Statewide Vulnerability Assessment

Second Report to Focus Group

November 30, 2014

FLORIDA DEPARTMENT of ECONOMIC OPPORTUNITY

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Opportunities for Conducting a Statewide Vulnerability Assessment

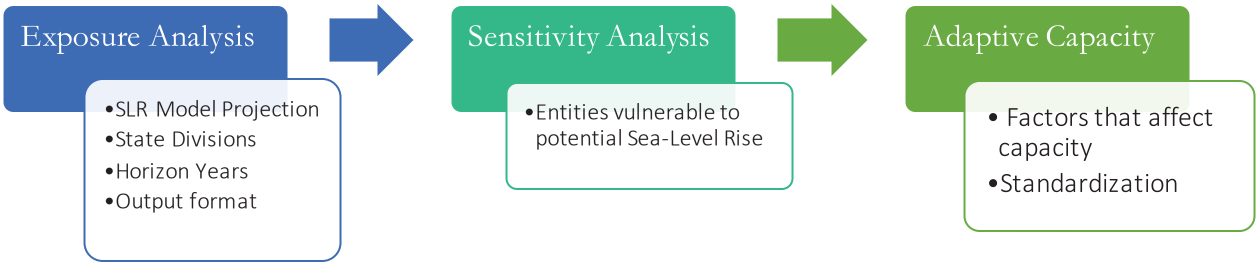
Stretching more than 1260 miles, host to 25 percent of Florida's wetlands, and the base for much of the state's $35.3 billion tourism economy (Florida Geological Survey, 2014), the Florida coast is arguably our most valuable asset. Like non-renewable resources, however, this asset may be subject to potential depletion. Major scientific efforts are pointing to potential sea-level rise during the next century that may put communities at risk ((IPCC, 2007), (National Climate Assessment, 2014)). Providing a baseline analysis of vulnerability along Florida's coasts can assist in conceptualizing the structures, populations, and natural areas that are at risk to potential sea-level rise, and a statewide vulnerability assessment may provide an entry point from which Florida communities can engage in complimentary planning. This report presents an overview of the choices involved in conducting a statewide vulnerability assessment that is informed by the Florida Planning and Development Lab's recommendations for carrying out sea-level rise projection analysis (2013) and a survey of other existing assessments and guides. The following sections will discuss a proposed assessment methodology, funding opportunities, and sea-level rise visualizers that can be emulated in order to create a state-wide vulnerability assessment.

A Condensed Assessment Method

The first section of this report proposes and explains a condensed sea-level rise assessment method. A condensed assessment method may consist of three essential steps – identifying the scope of hazard exposure, determining structures and populations sensitive to the exposure, and ranking each community's adaptive capacity. The designation "condensed" originates from the finding that other vulnerability assessments incorporate activities intended to catalogue *all* possible hazards that may affect a community. For example, a guide written by the California Emergency Management Agency (2012), recommends that "Potential Impacts" and "Risk and Onset" be included as individual steps in the assessment process. Because potential sea-level rise is the single focal point of the assessment discussed in this report, "risk and onset" is contained within the exposure step. Similarly, "potential impacts" is explored within the sensitivity step. For a full reflection on the incorporation of the above steps into a three-step process, Appendix 1: Auxiliary Materials provides additional discussion of the merits of employing a condensed vulnerability assessment method. Accounting for these best practices, applicable methods for analyzing sea-level rise are included in the condensed method shown by

Figure 1.

Figure 1: Sea-level rise Vulnerability Assessment Process



The first step, exposure analysis, involves choosing a sea-level rise projection and applying it to a future time horizon in the community. Sensitivity analysis follows by including analysis of how infrastructure and other entities will be affected by the projected rise. Adaptive capacity ranking concludes the process by measuring communities' ability to prepare for and respond to potential sea-level rise. The following three sections will address decisions to be made, available options for fulfilling those decisions, and recommendations toward conducting a statewide Exposure Analysis, Sensitivity Analysis, and Adaptive Capacity Ranking.

Step 1: Exposure Analysis

An exposure analysis sets the parameters that will guide *when* and *how much*, in order to find *where* sea-level rise is likely to occur depending upon the inputs discussed in this section. The exposure analysis process may be defined in four steps. First, a sea-level rise model is chosen. Secondly, horizon dates (e.g. 2040, 2070) are selected to guide the model's first output. Then, the model calculates static sea-level rise elevations (and can also predict other changes to local coastal landscapes) for "how much" sea-level rise is probable at the chosen horizon time points. Finally, future inundation areas are located (typically within a Geographic Information System (GIS) map window). The output of this step is important because it generates a listing or mapping of the coastal areas that are likely to be impacted. Exposure analysis asks that assumptions be made about the manner in which the eustatic (the total volume of ocean water) and vertical changes in sea levels could affect Florida.

EXPOSURE ANALYSIS CHOICE GUIDE

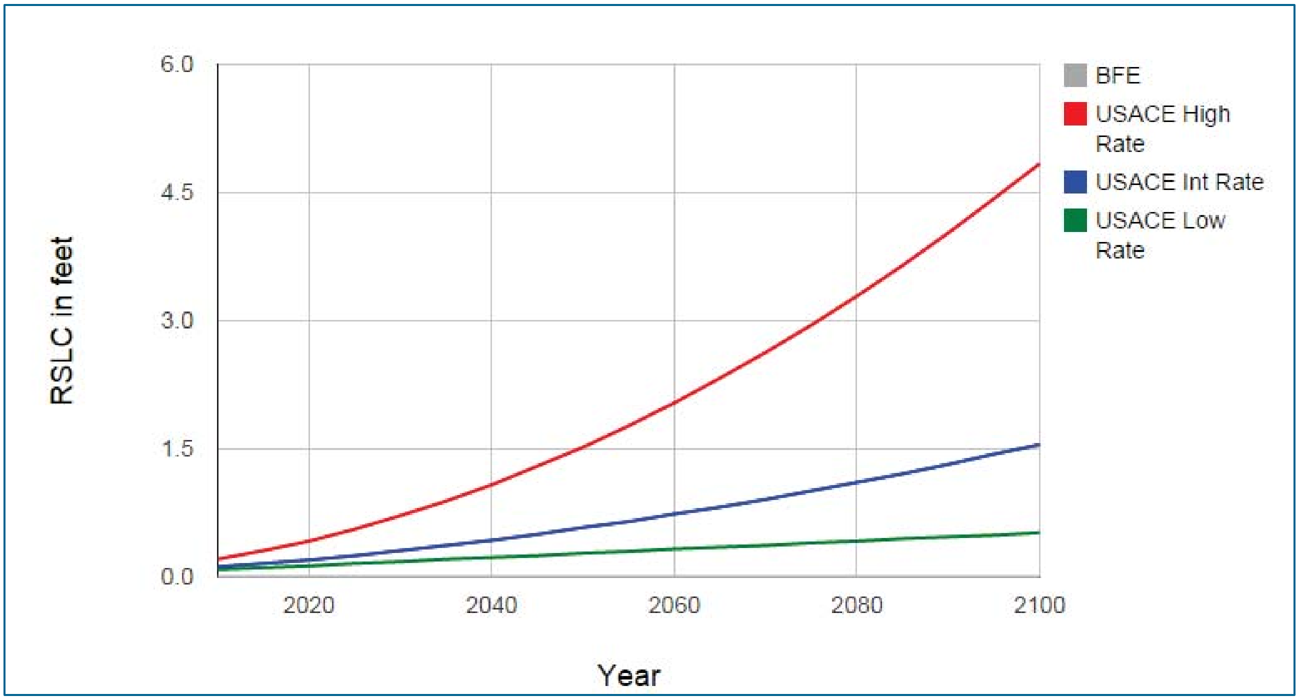
The principle choices for creating an exposure analysis are:

1. Which model/projection will be used?
2. How many "divisions" based on tidal gauge stations will be made?
3. Which horizon years will be projected to?
4. Which output format is preferred (tabular, point projection)?

Available Options

Sea-level rise has been documented worldwide throughout the twentieth century. Tide gauge stations around the United States have measured historic rises of around 1.5 mm per year in the 20th century (Gregory, 2013). These historical trends, when plotted, usually take a linear form, meaning that if future sea-level rise were projected *solely* based upon the historically measured rise, it would increase by the average amount recorded locally during the past 100 years. What General Circulation Models interject is that due to new factors, such as accelerated glacial melt, the rate of global and local sea-level rise will increase more quickly in the 21st century than was observed in the 20th. Consequently, many climate scientists now project sea-level rise along a curve which accelerates mean sea-level rise over the next 100 years. Figure 2 depicts the different projection styles described in this paragraph (USACE, 2014). The green line extrapolates the historic rise out to 2100, whereas the blue and red curves draw from projected accelerations in the rate of rise. The outcomes, especially later in the 21st century, amount to sizeable differences in what the projections inform communities to expect.

Figure 2: U.S. Army Corps of Engineers Sea-level rise Curves, Apalachicola



If the statewide assessment considers using a "curve" projection, the Florida Planning and Development Lab (2013) recommends the use of expert consensus judgments such as those of the National Climate Assessment and Intergovernmental Panel on Climate Change (IPCC). The IPCC projection function employs six Special Reports on Emissions Scenarios and 17 Atmosphere-Ocean General Circulation Models in order to produce estimates of future eustatic sea-level rise in a tabular format. A tabular format utilizes a spreadsheet or table to organize the projected sea-level rise based upon information in rows and columns. Information commonly held in rows may include location or scenario (as shown in Table 1). Columns may hold information on horizon year, or associated climatic disruptions such as temperature change. Table 1 presents the IPCC's Fourth Annual Report tabular output on sea-level rise, with values for predicted temperature change, in degrees Celsius, and global eustatic sea-level change, in meters.

Table 1: IPCC AR4 Sea Level Rise in tabular format

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a] Best estimate	*Likely* range	Sea Level Rise) (m at 2090-2099 relative to 1980-1999) Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Source: IPCC AR4 website: "Projections of Future Changes in Climate"

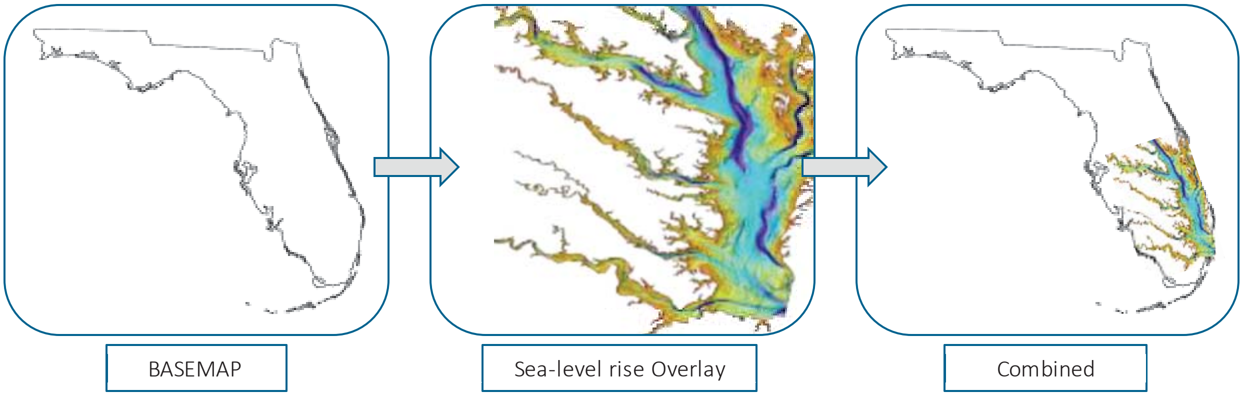
Although it may have the highest consensus regarding future world average sea levels, the IPCC projection does not account for local vertical land movements (e.g., *subsidence*: sinking/settling of land; which is recorded at .240mm per year in Apalachicola (USACE, 2014)). The U.S. Army Corps of Engineers' sea-level rise Curve Calculator – shown by Figure 2 - creates regionally specific sea-level rise projections derived from National Research Council projection curves and local tide gauge measurements. FPDL recommends the utilization of relative sea-level rise projections from the closest tide station.

Because historically measured rates of sea rise depend on the tide gauge station at which they are recorded, an exposure analysis covering the entire state will entail choosing how many "subdivisions" the state is divided into for analysis purposes. With 19 active NOAA tide gauge stations and numerous other stations, the state could hypothetically be divided up to 19 or more times; however, Florida Department of Transportation (FDOT) has utilized its seven districts as divisions toward the creation of its own sea-level rise assessment of transportation infrastructure vulnerability (FDOT; UF Geoplan Center, 2014). FDOT's approach provides a strong basis for other state-wide assessments. For additional commentary on sea-level rise projection methods, see Appendix 1: Auxiliary Materials.

