RECOMMENDED PROJECTIONS OF

Sea Level Rise
in the Tampa Bay Region

Tampa Bay Climate Science Advisory Panel

Updated April 2019

EXECUTIVE SUMMARY

In this document, the Tampa Bay Climate Science Advisory Panel (CSAP) recommends a common set of sea level rise (SLR) projections for use throughout the Tampa Bay region. The recommendation establishes the foundation for a coordinated approach to address the effects of a changing climate, which advances the objectives of the newly-established Tampa Bay Regional Resiliency Coalition. Local governments and other agencies planning for SLR in the Tampa Bay region should incorporate the following key findings of this CSAP recommendation.

- Data measured at the St. Petersburg tide gauge shows that water levels in Tampa Bay have already increased approximately 7.8 inches since 1946.
- Based upon a thorough assessment of scientific data and literature, the Tampa Bay region can expect to see an additional 2 to 8.5 feet of SLR by 2100.
- Projections of SLR should be consistent with present and future National Climate Assessment estimates and methods. The National Oceanic and Atmospheric Administration (NOAA) Low scenario should not be used for planning purposes.
- Projections of SLR should be regionally corrected using St. Petersburg tide gauge data.
- Adaptation planning should employ a scenario-based approach that, at minimum, considers location, time horizon, and risk tolerance.

INTRODUCTION

Formed in spring 2014, the CSAP is an ad hoc network of scientists and resource managers working in the Tampa Bay region (Figure 1). The group's goal is to collaboratively develop science-based recommendations for local governments and regional agencies as they respond to climate change, including associated sea level change. The CSAP first released a recommended projection of SLR in the Tampa Bay region in 2015. The original recommendation (CSAP 2015) included a set of projections that were regionally corrected to the St. Petersburg tide gauge and consistent with the 3rd National Climate Assessment (NCA3). The original guidance called for the recommendation to be revisited at a minimum of every five years, or sooner if significant new scientific information on future SLR became available.

Figure 1. *Map of the four-county region served by the CSAP.*

This document, which is an update of the 2015 report, assesses the 4th National Climate Assessment (NCA4) that was released in November 2018 and recently published literature synthesizing observed changes in sea level using satellite altimetry (Nerem et al. 2018). The update explains the technical methods used to produce SLR projections and offers the rationale for the selection of SLR projections recommended for the Tampa Bay region through 2100. With these shared projections, local governments can coordinate, develop, and implement appropriate coastal adaptation and risk reduction strategies.

Storm surge
Source: Pinellas County

The Tampa Bay region, with nearly 700 miles of shoreline and 3 million residents – most of whom live near Tampa Bay or the Gulf of Mexico – is highly vulnerable to the potential effects of SLR (BEBR 2019). Citizens, emergency managers, and regional leaders have been accustomed to thinking of hazards in terms of the episodic effects of hurricanes or coastal storms; however, it is also important for local governments and regional agencies to consider the long-term, sustained effects of SLR on real property, quality of life, and perhaps most importantly, our ability to sustain growth in the regional economy.

The Tampa Bay regional economy is closely tied to both the Gulf of Mexico and Tampa Bay. It is valued at $170 billion, with $51 billion directly influenced by the bay itself (TBEP and TBRPC 2014). A number of recent reports have identified the Tampa Bay region as one of the most vulnerable coastal metropolitan areas throughout the world due to SLR and flooding (World Bank 2013, Climate Central 2017). Regional measurements show the Tampa Bay region is already experiencing SLR (Figure 2, p. 5) and there is broad scientific consensus that this trend will continue into the next century. If adaptation strategies are not implemented, cities throughout the Tampa Bay region will likely experience the following conditions, all of which may incur substantial economic costs:

- Flooding of public infrastructure and private property;
- Shoreline and beach erosion;
- Impacts to the operation and management of coastal drainage systems;

- Threats to drinking water and wastewater treatment facilities and distribution infrastructure; and
- Shifts in wetlands and other tidal habitats, resulting in the loss of ecosystem services.

