. = 28,000)—is in the process of developing a vulnerability assessment and adaptation plan. The City's plan will contain strategies that address the risks identified during the vulnerability assessment. The vulnerability assessment utilized the Surging Seas tool to conduct financial assessments of impacts of future sea-level rise.

Florida, New Jersey, New York, and Washington, D.C. (Pop. = 19.9 million; 8.9 million; 19.7 million; 646,000; respectively)—reports were released to summarize the major themes and findings taken from the results accessible via the Surging Seas Risk Finder. These reports have been used to build regional awareness about vulnerability due to projected sea-level rise and coastal flood risk. The research in the reports served to highlight the high concentration and wide range of populations, property, infrastructure, buildings, and potential contamination sources in low-lying coastal areas.

When & Where to Use

Climate Central's Surging Seas is designed to provide local regions and policy makers with the tailored information they need to understand and respond to the risks of sea-level rise and coastal flooding. However, users should note that the map provides aggregated site-specific projection, meaning that while the resolution of demographics and sea-level rise projection is detailed at the parcel level, that data can only be viewed as part of the larger map mosaic. The tool allows users to visualize sea-level rise scenarios plus the historic 1 percent annual coastal flood and identify vulnerable populations, infrastructure, and assets.

FDOT Sea Level Scenario Sketch Planning Tool



High Projection - 2080

Tool/Resource Type: **Visualization Tool (Online Mapper, Data Download)**

Sector(s): **Transportation**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis**

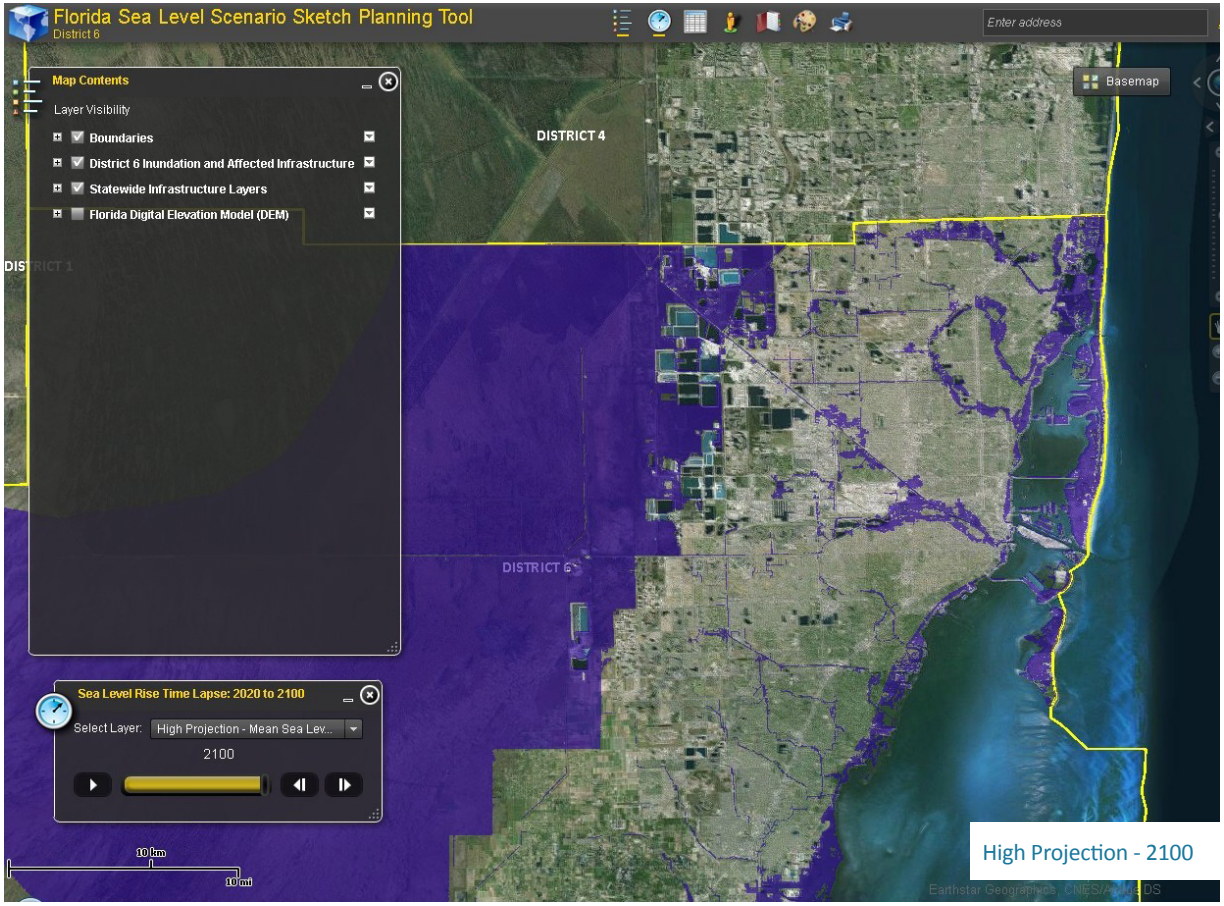
Geographic Scale: **Local, Regional, Statewide**

Cost: **Online Map Viewer = Free; Data Download = Free; Sea-Level Rise Inundation Surface Calculator Download = Free**

Data Input(s): **None**

Website: **http://sls.geoplan.ufl.edu/**

Developer/Sponsoring Agency: **Florida Department of Transportation**



High Projection - 2100

Description

The Sea Level Scenario Sketch Planning Tool allows for visualization of areas that can potentially be inundated by sea-level rise, identification of transportation facilities potentially at risk from sea-level rise inundation, report creation to summarize and prioritize affected infrastructure, and the ability to create custom inundation surfaces. The Sketch Planning Tool consists of three tools: a map viewer, GIS data layers, and a sea-level rise inundation surface calculator, which can be used independently or together to conduct a preliminary assessment of vulnerable transportation infrastructure and assist transportation planners in assessing and prioritizing transportation facility investments. For communities who wish to use the data in their own software, assistance by someone with modeling experience in GIS is recommended.

The tool enables users to view map images online that depict sea level inundation scenarios for three sea-level rise projection ranges, three time horizons, and up to four tidal datums. Users can overlay these scenarios with an array of transportation infrastructure layers and a variety of base maps. Users can also run an animated time-lapse that illustrates how inundation boundaries may change over time. The selection procedure and small scale analysis may in some cases overestimate the affected infrastructure. However, applied at the appropriate scale, those errors, while potentially significant, do not diminish the utility of the toolkit as a useful statewide and regional indicator of potentially vulnerable infrastructure.

Examples of Use

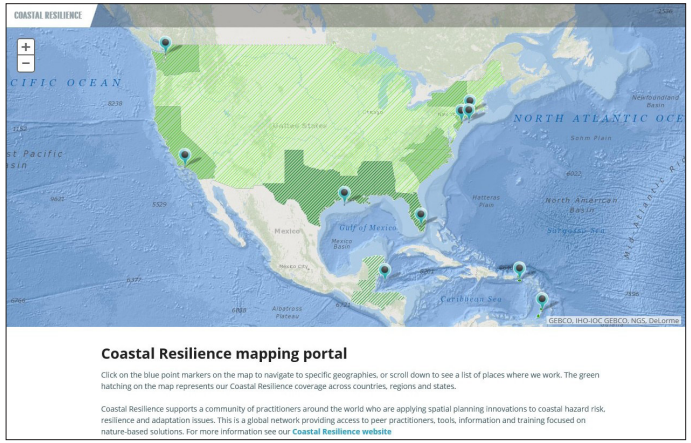
Hillsborough County, FL (Pop. = 1.3 million)—the Hillsborough County MPO 2040 Long Range Transportation Plan Needs Assessment used the Sketch Planning Tool's "high" 2040 scenario (current mean sea level plus 14 inches) to illustrate sea-level rise and help estimate disruption to the entire county and its transportation needs.

Monroe County, FL (Pop. = 76,000)—the county's Climate and Sustainability Program adaptation planning efforts included conducting a preliminary assessment using the FDOT Sea Level Sketch Scenario Planning Tool. The tool was used to identify the transportation facilities in the county that are potentially vulnerable to sea-level rise using the tool's inundation and affected infrastructure layers. Low/High projections for the years 2040 and 2060 were used model scenarios based on those adopted by the Southeast Regional Climate Compact sea-level rise projections. The results from the assessment were used to determine, for county maintained roads, where "low" and "high" daily inundations of would occur in 2040 and 2060.

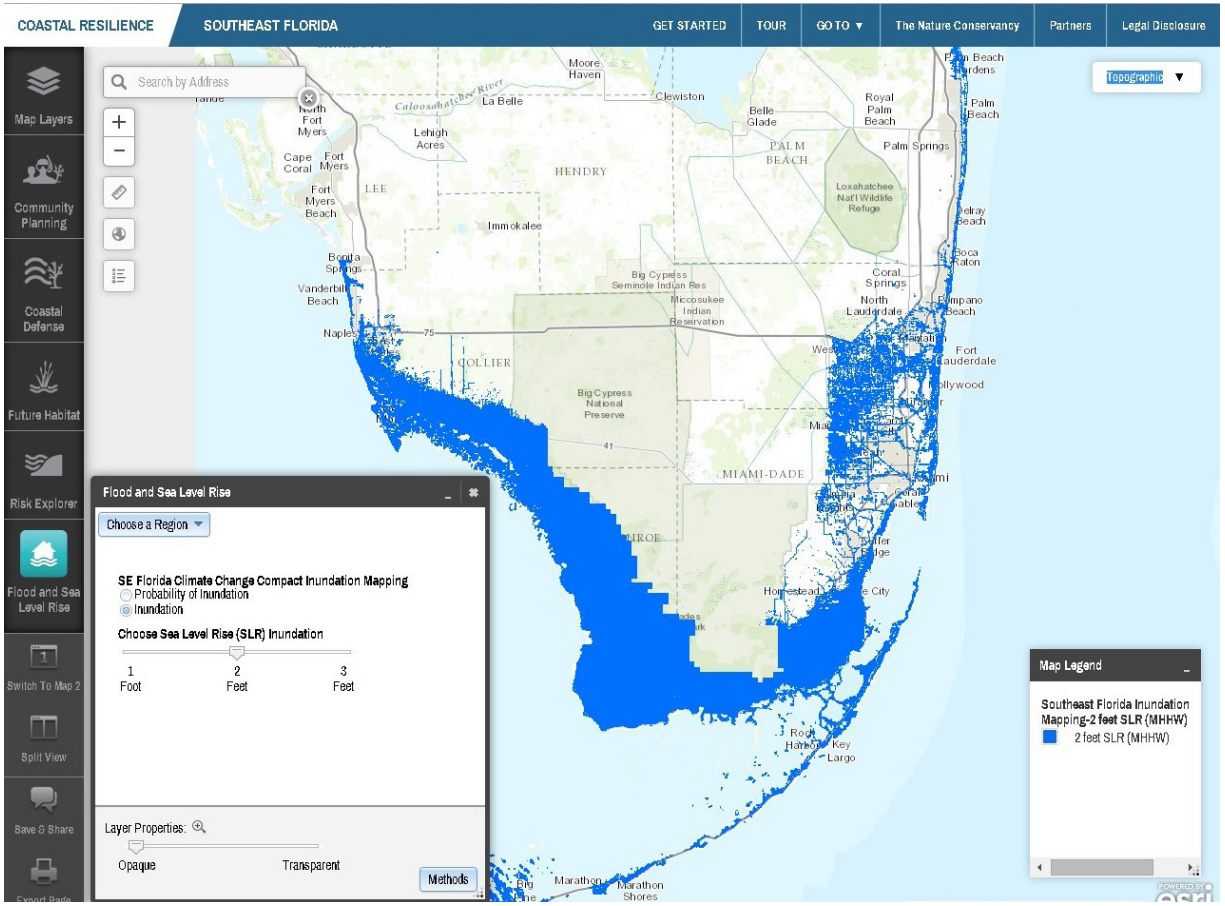
When & Where to Use

This tool displays statewide and regional vulnerability assessments of transportation facilities. More advanced users can download the base maps, infrastructure layers, and inundation layers as well as the underlying statewide digital elevation model (DEM) to create their own inundation scenarios and conduct their own local vulnerability assessments.

The Nature Conservancy Coastal Resilience Mapping Portal



- Tool/Resource Type: **Visualization Tool (Online Mapper)**
- Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation**
- Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis**
- Geographic Scale: **Local, Regional, Statewide**
- Cost: **Online Map Viewer = Free**
- Data Input(s): **None**
- Website: **http://maps.coastalresilience.org/network/**
- Developer/Sponsoring Agency: **The Nature Conservancy**



Description

The Nature Conservancy Coastal Resilience Mapping Portal gives users access to interactive tools to visualize future flood risks from sea-level rise and storm surge. The tool compiles social and natural resource data, inundation scenarios, and spatial analysis results in an interactive web mapping tool. To utilize, assistance by personnel with GIS experience is recommended.

The Mapping Portal is part of a suite of tools, Costal Resilience 2.0, released by the Nature Conservancy to enable decision makers to assess risk to coastal hazards in terms of land use, environmental characteristics, and social vulnerability. The mapping portal can help users identify areas and populations at risk from coastal hazards and gain a better understanding of ecological, social, and economic impacts. This information is particularly helpful for officials in coastal planning, zoning, and land acquisition who must take rising sea levels and increased storm intensity and frequency into consideration.

The Mapping Portal includes a "Global" interactive map that provides comparative statistics regarding coastal resilience, as well as detailed interactive maps at select locations. Detailed maps are currently available for Southeast Florida and the Florida Keys. The Portal supports open-ended "what-if" exploration of the magnitude and extent of sea-level rise. Users can adjust the hypothetical amount of sea-level rise and view model-based projections for 2020, 2050, and 2080. Users can also weigh a series of environmental and socio-economic variables to explore how sea-level rise might degrade habitats. Users can view side by side comparisons of different model parameters using the "Split View" feature.

Examples of Use

Mobile Bay, AL—local and state governments are using the Community Resilience Tool to site oyster reef restoration projects using the Risk Explorer application. The Risk Explorer allows decision makers to assess risk and vulnerability to waves, storms, and other coastal hazards and identify habitat restoration and management priorities that may be most useful for risk reduction.

Puget Sound, WA—used the Community Resilience Tool to visualize potential future potential impacts to infrastructure, such as Interstate 5. The tool is being used by state agencies, county governments, and tribal organizations in the area to make decisions about floodplain management. It also is assisting in bringing in funding for floodplain-related projects.

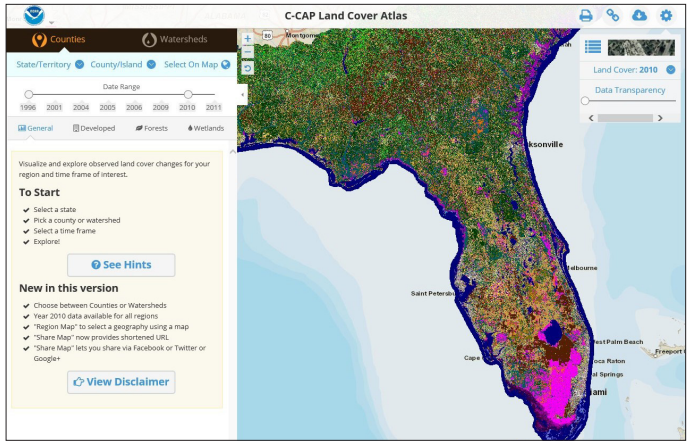
Waterford, CT (Pop. = 20,000)—the Coastal Resilience Program helped planners identify and assess risks and vulnerability to storms. The tool enabled the town to quickly prioritize actions to reduce risk. Now 20 municipalities (coastal and inland) and five regional planning organizations are engaged via the Coastal Resilience Program, reaching 500,000 people.

When & Where to Use

The Coastal Resilience Mapping portal can be used to build awareness, set principles and goals, and define the planning context. Like other visualizers, it may be used with stakeholders to define a preferred exposure analysis projection.

Data types differ slightly between the Florida Keys and the Gulf of Mexico Maps.

NOAA Coastal Change Analysis Program (C-CAP) Land Cover Atlas and Coastal Comparison Tool



Tool/Resource Type:
Visualization Tool (Online Mapper)

Sector(s): **Natural Resources, Agriculture, Built Environment**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory**

Geographic Scale: **Countywide, Statewide**

Cost: **Data Download = Free;**
Online Viewer = Free;
Online Comparison Tool = Free

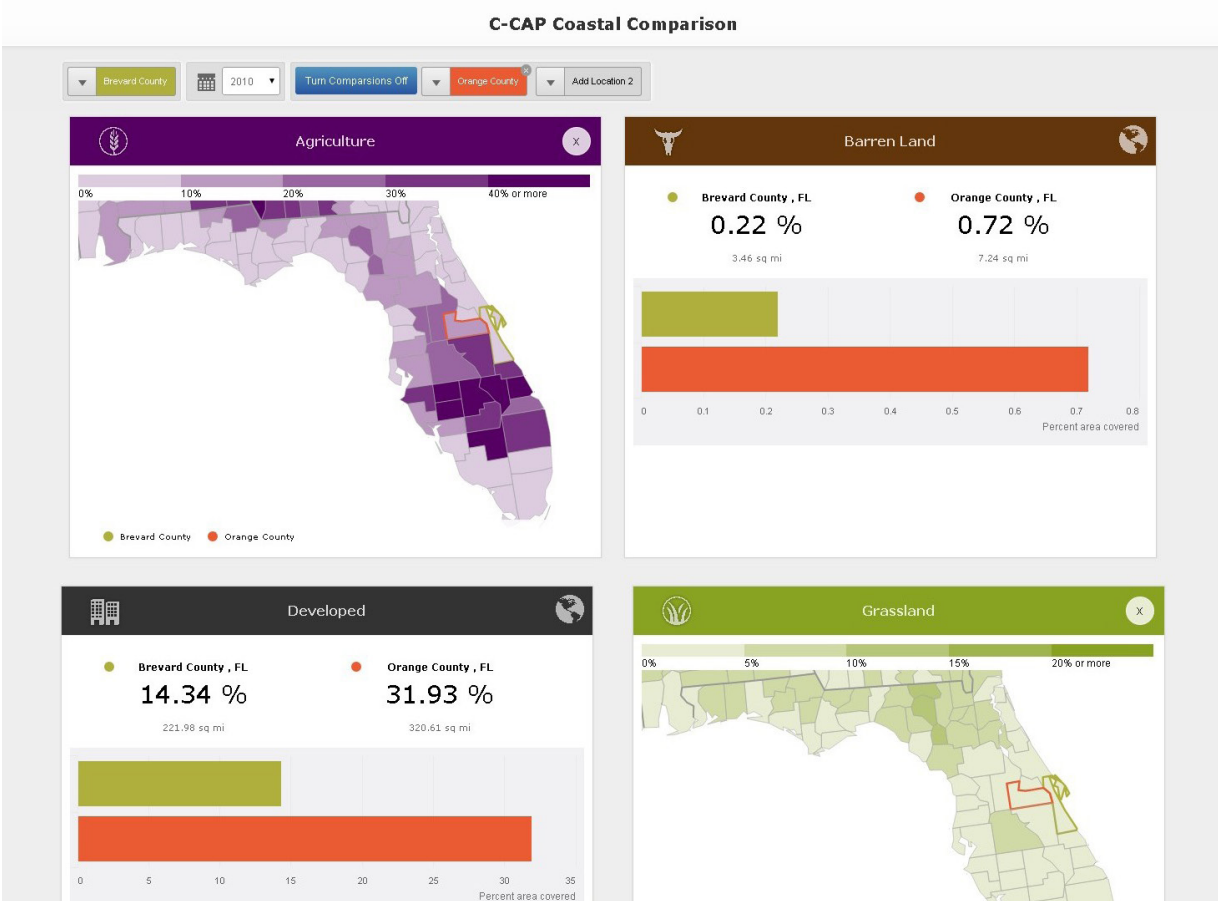
Data Input(s): **None**

Website:
http://coast.noaa.gov/digitalcoast/data/ccapregional

http://coast.noaa.gov/digitalcoast/tools/lca

http://coast.noaa.gov/digitalcoast/tools/ccap-comparison

Developer/Sponsoring Agency:
National Oceanic and Atmospheric Administration



Description

The NOAA Coastal Change Analysis Program (C-CAP) produces a nationally standardized database of land cover and land change information for the coastal regions of the U.S. that can be used to explore changes and trends in land cover that may be caused by sea-level rise. C-CAP products provide inventories of coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years. C-CAP products are developed using multiple dates of remotely sensed imagery and consist of raster-based land cover maps for each date of analysis as well as a file that highlights changes that have occurred and where the changes were located. To utilize, assistance by personnel with GIS experience is recommended.

The C-CAP Land Cover Atlas is an online viewer that provides user-friendly access to regional C-CAP land cover change information. The Atlas eliminates the need for desktop GIS software, or advanced technical expertise, by processing C-CAP data for users and providing access to that distilled information. The tool summarizes general change trends, such as forest losses or new development, and can highlight specific changes of interests, such as marsh losses to open water or evergreen forest losses to new development. The viewer also allows users to determine which areas experience accretion, erosion, or frequently change between the two and decide if implementation of coastal building buffers is warranted.

The C-CAP Coastal Comparison Tool is an interactive tool that compares land cover between different coastal geographies using baseline data from C-CAP that allows users to compare land cover data for a county to the coastal portion of its state and the contiguous U.S. Users can compare counties to assess differences and similarities in land cover and land use practices between multiple locations

Examples of Use

Breton Sound, LA—C-CAP land cover data were used to compare flood conditions in the two-week period following Hurricane Katrina (August 2005) with 2006 conditions to quickly and accurately assess the potential impacts and recovery from the storm. The most prominent changes observed were the dramatic flooding in the weeks following Katrina and the subsequent emergent wetlands. In less than one year, the state experienced a loss of over 150 square miles of estuarine emergency marsh and an increase of over 200 square miles of open water, mostly attributed to Katrina. Future land cover updates will help assess longer-term recovery or additional habitat losses.

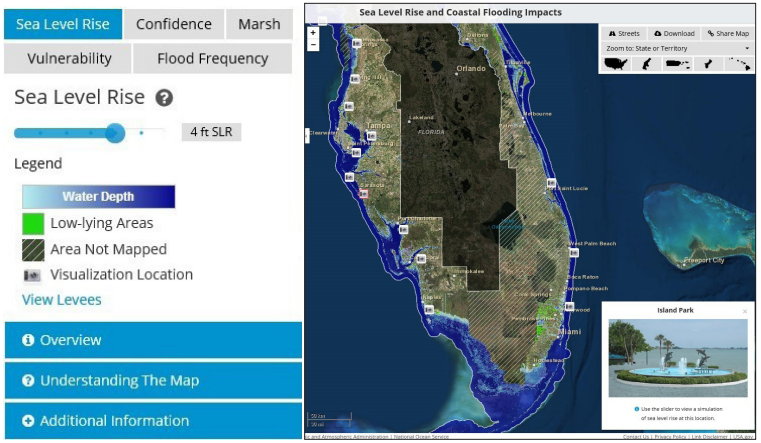
California Coast—a study was conducted to provide an analysis of the current population, infrastructure, and property at risk from projected sea-level rise if no actions are taken to protect the California Coast. This included evaluating the impacts of sea-level rise on wetlands. The land cover in the potential wetland migration zone was analyzed using 2001 land cover data from C-CAP. Each land cover type was rated according to its suitability to support wetland habitat in the future.

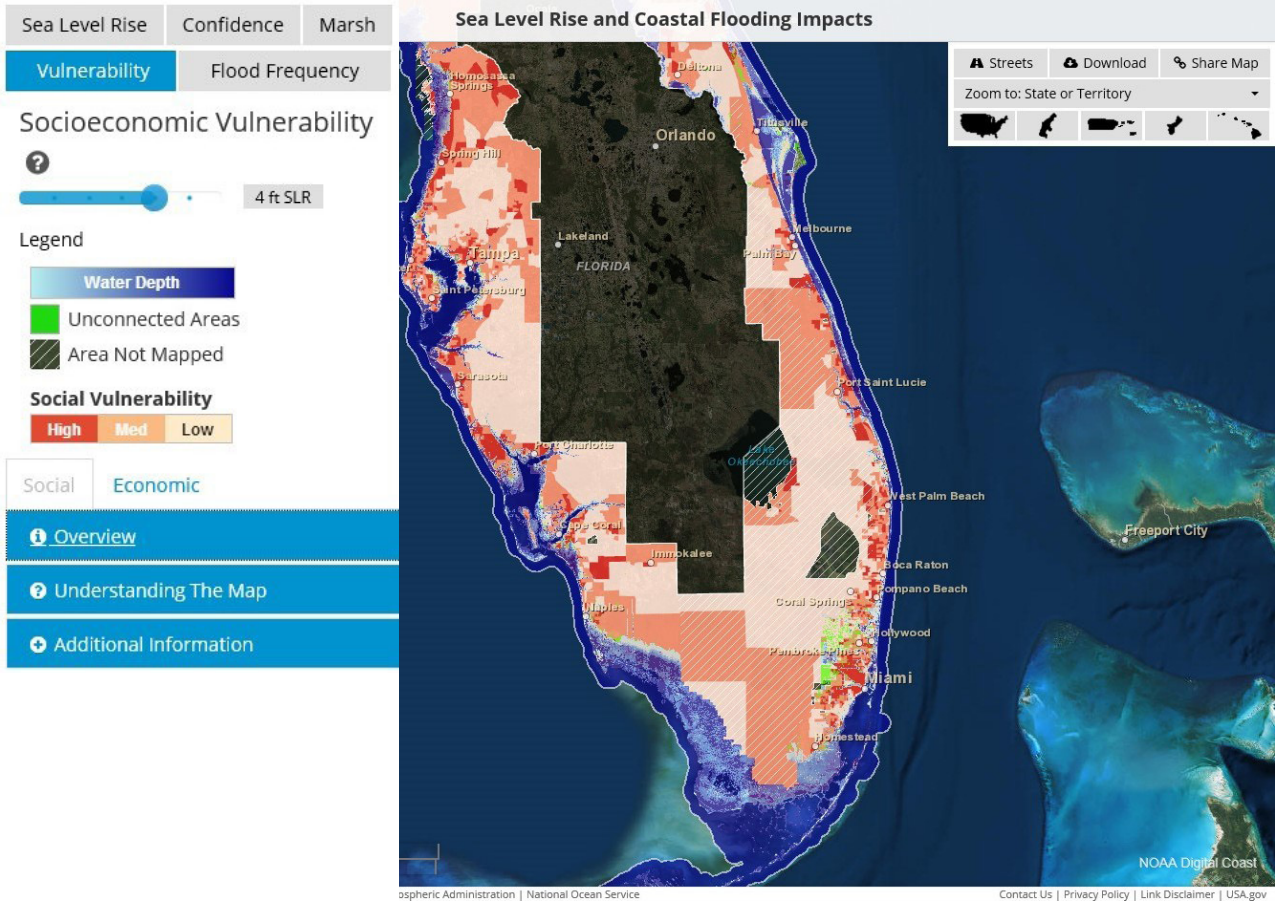
When & Where to Use

The C-CAP tool may be used during the awareness building, goal-setting, and planning context phase.

The tool allows users to compare land cover data for coastal and non-coastal areas, enabling them to explore changes and trends in land cover that may be caused by sea-level rise. It presents data at the county and watershed levels through a raster (pixel based) map.

NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer





Tool/Resource Type: **Visualization Tool (Online Mapper)**

Sector(s): **Natural Resources, Built Environment, Transportation**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis**

Geographic Scale: **Local, Regional, Statewide**

Cost: **Data Download = Free; Online Viewer = Free**

Data Input(s): **None**

Website: **http://coast.noaa.gov/digitalcoast/tools/slr**

Developer/Sponsoring Agency: **National Oceanic and Atmospheric Administration**

Description

NOAA's Sea-Level Rise and Coastal Flooding Impacts Viewer is an online viewer that allows users to visualize potential impacts from sea-level rise. Users will select a geography in the viewer and move a slider bar to simulate various sea-level rise scenarios (at one-foot increments, from one to six feet above the average highest tide) to show the corresponding areas that could be impacted by flooding. Simulations that depict how local landmarks could be affected by potential future sea levels are also available anywhere a camera icon is located on the viewer. Additional tabs provide information about marsh impacts, nuisance flood frequency, socioeconomic vulnerability, and mapping confidence levels. To utilize, assistance by personnel with GIS experience is recommended.

Sea-level rise and coastal flooding mapping data for all the states and territories are currently available in the viewer, except for Alaska and Louisiana. However, new elevation data are being constantly collected by various federal, state, and local entities so it is possible that newer data have been collected since the mapping areas were originally populated.

Users can obtain the underlying digital elevation models (DEM) used in the viewer as well as the coastal flood inundation data files. Users will need their own GIS platform to manipulate the digital data or create related image outputs.

Examples of Use

Tybee Island, GA (Pop. = 3,000)—the city identified the areas of the island most vulnerable to sea-level rise using the Sea-Level Rise and Coastal Flooding Impacts Viewer. Once these areas were identified, a plan was developed and actions were prioritized for dealing with the current problems of flooding and frequent high tides as well potential impacts from future sea-level rise. City staff members also used the visual provided by the viewer at public meetings to display vulnerable areas and increase awareness of the impact that future sea-level rise could have on the community.

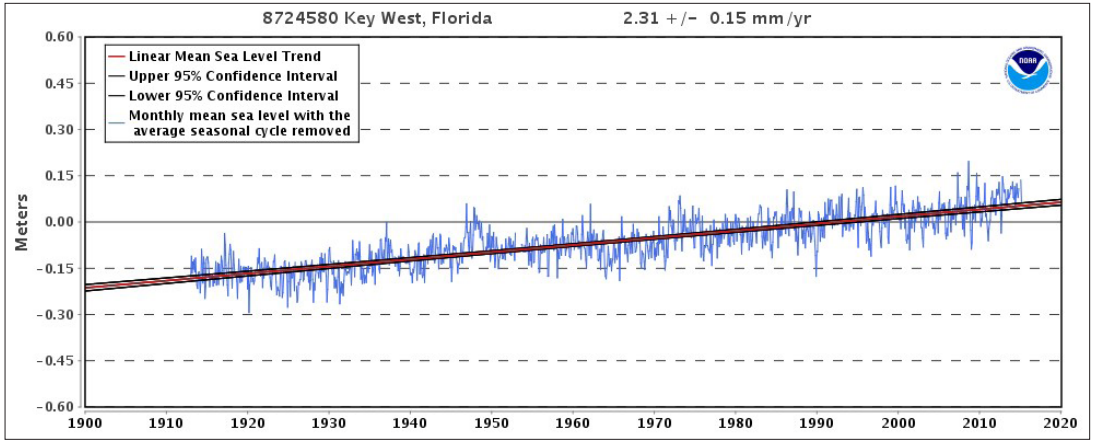
Biloxi, MS (Pop. = 45,000)—a hazards exhibit was set up in a regional shopping mall to help local residents and floodplain managers get a sense of what their town and neighborhoods could experience at various sea-level rise scenarios. Potential flooding impacts were demonstrated using the Sea-Level Rise and Coastal Flooding Impacts Viewer on a large screen at the exhibit. People were able to use the tool to visualize the extent of flooding and zoom in to local landmarks to see a simulation of flooding under various degrees of sea-level rise.

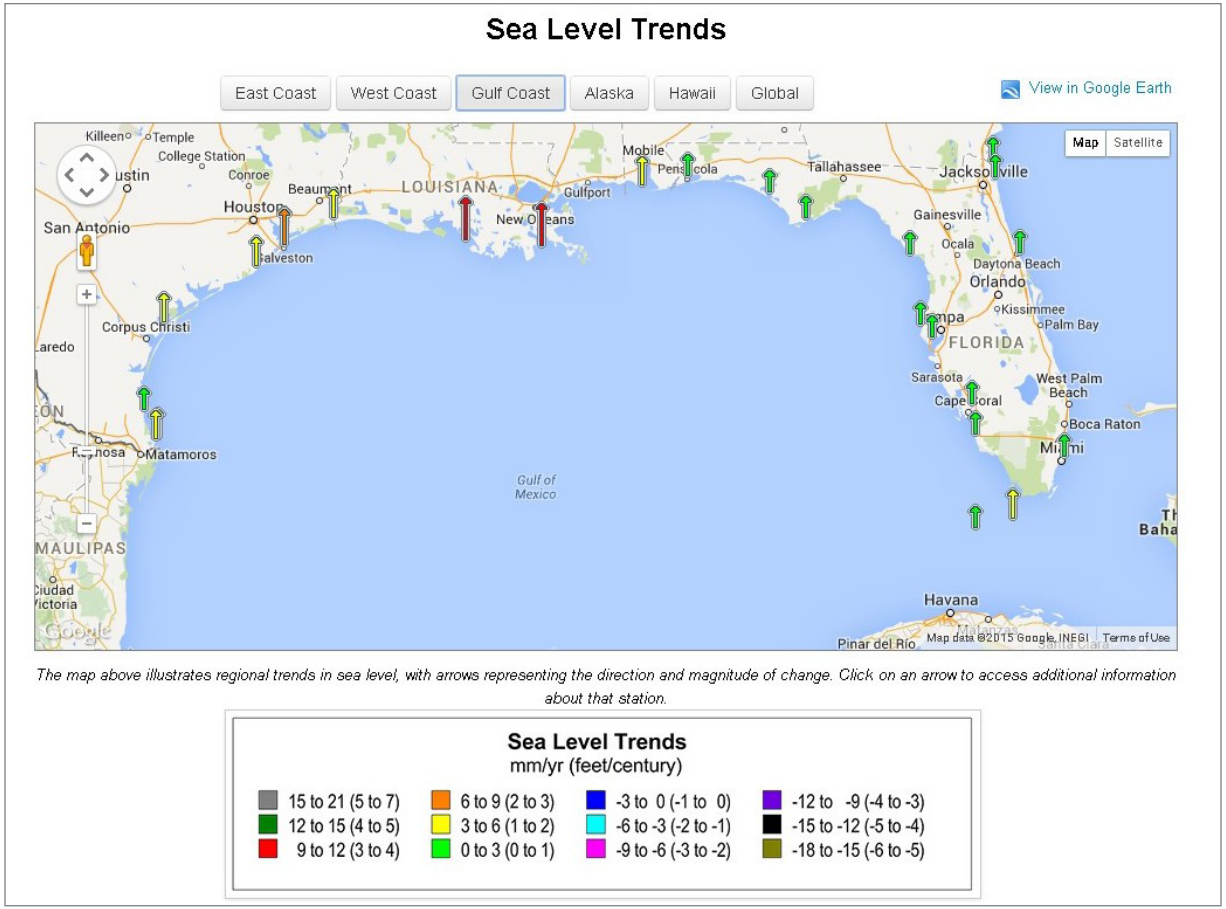
Southeast Florida (Pop. = 5.9 million)—the same methods used to create the Sea-Level Rise and Coastal Flooding Impacts Viewer were used to develop a unified set of methods and criteria for creating sea level inundation maps for the Southeast Florida counties of Monroe, Miami-Dade, Broward, and Palm Beach. After consistent mapping methods were developed, the counties and the South Florida Water Management District worked together to develop a vulnerability assessment of the Southeast Florida region for one, two and three-foot sea-level rise scenarios.

When & Where to Use

The Sea-Level Rise and Coastal Flooding Impacts Viewer allows users to conduct an exposure analysis and visualize how various levels of sea-level rise may impact a coastal community. This tool can also be used to help build awareness and facilitate public engagement during the adaptation planning process, and with the downloadable layers, to conduct a partial vulnerability analysis.

NOAA Sea Level Trends





The map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

Sea Level Trends
mm/yr (feet/century)

15 to 21 (5 to 7)	6 to 9 (2 to 3)	-3 to 0 (-1 to 0)	-12 to -9 (-4 to -3)
12 to 15 (4 to 5)	3 to 6 (1 to 2)	-6 to -3 (-2 to -1)	-15 to -12 (-5 to -4)
9 to 12 (3 to 4)	0 to 3 (0 to 1)	-9 to -6 (-3 to -2)	-18 to -15 (-6 to -5)

Tool/Resource Type: **Visualization Tool (Online Mapper)**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Assessment / Analysis**

Geographic Scale: **Local, Regional**

Cost: **Online Viewer = Free**

Data Input(s): **None**

Website: **http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml**

Developer/Sponsoring Agency: **National Oceanic and Atmospheric Administration**

Description

NOAA Sea Level Trends is a tool that illustrates regional trends in sea level with arrows representing the direction and magnitude of change. The tool can be used to determine areas which have experienced the highest rates of change and may be most vulnerable to future sea-level rise. To utilize, assistance by personnel with GIS experience is recommended.

The Center for Operational Oceanographic Products and Services has been measuring sea level for over 150 years, with tide stations of the National Water Level Observation Network (NWLON) operating on all U.S. coasts. Changes in Mean Sea Level (MSL), either a sea-level rise or sea level fall, have been computed at 128 long-term water level stations using a minimum span of 30 years of observations at each location. These measurements have been averaged by month to remove the effect of higher frequency phenomena in order to compute an accurate linear sea level trend.