If future sea-level rise assessments resemble the majority of other analyses being conducted in Florida and around the nation, then the exposure will be depicted in "point projection" format. Point projection utilizes

GIS software to produce maps of inundation / conversion during the exposure analysis step. Figure 3 depicts the overlay analysis process.

Figure 3: Point Projection for sea-level rise



At first, a "basemap" of the assessment area is obtained. This map usually contains information about land elevations (which are represented as averages for units of area, such as 25x25 meter squares). Then, a sea-level rise projection method is applied. Modelling software, such as S.L.O.S.H or S.L.A.M.M. calculates how rising waters will affect the landscape. Figure 4 describes two types of modelling software that can be used to illustrate the effect of sea-level rise on coastal areas (for a full description of modelling software, see DEO's Adaptation Tools database, 2013) Finally, the combined basemap and spatial representation of changing water levels are shown in relation to one another. These map representations may be cropped to appear for only one state division or shown for the state as a whole.

Figure 4: SLR Modelling Software

GIS Projection Software

S.L.O.S.H. Sea, Lake, and Overland Surges from Hurricanes (static) – The SLOSH model is a simple bathtub model. As the bathtub, or ocean, fills up with more water, the water levels get higher, thus covering more land along the coast (or side of the tub). In GIS software, this model overlays at least two different Digital Elevation Models (DEM). The first DEM is a land layer and the second is a water layer. The values of the water layer are adjusted to reflect new sea levels, and then compared with previous sea levels to determine change.

S.L.A.M.M. Sea Level Affecting Marshes Model (dynamic) – The SLAMM model projects not only bathtub effects of SLR, but also simulates the way in which ocean water will change the natural landscape. A simplistic representation of changing habitats from the ocean into land is: Ocean Water > Wetlands > Dry lands. What SLAMM does differently than SLOSH is that, rather than predicting all dry land will become ocean water, it analyzes whether a part of the land will become new wetland.

Recommendations:

For the model/projection, this report recommends utilizing the U.S. Army Corps of Engineers' (USACE) sea-level rise Curve Calculator, coupled with a static point projection of inundation. Because point projection also generates attribute files, an accompanying table can be created that indicates sea-level rise over the given time period (i.e., rise amount for each projection year). FDOT's Sea Level Scenario Sketch Planning Tool website includes an add-in download that calculates sea-level rise in GIS software utilizing the USACE method. This recommendation may mean that coastal sea rise will be projected along seven delineations that reflect the 7 FDOT districts. For the planning horizon years, this report recommends that model years of 2020, 2040, 2060, 2080, and 2100 be projected, in order to establish continuity with the FDOT tool. Future assessments may use Digital Elevation Models with a similar grid size, or 25 meters square (Florida Planning and Development Lab, 2013) to map exposure, which is the method employed by FDOT's Sketch Plan Tool.

Step 2: Sensitivity Analysis

Sensitivity analysis builds on the findings from the exposure analysis to create a greater understanding of impacts. A sensitivity analysis is also important to include in a vulnerability analysis because it can answer the question: *who and what will be affected by potential sea-level rise*? For such an analysis, additional GIS data layers are needed in order to assess where the projected inundation is likely to affect structures, populations, conservation areas, and other entities.

SENSITIVITY ANALYSIS CHOICE GUIDE

The principle choice for creating a sensitivity analysis is:

1. Which entities (infrastructure, population, natural areas, etc.) are necessary to include in a sensitivity analysis?

Available Options

Unlike exposure analyses, sensitivity analyses do not rely on new methods and models to be integrated into the assessment. Rather, sensitivity analyses requires the choice of geospatial data (i.e., points, lines and polygons) that can represent structures, functions, and people (California Emergency Management Agency , 2012).

The state may consult other sensitivity analyses created by groups such as the Southeast Florida Regional Climate Change Compact (2012) or Climate Central (2014) when deciding upon the features to include in its own analysis. These two sensitivity analyses focus on many aspects of land use that could enter into the DEO vulnerability assessment. The structures and populations covered by the two groups' sensitivity analyses are detailed by Table 2.

Table 2: Sensitivity Analysis Elements from two Florida vulnerability assessments

Analysis Layer	Plan(s) Included In
Land	Climate Central
Property Value (Taxable Value)	Climate Central, SeFRCCC
Homes	Climate Central
Population	Climate Central
High Social Vulnerability Population	Climate Central
Population of color	Climate Central
EPA listed sites	Climate Central
Roads	Climate Central, SeFRCCC
Railroads	Climate Central, SeFRCCC
Passenger stations	Climate Central
Power Plants	Climate Central, SeFRCCC
Sewage Plants	Climate Central, SeFRCCC
Water Plants	SeFRCCC
Hospitals	Climate Central, SeFRCCC
Evacuation Routes	SeFRCCC
Public Schools	Climate Central, SeFRCCC
Houses of Worship	Climate Central
Marinas	SeFRCCC
Ports and Airports	SeFRCCC
Emergency Shelters	SeFRCCC
Acres of Future Land Use	SeFRCCC
Habitat Type	SeFRCCC

Both groups opted to represent sensitivity in point projection format, meaning that (utilizing GIS software), a sea-level rise layer was created and examined to show intersections with a layer containing one or more of the rows described by the table. The feature in question – for example, public schools – would have all locations depicted on the map in relation to sea-level rise, and affected schools could then be identified.

Recommendations:

This report recommends pairing or overlaying the exposure analysis model outputs (i.e., GIS data layer of coastal inundation) with all entities described in Table 2 to determine which entities are sensitive to sea-level rise. Beyond the entities listed in Table 2, a statewide sensitivity analysis may include mapping of more conservation areas (e.g. parks and open space), business locations by sector/size, agricultural facilities, university facilities, and government services (such as municipal courthouses), and communications infrastructure. The array of data inputs may help to create a broad survey of affected structures, populations, and natural areas.