City skyline
Source: City of Tampa

The economic costs of inaction given the known threats of SLR must be carefully weighed against the costs of implementing adaptation strategies, technological solutions, and infrastructure investments necessary to protect the health, safety, and quality of life for the community. The Tampa Bay Regional Planning Council estimates that without a coordinated response, the regional economy may lose more than $15 billion in real estate value, $5 billion in property tax revenue, and approximately 17,000 jobs as a direct result of SLR (TBRPC 2017). However, local governments in the Tampa Bay region should feel confident that there are viable opportunities to implement adaptation strategies that increase resilience to SLR and other coastal hazards and protect the region from substantial economic losses. These opportunities benefit from a common set of regional SLR projections that promote coordinated planning and policy efforts; providing such a projection is the fundamental purpose of this recommendation.

TECHNICAL METHODS AND RECOMMENDATIONS

Estimates of future SLR are typically expressed by plotting or tabulating a quadratic function. This function is chosen because it is the simplest mathematical function that can effectively capture a wide range of possible SLR scenarios, from a constant rate of increase to various accelerated rates of increase. Defining a specific SLR scenario requires three numbers: a datum, the point in time the sea level is defined to be zero; a rate of change, how rapidly sea level is changing (increasing or decreasing) at time zero; and a projection, the amount global sea level is expected to change between time zero and some point in the future[1].

[1] Most often, this point in the future is the year 2100. However, this does not mean that SLR will stop in 2100, nor does it mean that we only know what the predicted sea level will be in 2100. The quadratic function can show possible sea levels at any point along the curve, between now, 2100, and beyond.

Both the datum and the rate of change are defined using present-day observations from a tide gauge proximate to the region of interest. Local sea level change rates reflect a variety of local factors, including vertical land motion (subsidence or uplift) and changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns, and hydrologic cycles (river flow). So, while global measurements and projections are important for estimating SLR, local measurements and projections are needed for realistic regional planning efforts. For the Tampa Bay region, the CSAP recommends using data collected from the tide gauge located near downtown St. Petersburg to adjust the first two parameters necessary to predict regional SLR. The St. Petersburg tide gauge (NOAA 2019a) has the longest reliable period of record in the region and is consistent with other nearby tide gauges, including one located in the Gulf of Mexico at Clearwater (NOAA 2019b). Data measured at the St. Petersburg tide gauge shows that water levels in Tampa Bay have increased 7.8 inches (~1 inch/decade) since 1946 when water levels were first recorded at this tide gauge (Figure 2).

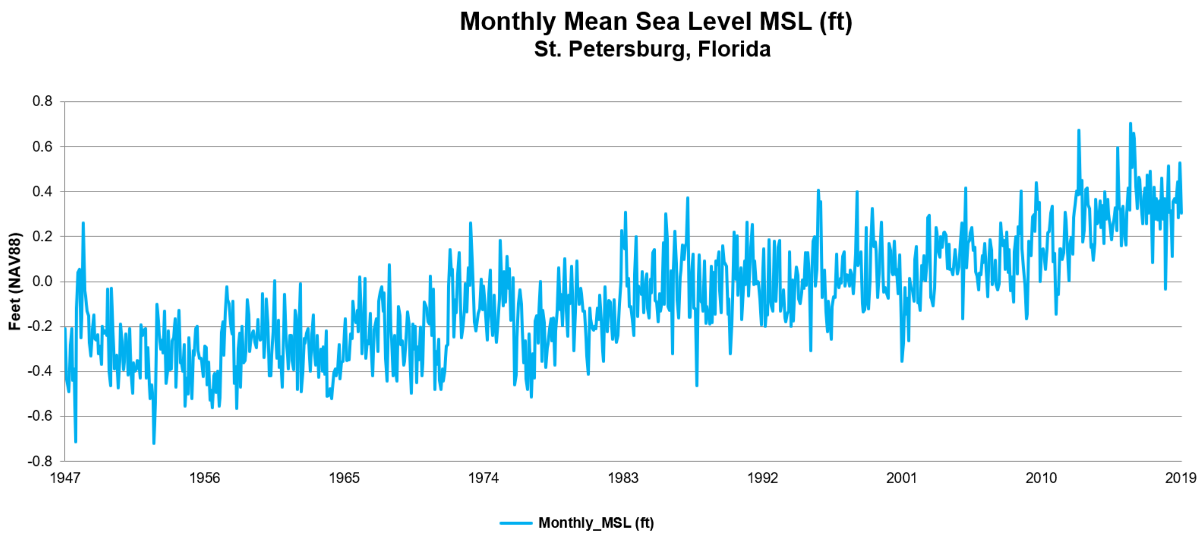

Figure 2. *1946-2018 Monthly Mean Sea Level Trend in St. Petersburg, FL, NOAA Tide Gauge #8726520*