The MSL trends measured by tide gauges that are presented by the Sea Level Trends tool are local relative MSL trends as opposed to the global sea level trend. Tide gauge measurements are made with respect to a local fixed reference level on land; therefore, if there is some long- term vertical land motion occurring at that location, the relative MSL trend measured there is a combination of the global sea level rate and the local vertical land motion. It is important for the user to note that individual location tide gauge measurement values can vary significantly from global average values generally because of the consequences of location specific topography- and geology-related impacts.

Examples of Use

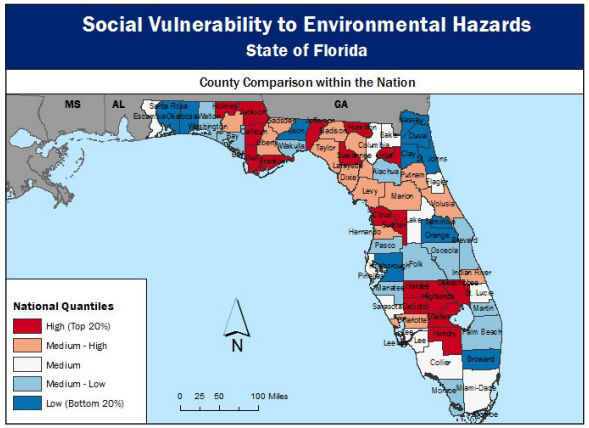
Massachusetts (Pop. = 6.7 million)—The Massachusetts Office of Coastal Zone Management (CZM) developed a guidance document to help coastal communities and others plan for and address potential sea-level rise effects on residential and commercial development, infrastructure and critical facilities, and natural resources and ecosystems. The document includes background information on local and global sea-level rise trends that was obtained from NOAA's Sea Level Trends. This information includes data from three long-term tide gauge stations in Boston, Woods Hole, and Nantucket.

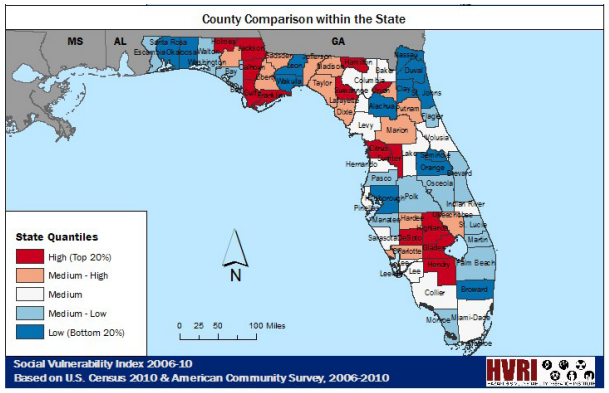
Chesapeake Bay, VA and MD—the Virginia Institute of Marine Science developed a report titled "Chesapeake Bay Land Subsidence and Sea Level Change: An evaluation of past and present trends and future outlook" for the U.S. Army Corps of Engineers Norfolk District. This report included information on Chesapeake Bay Sea Level trends that was obtained from records for 10 of the tide gauge stations included in NWLON network used by NOAA Sea Level Trends. The report found that land subsidence in Chesapeake Bay is likely to continue at or near present rates.

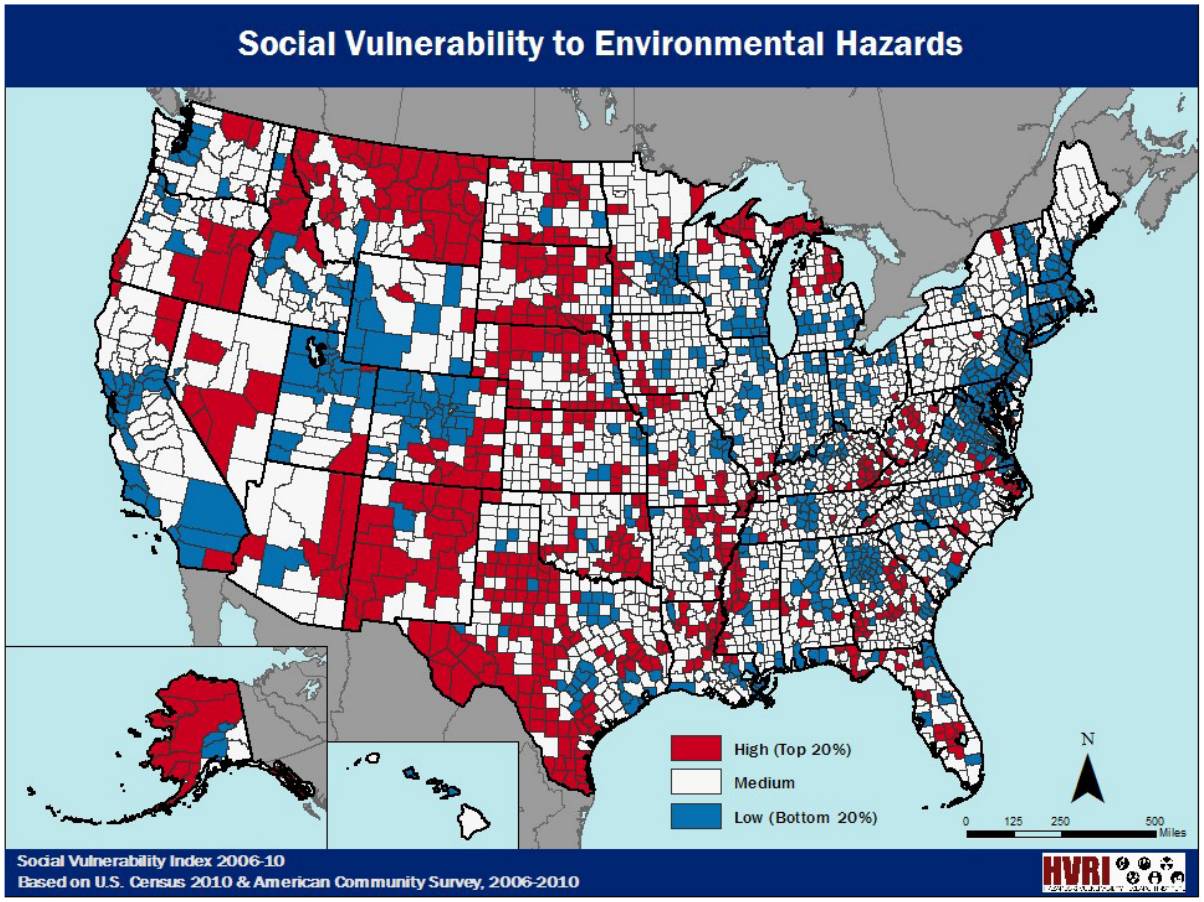
When & Where to Use

The NOAA Sea Level Trends tool illustrates regional trends in sea level and can be used to identify areas that may be most impacted by future sea-level rise. It may be used for community wide awareness building, goal-setting, and decisions about the rate of rise selected for an exposure analysis.

Social Vulnerability Index (SoVI)







Tool/Resource Type: **Visualization Tool (Online Mapper, Data Download)**

Sector(s): **Built Environment**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Assessment / Analysis**

Geographic Scale: **Census Tract to Countywide**

Cost: **Results = Free; Data Download = Free**

Data Input(s): **None**

Website: **http://webra.cas.sc.edu/hvri/products/sovi.aspx**

Developer/Sponsoring Agency: **University of South Carolina, Hazard and Vulnerability Research Institute**

Description

The Social Vulnerability Index (SoVI) measures the social vulnerability of U.S. counties to environmental hazards, including sea-level rise. The index is a comparative metric that facilitates the examination of the differences in social vulnerability among counties. SoVI graphically illustrates the geographic variation in social vulnerability. It shows users where there is uneven capacity for preparedness and response and where resources might be used most effectively to reduce pre-existing vulnerabilities. To utilize, assistance by personnel with GIS experience is recommended.

The index synthesizes 30 socioeconomic variables, which the research literature suggests contribute to reduction in a community's ability to prepare for, respond to, and recover from hazards. SoVI data sources are primarily from the U.S. Census Bureau.

Generally, SoVI is classified using standard deviations, and SoVI scores that are greater than two standard deviations above the mean are considered the most socially vulnerable, while scores below two standard deviations less than the mean are the least vulnerable. SoVI scores are re-calculated based upon the unit of geographic analysis (country, state, county), and change in relation to the available ranges of values.

County-level SoVI scores and maps are freely available online and census tract-level results can be requested by email. This data is available for the entire nation. Additionally, SoVI GIS data shapefiles at the census tract-level are available for download for all coastal states through NOAA's Digital Coast Data Registry.

Examples of Use

South Carolina (Pop. = 4.8 million)—conducted a social vulnerability assessment using SoVI as part of the state hazards assessment. The SoVI metric at both county and tract levels for the entire state allow planners and emergency managers to quickly identify broad differences across the state and begin to understand (at sub-county levels) the characteristics of their populations and how populations are increasing or decreasing vulnerability. This assessment demonstrates where social vulnerability is concentrated in the state and provides information for individual counties in determining where their resources might be most effectively utilized to enhance preparedness, response, and recovery.

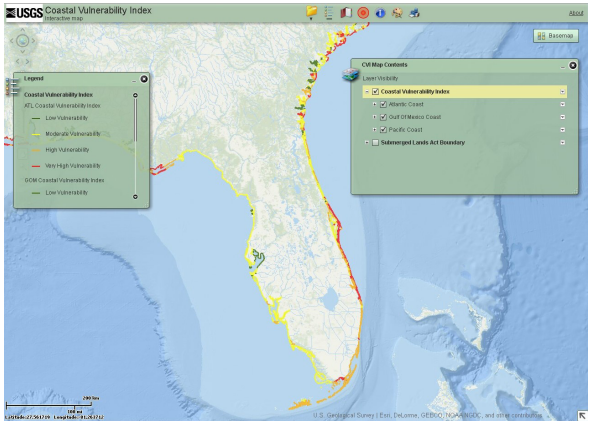
Colorado (Pop. = 5.4 million)—used SoVI to conduct a social vulnerability analysis at the census tract level. Local socioeconomic and demographic data were used to identify spatial patterns in social vulnerability across the state and have been applied to the hazard profiles in the Colorado State Hazard Mitigation Plan.

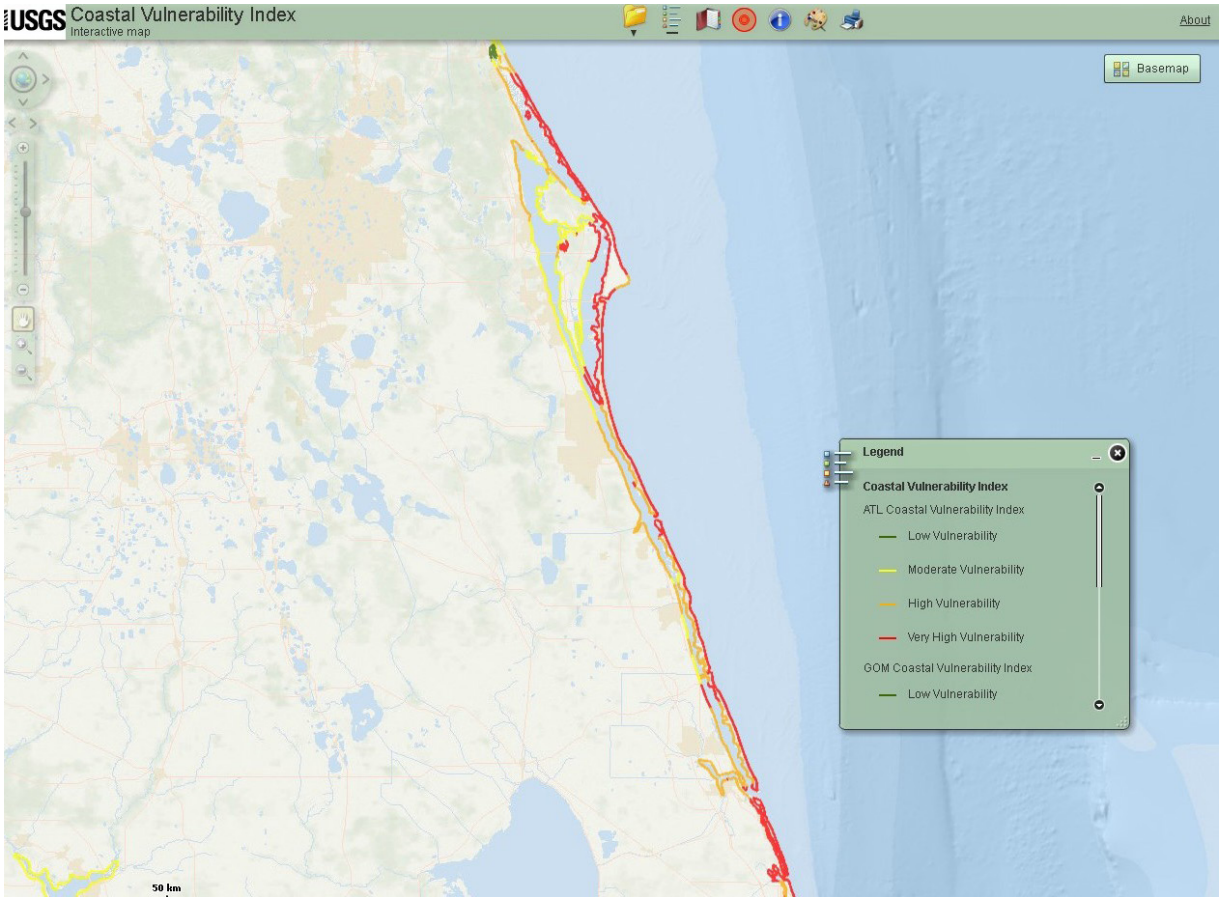
Southeast U.S.—Oxfam America released new maps about the geography and the people of the Southeast U.S., specifically Louisiana and Mississippi. The analysis was adapted from the SoVI index and the maps illustrate how climate hazards pose the most risk to communities that share certain characteristics of social vulnerability, such as poverty, larger populations of elderly or young, and substandard housing stock. The maps assist in identifying hotspots which are at significant risk in the face of four particular climate hazards, including sea-level rise. The research found that coupled with social vulnerability, the bayou parishes in Louisiana are at the highest risk to sea-level rise.

When & Where to Use

SoVI can provide valuable information during the Impacts Analysis phase. Because it shows differences in capacity for preparedness and response as well as areas where resources might be used most effectively, the tool can be used to identify census-tract focus areas where adaptation strategies are merited.

USGS National Assessment of Coastal Vulnerability to Sea-Level Rise: Coastal Vulnerability Index (CVI)





Tool/Resource Type: **Visualization Tool (Online Mapper)**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Assessment / Analysis**

Geographic Scale: **Local, Regional, Statewide**

Cost: **Map Viewer = Free**

Data Input(s): **None**

Website: **http://coastalmap.marine.usgs.gov/FlexWeb/national/cvi/**

Developer/Sponsoring Agency: **United States Geological Survey**

Description

The USGS National Assessment of Coastal Vulnerability seeks to determine the relative risks due to future sea-level rise for the U.S. Atlantic, Pacific, and Gulf of Mexico coasts. The interactive map, including the CVI, is available online and it is part of the USGS Coastal and Marine Geology Program (CMGP) Interactive Maps. This map includes the Coastal Vulnerability Index (CVI) data layer that expresses the relative vulnerability of the coast to physical changes due to sea-level rise, geomorphology (which indicates the relative susceptibility to erosion of a given shoreline), and shoreline erosion rates (which indicate how the given section of shoreline has been eroding). To utilize, assistance by personnel with GIS experience is recommended.

Through the use of CVI, the relative risk that physical changes will occur as sea-level rises is quantified based on the following criteria: tidal range, wave height, coastal slope, shoreline change, geomorphology, and historical rate of relative sea-level rise. The combination of these variables and the association of these variables to each other furnish a broad overview of regions where physical changes are likely to occur to due to sea-level rise. This approach combines a coastal system's susceptibility to change with its natural ability to adapt to changing environmental conditions, and yields a relative measure of the system's natural vulnerability to the effects of sea-level rise. Users will be able to easily determine which coastlines are the most vulnerable to potential future sea-level rise using this interactive map.

Examples of Use

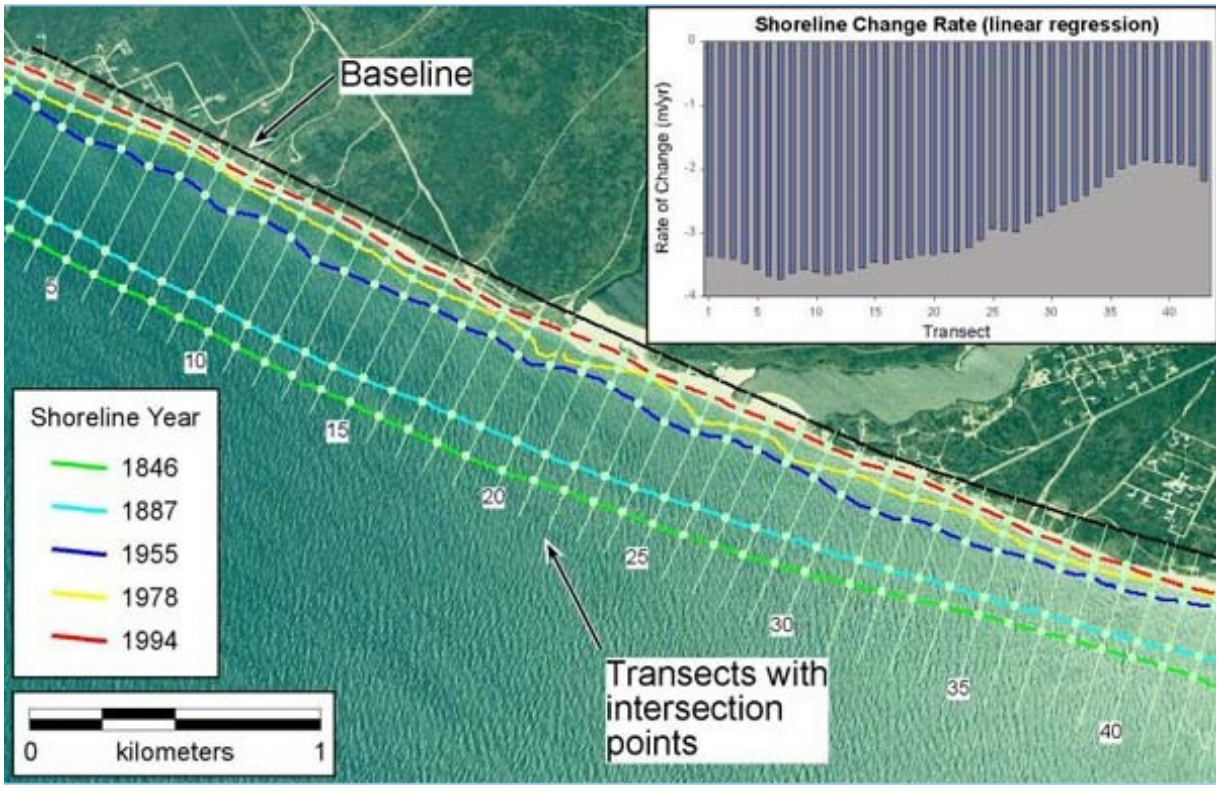
California (Pop. = 38.8 million)—according to studies conducted by the USGS, relative sea level is rising at 2.29 mm/year in the San Francisco-Monterey Bay region. Additionally, in contrast to the northern Pacific coast, the wave energy in this area is moderate to high and decreases as you move down the coast to areas of low wave energy in southern California. This reflects data obtained from the Coastal Vulnerability Index (CVI) which was developed to determine the physical response of the coastline to sea-level rise. Based on this research, the USGS estimates that sea-level rise will have a large, sustained impact on coastal evolution over the next decade. This could potentially result in the loss of cultural, natural, and recreational resources in California's coastal State Parks.

Cape Hatteras National Seashore, NC—A coastal vulnerability index (CVI) was used to map the relative vulnerability of the coast to future sea-level rise within Cape Hatteras National Seashore. The CVI provides insight into the relative potential of coastal change due to future sea-level rise. Over 70 miles of shoreline was evaluated, and, of this total, 26 percent of the mapped shoreline is classified as being at very high vulnerability due to future sea-level rise. Another 24 percent is classified as high vulnerability, 26 percent as moderate vulnerability, and 24 percent as low vulnerability. Ranking will allow coastal managers to define planning focus areas.

When & Where to Use

This tool may be used to describe the planning context, and to inform the exposure analysis. It includes continuous data for the entire coast of Florida, and communities may use the identify tool on their particular stretch of shoreline to examine USGS' six characteristics of sea-level rise. Data download was unavailable at the time of publication of this current resource.

USGS Digital Shoreline Analysis System (DSAS)



Tool/Resource Type:
Visualization Tool (Software)

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Assessment / Analysis**

Geographic Scale: **Shoreline**

Cost: **Software Download = Free**

Data Input(s): **National shoreline data**

Website:
http://pubs.usgs.gov/of/2003/of03-076/

Developer/Sponsoring Agency:
United States Geological Survey

Description

The USGS Digital Shoreline Analysis System (DSAS) can be used to measure coastal erosion and accretion which can assist users determine which areas have experienced the highest rates of change and may be most vulnerable to sea-level rise. DSAS version 2.0 extends the normal functionality of the ESRI's ArcView GIS to include historic shoreline change analysis. The application extension is designed to efficiently lead a user through the major steps of shoreline change analysis in a clearly organized and attractive user interface. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

DSAS facilitates the shoreline change-calculation process, providing both rate-of-change information and the statistical data necessary to establish the reliability of the calculated results. The software will guide users through the steps to define a baseline, generate transects at user-defined intervals along the coast, and calculate rates of change that are based on multiple historic shoreline positions. In addition to measuring shoreline change, the software can be used to measure the positional change over time of river channel boundaries and land cover changes.

It is important for users to note that the calculated measures of change provided by DSAS are only as reliable as the sampling and measurement accuracy associated with the source materials/data used. The resolution of shoreline data derived from various sources may result in inaccuracies.

Examples of Use

Santa Rosa Island, FL—DSAS was used to analyze shoreline data for nearly two dozen historical shoreline positions that were compiled and georeferenced from surveys and aerial photos dating from the 1850s to the present and were used to determine the barrier island's response to storms and sea-level rise. Analysis of the dataset revealed that storms have heavily influenced shoreline position. Shoreline retreat during the period from 1851 to present (2013) has averaged less than one meter per year. Periods of more rapid retreat have been associated with the occurrence of major storms. The historical shoreline data underscore the dominant influence of storm frequency and intensity in determining coastal change.

Assateague Island National Seashore, MD—used DSAS software to calculate shoreline rates of change (m/year) at 20 meter intervals (transects) along the Assateague coast to derive the rate of shoreline change over time. Shoreline change rates on Assateague Island were found to range from greater than 2 m/year of accretion (very low vulnerability to future sea-level rise) to greater than 2 m/year of erosion (very high vulnerability to future sea-level rise).

National Assessment of Shoreline Change Project—DSAS is being used as part of the National Assessment of Shoreline Change Project to calculate rates of long-term and short-term change along open-ocean sandy shores of the conterminous U.S. A primary goal of this work is to develop standardized methods for mapping and analyzing shoreline movement so that internally consistent updates can periodically be made to record shoreline erosion and accretion.

When & Where to Use

DSAS calculations can be used to identify areas, at the sub-community level, that may be most impacted by future sea-level rise. Communities may use this GIS extension during the exposure analysis and impact analysis phases.

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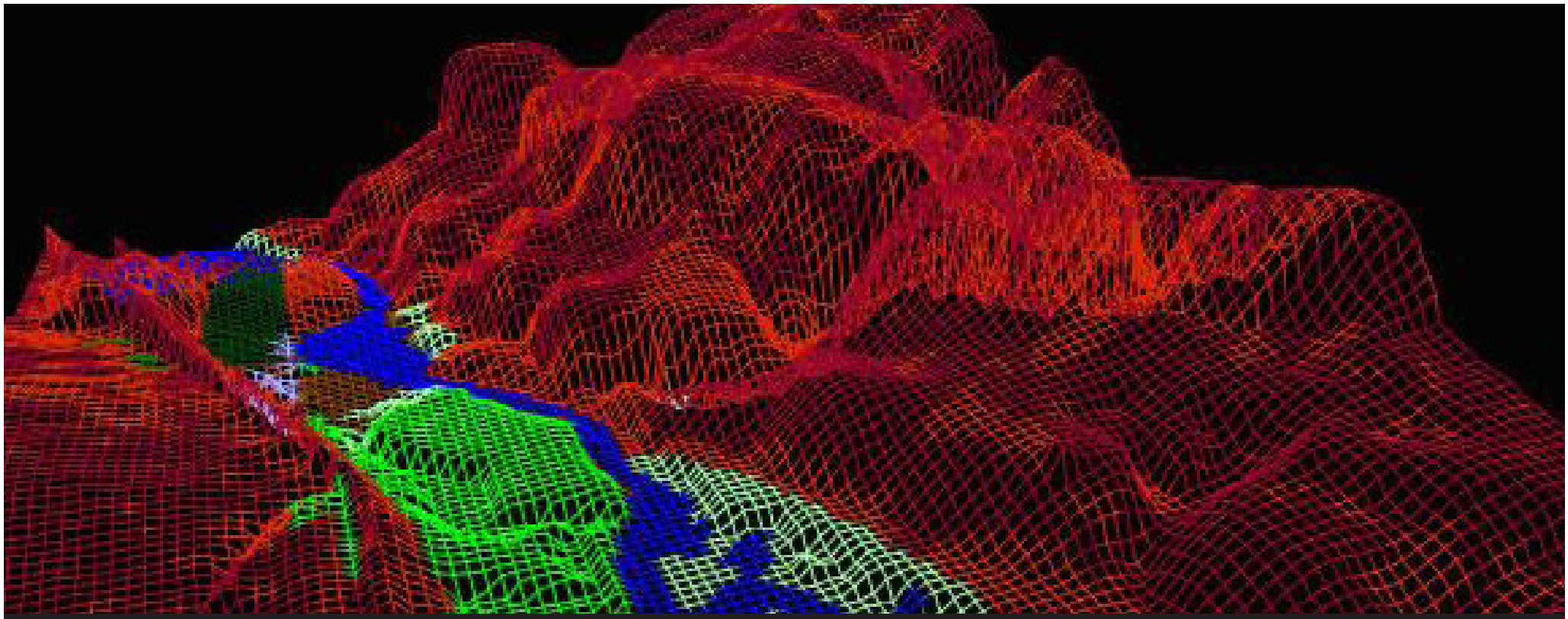
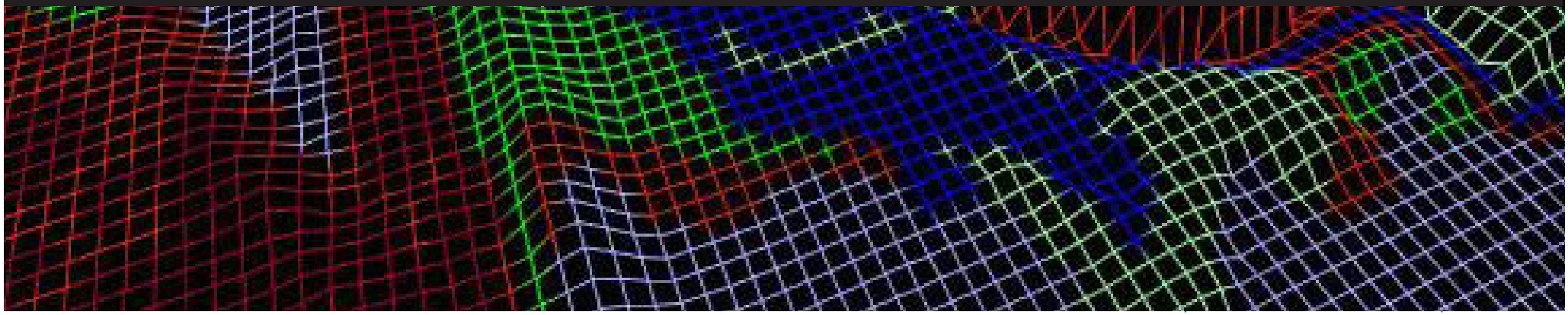
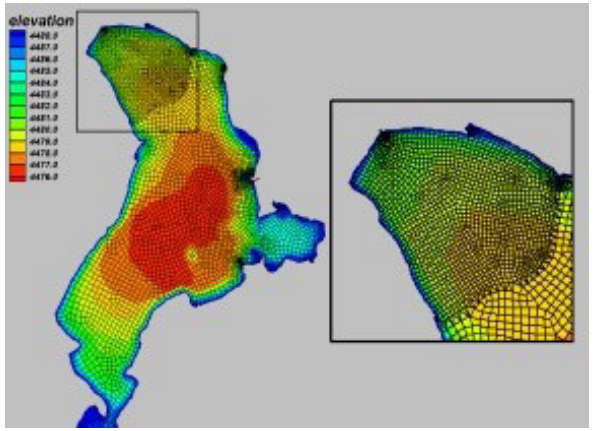


Modeling Tools



ADvanced CIRCulation Model (ADCIRC)



Tool/Resource Type: **Modeling Tool**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis**

Geographic Scale: **Deep Ocean, Continental Shelves, Coastal Seas, or Small-scale, Estuarine Systems**

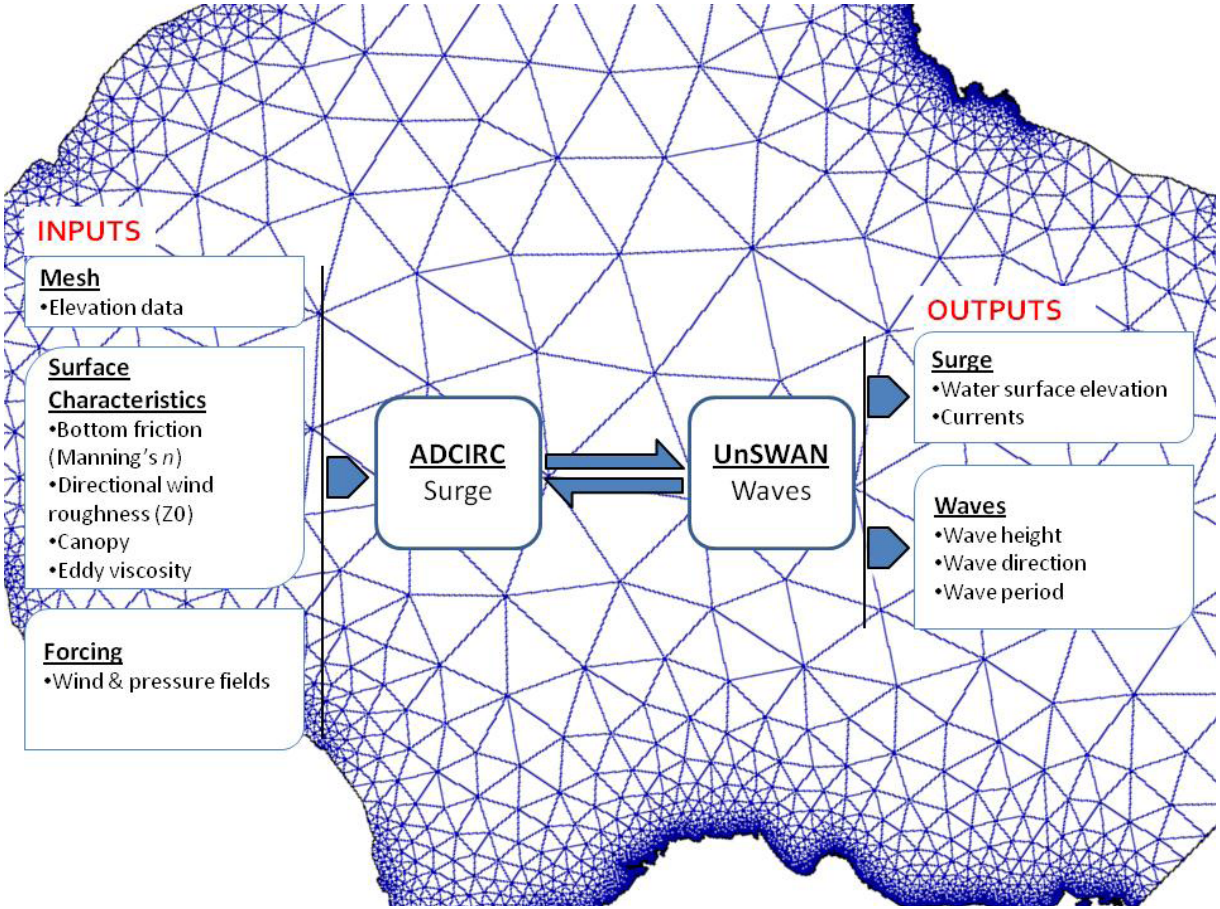
Cost: **ADCIRC Software Component = $3,950; Custom ADCIRC Package = $6,350; SMS Package = $2,400-$47,600; Educational Package Discount = 50% off**

Data Input(s): **Bathymetry, gridded wind measurements across the model domain, freshwater discharge**

Website: **http://adcirc.org/**
http://www.aquaveo.com/software/sms-adcirc

http://www.veritechinc.com/products/sms_adcirc/index.php

Developer/Sponsoring Agency: **University of North Carolina at Chapel Hill, University of Notre Dame, University of Texas at Austin**



Description

The ADvanced CIRCulation Model (ADCIRC) can be used to analyze the effects of sea-level rise on storm surge. Future scenarios can consider a given rate of sea-level rise and determine how much additional inundation is predicted during a storm event compared to inundation under initial conditions. ADCIRC can be applied to coastal oceans, inlets, rivers, and floodplains to solve the equations of motion for a moving fluid on a rotating earth. Typical applications have included prediction of storm surge and flooding, modeling tides and wind driven circulation, larval transport studies, near shore marine operations, and dredging feasibility and material disposal studies. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

ADCIRC is a highly-vetted, physics-based circulation model that is commonly utilized as the standard coastal storm surge model by the U.S. Army Corps of Engineers and Federal Emergency Management Agency (FEMA). Non-U.S. Army Corps of Engineer users can obtain ADCIRC in the Surface- Water Modeling System (SMS) distribution available through Aquaveo (provides all new development and support) and Veri-Tech (licensed vendor). However, knowledge of the SMS software is practically required for new ADCIRC users.

The advantage of using ADCIRC over other storm surge models is that input conditions can include all or part of wind stress, tides, wave stress, and river discharge to make the model output more accurate. Disadvantages include the matter in which input/output affects model performance since each output file must be written sequentially and usability is not ideal.

Examples of Use

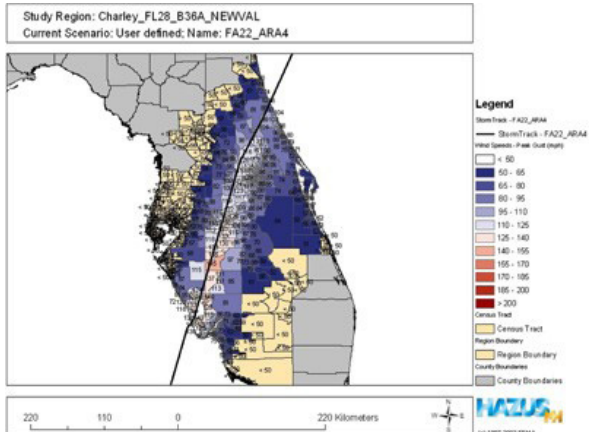
Corpus Christi Bay Area, TX—the ADCIRC model was used to analyze the effects of future landscapes and sea-level rise on storm surge. Future scenarios include changes in land cover type in the area as well as a sea-level rise rate for 2050 and 2100 conditions. The 2050 simulation predicted an addition of 936 square miles of inundation to the initial conditions (in 2006) along the entire coast of Texas during a hypothetical storm scenario. The 2100 simulation predicts an increase of 2,046 square miles of inundation along the entire coast of Texas, which is double the area impacted when compared to the 2050 scenario.

Galveston Bay and Jefferson County Area, TX—the ADCIRC model was used to conduct a storm surge analysis of sea-level rise. The simulation of Hurricane Ike for the base condition (in 2004) produced a peak surge of approximately 19 feet. The same Hurricane Ike simulation was applied to the future scenario models and the maximum surge was computed. The maximum surge for the 2050 scenario varied throughout the region from a minimum of approximately 1.3 feet offshore to a maximum of approximately 6 feet (compared to the analyzed sea-level rise value of 1.343 feet). The maximum surge for 2100 scenario also showed variation throughout the region from a minimum offshore to a maximum of 8 feet (compared to the analyzed sea-level rise value of 3.039 feet).

When & Where to Use

ADCIRC can model tide and storm surge elevations and velocities for areas encompassing the deep ocean, continental shelves, coastal seas, and small-scale estuarine systems. Simulations can also be run to determine how sea-level rise will impact future storm surge inundation. ADCIRC is useful for exposure and impact analyses.