Step 3: Adaptive Capacity Ranking

Once exposure and sensitivity to sea-level rise are surveyed, a form of adaptive capacity ranking can be used to determine the extent to which the community is responding, and is prepared to respond further, to potential rising sea-levels. The IPCC defines Adaptive Capacity as (2007): "the ability or potential of a system to respond successfully to climate variability and change, and includes…both behavior and…resources and technologies." This step can help to identify the levels of attention, expertise, resources, and other proactive responses that communities are utilizing to address changes in sea levels. It may also help to characterize the potential resources the community has at its disposal to confront potential changes in sea levels. Finally, the adaptive capacity ranking can serve as a baseline by which communities examine what needs to be done in order to create locally specific sea-level rise adaptation plans.

ADAPTIVE CAPACITY RANKING CHOICE GUIDE

The principle choices for creating an adaptive capacity ranking are:

1. Which factors will make a community *more* or *less* capable of sea-level rise adaptation?
2. If more than one characteristic is scored, how will the scores be standardized?

Available Options

Important to this step is the ability to define adaptive capacity, in a broad and measurable fashion, for every community in the state. Expanding upon this concept, Preston and Stafford-Smith find (2009, p. 12):

Capacity is often measured in terms of resource availability (e.g. human, technological, and financial capital….). Yet the institutional and governance networks that exist to deploy those resources are also essential.

In order to assess adaptive capacity across communities in Florida, the state is encouraged to develop a framework to evaluate each community's ability to employ the resources mentioned above toward addressing sea-level rise. This may include the following variables (Russell & Griggs, 2012):

1. Regulatory and planning capabilities (e.g., development restrictions, coastal management regulations, hazard mitigation, sustainability, shoreline management, post-disaster recovery/emergency plans, etc.);
2. Administrative and technical capabilities (e.g., the number of sea level rise experts, planners, engineers, GIS and mapping resources and modelling capabilities, etc.);
3. Fiscal capacity (e.g., taxes, bonds, grants, impact fees, withholding spending in hazard zones and insurance);

4. Infrastructure (e.g., flood and erosion control structures, evacuation routes and redundant water, wastewater, and power systems)"

It may be time-prohibitive for the state to develop an adaptive capacity score for the 410 incorporated areas in the state. Therefore, some form of "districting" similar to that described for the exposure analysis is recommended.

Recommendations:

The spectrum of adaptive capacities across the state can reveal profound new implications beyond those of sensitivity and exposure analysis, and this report recommends that an adaptive capacity ranking, by county, be integrated into the vulnerability assessment. This ranking may include regulatory, administrative, fiscal, and infrastructure rankings that are generated by a panel of experts, such as FPDL, who have already made inquiries into the capacity category. A mock-up of the way in which the state could conduct such a ranking is shown on page 22, Appendix 1: Auxiliary Materials. Although four capital areas are presented by the example ranking table, the group who conducts the assessment is encouraged to dig more extensively into community indicators of sea-level rise adaptive capacity.

Funding Opportunities

This project may be able to acquire funding through a Coastal Zone Management Act "Projects of Special Merit" allocation. This mechanism is the same as the one used to fund the Adaptation Action Areas pilot project in Fort Lauderdale. Project of Special Merit criteria take into account the merit, financial , and technical aspects of a proposal, with emphasis on the likelihood that the project would result in improved management of coastal resources (amongst other things). In this respect, the project may illuminate numerous hazard impacts across the state and assist many local communities to plan accordingly. By integrating data from social vulnerability to land uses and structures, the DEO vulnerability assessment will vastly increase the knowledge released at the state level concerning adaptation.

A second potential funding source is the NOAA Ecological Effects of Sea Level Rise Program. This program would allocate funding to a vulnerability assessment that placed a high priority on "regional and local ecosystem effects of sea level rise and coastal inundation".

DEO may be able to partner with a large non-profit in order to carry out the vulnerability assessment. USHUD names the Rockefeller Foundation as a provider of technical assistance collaboration during the execution of the National Disaster Resiliency Competition. By uniting, DEO may be able to access the Foundation's technical expertise available to further the assessment.

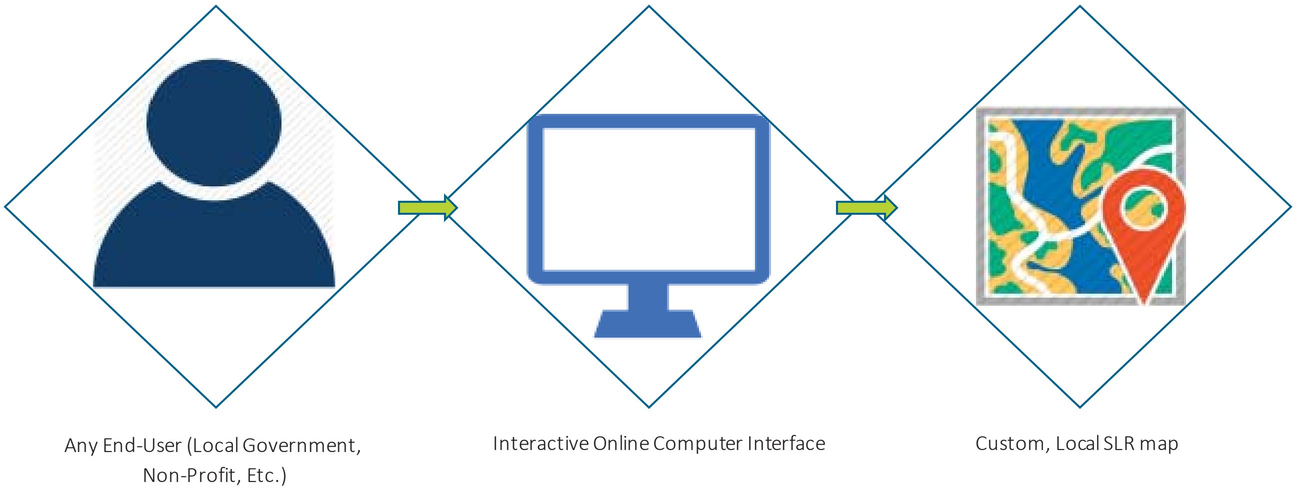
In the event that the DEO vulnerability assessment builds heavily off of FDOT's Sketch Planning Tool, the staff already at work measuring Florida's response to sea level rise could be partnered with so as to efficiently incorporate new data layers into the pre-existing tool. This could dramatically decrease the cost of conducting the assessment and potentially render the deliverable feasible to complete without seeking contract services.