Hazus-MH



Tool/Resource Type:
Modeling Tool

Sector(s): **Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis**

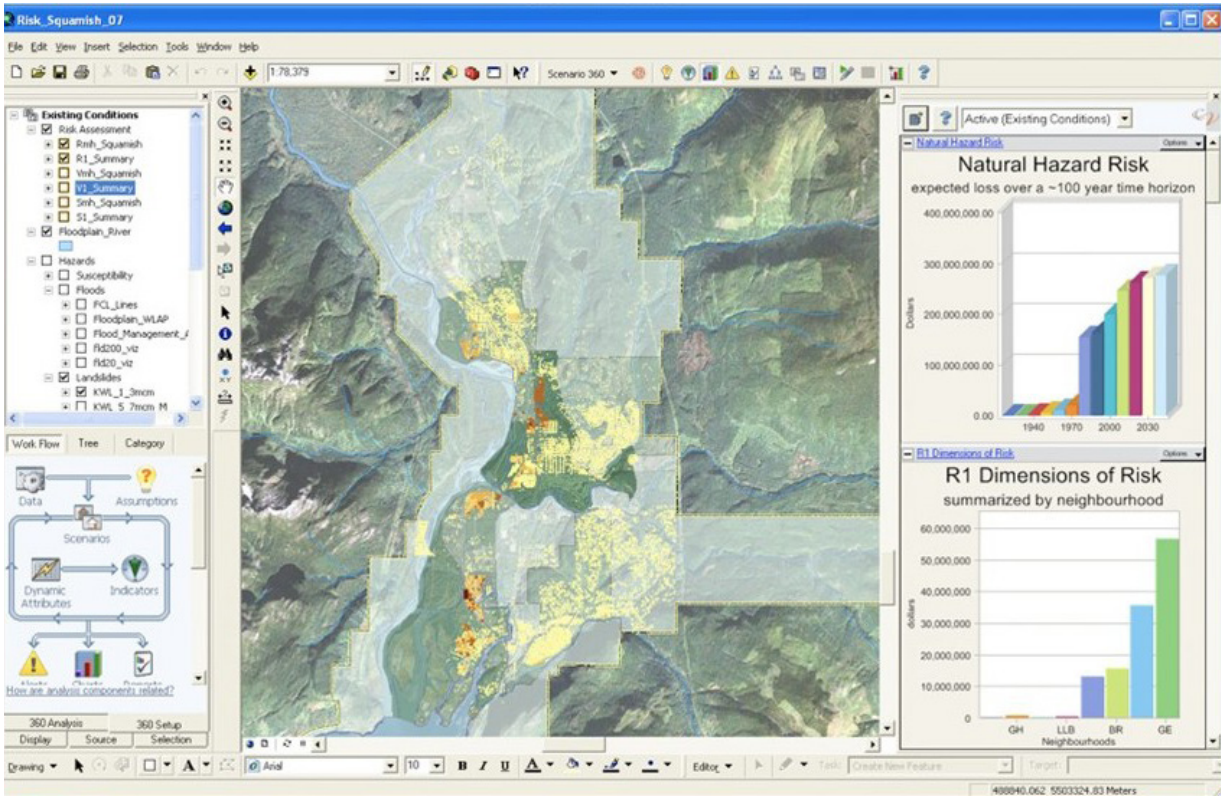
Geographic Scale: **Local, Regional, Statewide**

Cost: **Software Download = Free**

Data Input(s): **None (contains all necessary data but users can supply additional data, such as specific building data, soil maps, and stream gauges)**

Website:
http://www.fema.gov/hazus

Developer/Sponsoring Agency:
Federal Emergency Management Agency



Description

Hazus-MH is a risk assessment methodology for analyzing potential losses from hazards. Although it is not specifically designed for sea-level rise planning applications, many communities have used Hazus-MH to assess potential losses due to sea-level rise by using the flood model. The flood analysis portion of Hazus-MH can incorporate coastal flooding and riverine flooding models and generate flood footprints that are used to calculate economic, social, and infrastructure impacts. The flood footprints from the inundation models can be substituted in Hazus-MH and the impacts of sea-level rise can be calculated based on the new inundation information. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

In addition to estimating the physical damage, economic loss, and social impacts of sea-level rise, users will be able to visualize the spatial relationships between populations, assets, and resources and sea-level rise using the Hazus-MH software.

It is important to consider that the Hazus-MH flood model performs its analysis at the census block level with small numbers of buildings. Damage analysis of a small number of buildings makes the flood model more sensitive to rounding errors so results should be used with suitable caution. Additionally, while Hazus-MH can be used to estimate losses for an individual building, the results must be considered as an average for a group of similar buildings. Nominally similar buildings are often noted to experience vastly different damage and losses during a natural hazard. Another consideration is that the embedded databases and assumptions used to characterize the lifeline (e.g., transportation, utilities) systems in a study region are necessarily incomplete and oversimplified; therefore, when using embedded inventories, accuracy of losses associated with lifelines may be less than losses from the general building stock.

Examples of Use

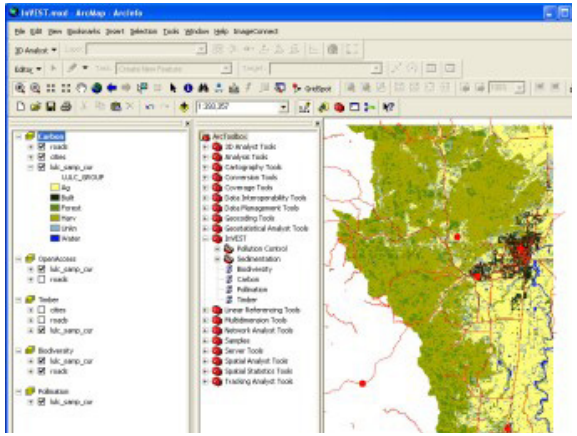
Galveston Bay Region, TX (Pop. = 4.7 million)—calculated the socio-economic impact of sea-level rise using Hazus-MH. The Hazus-MH flooding module was used to analyze the effects of two sea-level rise scenarios on the Galveston Bay community (made up of Harris, Galveston, and Chambers counties). For each of the two scenarios, the software was used to estimate the impact on displaced population; expected number of buildings impacted; building-related economic loss; industrial, hazardous, superfund, and solid waste; and water treatment plants.

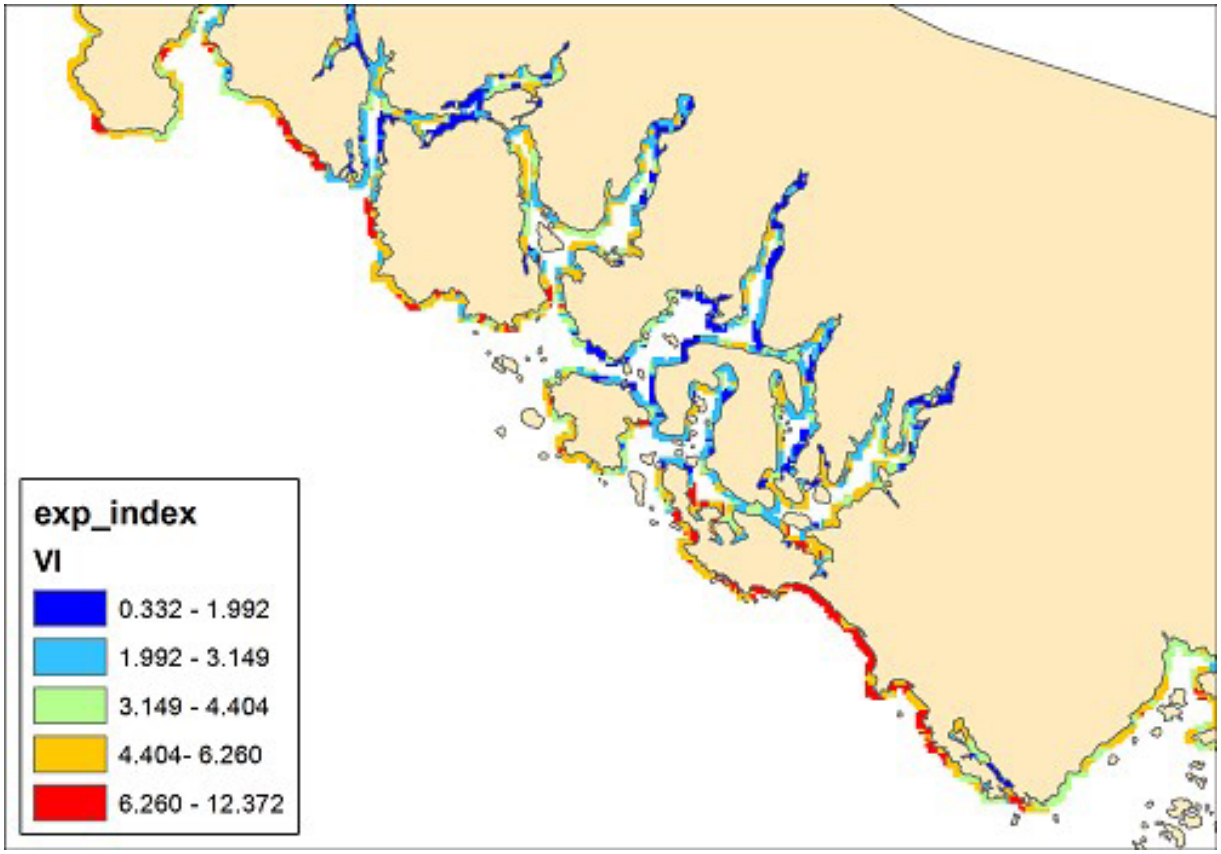
Long Island, NY (Pop. = 7.7 million)—estimated economic loss per census block due to flooding from storm surge and sea-level rise using the Hazus-MH flood model software. Economic loss was determined based on the value of estimated building damage (replacement value) under different storm surge and sea-level rise conditions.

When & Where to Use

Hazus-MH can be used to perform exposure, impact, and adaptive capacity analyses on parcels. With sufficient computing power, property level dollar impacts of future coastal flooding may be provided for the entire community.

Integrated Valuation of Environmental Services and Tradeoffs (InVEST)





Tool/Resource Type: **Modeling Tool**

Sector(s): **Natural Resources, Agriculture, Energy**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis Strategy / Scenario Development**

Geographic Scale: **Local, Regional, Statewide, Global**

Cost: **Software Download = Free**

Data Input(s): **Spatial data and parameter values (much of the data are included within the software, users can input data more specific to the region)**

Website: **http://www.naturalcapitalproject.org/InVEST.html**

Developer/Sponsoring Agency: **Natural Capital Project**

Description

Integrated Valuation of Environmental Services and Tradeoffs (InVEST) is a suite of software models that is used to map and model ecosystem services and their variation under different management and climate scenarios. The Coastal Vulnerability Model (CVM), part of the multi- dimensional InVEST tool, can be used to calculate a vulnerability index for the impacts of erosion and inundation on coastal communities that accounts for projected change in sea level. By showing the areas where coastal populations are threatened and highlighting the relative role of natural habitat at reducing exposure, the model can be used to investigate how some management action or land use change can affect the exposure of human populations to erosion and inundation. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

InVEST is most effectively used within a decision-making process that begins by identifying different management options. Decision makers develop future scenarios to show, for example, where sea-level rise may impact a community, and InVEST can estimate how the current distribution and value of relevant ecosystem services are likely to change under alternative futures. Results can be shared with stakeholders and policy makers to inform upcoming decisions.

The software can be run using ESRI's ArcGIS or other GIS software and the User's Guide is a comprehensive resource for technical and general users of InVEST models and results. Of note, data for some models can be difficult to obtain. As an example, many models use annual average data and depending on the model used, scale (data resolution) can be a limiting factor.

Examples of Use

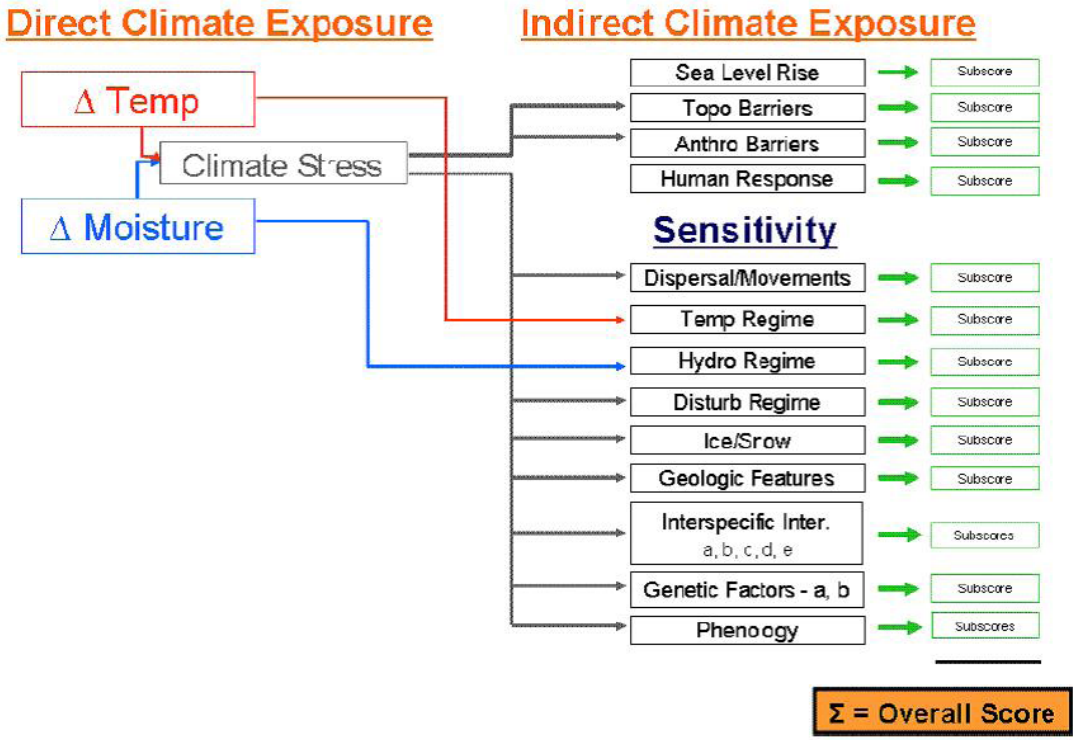
Placencia, Belize (Pop. = 750)—used InVEST to assess the ecosystem service impacts and possible costs and benefits of alternative adaptation scenarios. InVEST was able to account for expected costs related to sea-level rise, including changes in annual catch of spiny lobster and expected property damage from erosion and storms.

Yucatan, Mexico (Pop. = 2 million)—used the InVEST Coastal Vulnerability model to help understand how modifications of the biological and physical environment can affect coastal exposure to storm-induced erosion and flooding. The output was a qualitative Vulnerability Index, which differentiated areas with relatively high or low exposure to erosion and inundation during storms. The results found that sea-level rise will have a greater negative impact on costal vulnerability in those areas with medium-to-low coastal vulnerability values. This information can help coastal managers, planners, landowners, and other stakeholders identify regions of greater risk to coastal hazards.

When & Where to Use

InVEST can be used to determine how natural areas, sea-level rise, and the community at large, will interact. It is useful as a vulnerability assessment and adaptation strategy prioritization tool.

NatureServe Climate Change Vulnerability Index (CCVI)



Tool/Resource Type: **Modeling Tool**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis**

Geographic Scale: **Regional**

Cost: **Software Download = Free**

Data Input(s): **Species-specific sensitivity or life history data, data on exposure to climate change, land use data**

Website: **http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index**

Developer/Sponsoring Agency: **NatureServe**

Species	Natural barriers	Anthropogenic barriers	Dispersal & movements	Historical thermal niche	Physiological thermal niche	Historical hydrological niche	Physiological hydrological niche	Dependence on ice/snow	Restriction to geological feature	Dietary versatility	Genetic variation	Index Score
Aplodontia rufa	Inc	N	Inc	SI	SI	Inc-SI	N	N	N	N	U	EV
Rhinichthys osculus oligoporus	N	N	Inc	N	N	GI-Inc	GI	N	N	N	U	HV
Limenitis archippus lahontani	N	N	Inc	N	SI	SI	GI	N	N	Inc	U	HV
Ochotona princeps	GI-Inc	N	SI	SI-N	N	SI-N	N	N	Inc	N	U	HV
Sorex palustris	Inc	N	Inc	N	SI	SI-N	GI-Inc	N	N	N	U	HV
Oncorhynchus clarkii henshawi	N	N	N	N	Inc-SI	SI	Inc-SI	N	N	N	U	HV
Rana pipiens	N	N	N	N	SI	SI	GI-Inc	N	N	N	U	MV
Draba cusickii var. *pedicellata*	N	N	Inc	N	SI-N	SI	N	N	SI	N/A	U	MV
Leucosticte atrata	GI	N	Dec	SI	U	SI	N	SI	Inc-SI	N	U	MV
Populus tremuloides	N	N	GI	N-SD	Inc	SI-N	SI	N	N	N/A	SD	MV
Asclepias eastwoodiana	N	N	SI	N	N	SI	Inc	N	N	N/A	U	PS
Phrynosoma platyrhinos	N	N	N	N	SD	Inc-SI	N	N	N	SI	U	PS
Quiscalus mexicanus	N	SD	Dec	N	N	N	N	N	N	SD	U	IL

Description

The NatureServe Climate Change Vulnerability Index (CCVI) is an Excel-based tool that identifies plant and animal species that are particularly vulnerable to the effects of climate change and can help assess the relative vulnerability of species of interest occurring on the coast that are affected by sea-level rise. Using the index, users apply readily available information about a species' natural history, distribution, and landscape circumstances to predict whether a species will likely experience a range contraction and/or population reductions due to climate change. To utilize, assistance by personnel with experience using Microsoft Excel is recommended.

The index separates vulnerability into two primary components: a species' exposure to climate change within a particular assessment area and its inherent sensitivity to climate change. The tool then gauges 20 scientifically documented factors and indicators of these components as well as documented responses to climate change where they exist. While the index calculates anticipated increases or declines in populations of individual species, the index also accommodates inherent uncertainties about how species respond within their ecological contexts. However, the tool is not a substitute for an in-depth vulnerability assessment of high profile species.

Exposure to sea-level rise is considered only in cases where all or a portion of the range within the assessment area may be subject to the effects of a 0.5 to 1 meter sea-level rise and the consequent influence of storm surges. Sea-level rise is a factor related to indirect exposure to climate change that is not weighted by the exposure measures in the index. The magnitude of sea-level rise within an assessment area will reflect global rather than local changes.

The tool is only designed for terrestrial and aquatic plants and animals in the contiguous 48 U.S.

Examples of Use

Florida (Pop. = 19.9 million)—a case study using CCVI was developed to inform conservation planning for species in Florida. The report was prepared for the Florida Fish and Wildfire Conservation Commission. CCVI was used to identify factors contributing to vulnerability to climate change for a set of species occurring in Florida. Exposure to sea-level rise assessed by estimating the percentage of the species' range that occurs at low elevations (<1 meter suggested) was one of the parameters used in the CCVI.

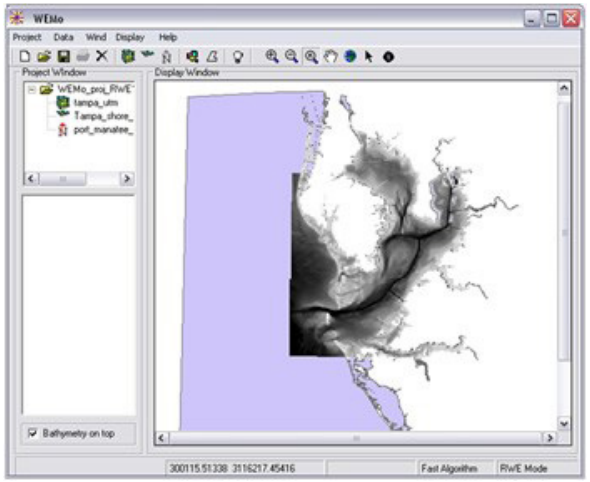
California (Pop. = 38.8 million)—conducted a climate change vulnerability assessment for rare plants in California using CCVI. The assessment considered direct and indirect climate exposure factors as well as ecological sensitivity to model the rare plant species' predicted range size change and overlap. Sea-level rise was one of the indirect climate exposure factors considered during the assessment. The assessment found that of the 156 rare plants, 99 are classified as "vulnerable" to climate change.

Arctic Alaska—used CCVI to conduct a climate change vulnerability assessment for arctic breeding birds to help guide climate-informed wildfire management in the region. The assessment compared the added vulnerability posed by climate change projected for 2050 in the Alaska portion of the Arctic Landscape Conservation Cooperative (LCC). The CCVI integrated information on species sensitivity, direct exposure to projected atmospheric changes in climate, and indirect exposure factors including sea-level rise. The CCVI results ranked two species as highly vulnerable, seven as moderately vulnerable, and five as likely to increase.

When & Where to Use

CCVI can be utilized to conduct impact analyses on species and parts of the natural environment. With appropriate data, it may apply to sub-community, whole community, or regional areas. Outputs can be used to prioritize adaptation focus areas, taking into consideration habitat migration and preservation needs.

NOAA Wave Exposure Model (WEMo)



Tool/Resource Type: **Modeling Tool**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis**

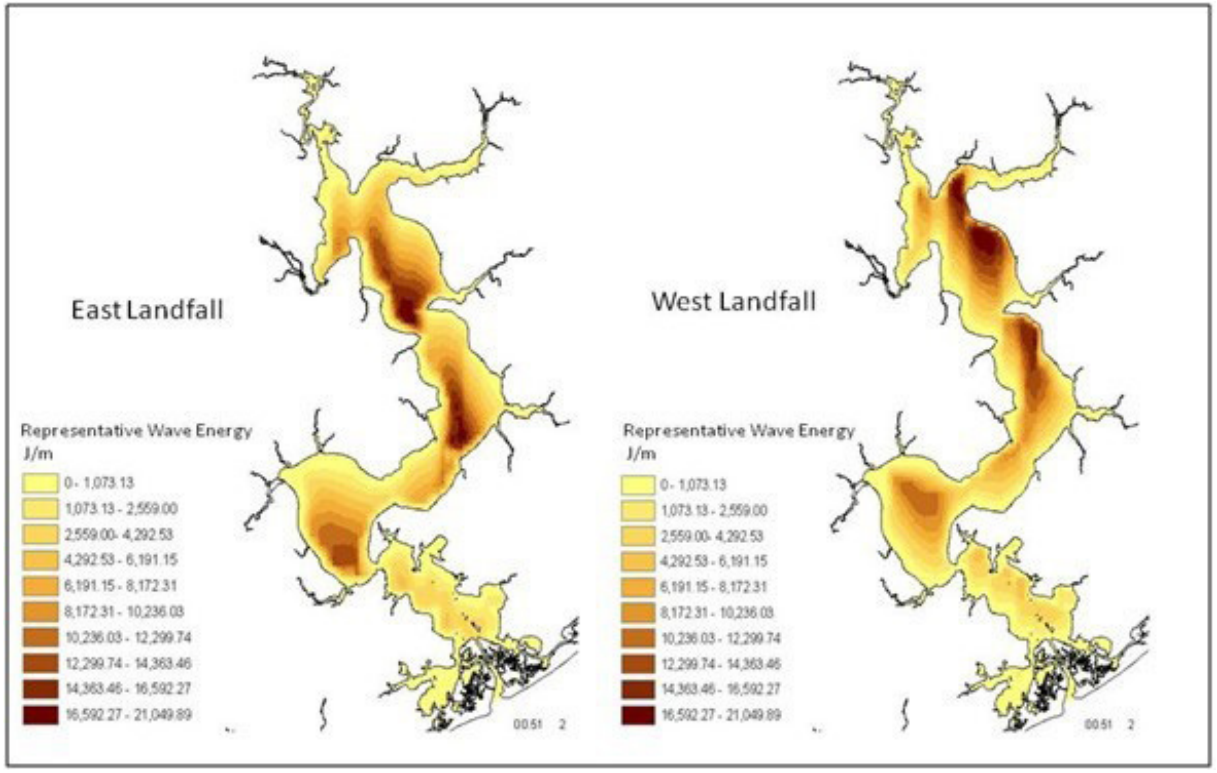
Geographic Scale: **Regional**

Cost: **Software Download = Free**

Data Input(s): **Bathymetry grid data, shoreline coverage data, wind data**

Website: **http://coast.noaa.gov/digitalcoast/tools/wemo**

Developer/Sponsoring Agency: **National Oceanic and Atmospheric Administration**



Description

WEMo is a free tool that estimates wave energy and its effects on ecosystem functions as well as on developed coastal and inland-water areas. The tool was designed to provide quantitative forecasts of wave energy in estuarine environments without the need for extensive advanced physical models. WEMo works in a GIS format in association with ESRI's ArcGIS and requires users to have basic knowledge of GIS. As such, assistance operating this tool by personnel with GIS experience is recommended.

WEMo calculates actual wave height and derived wave energy while taking into consideration wind generation and local water depth characteristics, such as shoaling and dissipation from breaking waves. It also provides predictions of seafloor sediment movement. WEMo could be used to hindcast the possible influence of hydrodynamics on shoreline and wetland habitat change as well as to represent future sea-level rise scenarios.

Potential applications include modeling seagrass exclusion areas (i.e., areas where wave energy is too high for persistent seagrass habitat), the potential for restoration of seagrass, submersed and shoreline habitat landscape pattern, shoreline susceptibility to hurricanes and other extreme wind events, and effect of shoreline structures on habitat.

WEMo offers a quick estimation of wave exposure at a very low computation cost. However, it does not account for complicated wave processes nor does the model account for remotely-forced ocean swells. The software is more suited for comparing sites under seemingly-like conditions.

Examples of Use

New River Estuary, NC—used WEMo to hindcast the wind wave energy distribution of the New River Estuary during Hurricane Isabel (2003). Two hurricane simulations were run for the area, first by passing the hurricane along its actual path with a landfall east of the New River Estuary, and second by passing the same storm to the west of the estuary. The simulations produced a geographically accurate description of wave energy in three-hour time steps, revealing the changing exposure of the region as a consequence of landfall location. The simulations were then applied to the development of a shoreline management plan. When joined with other factors such as storm surge modeling, the findings are useful to local emergency agencies and the public in anticipating the relative exposure of shoreline property.

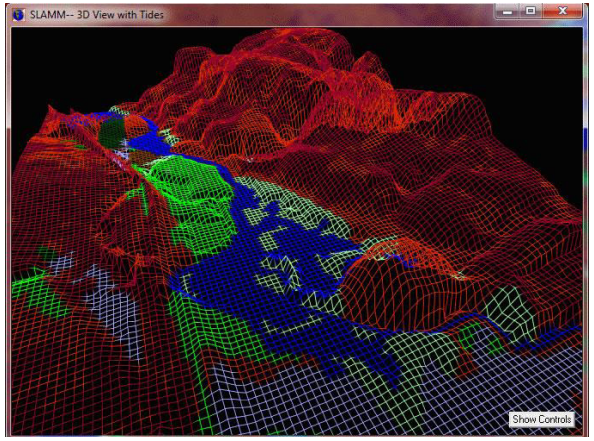
Carteret County, NC (Pop. = 68,000)—used WEMo to understand the link between marsh distribution and wave energy generated by extreme winds. Marsh coverage maps were created from aerial imagery and used to randomly select marsh sites. The width of the marsh was calculated for each site, and wave energy was estimated using WEMo. Sites were divided into five zones ranging from high to low wave energy, and marsh occurrence and width versus wave energy was plotted. The marsh coverage maps are being used for restoration projects in the high wave energy areas where considering the anticipated landscape pattern (narrow fringing marshes) of restored salt marshes is necessary for the best project design.

Camp Lejeune, NC (Pop. = 19,000)—used WEMo to determine the wave exposure of the shoreline to help understand the relationship between shoreline change, composition, and processes. The results were incorporated into a Shoreline Management Plan.

When & Where to Use

WEMo provides quantitative values of wave energy for locations not in the open ocean. It can be used to estimate wave energy in coastal regions or in inland waters to gauge susceptibility of developed areas and determine wave effects on ecosystem function. WEMo can also be used to represent future sea-level rise scenarios.

Sea Level Affecting Marshes Model (SLAMM)



Tool/Resource Type:
Modeling Tool

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis**

Geographic Scale: **Local**, **Regional**

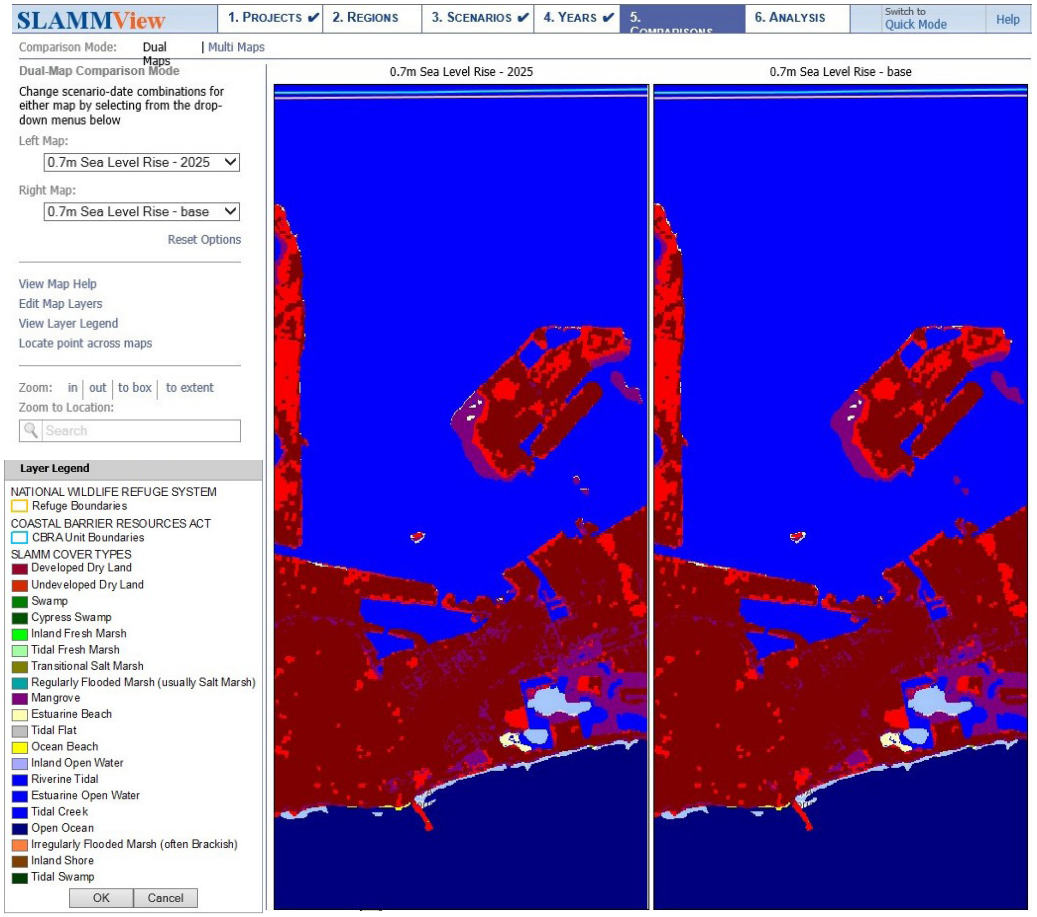
Cost: **Software Download = Free; Online Viewer = Free**

Data Input(s): **National Wetlands Inventory data, digital elevation data, optional datasets include: protected area/dike data and site parameters to change water depth, accretion rates, erosion rates, and many more**

Website:
http://warrenpinnacle.com/prof/SLAMM/index.html

http://www.slammview.org/slammview2/auto.rcp

Developer/Sponsoring Agency:
Warren Pinnacle Consulting, Inc.



Description

The Sea Level Affecting Marshes Model (SLAMM) simulates wetland conversion and shoreline modification resulting from long-term sea-level rise. As such, the tool can be used for projecting the effects of sea-level rise on the distribution of coastal wetlands and the landcover found within coastal areas. It identifies potential changes in both extent and composition of wetland types and accounts for inundation, subsidence, soil saturation, erosion, accretion, and barrier island overwash. SLAMM also integrates a uncertainty module to provide best and worst case sea-level rise scenarios and provides likelihood and confidence statistics accounting for uncertainty in future sea-level rise, future erosion rates, and feedbacks between marsh vertical-accretion rates and sea-level rise. Although SLAMM is able to simulate the dominant processes involved in wetland conversions and shoreline modifications during long- term sea-level rise, the model's complexity is limited and its outputs are simplifications that are only as reliable or accurate as the information used as inputs. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

Summary tables provide the means to present the large volume of geospatially-referenced, gridded output from SLAMM in a condensed form; however, the spatial context of where the changes occur is lost. The SLAMM-View 2.0 web-mapping application facilitates the examination and evaluation of differences between pairs of output from the SLAMM model and makes the data geospatially accessible for users. The pairs of output are either from different dates within the same sea-level rise scenario or from the same date from different scenarios.

Examples of Use

Cook Inlet, AK—used SLAMM to simulate the dominate processes involved in wetland conversions and shoreline changes during long-term sea-level rise. It was found that the wetland habitat in the study region does not appear to be particularly vulnerable to sea-level rise and most impacts that were noted do not occur until after about a 1.5 meter rise in sea level, which some studies suggest may occur by 2100.

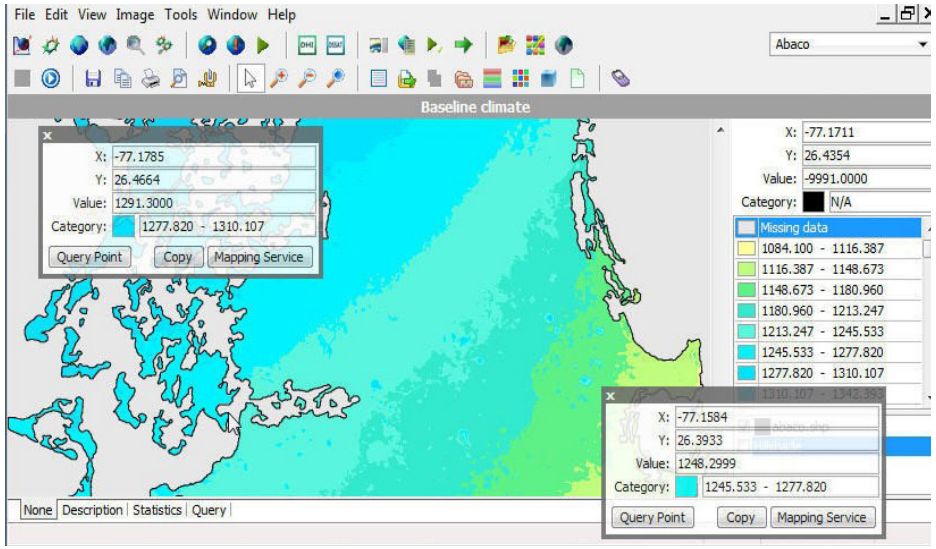
Southeastern Louisiana—conducted a study to investigate the potential impact of current and accelerating sea-level rise rates on key coastal wetland habitats in southeastern Louisiana using SLAMM. Results indicate a range of potential wetland losses by 2100 under the lowest sea-level rise scenario to the highest sea-level rise scenario. The model results suggest that one area of particular concern is the potential vulnerability of the region's baldcypress-water tupelo swamp habitat which is projected to become permanently flooded under all modeled scenarios for sea-level rise.

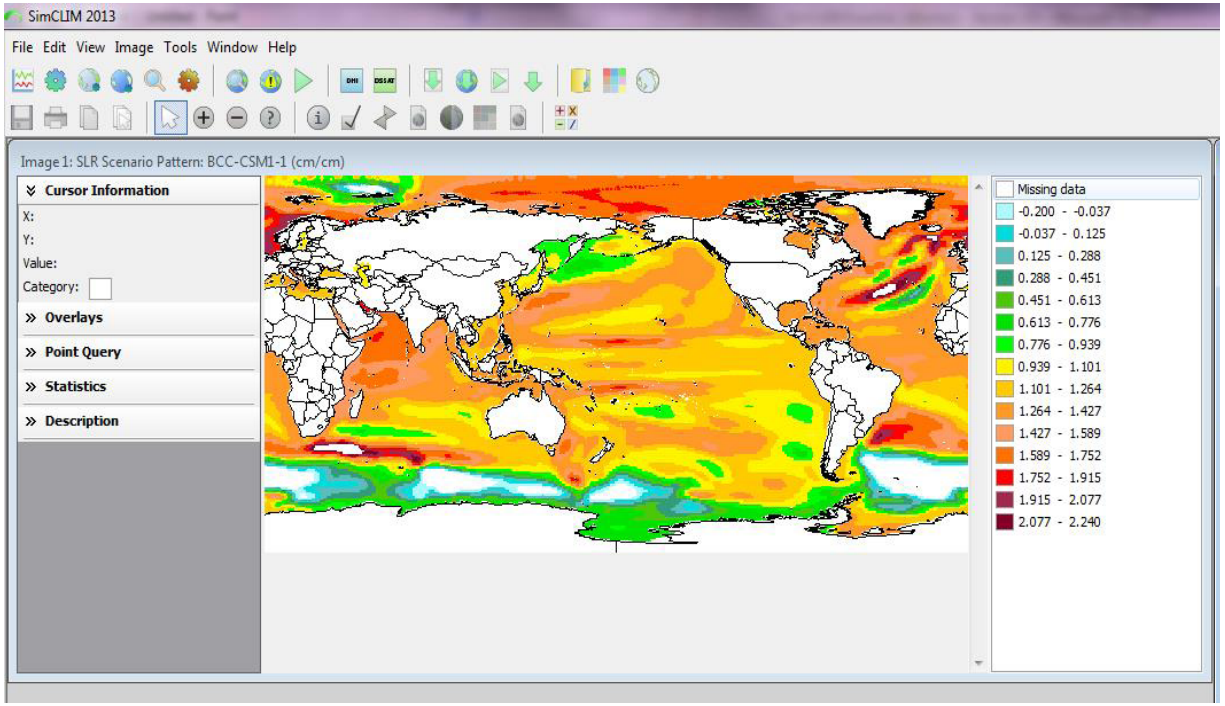
Waccamaw National Wildlife Refuge, SC—used SLAMM to map predicted distributions of wetlands within the refuge and the nearby North Inlet-Winyah Bay National Estuarine Research Reserve if sea level were to rise 1 meter over a 100-year period. SLAMM has typically been run at a regional scale; however, for this study, local accretion rates, tidal information, habitat data, and locally-available LIDAR data were used, resulting in more site-specific marsh migration predictions. The SLAMM outputs predicted that some of the tidally influenced freshwater wetlands that are key habitats for the swallow-tailed kite and black bear will be lost as sea-level rises. The outputs were used to help target areas for conservation.

When & Where to Use

SLAMM and SLAMM View 2.0 can be utilized throughout the first half of the adaptation process – from awareness building, through exposure and impact modeling. The extent of its analysis is determined by data for landcover and a digital elevation model, and can be applied to the whole community.

Simulator of Climate Change Risks and Adaptation Initiatives (SimCLIM)





Tool/Resource Type:
Modeling Tool

Sector(s): **Natural Resources, Agriculture, Built Environment**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis**

Geographic Scale: **Local, Regional, Statewide, Global**

Cost: **Annual Seat License = $149 to $6,000 per (depending on user); Downscaled AR5 Spatial Areas = $150 to $300; 6-Week Trial Version = Free**

Data Input(s): **National Wetlands Inventory data, digital elevation data, optional datasets include: protected area/dike data and site parameters to change water depth, accretion rates, erosion rates, and many more**

Website:
http://www.climsystems.com/simclim/

Developer/Sponsoring Agency:
CLIMsystems Ltd.

Description

The Simulator of Climate Change Risks and Adaptation Initiatives (SimCLIM) software can be used to model local (site specific) sea-level rise. SimCLIM can create scenarios, and project impacts, of sea level change. The program contains generators for sea-level rise which are regularly updated and consistent with the latest Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC). Areas of potential inundation can be identified using the tool's custom-built GIS tools along with digital elevation data. SimCLIM also includes a simulation model of shoreline changes for beach and dune systems, which takes into account storm effects, local sea level trends , and lag effects in order to produce time-dependent response of the shoreline to sea-level rise at selected sites. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

SimCLIM allows users to input their own data and models and customize the system for their purposes. The software also has the capacity for both spatial and site time-series analyses that can be applied from local to global scales. Formats include spatial images, time-series projections, and graphical and tabular output.

There are several limitations and uncertainties in the methods employed to develop SimCLIM. First, the historical observation data values presented in the software must be viewed as best estimates since historical data observations are not compiled appropriately for use in climate modeling. Also, there is an underlying uncertainty in the projections of future climate change and precipitation which may affect the accuracy of the modeling.

Training sessions on how to use the tool are held regularly depending on demand, but take place in New Zealand. Webinars are also held to reach a larger range of end users. There are no specific requirements for using the tool; however, the program requires a license.

Examples of Use

Republic of Marshall Islands (Pop. = 53,000)—used a customized version of the SimCLIM Open Framework software modeling system to conduct an analysis of sea-level rise and storm surge as well as the associated impacts.

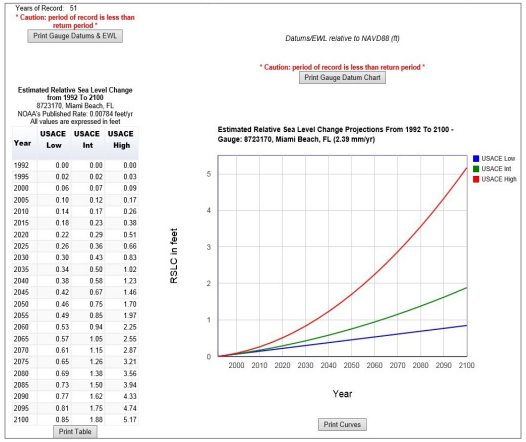
Alexandria, VA (Pop. = 149,000)—used a customized version of the SimCLIM Open Framework software modeling system to analyze storm sewer capacity issues, identify problem areas, develop and prioritize solutions, and provide support for public outreach and education. The software was used to help evaluate cost and risk of different mitigation scenarios and different assumptions for rain design storms and sea-level rise in 2050 and 2100.

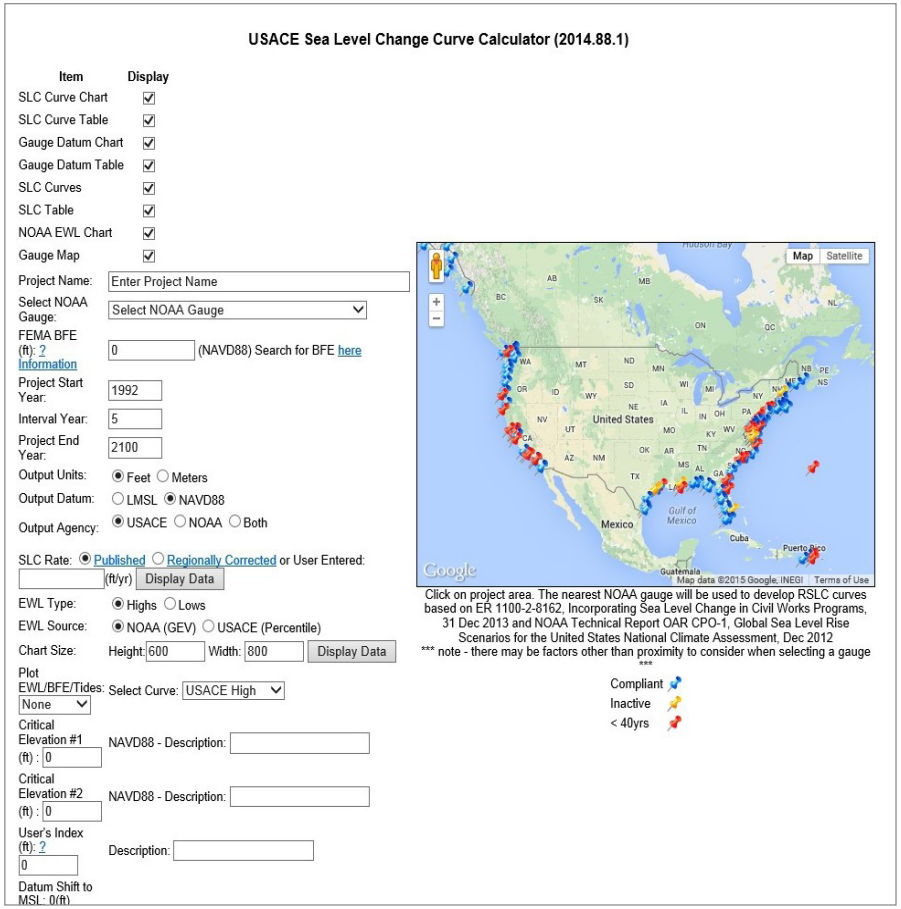
Pacific Basin—applied the SimCLIM modeling system to a range of scenarios for the entire Pacific Basin, including sea-level rise, as part of a larger study for Small Island Developing States.

When & Where to Use

The key output of SimCLIM is the ability to analyze scenarios of sea level changes as well as sectoral impacts, mainly for water, ecosystems, and agriculture. It is therefore useful for exposure and impact analyses, and can be applied at the community level, by sector.

USACE Sea Level Change Curve Calculator





Tool/Resource Type: **Modeling Tool**

Sector(s): **Natural Resources, Agriculture, Built Environment**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Assessment / Analysis**

Geographic Scale: **Local**

Cost: **Online Calculator = Free; Excel Calculator Download = Free**

Data Input(s): **Base flood elevation, project start and end years, interval year**

Website: **http://www.corpsclimate.us/ccaceslcurves.cfm**

Developer/Sponsoring Agency: **United States Army Corps of Engineers**

Description

The U.S. Army Corps of Engineers (USACE) Sea Level Change Curve Calculator was developed to support screening and assessing the vulnerability of USACE projects to the effects of sea level change. However, the tool can also be used to produce the amount of predicted sea level change for any location along the U.S. coast from 1992 forward.

The tool is a web-based interface that allows users to identify a NOAA tide station reference and generate relative sea level change curves and tabular data in five-year intervals for a selected project start year over the project life span. The output includes projections based on 1 and 1.5 meter curves plus a "historic trend" projection based on the tide gauge record for the selected tide station. The tool provides information on estimating the effects of sea-level rise on special flood hazard area (SFHA) 1 percent annual flood elevations, a way of accounting for sea-level rise in coastal storms and coastal flooding scenarios.

Since the outputs produced are specific to a tide station, use for evaluating surrounding areas may be limited. There also may be factors other than proximity to consider when selecting a gauge, such as rate of subsidence or uplift for that area of coastline.

Examples of Use

Hillsborough County, FL (Pop. = 1.3 million)—the USACE Sea Level Change Curve Calculator is built into FDOT's Sea Level Scenario Sketch Planning Tool. Since the Hillsborough County Metropolitan Planning Organization's 2040 Long Range Transportation Plan Needs Assessment used the Sketch Planning Tool's "high" 2040 scenario (current mean sea level plus 14 inches) to illustrate sea-level rise and help estimate disruption to the entire county and its transportation needs.

Southeast Florida—the Southeast Florida Regional Climate Compact (signed by Broward, Miami-Dade, Palm Beach, and Monroe counties) utilized the USACE Sea Level Change Curve Calculator when creating the regional unified sea-level rise projection. This unified sea-level rise projection for Southeast Florida projects a one foot rise in sea level above the 2010 levels to occur in the 2040-2070 time period with a two foot rise possible by 2060. Uncertainties exist in precisely predicting future sea-level rise rates and acceleration beyond 2060.

When & Where to Use

This tool can be used to calculate the rates of sea level change by selecting the closest NOAA tide gauge to the location of interest. It is useful during the planning context and exposure analysis phase for its sea-level rise projection information. It may also be utilized during adaptation project prioritization, to calculate sea-levels based upon adaptation project lifespans.

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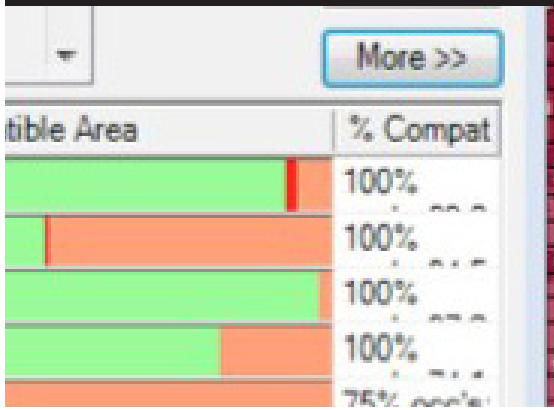
Decision Support Tools



Beach-fx

Tool/Resource Type:
Decision Support Tool (Software)

Sector(s): **Natural Resources, Built Environment**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis, Strategy / Scenario Development**

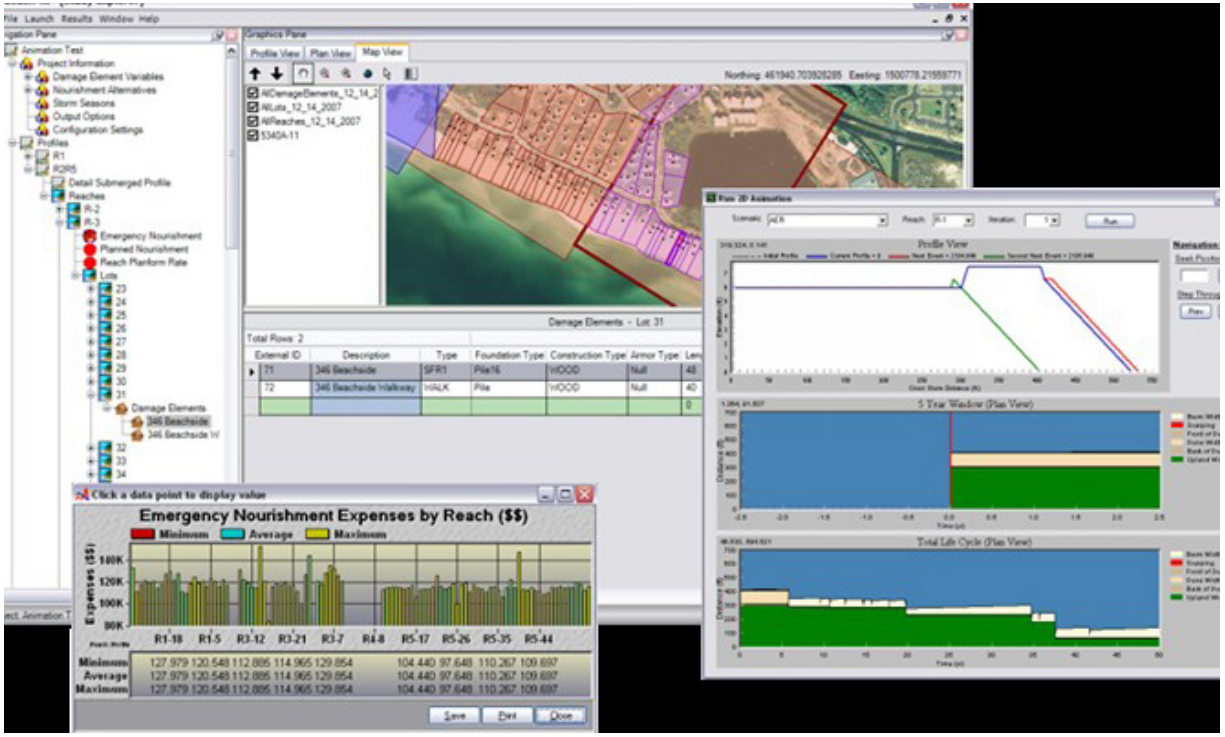
Geographic Scale: **Local, Regional, Statewide**

Cost: **Software Download = Free**

Data Input(s): **Coastal area description; plausible storm events; vulnerable infrastructure inventory; morphology response estimates; erosion, inundation, and wave impact design parameters**

Website: **http://hera.pmcl.com/beachfx/default.aspx**

Developer/Sponsoring Agency:
United States Army Corps of Engineers



Description

Beach-*fx* is a comprehensive, analytical modeling software that can be used to evaluate the physical performance and economic benefits and costs of shore protection projects, including sea-level rise adaptation projects. Beach-*fx* provides a realistic evaluation of shore protection projects and estimates the costs and benefits of alternative project designs. The software is used to evaluate proposed project alternatives in comparison with a "no-action" (i.e., with-out project) alternative. Currently, the U.S. Army Corps of Engineers (USACE) uses Beach-*fx* to assess the performance of beach nourishment projects and the influence of rising sea levels during their planning analysis. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

Beach-*fx* simulates the impacts of shore protection projects based upon their expected lifespan, and reaction to hazard events (e.g., hurricanes). The software is a data-driven model that relies on databases describing the coastal area under study that are populated by users as well as a suite of historically-based plausible storm events that can impact the area, an inventory of infrastructure that can be damaged, and estimates of the response of beach profile configurations to each storm in the plausible storm suite, together with damage driving parameters for erosion, inundation, and wave impact damage.

The analyses that Beach-*fx* makes are a combination of meteorology, coastal engineering, and economic evaluations that trigger an action based on the occurrence of previous events. As a data-driven transparent model, its technical framework incorporates: inherent risk and uncertainty associated with shore protection, represented coastal processes, and combination of engineering and economic behavior.

Examples of Use

Walton County, FL (Pop. = 60,000)—used Beach-*fx* to investigate, analyze, and recommend solutions to provide for hurricane and storm damage projection along the coastline of the county. The tool was used to estimate the average annual costs and benefits of with and without project alternatives.

Bogue Banks, NC—conducted a storm damage reduction study for the Bogue Banks shoreline in Carteret County. Beach-*fx* was used to develop and evaluate planned nourishment alternatives for the study area. Since Beach-*fx* allows for sea-level rise to be specified for a project, it was set to a rate of 0.0084 feet per year based on the long term sea-level rise measurement calculated at the Beaufort Inlet NOAA Tide gauge. The economic output from Beach-*fx* was used to select the optimum plan.

When & Where to Use

Beach-*fx* can be used during the adaptation strategy prioritization phase, on a project-by-project basis. Once adaptation strategies are proposed, the tool may be used to determine which projects will have the greatest economic returns.

Coastal Adaptation to Sea-Level Rise (COAST)

Tool/Resource Type:
Decision Support Tool

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development**

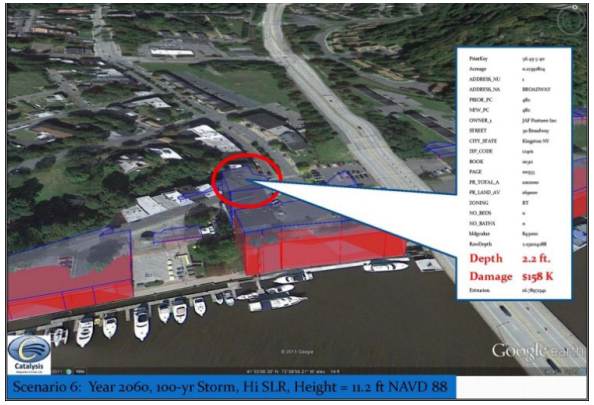
Geographic Scale: **Project Level**

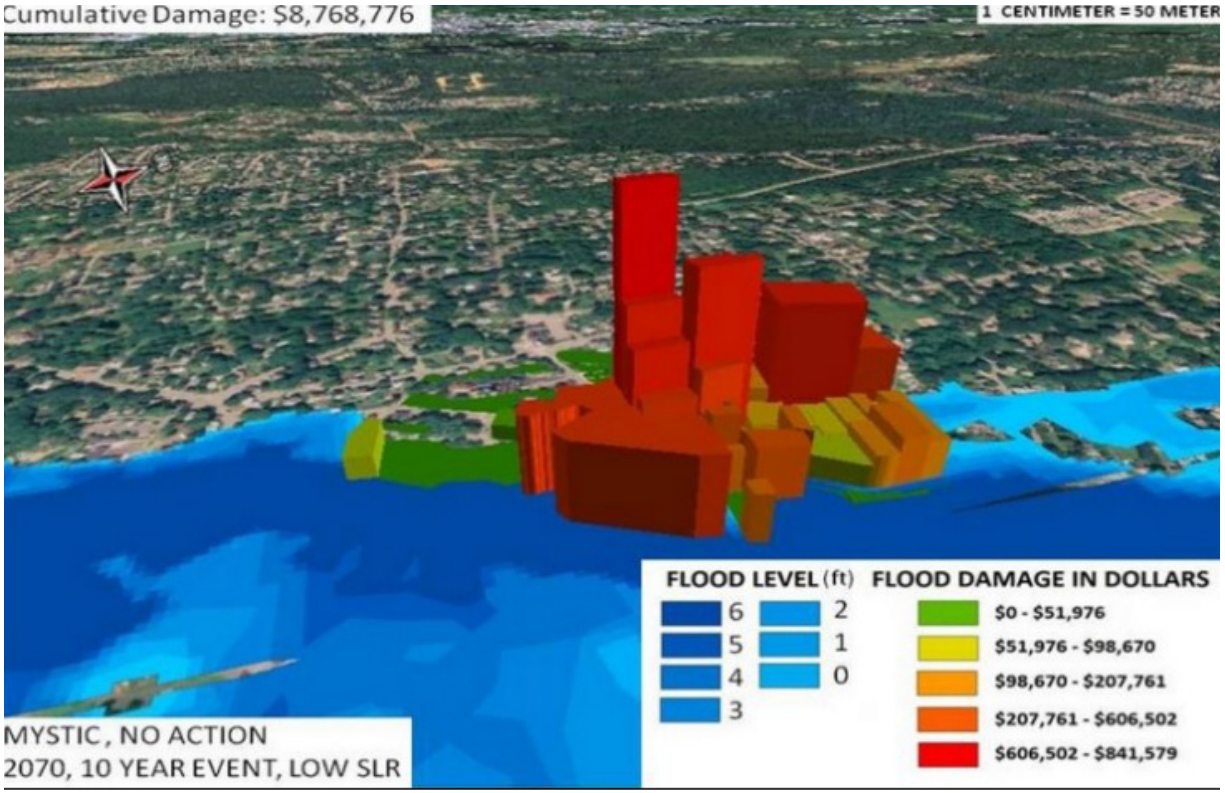
Cost: **SoftwareDownload = Free;**

Data Input(s): **Tide gauge data; local real estate, economic activity, infrastructure, natural resources, and human health data; candidate adaptation actions**

Website:
https://www.bluemarblegeo.com/products/COAST.php

Developer/Sponsoring Agency:
Developed at the University of Southern Maine with funds. EPA, and in collaboration with partners at Battelle, the Maine Geologic Survey, the University of New Hampshire, and Blue Marble Geographics





Description

The Coastal Adaptation to Sea-level rise Tool (COAST) helps users answer questions in regards to the costs and benefits of actions and strategies to avoid damages to assets from sea-level rise through 3D visualizations. COAST is a software product that predicts damages from varying amounts of sea-level rise and storms of various intensities and evaluates relative benefits and costs of adaptive response strategies. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

Users will input tide gauge data and locally derived data on vulnerable assets, such as real estate, economic activity, infrastructure, natural resources, and human health, as well as possible adaptation actions wherever possible. The software will then model adaptation actions for a given location under a selected sea-level rise scenario and storm event. Comparing multiple future scenarios provides stakeholders an opportunity to select their expectation of future conditions and visualize damages under action versus no-action scenarios.

Outputs are 3D spatial data representing damage from sea-level rise and storm surge that can be loaded and viewed in Google Earth as well as tables showing cumulative expected damages for the selected vulnerable assets under the adaptation scenarios that allow cost-benefit analysis of candidate adaptation actions. The files can also be converted to shapefiles for use with ESRI's ArcGIS. Depending on user skill sets and the nature of assets and adaptation actions being modeled, consulting assistance may be required.

Examples of Use

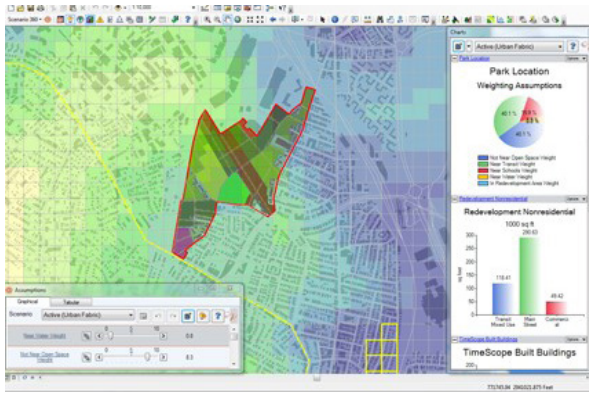
Groton, CT (Pop. = 9,000)—created a no-adaptation-action scenario for 1 meter sea-level rise and a 10-year flood event in 2070 for a portion of downtown Mystic Seaport. A graphic output was created to represent cumulative expected lost real estate and building contents value. Adaptation actions subsequently modeled in this location included installing a hurricane barrier, elevating a road, and building dikes, each of which could provide some protection to the vulnerable areas. Each adaptation action was represented in a map to show reduced or eliminated damage. This was an effective way to visually show up-front and maintenance costs of hard-structure approaches versus expected damages from particular inundation events.

Portland, ME and the Hampton/Seabrook Estuary, NH (Pop. = 66,000 and 24,000)— used COAST in their sea-level rise adaptation planning processes. Both communities and stakeholders examined potential impacts of sea-level rise and storm surge if no action is taken, specifically the costs and benefits of specific actions the communities might take to protect vulnerable assets they have prioritized. The communities also identified appropriate time horizons, sea-level rise thresholds, and storm surge frequencies and intensities to simulate. The 3D visualizations of avoided costs and expected damage were used to support the adaptation planning process and help stakeholders identify specific action steps to implement.

When & Where to Use

COAST, the ArcGIS add-in, can be utilized to conduct exposure and impact analyses applying to parcel-level data, for the entire community. It may also be used to prioritize adaptation strategies based upon their site-specific benefits.

CommunityViz



Tool/Resource Type:
Decision Support Tool

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development**

Geographic Scale: **Local, Regional, Statewide**

Cost: **30-Day Trial = free; Government/Non-Profit Use = $875; Commercial Use = $1,400**

Data Input(s): **GIS layers (e.g., parcels, zoning, roads, environmentally sensitive**

Website:
http://placeways.com/communityviz/index.html

Developer/Sponsoring Agency:
Placeways LLC

Description

CommunityViz is a tool for the purposes of visualizing and communicating possible future land use change scenarios driven by sea-level rise. It is a GIS software that helps visualize, analyze, and communicate about important land use decisions by creating 2D and 3D visual models that show the implications of various planning decisions and scenarios. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

Users can sketch and experiment with hypothetical scenarios and view the impacts of proposed changes. Concerning adaptation planning, the tool can illustrate the impacts of creating sustainable development patterns and limit building in areas vulnerable to sea-level rise. The software can also be used to help conduct risk and impact assessments such as counting buildings affected by potential floods or storm surge. This tool is not intended for engineering-level design and is best used for plans and directional decisions. There is no built-in data and relatively little built-in modeling so users must be knowledgeable to set up scenarios.

Since CommunityViz relies on GIS, communities without robust GIS programs and skilled practitioners may be unable to use the software. Some training and time is required even for advanced GIS users to learn the software.

This tool can also be integrated with other analytical tools such as N-SPECT and NatureServe Vista as a way to help a community visualize the results of potential adaptive management responses to sea-level rise.

Examples of Use

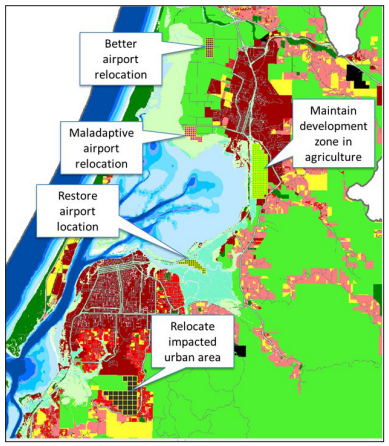
Cape Cod, MA (Year-round Pop. = 220,000)—Held a scenario planning pilot workshop that was built around CommunityViz. Four future scenarios were created for Cape Cod in 20 years using population growth forecasts and present-day land use and transportation plans. Alternatives used combinations of development, transportation system improvements, and transportation programs. CommunityViz allowed participants to see results of different scenarios like population served by new transit, and new growth in vulnerable areas.

Houston/Galveston Region, TX (Pop. = over 6 million)—Held a public outreach and education workshop for coastal resiliency. The centerpiece of the workshop was a hands-on tabletop sketching exercise using CommunityViz software. Participants sketched alternative growth scenarios to track the likely implications for a range of issues such as housing, economics, environment, hurricane risk, and water quality

When & Where to Use

CommunityViz may be used to depict future scenarios at the community-wide, and site-specific scale. Within the adaptation planning process, it can be used to evaluate potential future adaptation strategies that impact land use decisions driven by sea-level rise. The tool can also be used for building awareness and facilitating public engagement during the initial phase in the planning

NatureServe Vista



Tool/Resource Type: **Decision Support Tool**

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development**

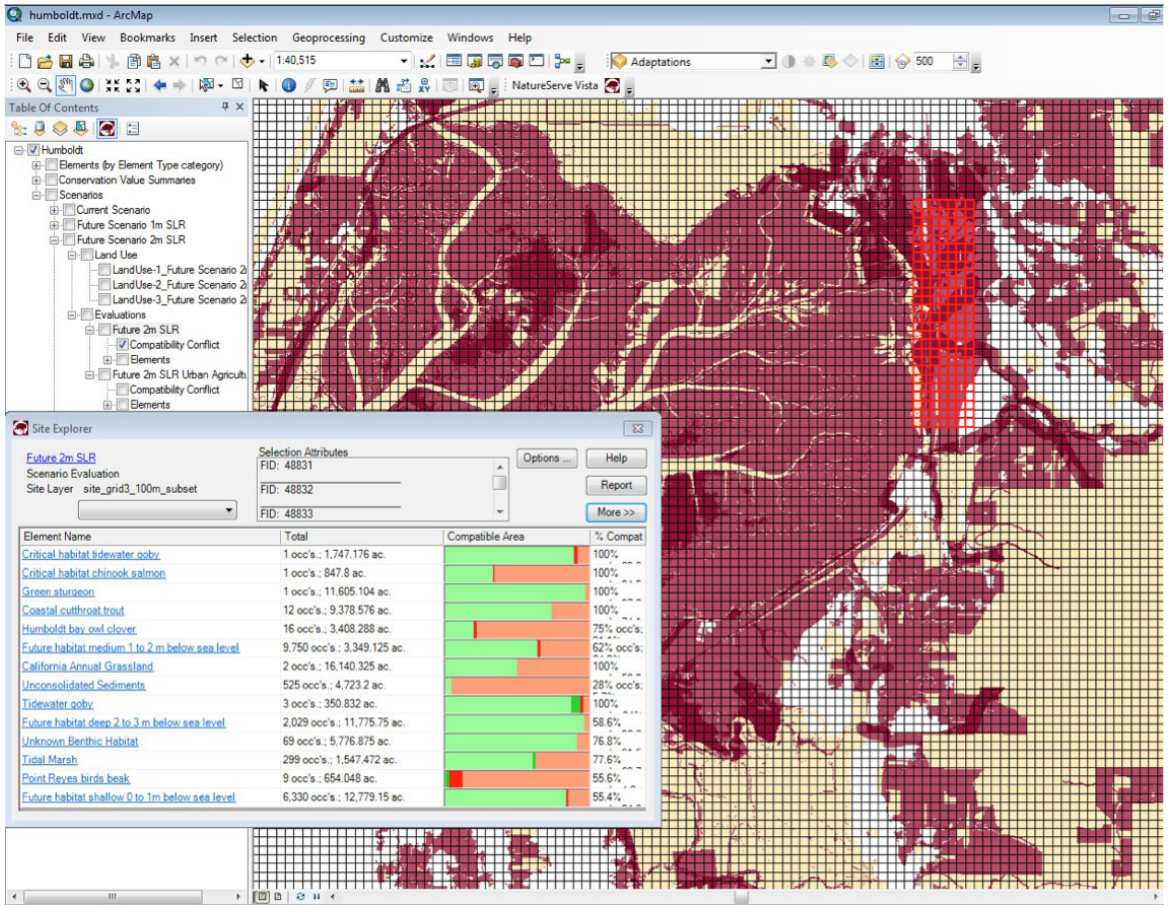
Geographic Scale: **Local, Regional**

Cost: **Software Download = Free**

Data Input(s): **Spatial data representing the elements to be conserved, represented, or restored; land cover and land policy scenario data**

Website: **http://www.natureserve.org/conservation-tools/natureserve-vista**

Developer/Sponsoring Agency: **NatureServe**



Description

NatureServe Vista enables users to create, analyze, implement, and monitor land use and resource management scenarios that achieve conservation goals. The tool is a spatial decision support system that can be used to conduct cumulative effects assessments, mitigation planning, and conservation planning. To utilize, assistance by personnel with technical modeling experience, including use of GIS software, is recommended.

Users can evaluate ecological, urban, and agricultural resources under current conditions and assess the impacts to those resources from various sea-level rise scenarios. The software can then be used to demonstrate the impact of mitigation and sea-level rise adaptation strategies. However, since this software is a raster-based platform, it will not be able to maintain precision of small features, such as point and linear features. Scale may also be a limiting factor although the software has previously been applied to projects 40,000 square miles in size.

This software is an ESRI ArcGIS extension designed to support non-GIS and non-conservation experts to assist integration of conservation with other assessment and planning activities. However, NatureServe Vista covers a broad suite of functions and requires the support of experts to build the database and train users in its analytical and planning functions. In addition to the Vista user's manual, fact sheet, and FAQs, NatureServe provides complete technical support, training, and consulting services.

Examples of Use

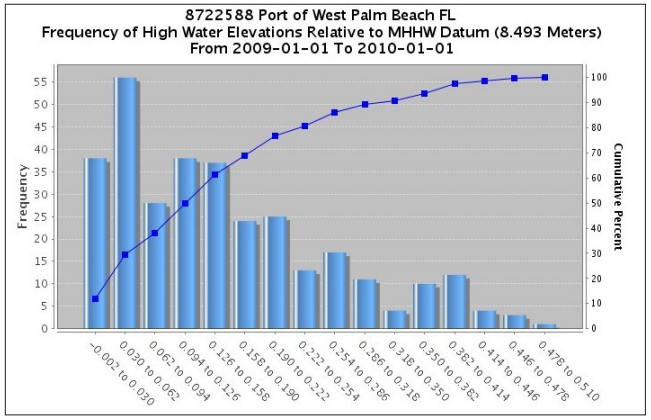
Humboldt Bay, CA (Pop. = 80,000)—used Vista to evaluate a variety of ecological, urban, and agricultural resources under current conditions and assess the impacts to these resources from urban expansion and sea-level rise scenarios of 1 and 2 meter inundation. Vista was then used to demonstrate the impact of mitigation and adaptation strategies through finding appropriate sites to: 1) relocate the airport and other inundated development; 2) conduct restoration; and, 3) conserve areas that should not be developed.

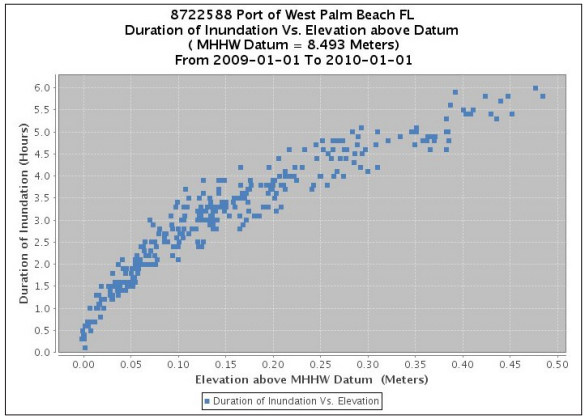
Eastern Shore of Virginia and Fisherman Island National Wildlife Refuges, VA—Conducted scenario assessment using Vista to assess and summarize expected changes to resources resulting from stressors, including sea-level rise, at four future time steps between 2010 and 2100. The results of these scenario evaluations indicated that most coastal resources (overwash flats, Northeastern Beach Tiger Beetle Populations, salt flats) and marshes are predicted to be impacted soonest and to the greatest extent. Maritime Upland forests were also found to be among those habitats showing the greatest degrees of conflict with sea-level rise. Vista was also used to develop a map of one exemplary strategy to address the resources with greatest potential conflicts in the scenario evaluations and meet conservation and management goals identified in the existing Comprehensive Conservation Plan (CCP).

When & Where to Use

NatureServe Vista can be used to show which resources and developed areas are potentially at risk to sea-level rise, through an impact analysis. It can also be used as a decision support tool at the site-scale for prioritizing strategies since it enables users to illustrate potential mitigation and adaptation options and determine which alternatives best achieve planning objectives.