Sea-level rise Visualizers

An important consideration for such an assessment is the manner in which findings are presented. Although a vulnerability assessment may be released as a report (i.e. paper, pdf), a new medium has emerged for conveying the information to a widespread audience. This section considers the use of an interactive website (referred to here as a sea-level rise visualizer) alongside a traditional report in order to disseminate customized information to a broad range of users. The creation of a DEO online visualizer may also be used to provide a unified, coordinated resource for Florida communities planning for rising seas, since there are already many tools offering information about sea-level rise in Florida.

Many of the findings about sea-level rise and other contemporary hazard assessments are provided through a website. NOAA (2014), California (2014), New Jersey (2014), FDOT (2014), and Climate Central (2014) are several groups that have assembled interactive mapping websites that allow users to depict different hazard and population overlays (for a listing of other sea-level rise visualizers and websites, see *Incorporating Adaptation into the Local Mitigation Strategy* (DEO, 2014)). Through these websites, a variety of end-users would be able to customize their data outputs and increase sea-level rise awareness and adaptation capacity (Figure 5).

Figure 5: The SLR Visualizer Process



A sample of the sea-level rise viewing websites mentioned above is included here with a short review of the information each site contains. Figure 6-Figure 10 display a screen shot from each of the above websites, with accompanying ease-of-use (where 1 = Least Easy and 5 = Easiest) and extent-of-content (where 1= least content and 5 = most content) ratings[1].

Figure 6: Cal-Adapt sea-level rise Visualizer

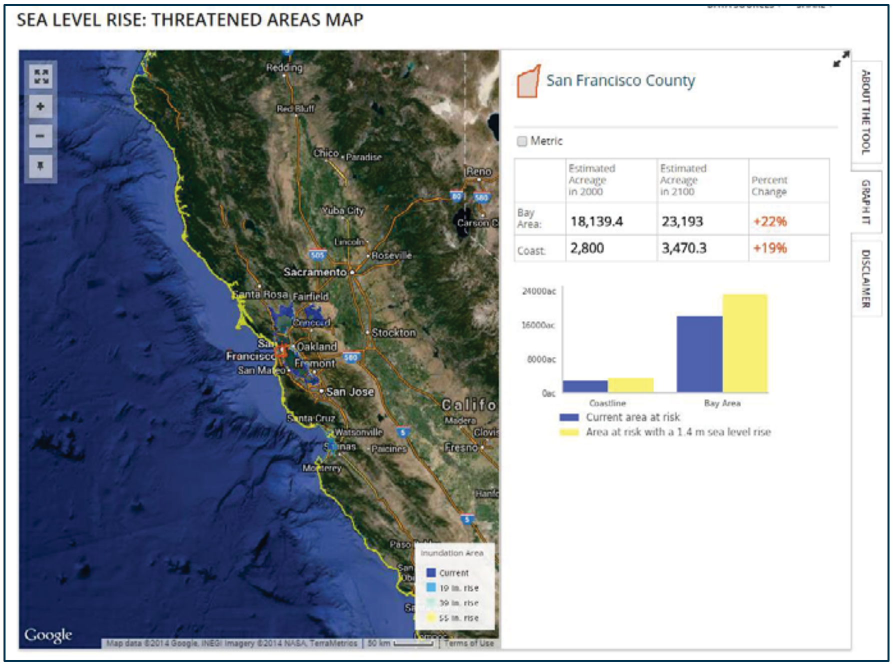


Figure 6 depicts the California Energy Commission's interactive, multi-hazard vulnerability tool. It offers calculations of acreage affected at different degrees of SLR, but does not overlay infrastructure or other layers. It provides a detailed exposure, but lesser sensitivity analysis.

Ease of Use – 3
Extent of Content - 2

[1] Ease of use considerations were made by accounting for the clarity with which each site makes its tools and processes known to the end-user and the simplicity of 'viewing' each tool. For example, the FDOT visualizer includes layers that appear checked although they do not appear unless further effort is made. The NJ-Adapt visualizer, on the other hand, involves 1-click full layer viewing, which is intuitive and effective. The FDOT tool, on the other hand, has a wealth of roadway information available to the capable us er, and so receives a 5 on the extent of content rating.

Figure 7: Climate Central sea-level rise Visualizer

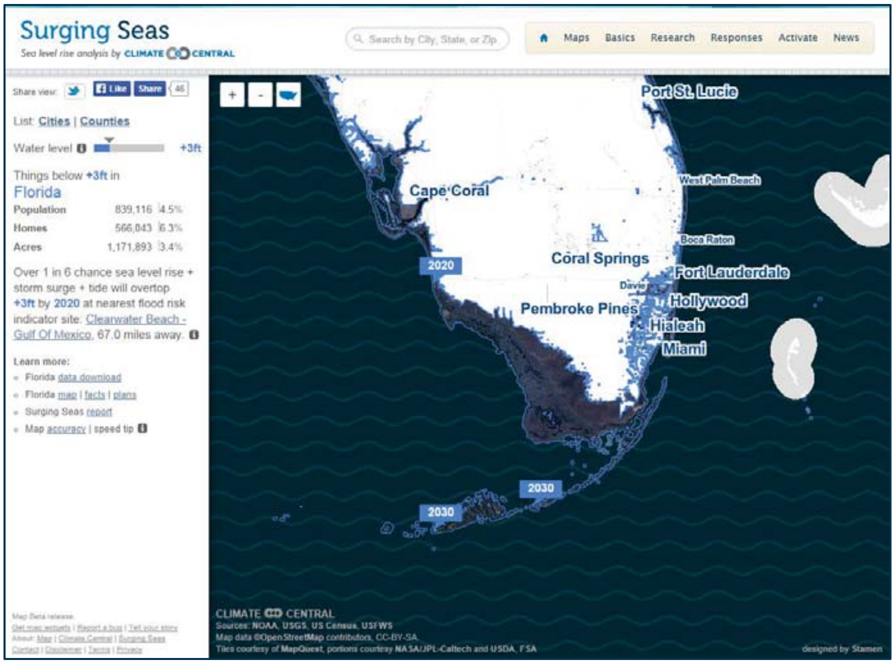


Figure 7 shows the Climate Central SLR tool. Similar to the Cal-Adapt visualizer, it depicts the land area affected in acres. To land area, it also adds homes and population that would be impacted. These operations represent a level of sensitivity analysis added to the baseline exposure.