NOAA Inundation Analysis Tool





Tool/Resource Type: **Decision Support Tool**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis, Strategy / Scenario Development**

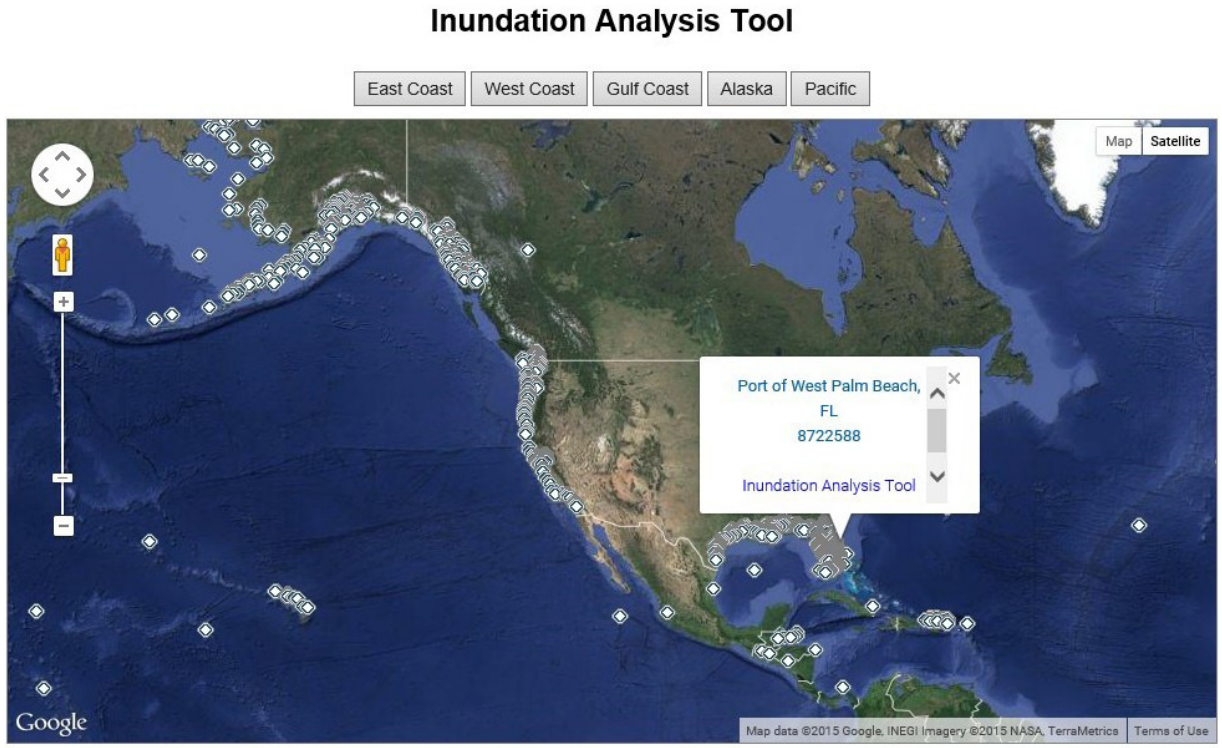
Geographic Scale: **Local**

Cost: **Online Tool = Free;**

Data Input(s): **Reference elevation, data range for evaluation**

Website: **http://tidesandcurrents.noaa.gov/inundation/**

Developer/Sponsoring Agency: **National Oceanic and Atmospheric Administration (NOAA)**



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Description

The NOAA Inundation Analysis Tool is an online tool that can be used to create scenarios of sea-level rise. The scenarios compare how many high tides and total hours of inundation would have been experienced during a selected time period assuming a given amount of sea-level rise versus the historical data. The tool employs data collected at NOAA tide gauge stations to provide statistical summaries of the historical frequency and duration of observed high waters. It captures normal changes in water levels from gravitational forces exerted by the moon, sun, and Earth's rotation as well as irregular changes associated with coastal storms and other meteorological events. To utilize, assistance by personnel with some coastal science experience is recommended.

After selecting a gauge, users will select a span of time and a water depth relative to a defined reference point. For example, the tool can be used to determine how many times a particular gauge has been over one meter higher than normal. Users can then compare the number of high tides and total inundation hours expected during that time period assuming different amounts of sea-level rise compared to the observed historical data. However, it is not easy for users to determine what time periods of data are available at each gauge without submitting a data query to check.

The Inundation Analysis Tool outputs include a data table, a histogram showing frequency of occurrence relative to threshold elevation, a histogram showing frequency of duration of inundation, and an X-Y scatter plot showing frequency of elevation versus duration of inundation for each event. Since these statistical outputs are station specific, use for evaluating surrounding areas may be limited. Furthermore, the length, seasonality, datum, and measurement errors of the data record result in some uncertainty of individual analysis results.

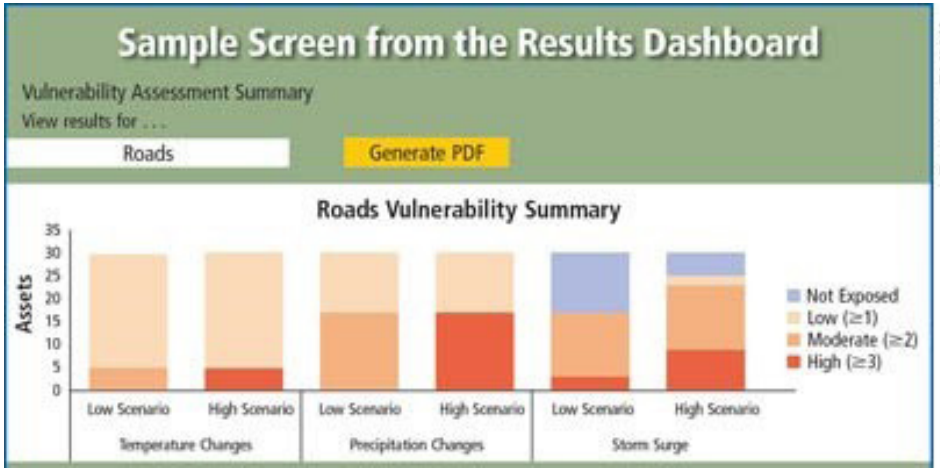
Examples of Use

Charleston, SC (Pop. = 128,000)—the Inundation Analysis Tool was used to calculate sea-level rise scenarios for Charleston Harbor and the vicinity. Using the flood threshold as defined by the Charleston Weather Forecast Office, the mean lower low water (MLLW) datum was calculated for the tide gauge that serves Charleston Harbor. This water level was then used as the "User Specified Elevation" to conduct the inundation analysis from January 1, 2012 to January 1, 2013. The results found that 27 high tides exceeded the threshold for a total of 46 hours of inundation. To create scenarios of increased sea-level rise, 0.5 meters and 1.0 meters were subtracted from the MLLW to represent the whole base shifting up with sea-level rise while the flooding threshold stays the same, thereby making the flood threshold a smaller number. Using the same time period dates, the analysis found 469 high tides at flood stage for a total of 1,344.5 hours of inundated with 0.5 meters of sea-level rise and 697 high tides at flood stage for a total of 3,751.6 hours of inundation with 1.0 meter of rise. Results similar to these, can be used by coastal communities to track the cumulative impacts of sea-level rise and determine how a community has already been impacted by sea level variations.

When & Where to Use

The Inundation Analysis Tool can be used during the planning context phase to gather information about historic inundation frequencies and durations. It is site-specific, although tidal gauge measurements may be applied to the nearest community.

U.S. DOT Vulnerability Assessment Scoring Tool (VAST)



Source: FHWA.

Tool/Resource Type: **Decision Support Tool**

Sector(s): **Transportation**

Relevant Adaptation Planning Process Phase(s): **Assessment / Analysis, Strategy / Scenario Development**

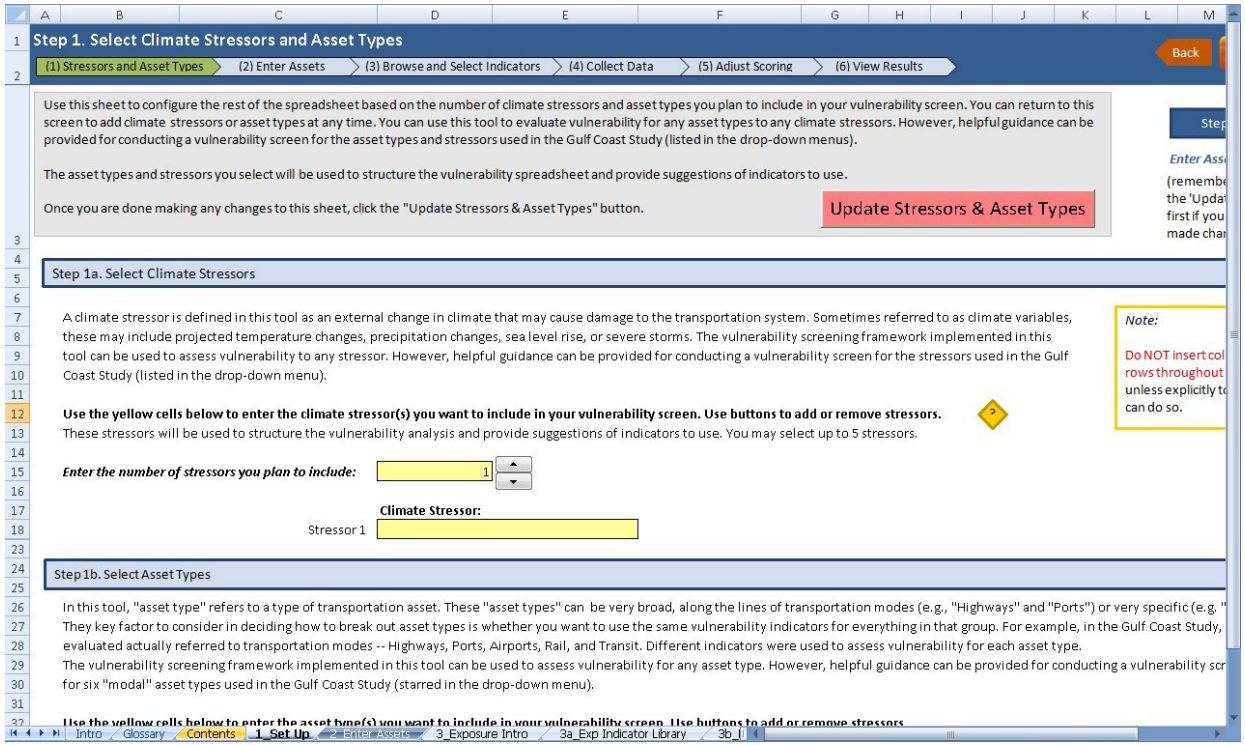
Geographic Scale: **Local, Regional, Statewide**

Cost: **Excel Download = Free;**

Data Input(s): **Asset inventory, climate information/stressors**

Website: **http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/**

Developer/Sponsoring Agency: **United States Department of Transportation**



Description

The Vulnerability Assessment Scoring Tool (VAST) is intended for state departments of transportation (DOT), metropolitan planning organizations (MPO), and other agencies interested in assessing how components of their transportation system may be vulnerable to climate stressors, including sea-level rise. The tool is a spreadsheet tool that was developed by the U.S. DOT to provide a framework for conducting a quantitative, indicator-based vulnerability screening for vulnerability. To utilize, assistance by personnel with transportation planning experience is recommended.

VAST enables users to calculate the vulnerability score of an asset as a function of exposure, sensitivity, and adaptive capacity. The score is derived from a series of indicators. For example, the vertical elevation of a coastal bridge's deck could be an indicator of the structure's sensitivity to sea-level rise. Therefore, the approach involves collecting information about indicators of each vulnerability component and operationalizing that information into relative vulnerability scores. This can be done for any combination of climate stressors and asset types.

The tool is designed to be highly flexible and users can choose from a set of indicators or make their own and adjust the scoring system based on a variety of factors, such as expert judgment, stakeholder input, or established thresholds. In addition, VAST is designed to be a transparent tool that helps users to decide which factors are most important and then apply those factors systematically to the data collected. However, it is important to remember that this type of broad, screening-level approach will inevitably have limitations.

Examples of Use

Anne Arundel County and Somerset County, MD (Pop. = 556,000 and 26,000 respectively)—the Maryland State Highway Administration used VAST to determine a vulnerability score for all structures (bridges and culverts), identify the 10 most vulnerable assets to each climate stressor, and produce maps and tables showing the most vulnerable structures.

Mobile, AL (Pop. = 195,000)—used VAST to prioritize assets for a detailed vulnerability assessment, quickly determine sensitivity of a diverse set of assets to climate stressors, and efficiently rate vulnerability across a large number of assets. The assessment found that all transportation modes except airports have assets highly vulnerable to sea-level rise and storm surge. However, public transit was found to have low vulnerability due to flexibility of the bus system and pipelines were also found to have low vulnerability as most are buried.

When & Where to Use

VAST helps users derive a vulnerability score for a given transportation asset at any scale, from a road segment to bridge to airport. It can assist with impact analysis at the single-asset level scale.

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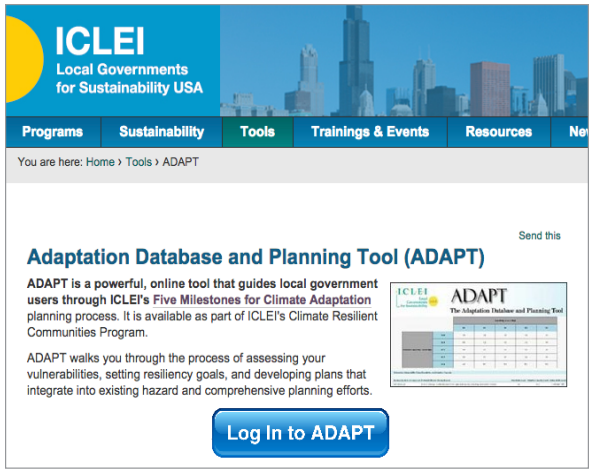
Database of Resources

Adaptation Database for Planning Tool (ADAPT)



- Tool/Resource Type: **Database of Resources**
- Sector(s): **Natural Resources, Agriculture, Built Environment**
- Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Strategy / Scenario Development**
- Geographic Scale: **Municipal Level**
- Cost: **Trial to ICLEI member local governments (requires log in) = Free**
- Data Input(s): **Data to assess vulnerabilities and risks**
- Website: **http://www.icleiusa.org/tools/adapt**
- Developer/Sponsoring Agency: **International Council for Local Environmental Initiatives-Local Governments for Sustainability**

Description

ADAPT is an online tool that guides local government users through ICLEI's Five Milestones for Climate Adaptation planning process. It is available as part of ICLEI's Climate Resilient Communities Program. The five milestones for climate adaptation include conduct a climate resiliency study (vulnerability assessment), set preparedness goals, develop a climate preparedness plan, publish and implement preparedness plan, and monitor and reevaluate resiliency. However, ADAPT is a proprietary tool and use is limited to ICLEI member local governments. To utilize, assistance by personnel with community planning experience is recommended.

ICLEI is the leading global network devoted to local governments engaged in sustainability, climate protection, and clean energy initiatives.

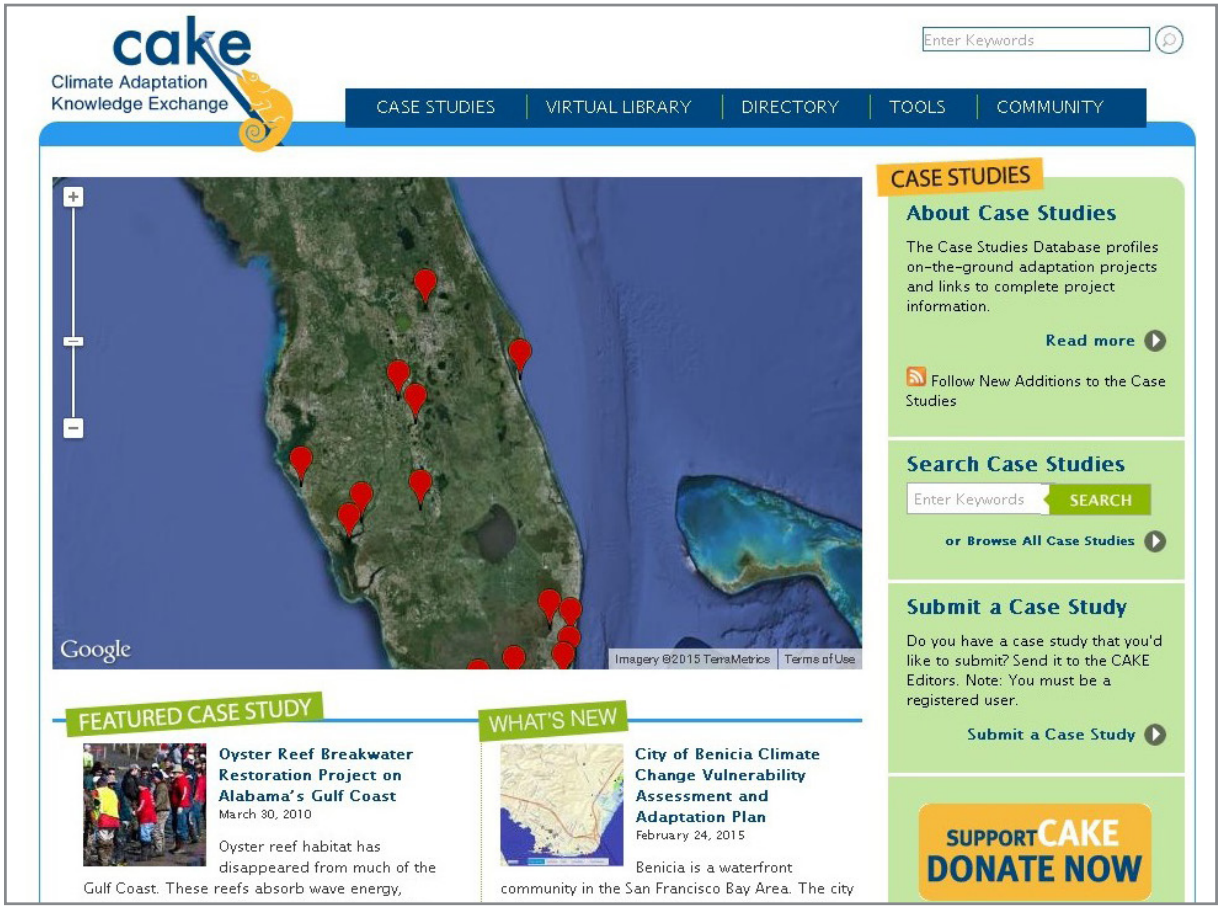
ADAPT walks users through the process of assessing their community's vulnerabilities, setting resilience goals, and developing plans that integrate into existing hazard and comprehensive planning efforts. ADAPT allows users to input data to assess vulnerabilities and risks. ADAPT consists of six modules: getting started; conducting a resiliency study; setting preparedness goals; creating a preparedness plan; implementing a preparedness plan, and monitoring, evaluating, and re-assessing the plan.

When & Where to Use

ADAPT is an online database that guides local government users through ICLEI's Five Milestones for Adaptation planning framework. The 'tool' proposes an adaptation planning process at the community scale. Local governments may gain access to ICLEI, and may refer to this tool for guidance at all phases while conducting their adaptation planning process.

Climate Adaptation Knowledge Exchange (CAKE)

- Tool/Resource Type: **Database of Resources**
- Sector(s): **Natural Resources, Built Environment**
- Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Strategy / Scenario Development**
- Geographic Scale: **Local, Regional, Statewide**
- Cost: **Online Database = Free**
- Data Input(s): **None**
- Website: **http://www.cakex.org/**
- Developer/Sponsoring Agency: **EcoAdapt, Island Press**



Description

The Climate Adaption Knowledge Exchange (CAKE) includes a database of tools to help explore climate change information and make adaptation decisions (including those related to sea-level rise); case studies of adaptation projects; a virtual library with literature and information focusing on adaptation and adaptation planning; and a directory of people/organizations engaged in climate change adaptation. It also houses community forums for the discussion of current issues in climate adaptation.

The Tools section of CAKE directs users to the tools available online to help process information and make adaptation decisions. Within each tool entry, users can also find related Case Studies, Virtual Library resources, and Directory entries in the green sidebar; these links provide users with more detailed information about how and by whom a tool has been used. Users can also recommend other key tools or resources for inclusion in the database, especially those that can be linked to projects to demonstrate how the tool has been used.

The Case Studies Database has been developed to provide quick access to information about on-the-ground adaptation projects. Interviews and surveys are used to synthesize how people are preparing for or responding to climate change. The information collected is compiled into case studies and shared through CAKE.

The Virtual Library is a complete, managed repository of documents relating to adaptation. It gathers the information relevant to adaptation appearing in traditional conservation journals, grey literature and reports, books on a range of subjects, videos, and state, local, and regional action plans in one place. There are filters to help users clearly target their search to help ensure they can find and access the information for which they are looking. Users can also contribute or recommend items to be included in the library.

The Directory includes people and organizations practicing on-the-ground adaptation. Users can see who is working on projects in a region or area of interests, how to contract practitioners for more information, and where to find them. If users have questions about a specific case study or method being used, they can simply click on their directory profile and find relevant contact information. The CAKE Directory is an open resource to find professionals engaged and/or interested in climate change adaptation and all CAKE users are invited to register and fill out a profile page.

When & Where to Use

CAKE's "case studies" may be utilized during context-phase activities such as for stakeholder engagement and description of the planning context. They include resources that apply to scales from the national to the site-specific. Its "tools" section includes resources for all phases, namely exposure analysis, funding surveys, and prioritization of strategies.

Ecosystem-Based Management (EBM) Tools Network and Database

Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory**

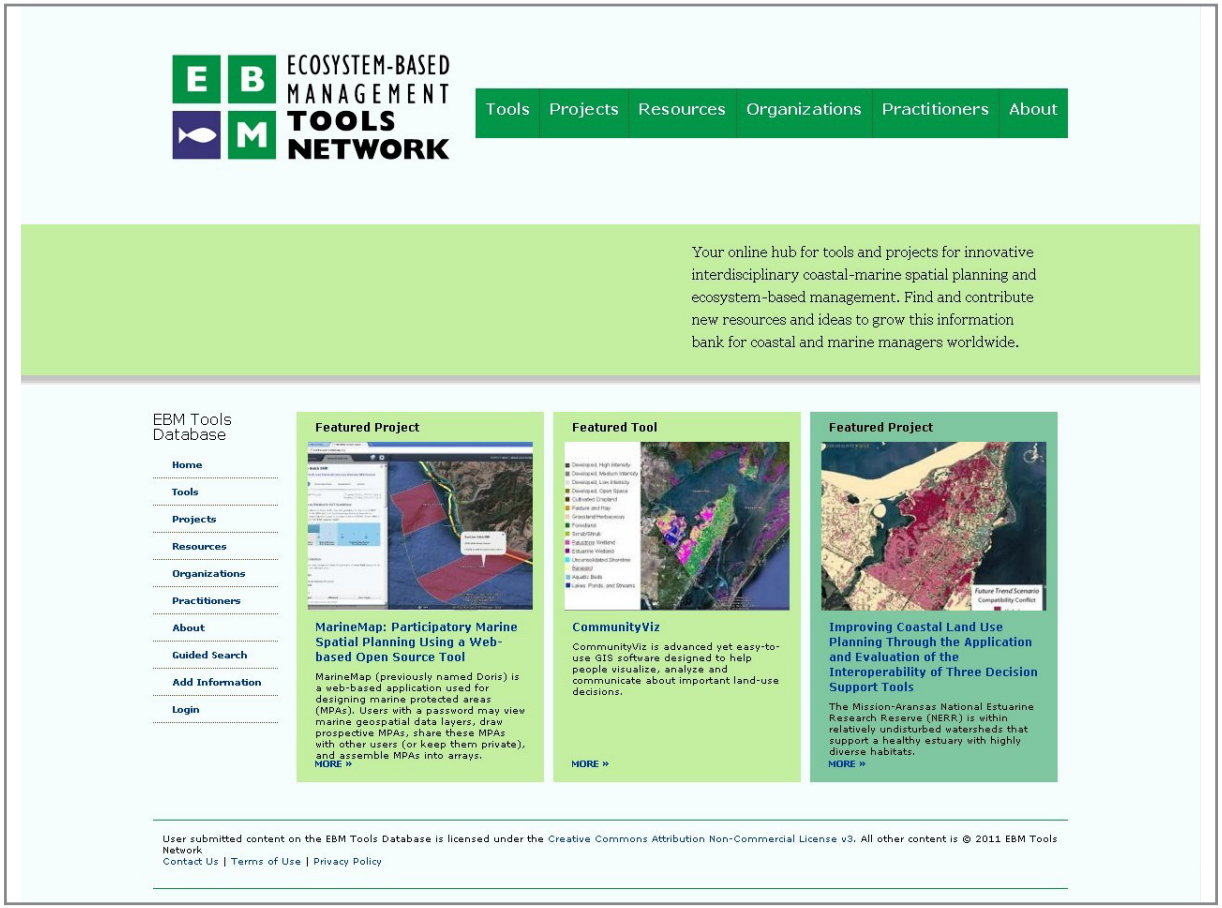
Geographic Scale: **Local, Regional, Statewide**

Cost: **Online Database = Free**

Data Input(s): **None**

Website: **https://ebmtoolsdatabase.org/**

Developer/Sponsoring Agency: **Ecosystem-Based Management (EBM) Tools Network, coordinated by NatureServe**



Description

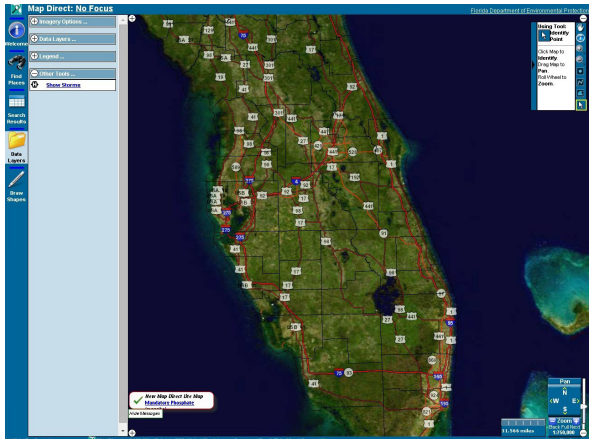
The Ecosystem-Based Management (EBM) Tools Network and Database is an online hub for tools and projects that involve coastal-marine spatial planning and ecosystem-based management. The EBM Tools Network's mission is to promote healthy ecosystems and communities through the use of tools that help incorporate ecosystem-based thinking into management decisions. Ecosystem-based management tools are methods and software that help practitioners incorporate scientific and socioeconomic information into decision making. EBM tools can help develop models of ecosystems, generate scenarios illustrating the consequences of different management decisions on natural resources and the economy, and facilitate stakeholder involvement in the planning processes. The EBM Tools Network is currently focusing on tools for: vulnerability assessment and adaptation planning, ecosystem-based coastal and marine spatial planning, and integrated land-sea planning to minimize the impacts of land use on coastal and marine environments.

The database organizes information and resources in five areas: Tools, Projects, Resources, Organizations, and Practitioners. Tools are methods and software/web tools to improve decision making; Projects are case studies representing a wide range of geographic locations, ecosystems, planning processes, tools, and outcomes; Resources include publications, toolkits, databases, and other resources to promote interdisciplinary coastal-marine spatial planning and ecosystem-based management; Organizations identify companies and organizations providing assistance with interdisciplinary coastal-marine spatial planning and ecosystem-based management including consultation, resources, and/or project management; and Practitioners lists professionals offering a tool, service, or resource to promote inter-disciplinary coastal-marine spatial planning and ecosystem-based management. Users are invited to add information about their own EBM tools, projects and resources.

When & Where to Use

The EBM Tools Network may be referred to during the Context and Vulnerability Analysis phases. Communities may search for case studies and tools to help expand the knowledge of their planning context, and conduct exposure and impact analyses.

FL DEP Map Direct Gateway



Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory**

Geographic Scale: **Local, Regional, Statewide**

Cost: **Online Map Viewer = Free; Data Download = Free**

Data Input(s): **None**

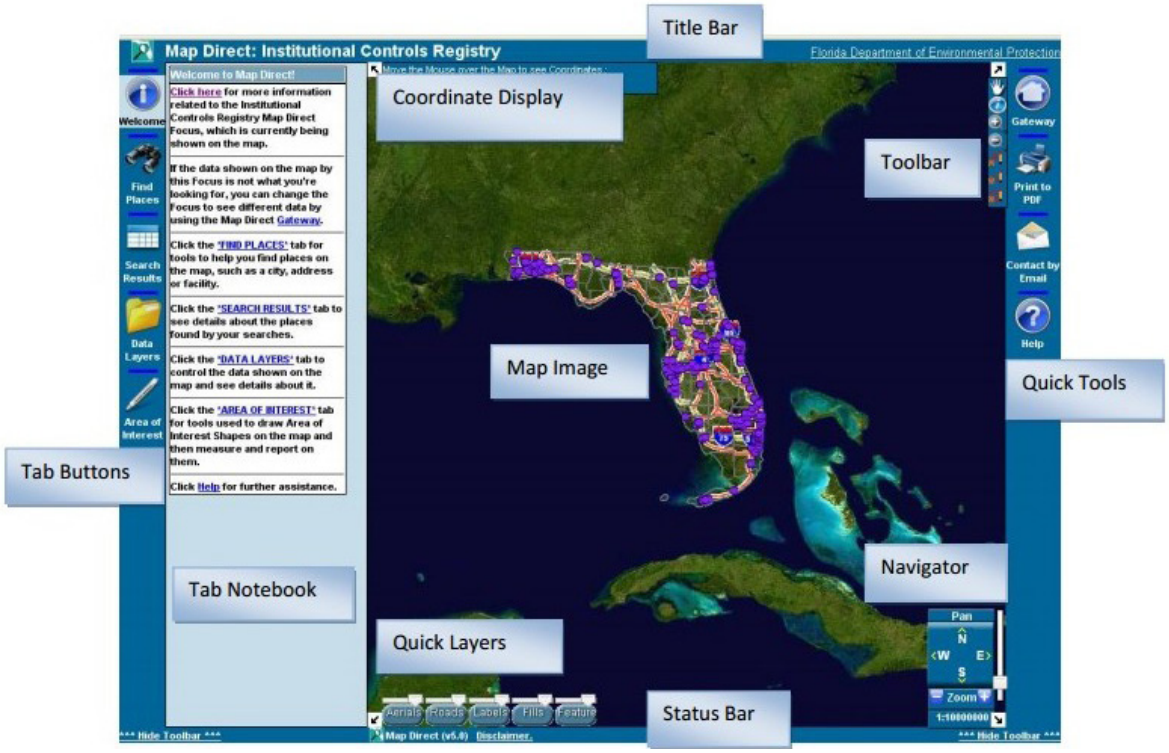
Website: **http://ca.dep.state.fl.us/mapdirect/gateway.jsp**

Developer/Sponsoring Agency: **Florida Department of Environmental Protection**

Map Direct **Quick Start** **8/31/2010**

1 General Appearance

The appearance of the Map Direct screen is shown below.



Description

The Florida Department of Environmental Protection's (FL DEP) Map Direct is a web-based map that uses information in FL DEP databases to provide locations and information for DEP facilities and sites. Map Direct is a powerful interactive mapping website that enables the user to display locations and data layers on a map including DEP regulated facilities, FEMA flood zones, land use/land cover, aerial photography, elevation, USGS quad maps, and much more. FL DEP's Map Direct Gateway is a resource for viewing and downloading GIS data. There are at least 58 base maps that can be used by state agencies, regional partners, and local governments. Base maps relevant to sea-level rise adaptation include: coastal access locations; coastal construction control line (CCCL); 2014 Property Appraiser Parcels; the location of state-owned buildings (Facility Inventory Tracking System (FITS)); the location of potable water wells and drinking water wells; conservation lands or waters; wastewater facilities; location of regulated storage tanks; and Florida Natural Areas Inventory data.

The Map Direct application replaces a number of existing single-purpose web mapping applications with a single integrated application with extensive capabilities. This integration enhances overall ease of use and will result in lower software development and maintenance costs for users. Map Direct has geolocation support to show current location, support for using other GIS Web Services (including those on ArcGIS Online), and better support for phones and tablets as well as desktop browsers. Map Direct will work in most major browsers. Data sites and sources, both from FL DEP as well as other agencies, can be followed to review available water data on a variety of subjects in a variety of formats and, in some cases, to manipulate and download the data.

Map Direct GIS interactive web application serves a variety of nonprofits and other associations and contains over 400 GIS layers from Water, Waste, Environmental Assessment, Air, State lands, Parks and Rec. Access can be achieved by any user with internet capabilities. Data layers are inventoried into categorizations to view applicable data. Imagery options are available. Map Direct does have the option to show historical and current storms. Find places and search results are available to obtain more detailed data. Map Direct allows the option to draw shapes on the GIS map and displayed datasets to customize the maps and datasets.

When & Where to Use

Map Direct provides access to a large number of FL DEP data layers and imagery layers, provides buffer analysis capabilities, provides "drill-down" reporting capabilities, and provides general data browsing. The Map Direct application replaces a number of existing single-purpose web mapping applications into a single integrated application with extensive capabilities.

Florida Natural Areas Inventory (FNAI)

Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory**

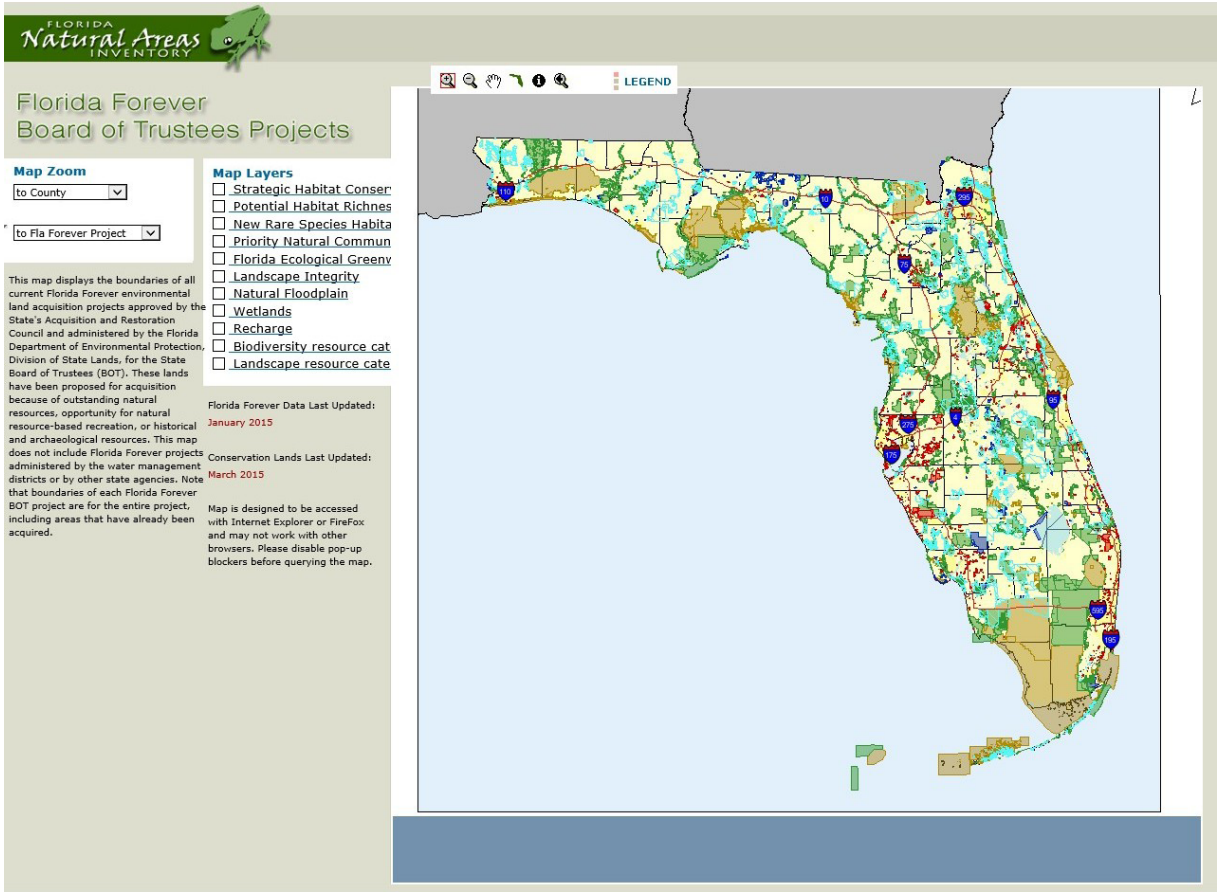
Geographic Scale: **Local, Regional, Statewide**

Cost: **GIS Data Download = Free; Online Map Viewers = Free**

Data Input(s): **None**

Website: **http://www.fnai.org/index.cfm**

Developer/Sponsoring Agency: **Florida Natural Areas Inventory, administered by Florida State University**



Description

The Florida Natural Areas Inventory (FNAI) offers spatial datasets and interactive maps that promote conservation of Florida's biological diversity, including sea-level rise adaptation. FNAI collects, interprets, and disseminates ecological information critical to the conservation of Florida's biological diversity. FNAI staff continually build and maintain a comprehensive database of the biological resources of Florida that are maintained in a GIS database for mapping and analysis. FNAI also serves as the primary source for information on Florida's conservation lands.

FNAI and its partners are working to develop a Florida Cooperative Land Cover Map (CLC) using ecologically-based statewide land cover from existing sources and expert review of aerial photography. The CLC map is revised continuously with new versions released every 6 to 12 months, and it incorporates major revisions to natural coastal land cover and natural communities potentially affected by sea-level rise. The statewide CLC map is available for download as either an ESRI File Geodatabase Feature Class or 15m Raster. This data allows users to identify natural communities that are potentially affected by sea-level rise.

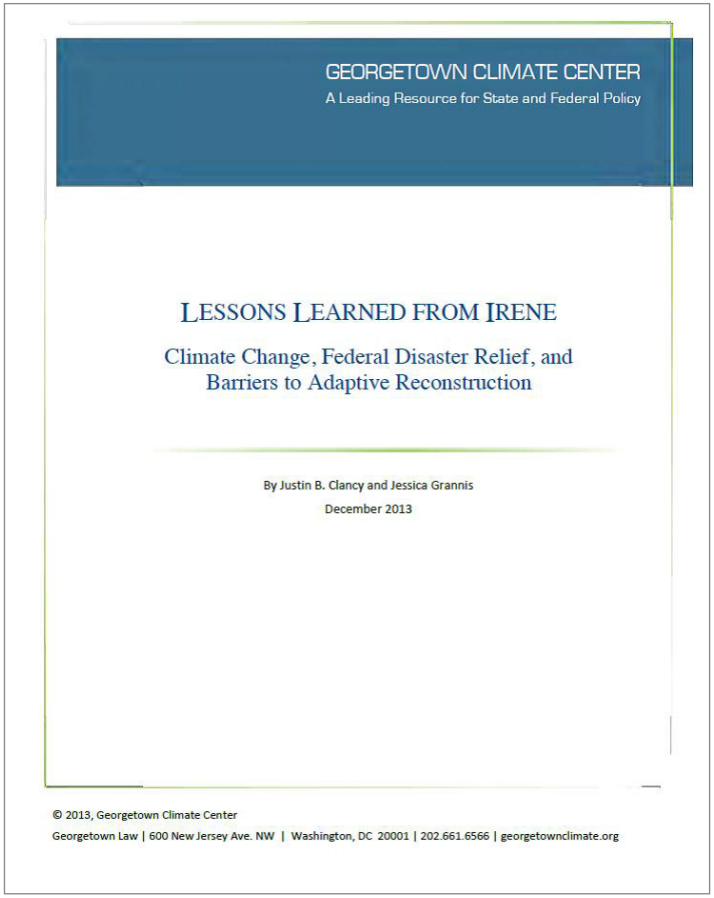
The Critical Lands and Waters Identification Project (CLIP) identifies those lands and waters in the state of Florida that are critical to the conservation of Florida's natural resources. CLIP is a GIS database of statewide conservation priorities for a broad range of natural resources, including biodiversity, landscape function, surface water, groundwater, and marine resources. CLIP allows users to visualize the location of critical habitats.

The Florida Forever Projects Map displays the boundaries of all current Florida Forever environmental land acquisition projects approved by the state's Acquisition and Restoration council and administered by the Florida Department of Environmental Protection, Division of State Lands, for the State Board of Trustees. These lands have been proposed for acquisition because of outstanding natural resources, opportunity for natural resource-based recreation, or historical and archeological resources. The Florida Forever Projects Map allows users to identify lands that have been acquired by the state for preservation. Communities interested in acquiring properties can use the map viewer to identify possible acquisitions adjacent to existing protected properties.

When & Where to Use

The FNAI database provides downloadable data that will assist communities to describe their planning context and conduct impact analysis (for natural areas). These can be performed at the asset-class scale, or the community scale.

Georgetown Climate Center



Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources, Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Strategy / Scenario Development**

Geographic Scale: **Local, Regional, Statewide**

Cost: **Online Database = Free**

Data Input(s): **None**

Website: **http://www.georgetownclimate.org/**

Developer/Sponsoring Agency: **Georgetown Law**

Description

The Georgetown Climate Center provides sea-level rise and flood-related work products intended to assists state and local governments become better prepared to cope with the threats posed by rising sea levels and higher storm surges. The Center is a nonpartisan organization that seeks to advance climate, energy, and transportation policies in the U.S.

The Center's Adaptation Clearinghouse identifies and maintains a list of sea-level rise resources for policymakers and provides a list of resources, expert organizations, assessments, and sample plans for the coastal sector.

The Center's Adaptation Tool Kit explores 18 different land-use tools that can be used to preemptively respond to the threats posed by sea-level rise to both public and private coastal development and infrastructure. The Adaptation Toolkit strives to assists governments in determining which tools to employ to meet their unique socio-economic and political contexts.

The Georgetown Climate Center also strives to help communities meet challenges by addressing the legal barriers that communities face when adapting to rising sea levels and seeks to help localities prepare for the potential increased frequency, scope, and severity of heat events and extreme weather. In addition, the Center strives to assists communities in spending disaster relief funds wisely by preparing for the next big storm—not just rebuilding to meet the status quo.

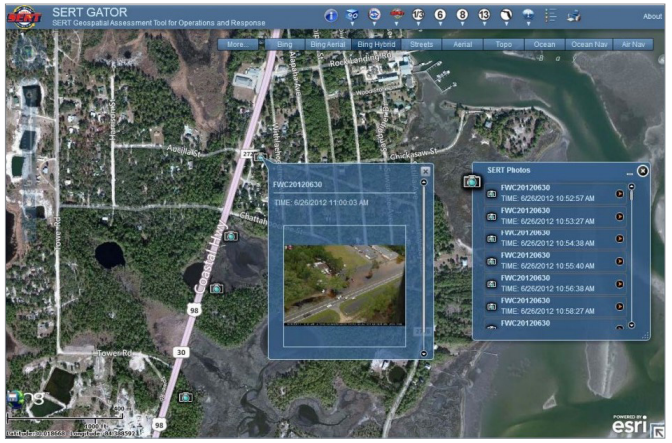
Examples of Use

Virginia (Pop. = 8.3 million) – The Georgetown Climate Center prepared and supported a case study that analyzes Virginia local governments' authority to use existing land use powers to adapt to the impacts of sea-level rise and flooding. Specifically, this study looks at local authority to implement policy options identified in Virginia's Climate Action Plan. State and local government officials can reference the study for help in determining how local government land use powers may be used as part of an adaptation plan.

When & Where to Use

The Climate Center can assist communities to define their planning context. The Adaptation Tool Kit is useful toward the creation of adaptation strategies. The information may be asset-specific, or community wide.

Geospatial Assessment Tool for Operations and Response (GATOR)



Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation, Energy**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory**

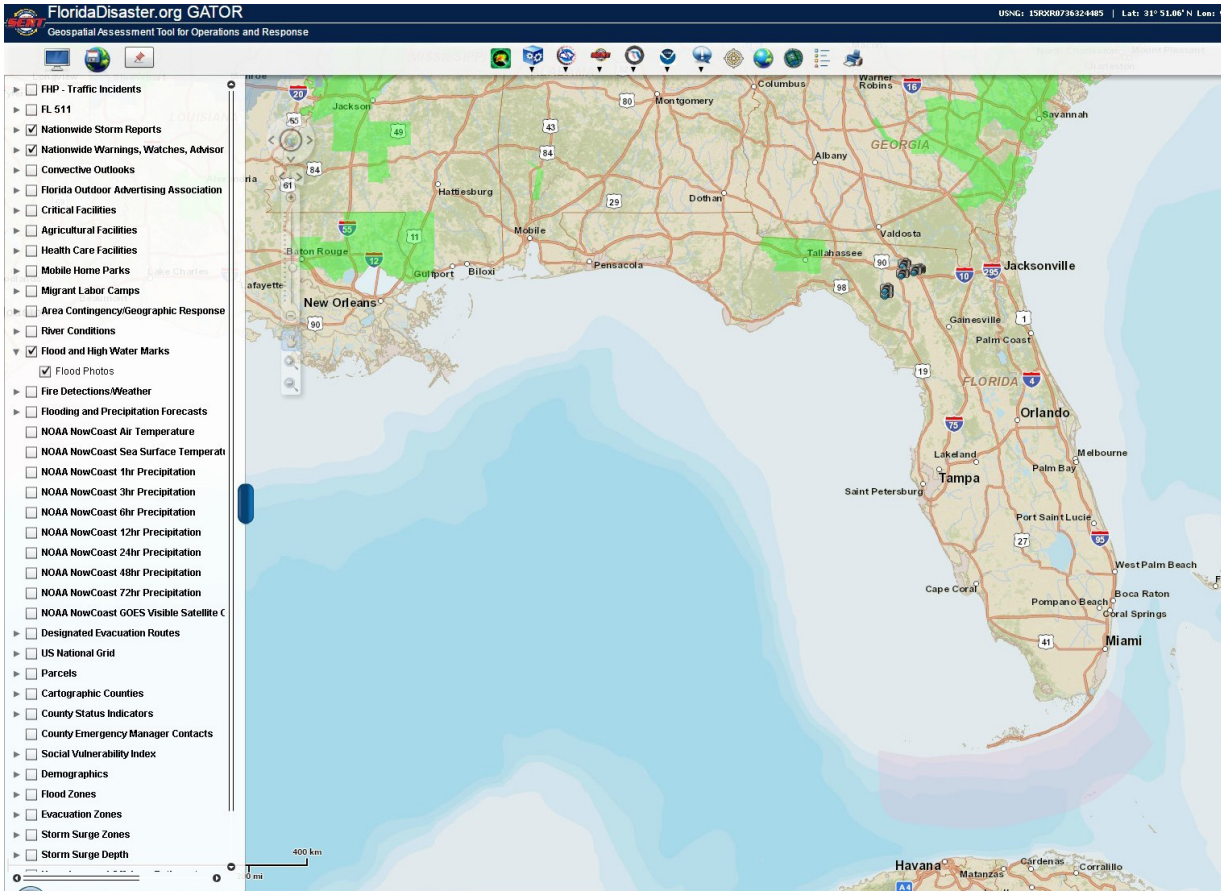
Geographic Scale: **Local, Regional, Statewide**

Cost: **Online Map Viewer = Free**

Data Input(s): **None**

Website: **http://map.floridadisaster.org/GATOR/map.html**

Developer/Sponsoring Agency: **Florida Division of Emergency Management, Florida State Emergency Response Team**



Description

The Geospatial Assessment Tool for Operations and Response, or GATOR, is an interactive web mapping tool for the display of geographic information to support emergency preparedness, operations, and response. GATOR is the flagship situational awareness application for the Florida Division of Emergency Management and the State Emergency Response Team. Real-time data like weather radar, weather watches and warnings, and tropical storm tracks are displayed along with base map data like roads, facilities, and aerial photographs. To bring in additional demographic, infrastructure, economic, and environmental data, direct access to NOAA's Coastal County Snapshots was added to the interface. To utilize, assistance by personnel with GIS and Emergency Management skills is recommended.

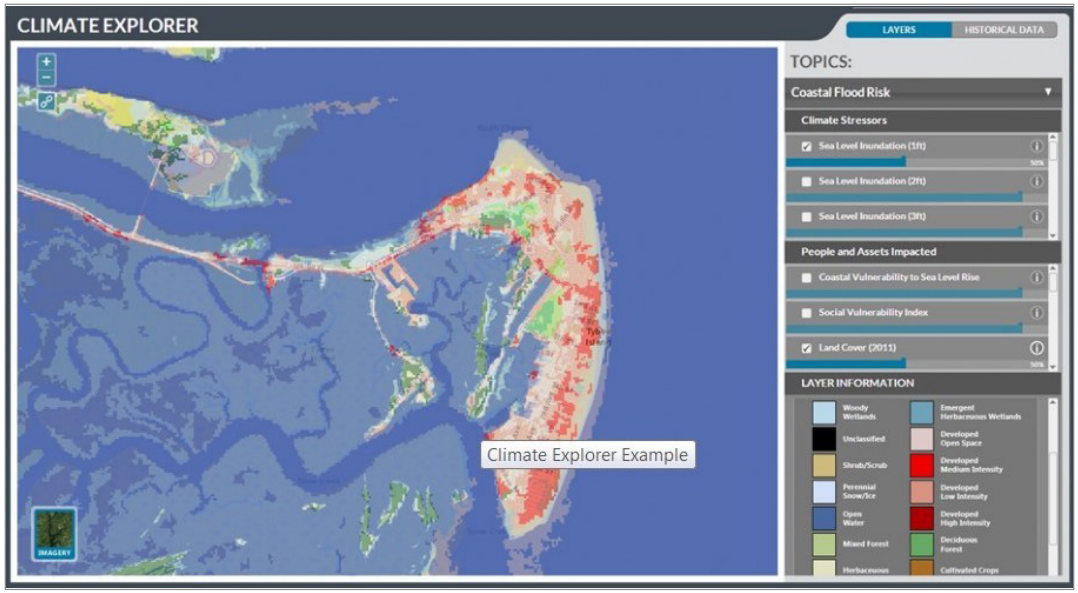
The GATOR website provides a mapping utility for users that outlines disaster situations around Florida. The map can either be used to see broad geographic areas or can be focused on particular neighborhoods. Tools allow the user to select particular geographic areas and determine the demographic make-up up impacted areas. Live maps, satellite maps, street maps, and nautical charts provide alternate means of determining impact of a pending disaster. When a disaster is in progress RECON data provides up-to-the-minute information. Various layers of mapping allow data on a variety of topics, including location of power plants, vessel t racking, critical facilities, storm surge zones, and natural resources.

This tool may be useful for quickly visualizing data that could be incorporated into a community's discussion of guiding principles and motivations and also into a vulnerability assessment. Storm surge zones, storm surge depth, hurricane evacuation zones, demographic information by census tract and block group, social vulnerability index, migrant labor camps, mobile home parks, and health care facilities are examples of the available data that may be useful during the adaptation planning process. It is important to note that many of these data layers are not readily available for viewing elsewhere, which makes this resource unique when trying to understand spatial distribution or potential vulnerabilities. Users can also export maps from the viewer as well as identify useful data and contact the respective data holder for data transfer.

When & Where to Use

GATOR can be used to visualize flood hazard data that informs a community's goal setting, description of the planning context, vulnerability assessment, and (thanks to its live disaster mapping) Monitoring and Evaluation. Information is displayed at the statewide level, although county-level data can be activated by the "Flood Exposure Profile" button.

U.S. Climate Resilience Toolkit



Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources, Agriculture, Built Environment, Transportation**

Relevant Adaptation Planning Process Phase(s): **Stakeholder Engagement, Scoping / Inventory, Strategy / Scenario Development**

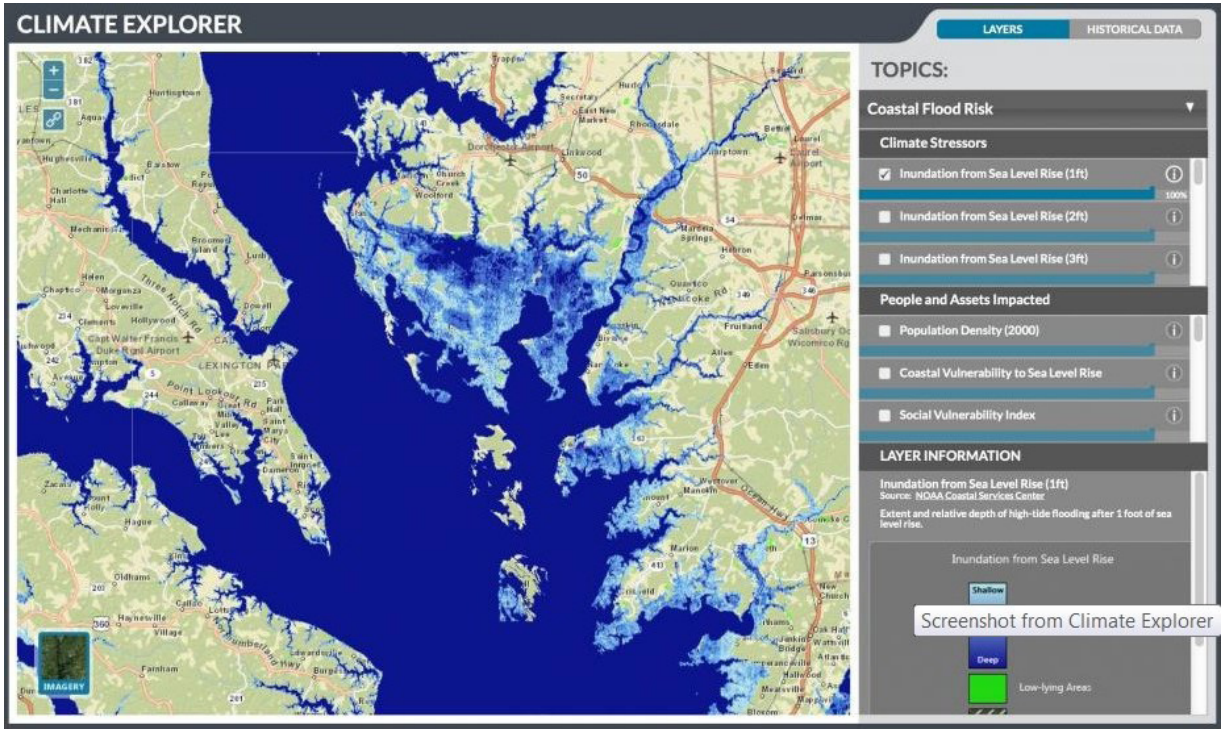
Geographic Scale: **Local, Regional, Statewide**

Cost: **Online Database = Free**

Data Input(s): **None**

Website: **http://toolkit.climate.gov/**

Developer/Sponsoring Agency: **National Oceanic and Atmospheric Administration**



Description

The U.S. Climate Resilience Toolkit contains multiple tools that can be used to estimate, simulate, visualize, and monitor sea-level rise and impacts throughout the country. Depending on the users' location and information needs, a tool can be selected to estimate and examine current and/or potential impacts related to sea-level rise.

The Toolkit provides resources and a framework for understanding and addressing climate issues that impact people and their communities. The Toolkit includes scientific tools, information, and expertise to help users manage their climate-related risks and opportunities and improve their resilience to extreme events. The site is designed to serve interested citizens, communities, businesses, resource managers, planners, and policy leaders at all levels of government.

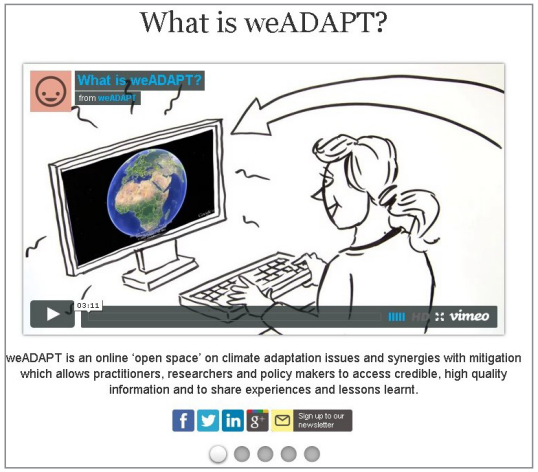
The Toolkit offers the following resources to help address identified issues and opportunities: Steps to Resilience; Taking Action stories; a catalog of freely available tools; Climate Explorer; topic narratives; pointers to free, federally-developed training courses; maps highlighting the locations of centers of where federal and state agencies can provide information; and the ability to search the federal government's entire climate science library and filter results according to interests.

Climate Explorer is a research application that was built to support the U.S. Climate Resilience Toolkit. It is an interactive tool that offers visualizations for exploring maps and data related to the toolkit's Taking Action case studies. Map layers in the tool represent geographic information available through the webpage climate.data.gov. Each layer's source and metadata can be accessed through its information icon. Users can also view coastal flood risk data including inundation from 1, 2, and 3 foot sea-level rise as well as the population density, coastal vulnerability to sea-level rise, and social vulnerability index. Users are also able to produce and interact with graphs showing daily observations and long-term averages from the historical data tab.

When & Where to Use

The U.S. Climate Resilience Toolkit can be utilized to explain a community's planning context. The Climate Explorer can be utilized to build awareness and facilitate decisions about a preferred exposure analysis scenario. The scale is statewide, although communities may adjust the scale to near site-specific resolution.

weADAPT



Tool/Resource Type: **Database of Resources**

Sector(s): **Natural Resources, Built Environment**

Relevant Adaptation Planning Process Phase(s): **Scoping / Inventory, Strategy / Scenario Development**

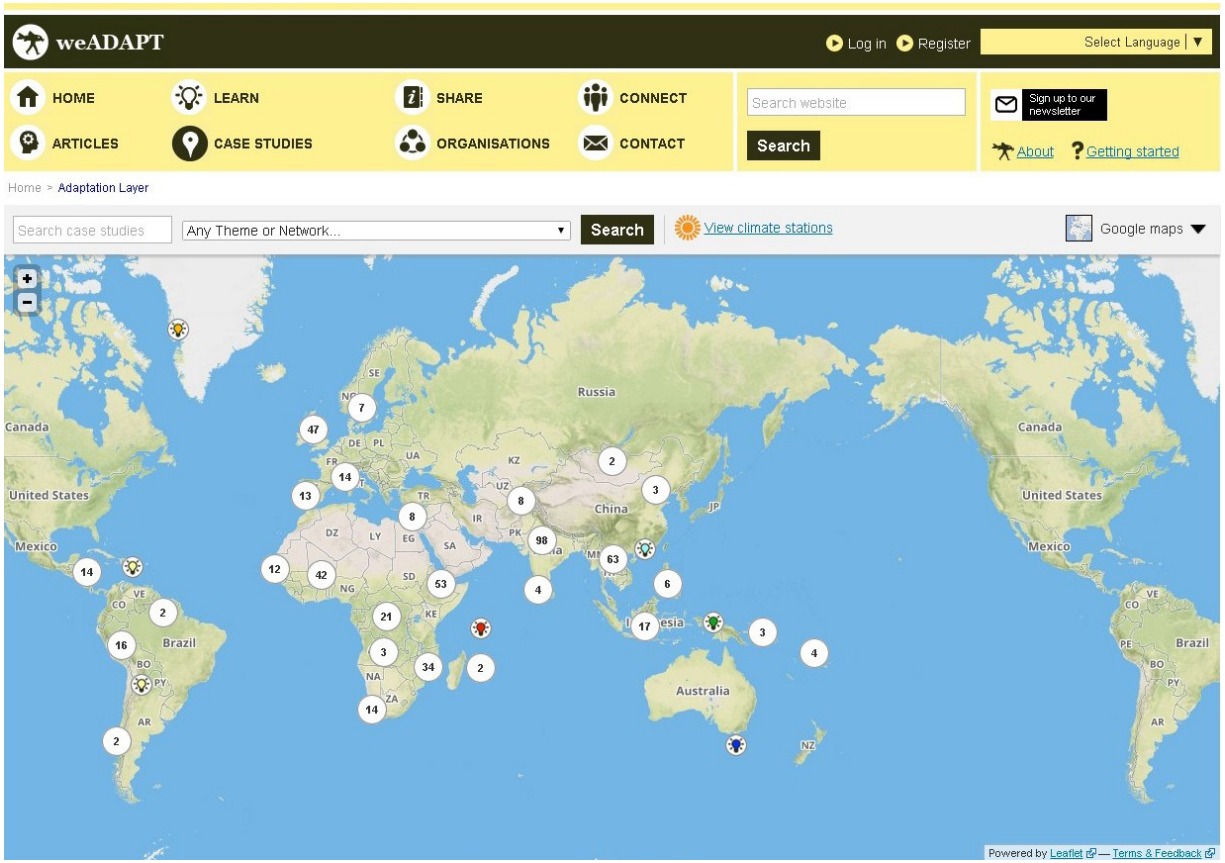
Geographic Scale: **Local, Regional**

Cost: **Online Database = Free (when registered)**

Data Input(s): **None**

Website: **https://weadapt.org**

Developer/Sponsoring Agency: **Stockholm Environment Institute**



Description

weADAPT is an online forum on climate adaptation issues which allows users to share experience, tools, case studies, and other information. The site includes over 192 articles and case studies that relate to sea-level rise and its impacts. The platform is designed to facilitate learning, exchange, collaboration, and knowledge integration by providing users with opportunities to learn, share, and connect.

Users can find information using the themes, networks, and projects categories to browse articles, case studies, tools, or methods of interest or through a key word search. Users can also share content on weADAPT by creating an article. The two main types of articles are short case studies and project summaries or more detailed articles. Users can include information about their latest project, reports, published articles, case studies, and other relevant information in their articles. Sharing articles on weADAPT can help potential collaborators and sponsors find users' work as well as help users connect with other users. Users can search the weADAPT online community based on name, organization, or interest to find and connect to people doing similar work. The Adaptation Layer also allows users to view projects that are operating in similar fields or that are located in the same geographic area. Social media channels are also used to increase communication between users.

To research sea-level rise, users can enter key words in the search tool to locate applicable information and data results, such as relevant websites and case studies. The website provides a platform that helps users to find the information for which they are looking.

When & Where to Use

weADAPT can assists communities to form a steering committee (with non-local experts), set goals, and receive advice from other communities concerning all adaptation plan phases. The nature of the website is geared towards communication about adaptation projects on a worldwide scale.

Sea-Level Rise Vulnerability Tools/Resources Inventory Matrix

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
Visualization Tools							
CanVis	This tool allows users to create photo-realistic simulations for visualizing the potential impacts from coastal development and sea-level rise.	Natural Resources, Built Environment	Stakeholder Engagement, Assessment / Analysis	Determine by horizontal width and depth of view shown in digital photograph uploaded by user	Software Download = Free	Digital photograph	http://coast.noaa.gov/digitalcoast/tools/canvis
Climate Central's Surging Seas	This tool includes an interactive Risk Finder and Submergence Risk Map. The Risk Finder shows populations, infrastructure, and assets exposed to coastal flooding aggravated by different sea levels, as determined by the user (i.e., 1 to 10 feet of rise). The Submergence Risk Map is a tool that depicts sea-level rise scenarios.	Natural Resources, Built Environment, Transportation	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis	Local, Regional, Statewide	Online Map Viewer = Free Data Download = Free	None	http://sealevel.climatecentral.org/
FDOT Sea Level Scenario Sketch Planning Tool	This tool allows for visualization of potentially inundated areas due to sea level rise, identification of transportation facilities potentially at risk from sea-level rise inundation, report creation to summarize and prioritize impacted infrastructure, and the ability to create custom inundation surfaces.	Transportation	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis	Local, Regional, Statewide	Online Map Viewer = Free Data Download = Free Sea-Level Rise Inundation Surface Calculator Download = Free	None	http://sls.geoplan.ufl.edu/
The Nature Conservancy Coastal Resilience Mapping Portal	This tool provides users with access to interactive tools to visualize future flood risks from sea-level rise and storm surge.	Natural Resources, Agriculture, Built Environment, Transportation	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis	Local, Regional, Statewide	Online Map Viewer = Free	None	http://maps.coastalresilience.org/network/

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
NOAA Coastal Change Analysis Program (C-CAP) Land Cover Atlas and Coastal Comparison Tool	The NOAA C-CAP program produces a Nationally standardized database of land cover and land change information for the coastal regions of the U.S. that can be used to explore changes and trends in land cover that may be caused by sea-level rise. The Land Cover Atlas and Coastal Comparison Tool are two products that allow users to easily access the C-CAP data.	Natural Resources, Agriculture, Built Environment	Stakeholder Engagement, Scoping / Inventory	Countywide, Statewide	Data Download = Free Online Viewer = Free Online Comparison Tool = Free	None	http://coast.noaa.gov/digitalcoast/data/ccapregional http://coast.noaa.gov/digitalcoast/tools/lca http://coast.noaa.gov/digitalcoast/tools/ccap-comparison
NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer	This tool is an online viewer that allows users to visualize potential impacts from sea-level rise.	Natural Resources, Built Environment, Transportation	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis	Local, Regional, Statewide	Online Viewer = Free Data Download = Free	None	http://coast.noaa.gov/digitalcoast/tools/slr
NOAA Sea Level Trends	This tool illustrates regional trends in sea level with arrows representing the direction and magnitude of change. This can be used to determine areas which have experienced the highest rates of change and may be most vulnerable to future sea-level rise.	Natural Resources	Scoping / Inventory, Assessment / Analysis	Local, Regional	Online Map Viewer = Free	None	http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml
Social Vulnerability Index (SoVI)	This tool measures the social vulnerability of U.S. counties and census tracts to environmental hazards, including sea-level rise.	Built Environment	Scoping / Inventory, Assessment / Analysis	Census Tract to Countywide	Results = Free Data Download = Free	None	http://webra.cas.sc.edu/hvri/products/sovi.aspx

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
USGS National Assessment of Coastal Vulnerability to Sea-Level Rise: Coastal Vulnerability Index (CVI)	This tool maps the Coastal Vulnerability Index (CVI) data layer, which expresses the relative vulnerability of the coast to physical changes due to sea-level rise, geomorphology, and shoreline erosion rates.	Natural Resources	Scoping / Inventory, Assessment / Analysis	Local, Regional, Statewide	Online Map Viewer = Free	None	http://coastalmap.marine.usgs.gov/FlexWeb/national/cvi/
USGS Digital Shoreline Analysis System (DSAS)	This tool can be used to measure coastal erosion and accretion, which can help users determine the areas that have experienced the highest rates of change and may be most vulnerable to sea-level rise.	Natural Resources	Scoping / Inventory, Assessment / Analysis	Shoreline	Software Download = Free	National shoreline data	http://pubs.usgs.gov/of/2003/of03-076/
Modeling Tools							
ADvanced CIRCulation Model (ADCIRC)	This tool can be used to analyze the effects of sea-level rise on storm surge. Future scenarios can consider a given rate of sea-level rise and determine how much additional inundation is predicted during a storm event compared to that under initial conditions.	Natural Resources	Assessment / Analysis	Deep Ocean, Continental Shelves, Coastal Seas, or Small-scale Estuarine Systems	ADCIRC Software Component = $3,950 Custom ADCIRC package = $6,350 SMS Package = $2,300-$47,000; Educational Package Discount = 50% off	Bathymetry, gridded wind measurements across the model domain, freshwater discharge	http://adcirc.org/ http://www.aquaveo.com/software/sms-adcirc http://www.veritechinc.com/products/sms_adcirc/index.php

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
Hazus-MH	This tool is a risk assessment methodology for analyzing potential losses. Although it is not specifically designed for sea-level rise planning applications, many communities have used it to assess potential losses due to sea-level rise.	Built Environment, Transportation, Energy	Assessment / Analysis	Local, Regional, Statewide	Software Download = Free	None (contains all necessary data but users can supply additional data, such as specific building data, soil maps, and stream gauges)	http://www. fema. gov/hazus
Integrated Valuation of Environmental Services and Tradeoffs (InVEST)	This tool is a suite of software models that is used to map and model ecosystem services and their variation under different management and climate scenarios. The Coastal Vulnerability Model can be used to calculate a vulnerability index for the impacts of erosion and inundation on coastal communities that accounts for projected change in sea-level rise.	Natural Resources, Agriculture, Energy	Assessment / Analysis, Strategy / Scenario Development	Local, Regional, Statewide, Global	Software Download = Free	Spatial data and parameter values (much of the data are required within the software, users can input data more specific to the region)	http://www.naturalcapitalproject.org/InVEST.html
NatureServe Climate Change Vulnerability Index (CCVI)	This is an Excel-based tool that identifies plant and animal species that are particularly vulnerable to the effects of climate change and can help assess the relative vulnerability of species of interest occurring on the coast that may be impacted by sea-level rise.	Natural Resources	Assessment / Analysis	Regional	Software Download = Free	Species-specific sensitivity or life history data, data on exposure to climate change, land use data	http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index
NOAA Wave Exposure Model (WEMo)	This is a free tool that estimates wave energy and its effects on ecosystem functions as well as on developed coastal and inland-water areas.	Natural Resources	Assessment / Analysis	Regional	Software Download = Free	Bathymetry grid data, shoreline coverage data, wind data	http://coast.noaa.gov/digitalcoast/tools/wemo

Sea-Level Rise Vulnerability Tools/Resources Inventory Summary Table (Continued)

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
Sea Levels Affecting Marshes Model (SLAMM)	This tool simulates wetland conversion and shoreline modification resulting from long-term sea-level rise. As such, the tool can be used for projecting the effects of sea-level rise on the distribution of coastal wetlands and the geomorphic configuration of coastal areas.	Natural Resources	Assessment / Analysis	Local, Regional	Software Download = Free Online Viewer = Free	National Wetlands Inventory data, digital elevation data, optional datasets include: protected area/ dike data and site parameters to change water depths, accretion rates, erosion rates, and many more	http://warrenpinnacle.com/prof/SLAMM/index.html http://www.slammview.org/slammview2/
Simulator of Climate Change Risks and Adaptation Initiatives (SimCLIM)	This tool can be used to model site-specific sea-level rise. The tool can create scenarios and project impacts of sea-level rise.	Natural Resources, Agriculture, Built Environment	Assessment / Analysis	Local, Regional, Statewide, Global	Annual Seat License = $149 to $6,000 (depending on user) Downscaled AR5 Spatial Areas = $150 to $300 6-Week Trial Version = Free	Additional regional climate variables (optional)	http://www.climsystems.com/simclim/
USACE Sea Level Change Curve Calculator	This tool can be used to calculate the amount of predicted sea level change for any location along the U.S. coast from 1992 forward. Results are shown as a graph.	Natural Resources, Built Environment, Transportation	Scoping / Inventory, Assessment / Analysis	Local	Online Calculator = Free Excel Calculator Download = Free	Base flood elevation, project start and end years, interval year	http://www.corpsclimate.us/ccaceslcurves.cfm

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
Decision Support Tools							
Beach-*fx*	This tool is a comprehensive analytical framework for evaluating the physical performance and economic benefits and costs of shore protection projects, including sea-level rise adaptation projects.	Natural Resources, Built Environment	Assessment / Analysis, Strategy / Scenario Development	Local, Regional, Statewide	Software Download = Free	Coastal area description; plausible storm events; vulnerable infrastructure inventory; morphology response estimates; erosion, inundation, and wave impact design parameters	http://hera.pmcl.com/beachfx/default.aspx
Coastal Adaptation to Sea-Level Rise Tool (COAST)	This software helps users answer questions in regards to the costs and benefits of actions and strategies to avoid damages to assets from sea-level rise, through 3D visualizations.	Natural Resources, Agriculture, Built Environment, Transportation, Energy	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development	Project Level	Software Download = Free	Tide gauge data; local real estate, economic activity, infrastructure, natural resources, and human health data; candidate adaptation actions	https://www.bluemarblegeo.com/products/COAST.php
CommunityViz	This tool provides a means for visualizing and communicating possible future land use change scenarios driven by sea-level rise.	Natural Resources, Agriculture, Built Environment, Transportation, Energy	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development	Local, Regional, Statewide	30-Day Trial =Free; Gov't/ Non-Profit = $875; Commercial = $1,400	GIS layers (e.g., parcels, zoning, roads, environmentally sensitive areas), demographics, future population projections, future land use plans or proposals	http://placeways.com/communityviz/index.html

Sea-Level Rise Vulnerability Tools/Resources Inventory Summary Table (Continued)

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
NatureServe Vista	This tool enables users to create, analyze, implement, and monitor land use and resource management scenarios that achieve conservation goals.	Natural Resources, Agriculture, Built Environment, Transportation, Energy	Stakeholder Engagement, Scoping / Inventory, Assessment / Analysis, Strategy / Scenario Development	Local, Regional	Software Download = Free	Spatial data representing the elements to be conserved, represented, or restored; land cover and land policy scenario data	http://www.natureserve.org/conservation-tools/natureserve-vista
NOAA Inundation Analysis Tool	This is an online tool that can be used to create scenarios of increased sea-level rise. The output may be used to compare how many high tides and total hours of inundation would have been experienced during a selected time period assuming a given amount of sea-level rise, versus the historical data.	Natural Resources	Assessment / Analysis, Strategy / Scenario Development	Local	Online Tool = Free	Reference elevation, data range for evaluation	http://tidesandcurrents.noaa.gov/inundation/
U.S. DOT Vulnerability Assessment Scoring Tool (VAST)	This tool is intended for state DOTs, MPOs, and other agencies interested in assessing how components of their transportation system may be vulnerable to climate stressors, including sea-level rise.	Transportation	Assessment / Analysis, Strategy / Scenario Development	Local, Regional, Statewide	Excel Download = Free	Asset inventory, climate information/ stressors	http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/
Databases of Resources							
Adaptation Database for Planning Tool (ADAPT)	This is an online tool that guides local government users through ICLEI's Five Milestones for Adaptation planning process.	Natural Resources, Agriculture, Built Environment	Scoping / Inventory, Strategy / Scenario Development	Municipal Level	Trial to ICLEI member local governments (requires log in) = free	Data to assess vulnerabilities and risks	http://www.icleiusa.org/tools/adapt

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
Climate Adaptation Knowledge Exchange (CAKE)	This resource includes a database of tools to help process information and make adaptation decisions (including sea-level rise); case studies of adaptation projects; a visual library with literature and information focusing on adaptation and adaptation planning; and a directory of people/organizations engaged in adaptation.	Natural Resources, Built Environment	Scoping / Inventory, Strategy / Scenario Development	Local, Regional, Statewide	Online Database = Free	None	http://www.cakex.org
Ecosystem-Based Management (EBM) Tools Network and Database	This database is an online hub for tools and projects featuring innovative interdisciplinary coastal-marine spatial planning and ecosystem-based management.	Natural Resources, Agriculture, Built Environment, Transportation, Energy	Scoping / Inventory	Local, Regional, Statewide	Online Database = Free	None	https://ebmtools database.org/
FL DEP Map Direct Gateway	This resource access to a large number of FL DEP data layers and imagery layers, provides buffer analysis capabilities, provides "drill-down" reporting capabilities, and provides general data browsing. The Map Direct application replaces a number of existing single-purpose web mapping applications into a single integrated application with extensive capabilities.	Natural Resources, Agriculture, Built Environment, Transportation	Scoping / Inventory	Local, Regional, Statewide	Online Map Viewer =Free Data Download = Free	None	http://ca.dep.state.fl.us/mapdirect/gateway.jsp

Sea-Level Rise Vulnerability Tools/Resources Inventory Summary Table (Continued)

Tool/Resource Name	Purpose	Sector(s)	Adaptation Planning Process Phase(s)	Geographic Scale	Cost	Data Input(s)	Website
Florida Natural Areas Inventory (FNAI)	This organization offers services and products, including spatial datasets and maps, that promote conservation of Florida's biological diversity, including sea-level rise adaptation.	Natural Resources	Scoping / Inventory	Local, Regional, Statewide	GIS Data Download = Free Online Map Viewer = Free	None	http://www.fnai.org/index.cfm
Georgetown Climate Center	This organization provides publically-available sea-level rise and flood-related work products intended to help state and local governments become "cost-smart" or better prepared to cope with the threats posed by rising sea levels..	Natural Resources, Built Environment, Transportation, Energy	Scoping / Inventory, Strategy / Scenario Development	Local, Regional, Statewide	Online Database = Free	None	http://www.georgetownclimate.org/
Geospatial Assessment Tool for Operations and Response (GATOR)	This is an interactive web mapping tool for the display of geographic information to support emergency preparedness, operations, and response, with data applicable to sea-level rise vulnerability analysis.	Natural Resources, Agriculture, Built Environment, Transportation, Energy	Scoping / Inventory	Local, Regional, Statewide	Online Map Viewer = Free	None	http://map.floridadisaster.org/GATOR/map.html
U.S. Climate Resilience Toolkit	This database contains multiple tools that can be used to estimate, simulate, visualize, and monitor sea-level rise and impacts throughout the country.	Natural Resources, Agriculture, Built Environment, Transportation	Stakeholder Engagement, Scoping / Inventory, Strategy / Scenario Development	Local, Regional, Statewide	Online Database = Free	None	http://toolkitclimate.gov/
weADAPT	This database is an online forum on adaptation issues which allows practitioners, researchers, and policy makers to access information and to share experiences and lessons learned with the weADAPT community.	Natural Resources, Built Environment	Scoping / Inventory, Strategy / Scenario Development	Local, Regional	Online Database = Free (when registered)	None	https://weadapt.org

Appendix B:

Incorporation into Local Planning

This appendix describes how the sea-level rise vulnerability tools inventoried in Appendix A can be incorporated into the following local planning efforts: local comprehensive plan, local mitigation strategy, special area management plan, economic development plan, post-disaster redevelopment plan, capital improvements plan, stormwater management plan, and historic preservation plan. A brief summary of each type of plan can be found below, and an explanation of how each of the identified sea-level rise vulnerability tools can be incorporated into those local planning efforts follows. A comparison crosswalk is also provided at the end of the appendix to summarize how all of the tools relate to the specific needs of each of the local planning efforts.