Ease of Use – 3

Figure 8: FDOT/ UF Sketch Planning Tool sea-level rise Visualizer

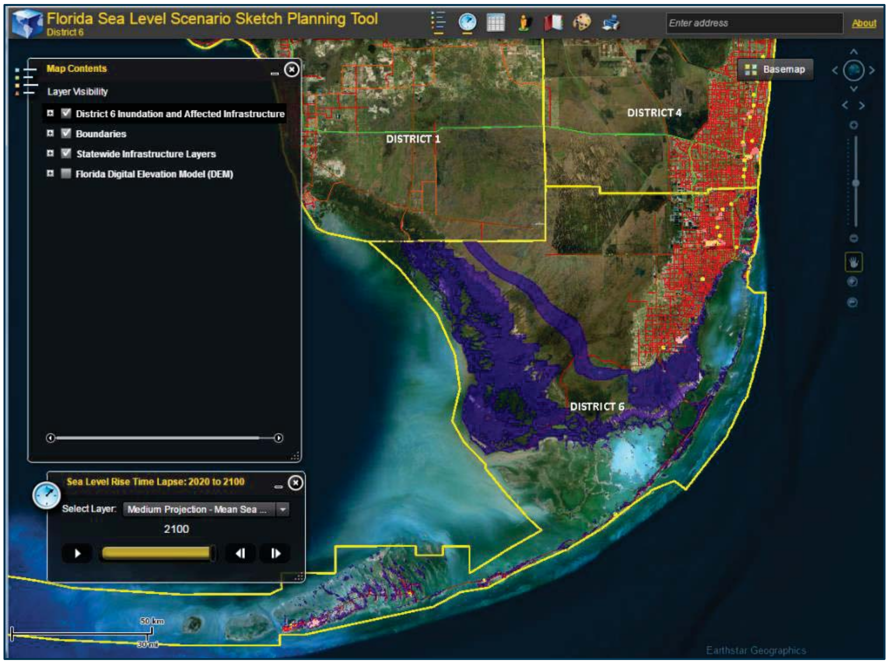


Figure 8 shows a still from the FDOT / UF Geoplan visualizer. This tool couples SLR projection with detailed transportation infrastructure layers, creating a dynamic sensitivity analysis. Nonetheless, it currently does not incorporate population, acreage, or other layers of sensitivity.

Ease of Use – 2
Extent of Content - 5

Figure 9: NJ-Adapt sea-level rise visualizer

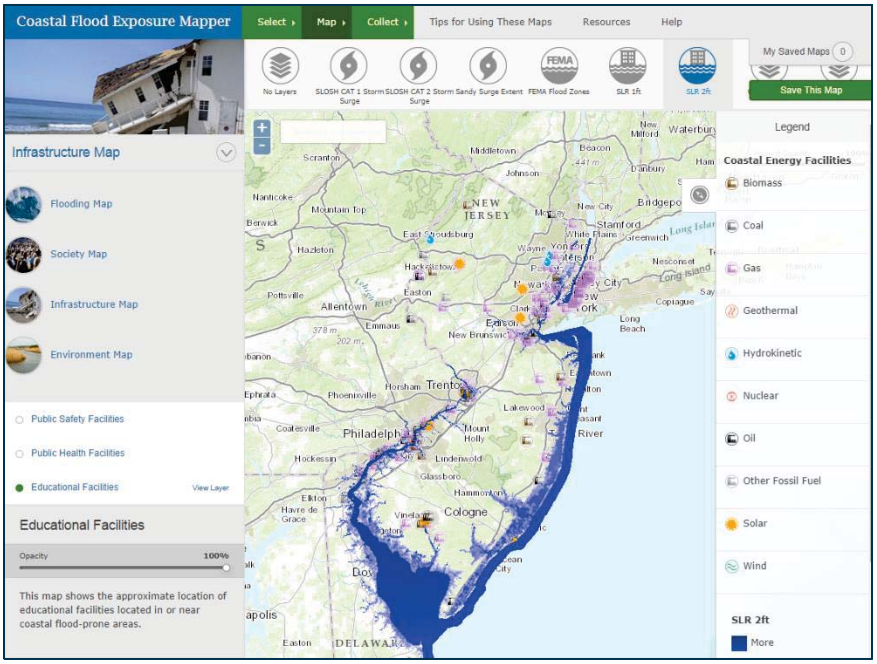


Figure 9 depicts the New Jersey Coastal Flood Exposure Mapper. This tool combines a range of inundation hazards – from flood to SLR – and visually pairs them to population, business, infrastructure, and environmental layers. In effect, it creates a compelling multi-layer sensitivity views to accompany exposure.

Ease of Use – 5
Extent of Content - 4

Figure 10: NOAA sea-level rise Visualizer

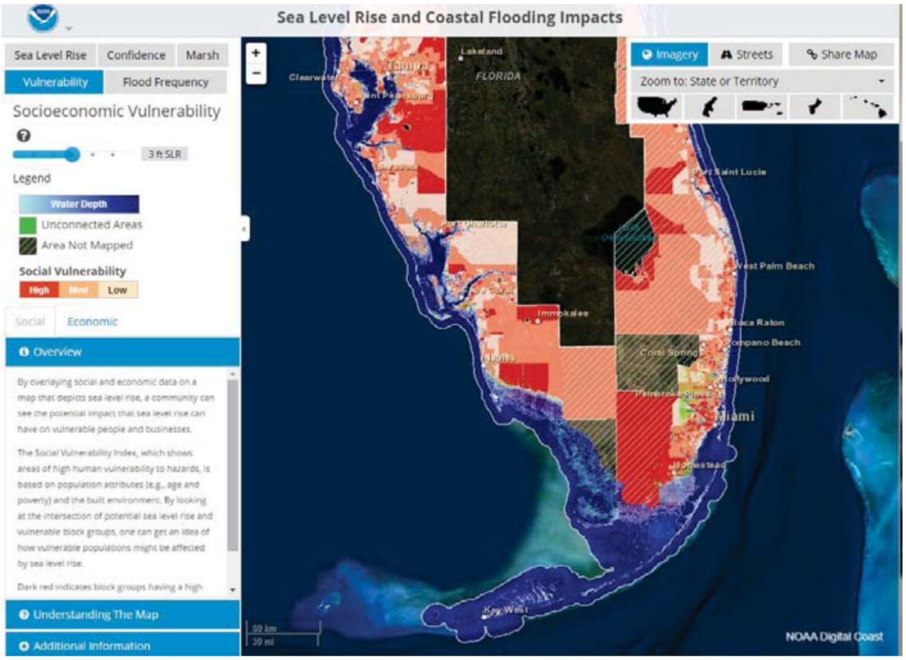


Figure 10 shows NOAA's Sea-level rise and Coastal Flooding Impacts visualizer. This tool presents consensus estimates of SLR along the US coast, which can be paired with a "Social Vulnerability" rank. Such a rank resembles that of the Florida BRACE program, which is a normalized score calculated from socio-demographic inputs.