Local Comprehensive Plan

All of Florida's counties and municipalities are required to adopt local comprehensive plans that guide future growth and development. Local comprehensive plans establish policies that are intended to guide a community's day-to-day land use decisions and capital facilities expenditures. These policies have a major impact on whether people and property are exposed to natural hazards as well as the extent to which they are vulnerable to injury and damage.

Local Mitigation Strategy

In Florida, a local mitigation strategy (LMS) is often a multi-jurisdictional plan developed collaboratively at the county level to reduce and/or eliminate the risks associated with natural and man-made disasters. The LMS identifies existing and potential hazards and proposes actions that would mitigate losses caused by those hazards. By identifying these vulnerabilities and proposing solutions for them, communities are able to prevent losses to lives and property.

Special Area Management Plan

A special area management plan (SAMP) is a comprehensive plan providing for natural resource protection and reasonable coastal-dependent economic growth containing a detailed and comprehensive statement of policies, standards, and criteria to guide public and private uses of lands and waters as well as mechanisms for timely implementation in specific geographic areas within the coastal zone. SAMPs provide for increased specificity in protecting natural resources, reasonable coastal-dependent economic growth, and improved protection of life and property in hazardous areas, including those areas likely to be affected by sea-level rise, as well as improved predictability in government decision making.

Economic Development Plan

An economic development plan provides a comprehensive overview of the economy, sets policy direction for economic growth, and identifies strategies, programs, and projects to improve the local economy. These policies and strategies can guide future investment and economic growth or activities to areas that are safe and that have reduced exposure to hazard risks.

Post-Disaster Redevelopment Plan

A post-disaster redevelopment plan (PDRP) is encouraged for all communities. A PDRP identifies policies, operational strategies, and roles and responsibilities for implementation that will guide decisions that affect long-term recovery and redevelopment of a community after a disaster. PDRPs emphasize seizing opportunities for hazard mitigation and community improvement consistent with the goals of the local comprehensive plan and with full participation of the citizens.

Capital Improvements Plan

A capital improvements plan (CIP) guides the scheduling of spending on public improvements, such as capital projects and equipment purchases. A CIP can serve as an important mechanism for guiding future investments and improvements away from identified hazard areas.

Stormwater Management Plan

A stormwater management plan is designed to address flooding associated with stormwater runoff. A stormwater management plan is typically focused on design and construction measures that are intended to reduce the impact of more frequently occurring minor urban flooding.

Historic Preservation Plan

A historic preservation plan is intended to preserve historic structures or districts within a community. An often overlooked aspect of the historic preservation plan is the assessment of buildings and sites located in areas subject to natural hazards and the identification of ways to reduce future damages.

The Local Comprehensive Plan

Local Comprehensive Plans in Florida require a Coastal Management Element by way of §163.3178, Fla. Stat., 2014. Within this section, they are held to create a coastal management element "based on studies, surveys, and data", and to create "an inventory map of existing coastal uses…and other areas of special concern to local government." A map of places where sea-level rise inundation or related flooding is projected to occur may comprise precisely those other areas of special concern.

Because the statute also prompts communities to incorporate environmental, socioeconomic, and fiscal considerations into the Coastal Management Element, the following tools are recommended in order to fulfill that requirement:

- Climate Central's Surging Seas Viewer
- NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer
- NatureServe Climate Change Vulnerability Index (CCVI)
- Sea-Level Affecting Marshes Model (SLAMM)
- Coastal Adaptation to Sea-Level Rise (COAST)
- Georgetown Climate Center

These five tools can provide a way to consider the social (Climate Central's Surging Seas and NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer, with socioeconomic vulnerability layer), environmental (CCVI and SLAMM), and built aspects of land vulnerable to sea-level rise (COAST). The Georgetown Climate Center database can be accessed to help compose the policies that would be included in the plan. As its name suggests, a major goal of this kind of plan is a comprehensive assessment of the interaction between the human and natural environment. The above visualizers, modeling tools, decision support tool, and database will assist a community to understand the planning context and the way in which sea-level rise will affect multiple kinds of assets.

The Local Mitigation Strategy

Local Mitigation Strategies are directed to assess and propose strategies to mitigate community hazards, which can include sea-level rise. The plan requirements of a local mitigation strategy facilitates the incorporation of sea-level rise analysis. Title 44 CFR §201.6 directs local governments to include:

"A risk assessment [with a] description of the type, location, and extent of all natural hazards that can affect the jurisdiction, [including] types and numbers of existing and future buildings, infrastructure, and critical facilities located in hazard areas; an estimate of the potential dollar losses to vulnerable structures; [and] a general description of land uses and development trends within the community."

Therefore, to incorporate sea-level rise as a hazard, it is important for the tool to consider buildings, infrastructure, and land use. In addition, the ability to calculate dollar losses is useful. For this reason, the following tools are recommended:

- Climate Central's Surging Seas Viewer
- Hazus-MH
- NatureServe Vista

While Climate Central's Surging Seas is accessible to all users, both Hazus-MH and NatureServe Vista demand some level of staff expertise to operate. Thus, a community may begin by viewing the property value and infrastructure ("Features") maps on Surging Seas and then progress to the other two tools in order to develop more precise community estimates of damage.

The Special Area Management Plan

Special Area Management Plans (SAMPs) cover a great breadth of options, but for the sake of this guide, focus will be directed at the Adaptation Action Area described by Section 163.3177 (6)(g) 10 , Fla. Stat., 2014. An Adaptation Action Area consists of a "designation for those low lying coastal zones that are experiencing coastal flooding due to extreme high tides…and are vulnerable to the impacts of rising sea level." Further, local governments who are considering implementing Adaptation Action Area policies are encouraged to analyze "coastal flooding resulting from high-tide events, storm surge, flash floods, stormwater runoff, and related impacts of sea-level rise."

In essence, the creation of this kind of SAMP requests that the overlay zone be accompanied by a general sea-level rise projection that can account for storm surge. Leaving the assets that may be impacted up to the community, recommended tools for supporting SAMP creation are:

- FDOT Sea Level Scenario Sketch Planning Tool
- NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer
- NOAA Inundation Analysis Tool
- ADvanced CIRCulation Model (ADCIRC)
- Georgetown Climate Center

The first two tools – FDOT Sea Level Scenario Sketch Planning Tool and NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer – are useful for characterizing the hazard. Should a community wish to convert screenshots of inundation to images and utilize those images to describe sea-level rise, it would be a valid method to illustrate inundation areas. NOAA's Inundation Analysis

tool can be used to compare how many high tides and total hours of inundation would have been experienced during a selected period of time assuming a given amount of sea-level rise versus the historical data. This will provide information on historical high tides as well as conditions that would be expected under a given amount of sea-level rise. The ADCIRC modeling tool will allow for a more sophisticated storm-surge analysis, but it requires a great deal of technical expertise to run properly and will likely necessitate additional support. Finally, the Georgetown Climate Center database can be accessed to help compose the policies that enter the Adaptation Action Area SAMP.

The Economic Development Plan

Sea-level rise poses economic and community development challenges, and it could impact transportation access, the environment, and resource availability. The Code of Federal Regulations approaches Economic Development from the vantage point of a Comprehensive Economic Development Strategy (CEDS). In Title 13 CFR §303.7, the regulation stipulates that communities must bring "an in-depth analysis of economic and community development problems and opportunities" to bear in the strategy. Among the goals and objectives, the Code requires strategies to include "fostering effective transportation access… enhancing and protecting the environment, [and] balancing resources through sound management of physical development."

In order to integrate sea-level rise assessment, communities may wish to pair the analysis of future economic development investments with a projection of sea-level rise. The following tools will support this analysis:

- FDOT Sea Level Scenario Sketch Planning Tool
- Integrated Valuation of Environmental Services and Tradeoffs (InVEST)
- U.S. DOT Vulnerability Assessment Scoring Tool (VAST)
- U.S. Climate Resilience Toolkit

These tools can boost the effectiveness of a local economic development plan in several ways. FDOT's Sea Level Sketch Tool will provide a baseline projection and inundation map of rise and show how it may affect transportation access and the built environment. If future investments fall within the inundation or flood range, it will show that as well. InVEST can display how coastal resources will be enhanced or degraded by development decisions – a consideration of utmost importance for many beach-based and tourism industry projects. U.S. DOT's VAST can help enhance the understanding of sea-level rise impacts on transportation access. Finally, the U.S. Climate Resilience Toolkit, like Georgetown Climate Center's library of resources, can inform the entire process and introduce new modes of thinking about the way in which long-term economic development will have to contend with future hazards.

The Post-Disaster Redevelopment Plan

Although the statutory framework that required communities to develop a post-disaster redevelopment plan (PDRP) has been repealed in Florida, the process is still furthered by the State's Emergency Support Functions (ESFs) and Recovery Support Functions (RSFs). Specifically, ESF 5, Information and Planning, could incorporate sea-level rise exacerbated storm surge projections within its Future Planning Unit[1] and Community Planning and Capacity Building Recovery Support Function.

A sea-level rise vulnerability assessment tool will assist emergency managers to promote transformative resilience, or the ability to build back stronger than before, in the event of coastal flooding. The usefulness of PDRP lies in its ability to spur ambitious change in the wake of a destructive disaster. So, rather than "No-Regrets" strategies that may be implemented in the present, this plan can utilize sea-level rise projections to direct where future development should be limited. Tools that can help to navigate the intersection between post-disaster planning, emergency response, and sea-level rise projection include the following:

- Georgetown Climate Center
- U.S. Climate Resilience Toolkit
- Geospatial Assessment Tool for Operations and Response (GATOR)
- Hazus-MH

[1] http://www.floridadisaster.org/emtools/documents/Future%20Planning%20Unit%20SOG.pdf

Because much of post-disaster redevelopment remains an emergent policy issue in Florida, the Georgetown Climate Center and U.S. Climate Resilience Toolkit contain resources that can further a community's understanding of transformative resilience. GATOR can assist in the emergency warning for hurricanes and other storm-surge events. It also maps locations of critical infrastructure. Finally, Hazus-MH projections that account for the effect of future rises in sea-levels on storm surge may be utilized to map transfer of development rights (TDR) areas or other zoning and adaptation strategy focus areas.

The Capital Improvements Plan

The Capital Improvements Plan (CIP) translates the blueprint of Comprehensive Plan land use and community functions into the major projects that realize new community form and function. Section 163.3164(4)(d), Fla. Stat. (2014) requires that: "public services, including water, wastewater, transportation, schools, and recreation facilities…are scheduled in the capital improvement element."

As the schedule for amenities protecting the health and welfare of community members, it is essential the Capital Improvements Plan react to the influence of sea-level rise vulnerability assessment, programming large community infrastructure away from the scope of coastal flooding. For this plan, decision support tools may play a large role, as they can assist public works and planners to decide which projects will have the most positive benefit-to-cost ratio.

- SLAMM
- Beach-*fx*
- ADCIRC
- CommunityViz

The CIP represents an adaptation planning stage when a high degree of detail and attention have been committed to understanding the effects of sea-level rise. As the plan directs multi-million dollar investments, modeling tools such as SLAMM will help to describe natural and built habitat changes that can inform how a project is scoped and designed. Beach-*fx* can directly examine the effects of a capital project, such as a levee, on natural coastal processes and estimate the costs and benefits of alternative project designs. Since it is a physics-based model, ADCIRC will provide the most accurate portrayal of exact locations where tides, surge, and other coastal water activity could damage structures. CommunityViz can also assist in cost-benefit considerations on a project by project basis.

Of note, these tools will likely need financing to be run locally. A specialist to input and interpret data and a license to run the program are needed for all of the above tools except Beach-*fx*, which is available for download at no cost.

The Stormwater Management Plan

Stormwater Management Plans address flooding caused by rainfall, passing through watersheds, and terminating at fresh and saltwater catchment areas (aquifers, rivers, lakes, estuaries, and oceans). Catchment areas' ability to absorb new inflow is crucial to the functioning of a stormwater system. Therefore, when the Florida Administrative Code states that "The primary goals of the State's stormwater management program are to maintain…during and after construction and development, the pre-development stormwater characteristics of a site" (Florida Administrative Code, 62-40.431 (2)(a)), the ability to project the impacts of sea-level rise could factor into the realization of this goal. Other objectives from the rule state:

"To reduce stream channel erosion, pollution, siltation, sedimentation and flooding…to maintain the appropriate salinity regimes in estuaries needed to support the natural flora and fauna; and to address stormwater management on a watershed basis."

With these directives in place, a community looking to integrate sea-level rise vulnerability assessment into a stormwater management plan will need to evaluate environmental changes that could be brought about by sea-level rise and impacts of flood hazards when combined with sea-level rise. For these activities, recommended tools include:

- NOAA Coastal Change Analysis Program (C-CAP)
- NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer
- Hazus-MH
- SLAMM
- Georgetown Climate Center

The NOAA C-CAP tool offers visualization and data download related to the change of community land use over time. This tool, utilized in conjunction with the NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer, can illustrate the ways in which land-cover change (to impervious surface) has concentrated near or within sea-level rise projection areas. Hazus-MH can potentially be used to illustrate exacerbated flood levels in the event of downpour mixed with future higher sea levels. SLAMM, by illustrating sea-level rise effects on estuarine habitats, can show pressures caused by adjacent development before and during storm events. Finally, Georgetown Climate Center, as for other plans, offers a strong database of policy options that can inform stormwater management plans that seek to strengthen the goals set forth in Florida Administrative Code 62-40.431.

The Historic Preservation Plan

Historic Preservation revolves around preserving a property's significance by way of ensuring that the integrity of significance-imparting property characteristics are protected or enhanced. Importantly, the National Parks Service[2] (responsible for the national registry of historic properties) states that historic significance can be achieved by virtue of "Distinctive physical characteristics of design, construction, or form." In relation to this form significance, the integrity can be altered by way of changes to the "location, design, setting, materials, workmanship, feeling, and association" of the property.

For historic properties situated near the coast, sea-level rise and associated coastal flooding can pose a threat to all seven qualities of integrity. Because historic properties take many forms – sculptures, open space, buildings, archeological sites, etc. – a detailed mapping of property locations, with a good exposure analysis that incorporates multiple types of flooding, is essential. For this task, the following tools are recommended:

- FDOT Sea Level Scenario Sketch Planning Tool
- Climate Adaptation Knowledge Exchange (CAKE)
- COAST

The projection add-in can be downloaded from FDOT's Sea Level Scenario Sketch Planning Tool and integrated into ArcGIS 10.1 or later versions. In addition, the Sketch Planning Tool offers digital sea-level rise inundation GIS data layers, by transportation district, for download. Thus, if the community obtains a detailed map shapefile of historic property locations, it can be combined with these the FDOT features to produce a map of vulnerable properties. CAKE offers case studies and the ability to connect to other communities. Through these options, a community who is undertaking historic property sea-level rise assessment may connect to others for specific information about vulnerability in the historic context. COAST can predict damages to historic properties from varying amounts of sea-level rise and storms of various intensities as well as evaluate the relative benefits and costs of adaptive response strategies.

Sea-Level Rise Vulnerability Tools and Local Planning Efforts Comparison Crosswalk[3]

The following crosswalk identifies how each sea-level rise vulnerability tool inventoried in Appendix A can support specific aspects of the eight local planning efforts previously described in this appendix. The general process used to determine if a tool was a "match" or "no match" included reviewing the description of each tool as well as the examples of when and where to use the tool found in the one page profiles in Appendix A. If the tool outputs can directly support and enhance a given local planning effort, the tool was considered a "match." This includes producing outputs that can be used during different stages of the planning process which are unique to each individual planning effort (e.g., visuals to facilitate public engagement, data to inform the planning context, identification of vulnerable assets, estimates of potential impacts to community assets, and effectiveness of potential adaptive strategies).

[2] http://www.nps.gov/nr/publications/bulletins/nrb16a/nrb16a_II.htm

[3] Note: This crosswalk identifies the local planning efforts into which each tool can be incorporated based on the most common applications of each tool. Keep in mind that if a planning effort is not checked, it does not necessarily exclude the tool from being utilized during that planning effort.

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Visualization Tools								
CanVis	✓ **Facilitate public engagement** using visuals that simulate the potential impacts of rising waters on local landmarks **Inform future land uses** by simulating potential impacts of rising waters on structures located in vulnerable areas	✓ **Facilitate public engagement** using visuals that simulate the potential impacts of rising waters on local landmarks **Inform hazard risk assessment** to assist in visualization of future conditions **Support mitigation strategies** that address sea-level rise	✗	✗	✗	✓ **Demonstrate impact of sea-level rise to infrastructure** by simulating the potential impacts of rising waters on infrastructure located in vulnerable areas	✗	✓ **Demonstrate impact of sea-level rise to historic structures** by simulating the potential impacts of rising waters on historic structures located in vulnerable areas **Support historic preservation zoning and land development designations** in non-vulnerable areas

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Climate Central's Surging Seas	✓ **Inform planning context** by identifying populations, infrastructure, and assets that are exposed to coastal flooding aggravated by sea-level rise **Facilitate public engagement and build awareness** by illustrating sea-level rise scenarios and showing what land will potentially be inundated by water **Inform future land uses** by limiting development in areas which are identified as vulnerable to potential impacts from sea-level rise **Inform plan goals and policies** based on community risk	✓ **Facilitate public engagement and build awareness** by illustrating sea-level rise scenarios and showing what land will potentially be inundated by water **Inform hazard risk assessment** by demonstrating how a community may be vulnerable to future sea-level rise and describing impact statistics such as the percentage of population that would be impacted **Support mitigation strategies** based on vulnerable areas and potential impacts identified	✓ **Inform management area boundaries** by depicting areas in a community that would be inundated by water under different sea-level rise scenarios and including these areas in natural resource protection areas to reduce the impact on people and property	✓ **Identify infrastructure and assets that are vulnerable** to various sea-level rise scenarios **Inform infrastructure investment and reinvestment priorities** to ensure assets are located outside of identified inundation areas **Identify and incentivize a less vulnerable growth center** to guide investments or reinvestments to non-vulnerable areas **Identify impacts to major employers and industries** from potential sea-level rise such as distribution area disruption and transportation route damage	✓ **Develop and/or inform applicable policies** that require post-disaster development and redevelopment to be located outside of areas that may be inundated by water under different sea-level rise scenarios in order to promote disaster-resilient development	✓ **Identify infrastructure and assets** that are vulnerable to various sea-level rise scenarios **Inform infrastructure investment and reinvestment priorities** to locate infrastructure outside of identified inundation areas and incentivize less vulnerable growth areas	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within potential inundation areas to be able to function under projected rises in sea level	✓ **Identify vulnerable historic structures, neighborhoods, and/or districts** located in areas which may be inundated by water under various sea-level rise scenarios

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
FDOT Sea Level Scenario Sketch Planning Tool	✓ **Inform future land** uses by encouraging development outside of areas that can be potentially inundated by sea-level rise and limiting infrastructure investments within those areas **Inform plan goals and policies** by providing information on community risk and vulnerability to future sea-level rise **Visualize potential future conditions** and guide development away from potential inundation areas **Identify vulnerable transportation infrastructure** that is located within areas potentially inundated by sea-level rise	✓ **Conduct preliminary assessment of transportation** infrastructure to identify existing infrastructure **Identify vulnerable transportation infrastructure** by visualizing areas that can be potentially inundated by sea-level rise **Prioritize mitigation strategies** for retrofitting and/or relocating facilities potentially at risk from sea-level rise inundation	✓ **Inform management area boundaries** by illustrating areas in a community that would be inundated by water under different sea-level rise scenarios and including these areas in natural resource protection areas to reduce the impact on people and property	✓ **Identify vulnerable transportation infrastructure** and prioritize the retrofit or relocation of facilities potentially at risk **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas vulnerable to sea-level rise	✓ **Inform policies for post-disaster redevelopment** that require infrastructure built or rebuilt within vulnerable areas to be able to function under projected rises in sea level	✓ **Identify vulnerable transportation infrastructure** and prioritize the retrofit or relocation of facilities potentially at risk **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas vulnerable to sea-level rise	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within potential inundation areas to be able to function under projected rises in sea level	✓ **Identify at-risk historic structures** by downloading the data features available and mapping historic properties in relation to sea-level rise inundation areas

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
The Nature Conservancy Coastal Resilience Mapping Portal	✓	✓	✓	✓	✓	✓	✓	✓
	Understand planning context and future conditions to guide future development away from areas vulnerable to future sea-level rise scenarios **Inform plan goals and policies** by providing information on community risk **Guide open space planning** by identifying locations vulnerable to future sea-level rise that should be used as open space	**Inform hazard risk assessment** by illustrating different magnitudes and extents of sea-level rise under different model-based projections **Explore how sea-level rise might degrade habitats** and create policies to promote habitat protection	**Inform management area boundaries** by identifying areas with high exposure and vulnerability to sea-level rise and choosing boundaries that include impacted areas in natural resource protection areas to reduce the impact on people and property	**Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas vulnerable to future sea-level rise scenarios **Identify and incentivize** a **less vulnerable growth center** to guide investments or reinvestments to non-vulnerable areas **Identify impacts to major employers and industries** under potential sea-level rise scenarios such as distribution area disruption and transportation route damage	**Identify locations for redevelopment,** outside of areas impacted under alterative sea-level scenarios **Develop policies for post-disaster development and redevelopment** that require development and redevelopment to be located outside of areas at risk to future sea-level rise	**Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas vulnerable to future sea-level rise scenarios **Incentivize less vulnerable growth areas** that are outside of areas vulnerable to future sea-level rise scenarios	**Develop policies for stormwater management infrastructure** that require any infrastructure built within potential inundation areas to be able to function under projected rises in sea level	**Identify vulnerable historic structures, neighborhoods, and/or districts** which are located in areas vulnerable to sea-level rise scenarios

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
NOAA Coastal Change Analysis Program (C-CAP) Land Cover Atlas and Coastal Comparison Tool	✓ **Understand planning context** by assessing existing land cover and general land use change trends **Identify land use trends** in community and guide development away from vulnerable areas	✓ **Understand planning context** by assessing existing land cover and general land use change trends **Indicate changes of interest,** such as marsh losses to open water, and identify solutions	✓ **Determine which natural resource areas may be vulnerable** to loss and identify policies to protect them **Inform management policy priorities** giving the highest priority to areas which have undergone land use changes and may be vulnerable to loss	✗	✗	✗	✓ **Inform policies for stormwater management infrastructure design** based on land use change trends over time **Guide stormwater facility construction** to areas that are not projected to be at risk to sea-level rise	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
NOAA Sea-Level Rise and Coastal Flooding Impacts Viewer	✓ **Understand planning context** by identifying specific vulnerable areas **Facilitate public engagement and build awareness** through visual demonstration of potential impacts from different increments of sea-level rise **Inform future land uses** and guide permitting for land uses in vulnerable areas **Inform plan goals and policies** by targeting areas which are at higher risk to various increments of potential sea-level rise	✓ **Facilitate public engagement and build awareness** by displaying sea-level rise in one foot increments from 1 to 6 feet showing which areas may be inundated and by how much **Inform hazard risk assessment** by identifying where the most vulnerable areas are located as well as potential sea level elevations **Identify local landmarks that could be impacted** by sea-level rise	✓ **Inform management area boundaries** by identifying areas which are most vulnerable, include magnitude of severity based on predicted sea-level rise increments, and choosing boundaries that include vulnerable areas in natural resource protection areas to reduce the impact on people and property	✓ **Inform infrastructure investment and reinvestment priorities** to target at-risk structures located in potential inundation areas **Identify and incentivize a less vulnerable growth center** to guide investments or reinvestments to non-vulnerable areas **Relocate economic resources and assets** outside of the potential inundation areas	✓ **Inform policies for post-disaster development and redevelopment** to ensure development and redevelopment are located outside potential inundation areas	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of potential inundation areas **Incentivize less vulnerable growth areas** that are outside of potential inundation areas	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within potential inundation areas to be able to function under projected rises in sea level	✓ **Identify vulnerable historic structures, neighborhoods, and/or districts** which are located in areas that are vulnerable under various sea-level rise scenarios
NOAA Sea Level Trends	✓ **Understand planning context** by assessing regional trends in sea level, including direction and magnitude of change, to guide future development	✓ **Inform hazard risk assessment** by describing the historic changes in sea level	✗	✗	✗	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Social Vulnerability Index (SoVI)	✓ **Understand planning context** and geographic variation in social vulnerability by determining which census tract have lower capacity for preparedness and response **Illustrate geographic variations in social vulnerability** to environmental hazards **Inform plan goals and policies** by providing information on the levels of social vulnerability across a community	✓ **Inform vulnerability assessment** by assessing which census tracts have lower preparedness and response and therefore are at greater risk **Prioritize mitigation strategies** by identifying which census tracts have the lowest capacity for preparedness and response and therefore have the greatest need for resources to reduce pre-existing vulnerability	✗	✗	✗	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
USGS National Assessment of Coastal Vulnerability to Sea-Level Rise: Coastal Vulnerability Index (CVI)	✓ **Understand planning context** and assess/ illustrate coastal vulnerability to physical changes and erosion **Inform natural resource element of the plan** by identifying which coastlines are most vulnerable to physical changes due to sea-level rise; this can inform overlay area or conservation area boundaries **Inform plan goals and policies** by providing information on the risk to which a community's coast is vulnerable	✓ **Inform hazard risk assessment** by demonstrating which sections of a community's shorelines are most vulnerable to future sea-level rise **Inform mitigation strategy priorities** by identifying which sections of a community's shoreline have the highest vulnerability to physical change and erosion and therefore have the greatest need for protection or restoration	✓ **Inform management area boundaries** by identifying which areas are most vulnerable to physical changes and including shorelines with high vulnerability in natural resource protection areas to limit future erosion	✗	✓ **Inform post-disaster restoration project priorities** to ensure development and redevelopment are located outside of coastline areas that are most vulnerable to physical change and erosion	✓ **Inform project priorities** to ensure armoring or coastal protection project and infrastructure investments protect the most vulnerable coastlines	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
USGS Digital Shoreline Analysis System (DSAS)	✓	✓	✓	✗	✓	✓	✗	✗
	Understand planning context and assess rates of erosion and accretion **Inform natural resource element of the plan** by identifying which areas of a community's shoreline are undergoing the highest rates of erosion and may be most vulnerable to sea-level rise; this can inform overlay area or conservation area boundaries **Inform plan goals and policies** by illustrating shoreline changes and providing information on the risk to which a community's coast is vulnerable	**Inform hazard risk assessment** by illustrating the historic rates of erosion and accretion along a community's shorelines **Inform mitigation strategy priorities** by identifying which sections of a community's shoreline have experienced the highest rates of erosion and therefore have the greatest need for protection or restoration	**Inform management area boundaries** by identifying which sections of a community's shoreline have undergone the greatest amount of erosion and including those sections in natural resource protection areas to limit future erosion		**Inform post-disaster restoration project priorities** to ensure development and redevelopment are located outside of shoreline areas that have undergone the highest rates of change and are most vulnerable to erosion	**Inform project priorities** to ensure armoring or coastal protection project and infrastructure investments protect the most vulnerable coastlines		

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Modeling Tools								
ADvanced CIRCulation Model (ADCIRC)	✓ **Inform future land uses** by limiting development in areas which are identified as being vulnerable to storm surge **Inform plan goals and policies** by providing information on the risk to which a community is vulnerable	✓ **Inform hazard risk assessment** by identifying areas that would be inundated by storm surge under future sea-level rise scenarios **Inform hazard risk assessment** by modeling future tide and storm surge elevations and velocities	✓ **Inform management area boundaries** by identifying areas in a community that would be inundated by storm surge and including those areas in natural resource protection areas to reduce impact on people and property	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of the identified inundation areas **Identify and incentivize a less vulnerable growth center** to guide investments or reinvestments to non-vulnerable areas **Relocate resources and assets** outside of the identified inundation areas	✓ **Inform policies for post-disaster development and redevelopment** to ensure development and redevelopment are located outside of areas that are vulnerable to storm surge under future sea-level rise scenarios	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of the identified inundation areas **Incentivize less vulnerable growth areas** that are outside of potential inundation areas	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within potential inundation areas to be able to function under projected storm surge impacts	✓ **Identify vulnerable historic structures, neighborhoods, and/or districts** which are located in areas vulnerable to storm surge under future sea-level rise scenarios

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Hazus-MH	✓ **Inform plan goals and policies** by providing information on the risk to which a community is vulnerable **Determine potential losses** that could be experienced due to future sea-level rise	✓ **Inform vulnerability assessment** by estimating potential losses due to sea-level rise **Prioritize mitigation strategies** based on potential loss estimates	✗	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of the identified vulnerable areas **Identify impacts to major employers and industries** from future sea-level rise such as distribution area disruption and transportation route damage	✓ **Inform policies for post-disaster development and redevelopment** to ensure development occurs outside of areas vulnerable to future sea-level rise and storm surge	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas vulnerable to sea-level rise	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within areas vulnerable to sea-level rise be able to function under projected storm surge impacts	✓ **Estimate potential damage to historic structures** due to sea-level rise; however, results for an individual building must considered an average for a group of similar buildings

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Integrated Valuation of Environmental Services and Tradeoffs (InVEST)	✓	✓	✓	✓	✗	✗	✗	✗
	Understand planning context and assess ecosystem and coastal vulnerability due to the impacts of erosion and inundation under projected sea-level rise **Inform natural resource element of the plan** by identifying which ecosystem services are vulnerable to sea-level rise; this can inform overlay area or conservation area boundaries **Inform comprehensive plan goals and polices** by providing information on which ecosystems and areas of a community's shoreline are most susceptible to sea-level rise	**Inform hazard risk assessment** by demonstrating which areas of a community are most vulnerable to future sea-level rise **Inform mitigation strategy priorities** by identifying which ecosystems in a community have the highest vulnerability to sea-level rise and therefore greatest need for protection	**Inform management area boundaries** by identifying ecosystems with high vulnerability to sea-level rise and including those areas in natural resource protection areas to limit future impacts	**Inform development decisions** by displaying how coastal resources will be enhanced or degraded under different management and climate scenarios **Inform development standards** within vulnerable areas to protect current ecosystem assets				

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
NatureServe Climate Change Vulnerability Index (CCVI)	✓ **Understand planning context** and assess plant and animal species vulnerability to impacts of erosion and inundation from projected sea-level rise **Inform natural resource element of the plan** by identifying species most likely to be impacted by sea-level rise; this can inform overlay area or conservation area boundaries **Inform comprehensive plan goals and policies** by providing information on the risk to which species are vulnerable due to future sea-level rise	✓ **Inform hazard risk assessment** by demonstrating which plant and animal species are most vulnerable to future sea-level rise **Inform mitigation strategy priorities** by identifying which species have the highest vulnerability to sea-level rise and therefore have the greatest need for protection	✓ **Inform management area boundaries** by identifying which plant and animal species are most vulnerable to sea-level rise and including species within high vulnerability in natural resource protection areas to limit future impacts	✗	✗	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
NOAA Wave Exposure Model (WEMo)	✓ **Inform future land uses** by limiting development in areas which may be affected by wave exposure under future sea-level rise scenarios **Inform natural resource element of the plan** by estimating wave energy and its effects on ecosystem functions; this can inform overlay area or conservation area boundaries **Inform comprehensive plan goals and policies** by providing information on risk from wave exposure	✓ **Inform hazard risk assessment** by identifying areas in a community that may be affected by wave exposure under future sea-level rise **Estimate potential impacts** on ecosystem functions and developed coastal areas	✓ **Inform management area boundary changes** by estimating wave energy and its effects on ecosystem functions and natural areas and including areas affected by wave energy in natural resource protection areas to reduce impact on people and property	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas which may be affected by wave exposure **Identify and incentivize** a **less vulnerable growth center** to guide investments or reinvestments to areas with low wave exposure	✓ **Inform policies for post-disaster development and redevelopment** to ensure development occurs outsides of areas that are vulnerable to wave exposure	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of areas that are vulnerable to wave exposure **Incentivize less vulnerable growth areas** that are outside of potential wave exposure areas	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within areas vulnerable to wave exposure be able to function under projected exposure impacts	✓ **Identify vulnerable historic structures, neighborhoods, and/or districts** that may be affected by wave exposure under future sea-level rise scenarios

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Sea Levels Affecting Marshes Model (SLAMM)	✓ **Inform natural resource element of the plan** by identifying coastal areas vulnerable to wetland conversion and shoreline modification resulting from long-term sea-level rise **Inform comprehensive plan goals and policies** by providing information on coastal vulnerability due to future sea-level rise	✓ **Inform hazard risk assessment** by identifying which coastal areas are most vulnerable to wetland conversion and modification resulting from long-term sea-level rise **Inform mitigation strategy priorities** by identifying which coastal areas are most vulnerable to conservation and modification resulting from long-term sea-level rise and therefore have the greatest need for protection or restoration	✓ **Inform management area boundaries** by identifying which coastal areas are most vulnerable to wetland conversion and shoreline modification resulting from long-term sea-level rise and including vulnerable areas in natural resource protection areas to limit future conversion and erosion	✗	✓ **Inform post-disaster restoration project priorities** to ensure the coastal areas most vulnerable to wetland conversion and shoreline modification resulting from long-term sea-level rise are restored	✓ **Inform project priorities** to ensure armoring or coastal protection project and infrastructure investments protect the most vulnerable wetlands and shorelines	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within coastal areas vulnerable to conversion and erosion be able to function under projected impacts from sea-level rise	✗

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Simulator of Climate Change Risks and Adaptation Initiatives (SimCLIM)	✓ **Inform future land uses** by limiting development in areas that may potentially be inundated by sea-level rise **Inform natural resource element of the plan** by simulating shoreline changes for beach and dune systems and identifying which areas most sensitive to sea-level rise **Inform comprehensive plan goals and policies** by providing information on which areas most sensitive to sea-level rise	✓ **Inform hazard risk assessment** by modeling projected impacts of sea-level rise; this can identify areas of potential inundation as well as simulate shoreline changes for beach and dune systems **Inform mitigation strategy priorities** by identifying which beach and dune systems in a community are most sensitive to sea-level rise and therefore have the greatest need for protection	✓ **Inform management area boundaries** by identifying which beach and dune systems are most sensitive to sea-level rise and including those systems in natural resource protection areas to limit future impacts	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of potential inundation areas **Identify and incentivize a less vulnerable growth center** to guide investments or reinvestments to non-vulnerable areas	✓ **Inform post-disaster restoration project priorities** to ensure development occurs outside of potential inundation areas	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of potential inundation areas **Incentivize less vulnerable growth areas** that are outside of potential inundation areas	✓ **Analyze storm sewer capacity issues, identify problem areas, and develop and prioritize solutions** by evaluating the cost and risk of different mitigation scenarios and different assumptions for sea-level rise	✓ **Identify vulnerable historic structures, neighborhoods, and/or districts** which are located in areas that may potentially be inundated by sea-level rise
USACE Sea Level Change Curve Calculator	✓ **Inform comprehensive plan goals and policies** by providing information on risk due to predicted future sea-level rise	✓ **Inform hazard risk assessment** by providing the predicted amount of sea level change for locations along the coast from 1992 forward	✗	✗	✗	✗	✗	✗