Ease of Use – 4
Extent of Content - 3

Through each of these products, non-governmental, state, and national groups have been able to bring sea-level rise impact visualizers to any person or community with internet access. Toward the end of facilitating a unified statewide sea-level rise response, DEO may support the adoption and enhancement of the FDOT Geoplan Sketch Tool. Adopting the FDOT tool may serve to eliminate some of the ambiguity facing communities who are already attempting to use a sea-level rise visualizer to plan, since there are many tools that currently provide assessments of Florida. A DEO-FDOT online visualizer may add value to the existing products by incorporating new land use, infrastructure, and population layers, and ensuring ease of use. It may also push toward a unified state product that communities who wish to regulate land uses may turn to as the authoritative sea-level rise visualizer. In order to unite and authorize one tool, the vulnerability assessment team may need to plan for lobbying efforts to incorporate language into Florida Statutes, such as for Adaptation Action Areas (F.S. 163.3164(g).

Recommendations:

This report recommends that the basic aspects of the FDOT Sketch Planning Tool – model algorithm, horizon year, state subdivisions, and DEM resolution - be adopted and added to by the DEO assessment to reflect the new layers of sensitivity analysis described above. Adaptive capacity can then be overlaid upon sensitivity by developing a cohort-rating depending on what is appropriate for each subdivision. Beyond adding the new levels, attempts should be made to create an interface that is as user friendly as the NJ-Adapt Coastal Flood Exposure Mapper. An attempt to create a user-friendly interface could result in a new website that presents the DEO vulnerability assessment layers.

Coordination with FDOT and University of Florida Geoplan Center

This report has endeavored to explore the preferred mechanisms for conducting an exposure and sensitivity analysis for the state of Florida. In so doing, it has developed a case for collaborating with FDOT and the University of Florida Geoplan Center, the groups behind the Sketch Planning Tool. The Sketch Planning Tool incorporates the projection method recommended by this report. In addition, the collaboration between FDOT and UF has already created an online visualizer. The FDOT/UF project, therefore, represents an unbiased awareness and capacity building exercise in the same vein as the assessment currently proposed by DEO. In order to avoid inter-agency redundancy, DEO reached out to FDOT in November, 2014 to discuss the possibility of incorporating new layers of data into the Sketch Planning Tool. FDOT currently possesses a large amount of high quality data beyond transportation infrastructure (see recommendations in Step 2: Sensitivity Analysis). In order to add these data, however, funding would need to be located to reimburse the UF Geoplan Center effort. From this initial outreach, FDOT and DEO will begin to formulate a plan to accommodate the new features proposed for the Sketch Planning Tool visualizer.

Conclusion

This report discusses the components of a statewide sea-level rise vulnerability assessment, including an exposure analysis, sensitivity analysis, and adaptive capacity ranking. It provides choices for each of the condensed assessment method steps and a recommendation grounded upon those choices and available information.

The report has also considered funding for such a project. Although its funds may not be directly available to conduct the assessment, the Coastal Zone Management Act Section 309 Funding for Projects of Special Merit may be able to support this project in parallel to the Community Resiliency Initiative (also funded by Section 309). A second NOAA grant that facilitates inquiries on the environmental impacts of sea-level rise may also be pursued. Finally, the Rockefeller foundation may be able to offer capacity and other support to DEO to conduct the statewide vulnerability assessment as part of its collaboration with communities to increase their understanding of climate effects through the HUD National Disaster Resiliency Competition. This guide recommends that once the assessment is completed, an online visualizer be developed to compliment other Florida sea-level rise visualizers and unite statewide sea-level rise adaptation planning. Finally, the guide reports on outreach efforts conducted between DEO and FDOT / UF that will set the stage for new layers of infrastructure and social characteristics to be displayed via the Sketch Planning Tool.

Input from focus group members about methodology choices will aid the optimal completion of a statewide vulnerability assessment. While recommendations have been made for the process, the flexible nature of this deliverable can accommodate changes that achieve greater consensus.

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Image Sources

1. Florida Outline, Figure 3: http://www.worldatlas.com/webimage/countrys/namerica/usstates/outline/fl.gif
2. River Basin image, Figure 3: http://www.virginiaplaces.org/chesbay/graphics/bathy.png
3. Person Icon, Figure 4: https://cdn1.iconfinder.com/data/icons/black-easy/512/538642-user_512x512.png
4. Computer Icon, Figure 4: http://icons.iconarchive.com/icons/cornmanthe3rd/metronome/512/System-computer-icon.png
5. Map icon, Figure 4: https://cdn1.iconfinder.com/data/icons/perfect-flat-icons-2/256/Maps_google_mobile_for_android_stack_sign.png
6. Cal-Adapt screenshot: http://cal-adapt.org/sealevel/
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9. Climate Central screenshot: http://sealevel.climatecentral.org/surgingseas/place/states/FL#show=cities&center=8/25.596/-80.995&surge=3
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Appendix 1: Auxiliary Materials

Five Steps of Vulnerability Analysis condensed – Discussion of the California Guide

The five steps of a Vulnerability Analysis, as explained by the California Emergency Management Agency (2012), are:

1. Exposure: What climate change effects will a community experience?
2. Sensitivity: What aspects of a community (people, structures, and functions) will be affected?
3. Potential Impacts – How will climate change affect the points of sensitivity?
4. Adaptive Capacity – What is currently being done to address the impacts?
5. Risk & Onset – how likely are the impacts and how quickly will they occur?