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Decision Support Tools								
Beach-*fx*	✗	✓ **Inform mitigation strategy priorities** by evaluating physical performance and economic benefits and costs of shore protection projects	✗	✗	✓ **Inform post-disaster project priorities** by evaluating the physical performance and economic benefits and costs of shore protection projects	✓ **Inform project priorities** by evaluating the physical performance and economic benefits and costs of shore protection projects	✗	✗

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Coastal Adaptation to Sea-Level Rise Tool (COAST)	✓	✓	✗	✗	✓	✓	✗	✓
	Understand planning context and assess vulnerable assets by visualizing damages under a specific sea-level rise scenario and storm event if no adaption actions are taken **Facilitate public engagement** by empowering stakeholders to compare multiple future scenarios, select expectations of future conditions, and visualize damages under action versus no-action scenarios **Inform land use planning** by helping to evaluate the relative benefits and costs of sea-level rise response strategies **Inform comprehensive plan goals and policies** by providing information on vulnerability due to future sea-level rise	**Facilitate public engagement** by empowering stakeholders to compare multiple future scenarios, select expectations of future conditions, and visualize damages under action versus no-action scenarios **Inform hazard risk assessment** by predicting the damages from varying amounts of sea-level rise and storms of various intensities **Inform mitigation strategy priorities** by evaluating the relative benefits and costs of adaptive response strategies to avoid damages to assets from sea-level rise			**Inform post-disaster project priorities** by evaluating the relative benefits and costs of adaptive response strategies to avoid damages to assets from sea-level rise	**Inform project priorities** by evaluating the relative benefits and costs of adaptive response strategies to avoid damages to assets from sea-level rise		**Inform project priorities** by predicting damages from varying amounts of sea-level rise and evaluating the relative benefits and costs of adaptive response strategies to avoid damages to historic structures

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CommunityViz	✓	✓	✓	✓	✓	✓	✗	✗
	Understand planning context and risk using 2D and 3D models that show implications of various planning decisions and scenarios **Facilitate public engagement** by visualizing and communicating possible future land use change scenarios driven by sea-level rise **Inform future land uses** by bringing to light possible future scenarios driven by sea-level rise and showing the implications of various planning decisions and scenarios **Inform comprehensive plan goals and policies** by providing information on sea-level rise vulnerability and the impacts of proposed changes	**Facilitate public engagement** by visualizing and communicating possible future land use change scenarios driven by sea-level rise **Inform hazard risk assessment** by helping to conduct risk and impact assessments such as counting buildings affected by potential floods or storm surge **Inform mitigation strategy priorities** by helping to analyze the impacts of potential planning and mitigation alternatives	**Inform management area boundaries** by analyzing potential adaptation strategies, such as implementing conservation or natural resource protection policies, that may help limit future impacts of sea-level rise	**Inform infrastructure investment or reinvestment and economic redevelopment initiative priorities** driven by future sea-level rise by analyzing how various transportation system improvements and development patterns could impact the community	**Inform post-disaster development and redevelopment** by analyzing how future land use changes and sustainable development patterns could impact the community	**Inform infrastructure investments or reinvestments** driven by future sea-level rise by analyzing how various transportation system improvements could impact the community		

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NatureServe Vista	✓	✓	✓	✗	✓	✗	✗	✗
	Understand planning context by evaluating ecological, urban, and agricultural resources under current conditions and assessing impacts under various sea-level rise scenarios **Inform land use planning** by assessing impacts to ecological, urban, and agricultural resources from various sea-level rise scenarios and showing which developed areas are potentially at risk **Inform comprehensive plan goals and policies** by providing information on vulnerability to future sea-level rise as well as potential mitigation and adaptation options that best achieve planning objectives	**Inform hazard risk assessment** by showing what resources and developed areas are potentially at risk to sea-level rise **Inform mitigation strategy priorities** by helping to demonstrate the impact of mitigation and sea-level rise adaptation strategies and determine which alternatives best achieve planning objectives	**Inform management area boundaries** by evaluating ecological and agricultural resources under current conditions, assessing the impacts to those resources under various sea-level rise scenarios, and analyzing resource management scenarios		**Inform post-disaster conservation efforts** by evaluating ecological, urban, and agricultural resources and analyzing various land use and resource management scenarios			

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NOAA Inundation Analysis Tool	✓ **Understand planning context** by determining the frequency and duration of observed high tides and creating scenarios of expected conditions given sea-level rise **Inform land use planning** by coupling historical high-water data with long-term sea-level trends **Inform comprehensive plan goals and policies** by providing information on risk and vulnerability based on scenarios of increased sea-level rise	✓ **Inform hazard risk assessment** by determining the historical frequency and duration of observed high tides at NOAA tide gauge stations; historical high-water data can also be coupled with long-term sea level trends to create scenarios of increased sea-level rise	✗	✗	✗	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
U.S. DOT Vulnerability Assessment Scoring Tool (VAST)	✓	✓	✗	✓	✗	✓	✗	✗
	Understand planning context by identifying transportation systems that may be vulnerable to sea-level rise **Inform transportation element of the plan** by identifying which components of the transportation system may be vulnerable to sea-level rise; this can be used to prioritize retrofits for the most vulnerable infrastructure **Inform comprehensive plan goals and policies** by providing information on infrastructure vulnerable to future sea-level rise	**Inform vulnerability assessment** by identifying the components of the transportation system that are most vulnerable to impacts from sea-level rise **Inform mitigation strategy priorities** by identifying the components of the transportation system that are most vulnerable to impacts from sea-level rise and therefore have the greatest need for upgrades and retrofits to lessen potential damage		**Inform infrastructure investment or reinvestment priorities** by identifying the components of the transportation system that are most vulnerable to impacts from sea-level rise and therefore have the greatest need for upgrades and retrofits to lessen potential damage		**Inform infrastructure investment or reinvestment priorities** by identifying the components of the transportation system that are most vulnerable to impacts from sea-level rise and therefore have the greatest need for upgrades and retrofits to lessen potential damage		

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Databases of Resources								
Adaptation Database for Planning Tool (ADAPT)	✓ **Inform planning process** by guiding local government users through a 5-step adaptation planning process **Inform comprehensive plan goals and policies** by helping conduct a vulnerability assessment, set preparedness goals, and develop a climate preparedness plan	✓ **Inform planning process** by using 5-step planning assessment to determine risk **Inform hazard risk assessment** by conducting a climate resiliency study or vulnerability assessment **Inform mitigation goals and strategies** by setting preparedness goals and developing a climate preparedness plan	✗	✗	✓ **Inform planning process** by using a 5-step adaption planning process **Inform preparedness goals** by developing a climate preparedness plan	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Climate Adaptation Knowledge Exchange (CAKE)	✓ **Inform planning process** by providing information on adaptation and adaptation planning	✓ **Inform planning process** by providing information on adaptation and adaptation planning **Inform hazard risk assessment** by providing a database of tools that can be used to help conduct risk and vulnerability assessments	✗	✗	✓ **Inform planning process** by providing information on adaptation and adaptation planning	✗	✗	✓ **Guide preservation efforts** by providing information about vulnerability in the historic context as well as opportunities to connect with other communities that are undertaking historic property sea-level rise assessment
Ecosystem-Based Management (EBM) Tools Network and Database	✓ **Inform planning process** by providing information on inter-disciplinary coastal-marine spatial planning and ecosystem-based management that can help improve decision making	✓ **Inform planning process** by providing information on inter-disciplinary coastal-marine spatial planning and ecosystem-based management **Inform hazard risk assessment** by providing a database of tools that can be used to help conduct risk and vulnerability assessments	✓ **Inform planning efforts** by providing information on inter-disciplinary coastal-marine spatial planning and ecosystem-based management	✗	✓ **Inform planning efforts** by providing information on inter-disciplinary coastal-marine spatial planning and ecosystem-based management	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
FL DEP Map Direct Gateway	✓ **Understand planning context** by providing information and access to a large number of DEP data layers that are relevant to sea-level rise adaptation	✓ **Understand planning context** by providing information and access to a large number of DEP data layers that are relevant to sea-level rise adaptation	✓ **Inform planning efforts** by providing information and access to a large number of DEP data layers that are relevant to sea-level rise adaptation	✗	✓ **Inform planning efforts** by providing information and access to a large number of DEP data layers that are relevant to sea-level rise adaptation	✗	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Florida Natural Areas Inventory (FNAI)	✓	✓	✓	✗	✓	✗	✗	✗
	Understand planning context by providing information and data on land cover, critical lands and waters, and land acquisitions **Inform natural resource element of the plan** by providing information and data on natural coastal land cover; this can inform overlay area or conservation area boundaries to protect lands and waters that are critical to conservation of natural resources **Inform natural resource element of the plan** by providing information on boundaries of environmental land acquisition projects; this can help identify possible acquisitions adjacent to existing protected properties	**Inform hazard risk assessment** by providing information and data on land cover and critical lands and waters **Inform mitigation strategy priorities** by providing information on the boundaries of environmental land acquisition projects and helping identify possible acquisitions adjacent to existing protected properties	**Inform management area boundaries** by providing information and data on land cover, critical lands and waters, and land acquisitions		**Inform post-disaster conservation efforts** by providing information on which critical lands and waters are most at risk to potential impacts from sea-level rise			

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Georgetown Climate Center	✓	✓	✓	✗	✓	✗	✓	✗
	Inform land use planning by providing information on 18 different land use tools that can be used to pre-emptively respond to threats to public and private coastal development and infrastructure posed by sea-level rise **Inform comprehensive plan policies** by helping to determine which tools to employ to make a community better prepared to cope with threats posed by rising sea levels and higher storm surges	**Inform mitigation strategy priorities** by providing information on 18 different land use tools that can be used to pre-emptively respond to threats to public and private coastal development and infrastructure posed by sea-level rise	**Guide preservation efforts** by providing information that can be used to help compose policies		**Inform post-disaster development and redevelopment efforts** by providing information on 18 different land use tools that can be used to pre-emptively respond to threats to public and private coastal development and infrastructure posed by sea-level rise		**Inform stormwater management policies and regulations** by providing information that can be used to help compose policies	

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
Geospatial Assessment Tool for Operations and Response (GATOR)	✓ **Understand planning context** by providing demographic, infrastructure, economic, and environmental data **Inform comprehensive plan goals and policies** by providing information on a community's vulnerability, including storm surge zones, storm surge depth, hurricane evacuation zones, and social vulnerability	✓ **Inform hazard risk assessment** by providing demographic, infrastructure, economic, and environmental data as well as information on a community's vulnerability, including storm surge zones, storm surge depth, hurricane evacuation zones, and social vulnerability	✗	✓ **Understand planning context** by providing infrastructure and economic data	✓ **Provide information on existing conditions** by identifying the locations of critical infrastructure **Assist in the emergency warnings** for hurricanes and other storm-surge events	✓ **Understand planning process** by providing infrastructure data	✗	✗

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
U.S. Climate Resilience Toolkit	✓ **Inform planning process** by offering resources to help address sea-level rise **Inform planning context** by helping to estimate and examine the current and/or potential impacts **Inform future land uses** by limiting development in areas which are identified as vulnerable to potential impacts from sea-level rise **Inform comprehensive plan goals and policies** by providing information on vulnerability due to future sea-level rise	✓ **Inform planning process** by offering resources to help address sea-level rise **Inform hazard risk assessment** by identifying areas that may be vulnerable to future sea-level rise and estimating potential impacts through the use of multiple tools that can be used to estimate, simulate, visualize, and monitor sea-level rise and its impacts	✓ **Inform management area boundaries** by depicting areas that would be inundated by water under different sea-level rise scenarios and including potentially impacted areas in natural resource protection areas to reduce the impact on people and property	✓ **Inform infrastructure investment and reinvestment priorities and relocation of economic resources** to ensure assets are located outside of identified inundation areas **Identify and incentivize a less vulnerable growth center** to guide investments or reinvestments to non-vulnerable areas	✓ **Inform planning process** by offering examples of communities that have taken action to reduce their vulnerability **Inform policies for post-disaster development and redevelopment** to ensure assets are located outside of identified inundation areas to promote disaster-resilient development	✓ **Inform infrastructure investment and reinvestment priorities** to ensure infrastructure is located outside of potential inundation areas **Identify and incentivize less vulnerable growth areas** to guide investments or reinvestments to non-vulnerable areas	✓ **Develop policies for stormwater management infrastructure** that require any infrastructure built within inundation areas to be able to function under projected rises in sea level	✓ **Identify vulnerable historic structures, neighborhoods, and/or districts** which are located in areas that may potentially be inundated by sea-level rise

	Local Comprehensive Plan	Local Mitigation Strategy	Special Area Management Plan	Economic Development Plan	Post-Disaster Redevelopment Plan	Capital Improvements Plan	Stormwater Management Plan	Historic Preservation Plan
weADAPT	✓ **Inform planning process** by providing information and data results related to sea-level rise and its impacts, including experience, tools, case studies, and other information	✓ **Inform planning process** by providing information and data results related to sea-level rise and its impacts, including experience, tools, case studies, and other information	✗	✗	✓ **Inform planning process** by providing information and data results related to sea-level rise and its impacts, including experience, tools, case studies, and other information	✗	✗	✗

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Appendix C:

Recommendations for Local, Regional, and State-Level Approaches for Determining Sea-Level Rise Vulnerability

This guidebook covers 33 tools and resources for consideration. This appendix is a report that highlights a selection of 10 of those tools and resources, divided by their origin as a federal, state, non-profit, or privately created product, which provide some of the most accessible features within their tool/resource group. While Appendix B presents plan-based recommendations, the recommendations presented in this appendix are centered around ease-of-use. The discussion is geared toward local governments who are newly approaching their vulnerability assessment options, and who have engaged with the pre-assessment questions set forth in the section *Selecting the Right Tool* (see page15). However, the information provided can also be used by communities that have already conducted a vulnerability assessment since the tools and resources discussed can be used to support previous findings or as references for future assessment changes and future actions.

Recommendations for Local Governments

While considering these recommendations, communities are encouraged to keep in mind their own needs in terms of population, vulnerability, and capacity/capability. Capacity and capability may be considered as a community's access to administrative, technical, fiscal, and political capital.

Important considerations for communities as they investigate appropriate sea-level rise vulnerability assessment tools and resources are: (1) what are the driving factor(s) that are leading the community to conduct the assessment?; and, (2) are the respective driving factor(s) planning-based (e.g., incorporation of the results into hazard mitigation plans, comprehensive plans, land use plans), decision-based (e.g., development studies, public health studies), or otherwise motivated? Understanding the purpose for the assessment will likely assist communities in better understanding the most appropriate tool or tools for their use.

Another important factor to consider will be how much funding (or staff time) a community has available or is willing to invest on the assessment. Funding allocations may ultimately help make the decision easier about which tool or resource to use. A community with more options for funding will have a larger selection of tools available.

The discussion below summarizes some of the key findings from the guidebook. Vulnerability assessment tools have been arranged into four categories, with recommended tools set forth within each category:

- Federal Government Resources
- State Government Resources
- Public Non-Profit Resources
- Private Resources

General recommendations for these resource categories are made within each narrative.

Federal Governmental Resources

For decades, NOAA, the U.S. Army Corps of Engineers (USACE), and the U.S. Geological Survey (USGS) have been leaders at the federal level in sea-level rise data and tool development. These agencies have demonstrated long-term commitment to bringing attention to potential impacts of sea-level rise and have dedicated significant resources on developing tools and providing information about hazards and how to estimate potential future impacts.

NOAA Tools

- **Sea-Level Rise and Coastal Flooding Impacts Viewer (Visualization Tool - Online Mapper)**
- **Sea Level Trends (Visualization Tool - Online Mapper)**
- **U.S. Climate Resilience Toolkit and Climate Explorer (Database of Resources)**

USACE Tools

- **Sea Level Change Curve Calculator (Modeling Tool)**

USGS Tools

- **National Assessment of Coastal Vulnerability to Sea-Level Rise: Coastal Vulnerability Index (Visualization Tool - Online Mapper)**

The major benefit of all of these tools is that they are continuously updated. By virtue of their connection to the network of NOAA-maintained tidal gauge stations, their projections will be continuously updated to reflect valid, current measurements of local sea-levels. The USACE Curve Calculator, for instance, reports on recent and historical measurements of sea-levels from a selected gauge station, and runs those values with the National Research Council sea-level rise low and high curve.

NOAA's *Sea Level Trends* visualization tool is recommended for starting a generalized discussion on historical sea level trends across the globe. This visual can help users understand or communicate that sea level fluctuations are constantly occurring all over the globe, at different rates and even in different directions – both up and down (e.g., Alaska's southern coast has been experiencing a significant sea level drop over the last 80 years due to geologic uplifting of the continental shelf).

USGS's *National Assessment of Coastal Vulnerability to Sea-Level Rise* is helpful for expanding on NOAA's observed trends by providing a coastal vulnerability index for the entire U.S. coast, with risk rankings from low to very high. These risk rankings can be helpful for identifying and prioritizing planning for areas in a community that are at a higher risk to the exacerbated coastal impacts associated with sea-level rise.

NOAA's *Sea-Level Rise and Coastal Flooding Impacts Viewer* is recommended for local governments to use for visualizing the local potential impacts of sea-level rise. The tool shows how various levels of sea-level rise will impact a coastal community through a "horizon year" slider bar that illustrates inundation levels based upon a future year, and it provides simulations of sea-level rise at local landmarks. The tool can also communicate the spatial uncertainty of mapped sea levels, model potential marsh migration due to sea-level rise, overlay social and economic data onto potential sea-level rise, and examine how tidal flooding will become more frequent with sea-level rise.

NOAA's *U.S. Climate Resilience Toolkit* is also recommended for local governments to use as a good source of information on the vulnerability assessment tools, data, resources, and other information and expertise available for sea-level rise adaptation planning. The U.S. Climate Resilience Toolkit also includes

Climate Explorer which is an interactive tool that offers communities visualizations for exploring maps and data related to sea-level rise. The maps available include inundation from 1, 2, and 3 feet of sea-level rise as well as the population density, coastal vulnerability to sea-level rise, and social vulnerability index, which conveys important information on risk as well as the people and assets potentially impacted.

Another resource available from NOAA is a short publication entitled *Incorporating Sea Level Change Scenarios at the Local Level.* This is an excellent resource for communities to review as they begin to investigate how to address sea-level rise as a hazard. The document outlines eight steps to help communities calculate sea level change scenarios and communicate impacts. Using the information provided in the document, communities can develop a process that incorporates a range of possibilities and factors. With this information, various scenarios can be developed, both in terms of projections and responses, to meet the specific circumstances of a community. Moreover, working through the scenario development process provides the data and information that officials will need to make communities readily adaptable to changing circumstances.

State Government Resources

The State of Florida has produced at least three resources that map hazards. More specific information about state-level efforts can be found later in this report in the discussion on Recommendations for State-Level Coordination (see pages C-5 to C-9). This report recommends the following for communities looking into sea-level rise:

- **FDOT Sea Level Scenario Sketch Planning Tool (Visualization Tool – Online Mapper, Data Download)**
- **Geospatial Assessment Tool for Operations and Response (Database of Resources)**

From the State of Florida-created tools, FDOT's *Sea Level Scenario Sketch Planning Tool* stands out for its commitment to directly addressing sea-level rise impacts. Generally, however, it can be utilized for visualizing potential impacts of sea-level rise. While the focus of the tool is on visualizing sea-level rise impacts on transportation infrastructure, it can also be used for more general planning purposes.

Florida Division of Emergency Management's (FDEM) *Geospatial Assessment Tool for Operations and Response (GATOR)* online Geographic Information System (GIS) visualizer is also recommended for its ability to map storm surge zones and storm surge depths. Since storm surge can be considered a hazard with the potential to occur annually, visualization of these zones and depths can help support longer-term sea-level rise planning strategies and decisions.

Public Non-Profit Resources

There are several non-profit organizations that have developed tools and resources for communities considering sea-level rise vulnerability. Several of these tools are highly effective and it is recommended that communities take a closer look at these tools as they consider which are most appropriate for them.

The Nature Conservancy Tools

- **Coastal Resilience Mapping Portal (Visualization Tool – Online Mapper)**

Other Non-Profit Resources

- **Social Vulnerability Index (Visualization Tool – Online Mapper, Data Download)**

The Nature Conservancy *Coastal Resilience Visualization Tool* offers a richly layered analysis of the Florida Keys and some visualization for other parts of the State. As a visualizer, it may also be utilized as a tool to use as a foundation (i.e., emulate or copy) if a community wishes to create its own layered analysis of sea-level rise within a GIS.

The *Social Vulnerability Index (SOVI)* is useful for examining a community's vulnerability to sea-level rise because it ranks locations (census tracts) based upon 32-42 variables that are believed to affect a human population's ability to respond to disasters, such as household income, number of cars owned, and age of inhabitants.

Private Resources

Solutions from the private sector can be very effective for helping communities take a more detailed look at determining and communicating sea-level rise vulnerability, but, at times, private tools can prove to be more expensive than what local governments can afford. Those communities that have the means to acquire and implement these resources are able to develop more specific and more detailed analyses than that which can be done with some of the more economical options. Consulting firms also provide other options for those communities interested in working with them. For those communities just beginning to engage with private sector vulnerability assessment options, the following is recommended:

- **Climate Central's Surging Seas (Visualization Tool)**

Climate Central's Surging Seas offers a free, web-based visualization tool called *Submergence Risk Map* that communities can use to depict scenarios of sea-level rise and identify vulnerable populations, infrastructure, and assets using its searchable data toolkit called *Risk Finder.* It provides an easily understood assessment of sea-level rise, including a mapping of social vulnerability, and a calculator of the total value of impacted structures (e.g., based upon the viewing area, and the amount of sea-level rise, "X" dollars of structural damage will result).

Recommendations for Regional Approaches for Sea-Level Rise

Florida Councils of Governments play a strong role in leading regional planning efforts in the State. COGs have the ability and expertise to take the lead with regional sea-level rise assessments and should consider the tools found in the guidebook for the purposes of conducting regional sea-level rise vulnerability assessments.

In addition, sea-level rise has spurred new regional partnerships to emerge, specifically with a focus on confronting sea-level rise and other climate-induced hazards. The Southeast Florida Regional Climate Compact (The Compact) represents a partnership between Monroe, Miami-Dade, Broward, and Palm Beach Counties. Together, they have created their own consensus sea-level rise projection and vulnerability assessment. Counties wishing to build social capital amongst one another within their own regions may visit The Compact's website (click here[1]) or refer to this list of contacts[2] in order to reach out for additional information.

One of the best ways to learn which tools and methodologies work best for different regions and local governments is to learn through multi-jurisdictional collaboration, including learning from other communities, other regions, and other states. The State's Community Resiliency Initiative is working to provide a clearinghouse for communicating lessons learned. More information about the Community Resiliency Initiative can be found under the discussion of state-level coordination in the following section.

[1] http://www.southeastfloridaclimatecompact.org/

[2] http://www.southeastfloridaclimatecompact.org/who-we-are/

Recommendations for State-Level Coordination

Community Resilience Initiative Background

In 2011-2016, the State's land planning agency, Department of Economic Opportunity (DEO) was responsible for coordinating the Community Resiliency Initiative, a five-year project to integrate adaptation to potential sea-level rise into current planning mechanisms including the local comprehensive plan, local hazard mitigation plan, and local post-disaster redevelopment plan. This effort was steered by a Focus Group of statewide experts on adaptation and coastal vulnerability as well as stakeholders in the coastal area. In the first year of the initiative, DEO researched similar efforts in other states as well as how the "adaptation action area" may be implemented at the local level. During the next phase of the initiative, adaptation planning was piloted in three coastal communities. Finally, after 2016 - all lessons learned will be compiled and disseminated statewide.

As the coasts of Florida continue to change, existing programs will likely be adapted for coordinating and guiding efforts to help Floridians safely adapt to changing conditions. In the near future, the Community Resiliency Initiative will be transitioning into its next five year initiative, which will likely continue to promote adaptation efforts across Florida communities. In addition to the promotion of adaptation planning, several kinds of monitoring will need to be in place, and undertaken by state agencies, to ensure that the phenomenon, and reactions and changes to it, are being recorded.

Opportunities for Sea-Level Rise Monitoring by Florida's State Agencies

There are many opportunities that exist for sea-level rise monitoring and evaluation activities to be overseen by state agencies. Monitoring sea-level rise many consist of several different activities, including the following list of recommended activities:

- **Monitoring coastal change from a human settlement standpoint**—Coastal change as it affects human settlements relates to the ways in which coastal flooding affects residential and business structures, as well as infrastructure. Extreme high tides may affect numerous city functions, from beach-dependent tourism activities, to stormwater infrastructure overload, to building damage. The job of monitoring this kind of coastal flooding should fall primarily to communities themselves, although the Division of Emergency Management may monitor and predict instances when coastal flooding will occur. The State Land Planning Agency (DEO, Division of Community Development) may monitor flooding and impacts over the long term and the way that communities are adapting their planning mechanisms, accordingly. Water Management Districts could also monitor the changes to the freshwater/saltwater found at different drinking water wells in their areas.
- **Monitoring coastal change from a geological standpoint**—Geologic change consists of sedimentary, dune, and coastal terrain changes brought about by eustatic sea-level rise (total volume of water increases and expands) and subsidence, among other forces. Coastal geological change would likely best be monitored by the Department of Environmental Protection (DEP) Florida Geological Survey in conjunction with NOAA's tidal gauge stations.
- **Monitoring coastal change from a biological standpoint**—Biological change consists of alteration to species habitats, and the living habitats themselves, as a result of flooding and sea-level rise. The Community Resilience Initiative references the Florida Natural Resources Inventory (FNAI), FDEP, FWC, and state national parks located in Florida, alongside other not-for-profit entities, when describing biological change as a result of sea-level rise. In the future, these same agencies may continue to monitor biological change, such as through FWC's "tipping points" mechanism[3], to determine how habitats and species migrate, expand, or shrink as a result of sea-level rise and coastal flooding.
- **Being aware of, compiling, and organizing sea-level rise planning occurring in the state**—Planning for sea-level rise (i.e., "adaptation planning") refers to the participatory process by which a community sets goals, assesses vulnerabilities, creates adaptation strategies, and develops a means by which those activities can be integrated into regulatory documents. The Community Resiliency Initiative has actively followed sea-level rise planning activities. In the future, the state land planning agency at DEO may be responsible for continuing to follow, document, and make visible these planning efforts for use and reference by other Florida communities.

[3] The *Tipping Point* mechanism was described to DEO as a system wherein wildlife managers, when noticing a change in a species or habitat, refer to a reference guide describing tipping point signs and effects. If the change expressed by the species or the habitat matches a predicted tipping point, it may mean that the species is adapting, thriving, or shrinking in response to sea-level rise and other climate change impacts.

- **Being aware of, compiling, and organizing sea-level rise policy making in the state**—Sea-level rise policy consists of regulatory mechanisms for surveilling or adapting to sea-level rise. Policy at the state originates at the legislature and may be monitored by the Department of State (DOS) or by the state land planning agency at DEO. In addition, hazard mitigation plans are prepared by the Division of Emergency Management. Instances of sea-level rise within these plans may be documented and shared with DEO and DOS. At the local level, these changes may appear in comprehensive plans, zoning ordinances, special area management plans, or other regulatory documents. The state land planning agency at DEO should continue to monitor developments in local policy and consolidate it as the Community Resiliency Initiate has done.
- **Being aware of, compiling, and organizing sea-level rise adaptation projects occurring in the state**—Adaptation projects cover a wide range of Protection, Accommodation, and Retreat activities. They may appear as zoning overlays, incentive programs, other regulation, and physical projects. At the regional level, these projects may be implemented during the building of inter-jurisdictional infrastructure, such as a road or a water supply network. They may also be highly localized, such as a permit to plant native landscaping on a single private parcel of land. Permitting and implementing agencies for these projects include Florida Department of Transportation (FDOT), DEP, and Water Management Districts. At the local level, they include the building and permitting section of the planning department, as well as the public works department through their Capital Improvements Plan. DEO can monitor local adaptation project policy, permitting, and construction. An agreement may be reached between FDOT, DEP, DEO and the Water Districts to amass data about projects within one central location, such as the University of Florida/Geoplan Sea-Level Scenario Sketch Planning Tool website.
- **Ensuring that state-level knowledge and understanding of sea-level rise and climate change science is current and sophisticated**—Sea-level rise science originates from numerous sources: the Intergovernmental Panel on Climate Change (IPCC), U.S. Army Corps of Engineers (USACE), NASA, the National Academy of Sciences (NAS), and academic institutions. Projections may apply to global eustatic rise (such as IPCC) or may include local rates of erosion and subsidence (USACE). Although the Community Resiliency Initiative follows general trends in climate science, it does not continuously evaluate the validity of different projections[4]. DEP Office of Coastal Resource Management may have a meteorologist review new projections as they arise, and prepare reports on them.

The above recommended activities address sea-level rise monitoring from a variety of perspectives and through numerous agency supports. While they provide a good level of detail about sea-level rise events, there is some lack of cohesion and central organization. Consequently, DEP may wish to coordination with Department of Agriculture and Consumer Services (FDACS), Office of Energy in order to revive or evolve the governor's task force on climate change that was created in 2007 by an executive order. Through a central coordinating entity at the state level, the monitoring activities and records of each agency could be compiled, organized, and outreach to interested communities facilitated.

[4] The resource *Sea Level Rise Projection, Needs Capacities and Alternative Approaches* examines 12 eustatic projections and 9 major sea level rise projection methods. This evaluation should remain valuable for years to come, although other projections and updates will need to be added.

Recommendations

If the State of Florida wishes to conduct a statewide vulnerability assessment, or drive a standard set of community assessments, it should determine different planning horizons (for example, 20-year, 40-year, etc.). This will help the State set realistic goals, adjust to changing science about the hazard, and help determine whether the message about the hazard should be revised over time. There are two recommended vehicles to consider using to help establish planning horizons: 1) through a Focus Group comprised of statewide experts on adaptation and coastal vulnerability; and, 2) through the State Hazard Mitigation Plan Advisory Team. The Focus Group was formed as part of the Community Resiliency Initiative to "establish sea-level rise scenarios, determine appropriate and comprehensive planning horizons based on the requirements of Title 44 CFR Sec. 201, determine data requirements for addressing sea-level rise in the State Hazard Mitigation Plan and to explore the feasibility of developing Memoranda of Understanding [between state agencies and partners]." As such, it is recommended that a similar Focus Group continue to be considered a strong proponent for promoting sea-level rise awareness statewide.

Other state agencies with direct involvement in communicating risks associated with rising sea levels include, but may not be limited to the following:

- Department of Environmental Protection
- Division of Emergency Management
- Florida Coastal Management Office (DEP)
- Florida Department of Transportation
- Department of State, Division of Historical Resources
- Department of Health
- Fish and Wildlife Conservation Commission

These agencies should be coordinated with closely when determining any state-wide priorities related to sea-level rise.

Coordination of sea-level rise vulnerability analyses at the state level may best take place through the State Hazard Mitigation Plan Advisory Team (SHMPAT). The State Hazard Mitigation Plan Advisory Team is comprised of a variety of stakeholders from State Government, Federal Government, the private sector and other non-governmental agencies and associations. The SHMPAT is charged with keeping the State Hazard Mitigation Plan updated every five years. The most recent version of the plan was last completed in 2013.

Sea-level rise is already identified in Florida's State Hazard Mitigation Plan in the discussion of the flood hazard, although sea-level rise is not identified as a separate hazard. General vulnerability assessment information from a Nature Conservancy analysis is provided in the plan.

Available opportunities for updating the State Hazard Mitigation Plan (in 2018/2019) are recommended to take advantage of the following:

- Recommendations from a Focus Group comprised of statewide experts on adaptation and coastal vulnerability.
- A review of updated sea-level rise vulnerability assessment tools and methodologies to determine what approaches may be most appropriate for conducting a statewide assessment.
- A review of the different approaches for incorporating results and products from the vulnerability assessment into existing state agency planning processes.
- Community Resiliency Initiative report entitled – *Recommendations for a Statewide Vulnerability Assessment* (Year 3, DEP agreement CM403, deliverable 3.13), which examines sea-level rise projection methodologies and tools, and provides recommendations for conducting a statewide vulnerability analysis.

- As part of the first year set of Community Resiliency deliverables, the Florida Planning and Development Lab produced recommendations for updating the State Hazard Mitigation Plan. The Florida Planning and Development Lab produced CM 223 Del. 3.9 “Final Proposed Amendments to Florida’s State Hazard Mitigation Plan….” (Butler et al., 2013) which included proposed amendments to incorporate sea level rise into the SHMP.

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Appendix D:

User Narratives

This appendix includes user narratives which provide fictional scenarios that define a user and the type of sea-level rise vulnerability analysis he or she would like to complete. These narratives describe the functionality required of a tool being used in each case and identify a vulnerability assessment tool the user would be able to utilize to accomplish the desired analysis.

Note: Both of the users presented below could determine which tool he or she would like to use with the help of this guidebook. To do so, they would use the Inventory of Sea-Level Rise Adaptation Assessment Tools and Resources found in Appendix A. First, the users would refer to the summary table (starting on page A-6) to narrow down which tools apply to the adaptation planning step they are trying to accomplish. Next, they would review the one-page profiles in the inventory (starting on page A-10), specifically the "When and Where to Use" section, to further refine the list of potential tools and determine which can best accomplish the tasks they are trying to complete. From the remaining tools, the users can select which tool also meets any local limitations, such as funding, data, or technical constraints, based on the information found in the profiles as well as the inventory matrix (starting on page A-82).

User Narrative #1: Exposure Analysis

Jim Smith is the town planner for a coastal community in Florida. The community is ready to conduct a vulnerability assessment to evaluate the potential impacts of sea-level rise. Jim has been tasked to identify the locations in the town that will potentially be inundated by future sea-level rise. He needs to be able to present visuals to the sea-level rise adaptation planning stakeholder group that illustrate where inundation areas will be located in the town if 1-, 2-, or 3-foot sea-level rise occur. He would also like to present illustrations that demonstrate how 1-, 2-, or 3-foot sea-level rise could impact the town hall, which is an important local landmark.

Jim can use NOAA's Sea Level Rise and Coastal Impacts Viewer to accomplish these tasks. The viewer, which is available online at no charge, will allow him to show the stakeholder group which areas in the town could be impacted by flooding under 1-, 2-, and 3-foot sea-level rise increments (or at 1-foot increments up to 6 feet). He can use the viewer to zoom into his town and then either capture static images of the map showing each of the desired increments or utilize the viewer during his presentation and move the slider bar to simulate the various sea-level rise scenarios. This will allow the stakeholder group members to clearly see which areas in the community are vulnerable to future sea-level rise. Additionally, the viewer includes simulations of sea-level rise at various local landmarks. If the town hall is one of these landmarks, Jim can use the simulations provided through the viewer to illustrate how 1-, 2-, and 3-foot sea level rise will impact the structure. If, a simulation is not available, he can create his own visualizations using NOAA's CanVis tool. CanVis will enable Jim to take a photograph of the town hall and add images of rising water that are equivalent to each of the three sea-level rise increments. Although this will require careful measurement and calibration, Jim will be able to simulate possible future conditions that could impact the town hall.

User Narrative #2: Impact Analysis

Susie Johnson is the town coastal resource manager for a coastal community in Florida. The community is ready to conduct a vulnerability assessment to evaluate the potential impacts of sea-level rise. Susie has been tasked to conduct an impact analysis to identify the town's population and property that could potentially be inundated by future sea-level rise. She needs to be able to present visuals to the sea-level rise adaptation planning stakeholder group that illustrate where inundation areas will be located if there is 1-, 2-, or 3-foot sea-level rise as well as identify the size of population and amount of property that could be impacted under each scenario. She would also like to highlight any socially-vulnerable populations that may be impacted.

Susie can use Climate Central's Surging Seas Submergence Risk Map to accomplish these tasks. The map viewer, which is available online at no charge, will not only allow her to show the stakeholder group which areas in the town could be impacted by 1-, 2-, or 3-foot sea-level rise, but it will also enable her to display the existing population and property relative to these areas. She can use the map viewer to zoom into her town and then either capture static images of the map showing each of the desired increments or utilize the viewer during her presentation and move the slider to simulate the various sea-level rise scenarios. She can then turn on the population layer and property layer (one at a time) to view the population per square mile and the property value per acre that are located in the inundation areas simulated under each of the three scenarios. This will allow the stakeholder group to clearly see the areas in the town that are vulnerable to future sea-level rise as well as identify those areas with the highest risk due to high population density or property values. Similarly, Susie can turn on the social vulnerability layer to show the group which potential inundation areas occur in places with high social vulnerability.