These five steps, although helpful in deconstructing the activities necessary to conducting a vulnerability assessment, can be consolidated in the case of a hazard that is already pinpointed. By concentrating on sea-level rise, the first step as defined above is unnecessary. Hence, *exposure* comes to mean the extent and manner in which sea-level rise affects the coast. Exposure can be projected via a SLAMM, bathtub, or other model. *Sensitivity* for the purpose of a DEO vulnerability assessment will mean an analysis of the model output (which should be point projection) for different "layers" of cartographic data. Creating new data layers entails collecting accurate shapefiles with not only Light Detection and Ranging (LiDAR) Digital Elevation Models (DEM), but also maps of census tract populations, infrastructure, land uses, and conservation areas. Potential impacts are subsumed under the *adaptive capacity ranking* procedure described above, wherein capital categories are given scores to assess each's ability to successfully deal with threat from sea-level rise inundation. Risk and onset are a function of the model and are subsumed under step one, exposure, for the purposes of the Florida DEO vulnerability assessment.

Projection Methods Comparison

The following figure is reproduced from "Sea-level rise Projection: Needs Capacities and Alternative Approaches" (Florida Planning and Development Lab, 2013). It looks into the parameters for nine of the most widely used sea-level rise projection methods. The 2100 estimates range by 2.06 meters, wherein the USEPA low estimate actually projects an insignificant *decline* (-.06m) and NOAA projects up to two meters of rise. The U.S. Army Corps of Engineers estimates, on the other hand, permit one half to one and a half meters of rise.

Table 3-3. Comparison of major sea level rise projection methods.

Projection Method	2100 Global Eustatic Sea Level Estimates (m)	Projection Benchmark	Projection Function Source	Adjusts for Local Vertical Land Movement	Data Presentation
Tide gauge trend (NOAA)	n/a	n/a	Linear fit to data	Yes	Trend line
USEPA (Titus & Narayanan, 1995)	-0.06 to 0.66	1990	Monte Carlo simulation & Delphi panels	Yes	Table (eustatic); calculate (relative)
IPCC TAR (Church et al., 2001)	0.11 to 0.77	1990	35 SRES scenarios and 6 AOGCMs	No	Curves/table
IPCC AR4 (Meehl et al., 2007)	0.18 to 0.76 (2090-2099)	~1990 (1980-1999)	6 SRES scenarios and 17 AOGCMs	No	Table
Vermeer and Rahmstorf (2009)	0.81 to 1.79	1990	Semi-empirical projection	No	Curves
SLAMM (Clough et al., 2010)	Flexible	1990	User option or IPCC(2001) for SRES A1B	Yes	Point projection
USACE Curve Calculator (2011)	0.5, 1.0, 1.5 (NRC, 1987)	1992	Expert opinion (NRC, 1987)	Yes	Curves/table (eustatic);
NOAA (Parris et al., 2012)	0.2 to 2.0	1992	Expert opinion (NRC, 1987)	No	Curves
NRC (2012)	0.50, 0.83, 1.40	2000	Curve fit to SRES A1B and extrapolation of ice sheet mass balance	No	Curves/table

From the method/model recommended by this report, FDOT built the USACE Curve Calculator Method into their own point projection extension for ArcGIS. The integrated USACE curve calculator accounted for tide gauge averages (when applicable) at each of the seven transportation districts and resulted in seven regionally-specific sea-level rise point projections. This diversification of projection numbers does not result in confusion, since the sea-level rise Geoplan Sketch Tool provides planning-appropriate resolutions for all parts of the state. It also reinforces the best practice that no two planning entities will have identical vulnerabilities to sea-level rise.

At this point, an exposure analysis requires decisions to be made concerning the way in which DEMs will be used within the projection analysis. For a good discussion of the ways in which land/sea barriers, transportation data, and the "fishnet" analysis tool were used to generate the most accurate projection of affected areas, the Southeast Florida Regional Climate Change Compact (Southeast Florida Regional Climate Change Compact Inundation Mapping and Vulnerability Assessment Work Group, 2012) explain the raft of decisions made to accompany their own sea-level rise vulnerability assessment analysis in Appendix C. For the purpose of their report, a bathtub, or simple inundation model was used; however, adaptations were made to this model, including removing the coastal water feature while preserving inland water bodies. In this respect, an exposure analysis (as well as sensitivity analysis) will always require 'cleaning' and 'processing' raw GIS data in order to achieve the most accurate depiction of:

a) Where water will actually inundate, and at what percentage of each unit of analysis
b) What the values contained within each unit (e.g. census tract, raster, etc.) will be.

In much the same manner, sensitivity analyses need for decisions to be made in order to clean and process data in order to be analyzed. One good example from the SeFRCCC example involved calculating buffers around road centerline data provided by FDOT NAVTEQ software. Whereas the centerline file counted only the middle of each road feature, additional space needed to be accounted for in the event of potential sea-level rise flooding. Appropriate buffers were established by applying a 12-foot buffer addition, per lane of traffic, which was found by road information taken from the attribute table (Southeast Florida Regional Climate Change Compact Inundation Mapping and Vulnerability Assessment Work Group, 2012).

Adaptive Capacity Ranking Table Example:

County	Regulatory	Administrative	Fiscal (in millions)	Infrastructure	Total Score	Total Standardized Score
Alachua	3	10	3	3	19	
Broward	6	15	5	4	30	
Monroe	5	14	3	3	25	
Levy	2	8	2	2	14	
Standardized Scores						
Alachua	.25	.29	.33	.5		1.37
Broward	1	1	1	1		4.00
Monroe	.75	.86	.33	.5		2.44
Levy	0	0	0	0		0.00

In the above table, values are awarded as follows:

Regulatory Capacity: Equals the number of sea-level rise-adaption supporting policies *less* the number of sea-level rise-adaptation obstructing policies (Data Source: community planning office)

Administrative Capacity: Equals the number of planners + marine biologists + coastal engineers + GIS sea-level rise mapping resources and modelling software available to the county for consultation. (Data source: community planning office)

Fiscal Capacity: Equals the taxes + bonds + grants + impact fees + withheld spending in hazard zones (Data Source: community planning office)

Infrastructure Capacity: Equals the number of flood and erosion control structures, evacuation routes, redundant systems and other adaptation structures (Data Source: community planners)

Total Score: Addition of all preceding column entries, by row

Standardized Score: $SS = \frac{Total\ Score_n - Min\ Score}{Max\ Score - Min\ Score}$

Wherein:

Total $Score_n$ is each row's individual score,

Min Score is the minimum overall Total Score

Max Score is the maximum overall Total Score