The final parameter, projections of how much sea level will change globally over the next 100 years, is derived from expert climate scientists. Currently, there are two primary sources of information regarding SLR projections: the Intergovernmental Panel on Climate Change (IPCC), and the U.S. National Climate Assessment (NCA). Although these assessments employ different methods (IPCC relies upon numerical process models; the NCA employs a semi-empirical, probabilistic approach to estimate contributions from oceanic, cryosphere, geologic, and anthropogenic processes), both approaches result in similar estimates of SLR. This implies that the results obtained through either approach are robust and should provide practitioners with a higher degree of confidence in using the recommended projections for planning purposes.

The National Oceanic and Atmospheric Administration (NOAA) Technical Report, *Global and Regional Sea Level Rise Scenarios for the United States* (Sweet et al. 2017b), was produced as a coordinated, interagency task force to identify nationally agreed-upon estimates for global and regional SLR to inform the 4th National Climate Assessment (hereinafter the NOAA projections). Notably, the report incorporates regional factors contributing to sea level change for the entire U.S. coastline and assigns conditional probabilities to six SLR projections based on future greenhouse gas emissions and associated ocean-atmosphere warming in order to help decision-makers assess and manage risk (Sweet et al. 2017a). These scenarios, known as representative concentration pathways (RCPs), describe four different 21st-century pathways of greenhouse gas emissions and atmospheric concentrations, air pollutant emissions, and land use (IPCC AR5) which are necessary for understanding future sea level change.

Habitat migration; Cypress tree stump in a salt barren
Source: Doug Robison

The CSAP advises that local governments and regional agencies continue to use the SLR scenarios included in the NCA, adjusted to local conditions, to inform adaptation and infrastructure planning efforts in the Tampa Bay region. Although the CSAP generally recommends following the NCA, only three of the six SLR scenarios included in the NCA4 are part of this recommendation: NOAA Intermediate-Low, Intermediate, and High. Further, until the private and public sectors make meaningful efforts to reduce greenhouse gas emissions, the CSAP advises that local governments and regional agencies assess the likelihood of the three SLR scenarios using RCP 8.5, which models climate change without additional efforts to constrain emissions (Van Vuuren et al. 2011, IPCC AR5).

Additional evidence published in 2018 was evaluated and incorporated into the updated recommendation. This recently published work, which was not available at the time the NCA4 was developed, uses satellite altimetry data to assess the rate of global sea level change (Nerem et al. 2018). Satellite radar altimeters have been measuring the open ocean surface height (sea level) since 1993 by quantifying the time it takes a radar pulse to make a round-trip from the satellite to the sea surface and back. Observed (not modeled) changes over 25 years demonstrate that the rate of SLR is increasing and that the increase is consistent with the mathematical models used to inform the IPCC and NCA. Based on these validating observations, the NOAA Low scenario (which depicts a linear rate of rise with no projected acceleration) is very unlikely and should be excluded. Therefore, the CSAP recommends that entities planning for SLR use the NOAA Intermediate-Low scenario as the lowest plausible bound for future sea level change.

Bayboro, St. Petersburg; sunny day flooding
Source: Maya Burke

Similarly, the NOAA Extreme scenario represents the maximum ice sheet melt that is physically possible. However, the probability of this occurrence is exceptionally low and not yet supported by established science. There is, however, emerging science that suggests there may be a new instability mechanism in the ice sheets that would lead to significantly higher melt rates (Alley et al. 2019). While this is not yet scientifically vetted, it does suggest that long-term sea level changes may be higher than the current best available science supports. Therefore, the CSAP recommends that entities planning for SLR use the NOAA High as the upper bound for future sea level change until additional information related to ice sheet processes is settled. The CSAP will continue to monitor this rapidly-evolving field of research.

Finally, the NOAA Intermediate scenario is recommended to fully capture the plausible range of likely SLR given the probabilistic framework laid out in the NCA4.

Future SLR estimates consistent with this recommendation that integrate data from the local St. Petersburg tide gauge, can be calculated for the Tampa Bay region using a flexible, well-supported tool developed by the U.S. Army Corps of Engineers (USACE)[2]. The tool takes the three parameters discussed above (datum, rate of change, projection) and produces the plots or tables that describe how sea level will change in the future, such as those included as Figure 3 and Table 1.

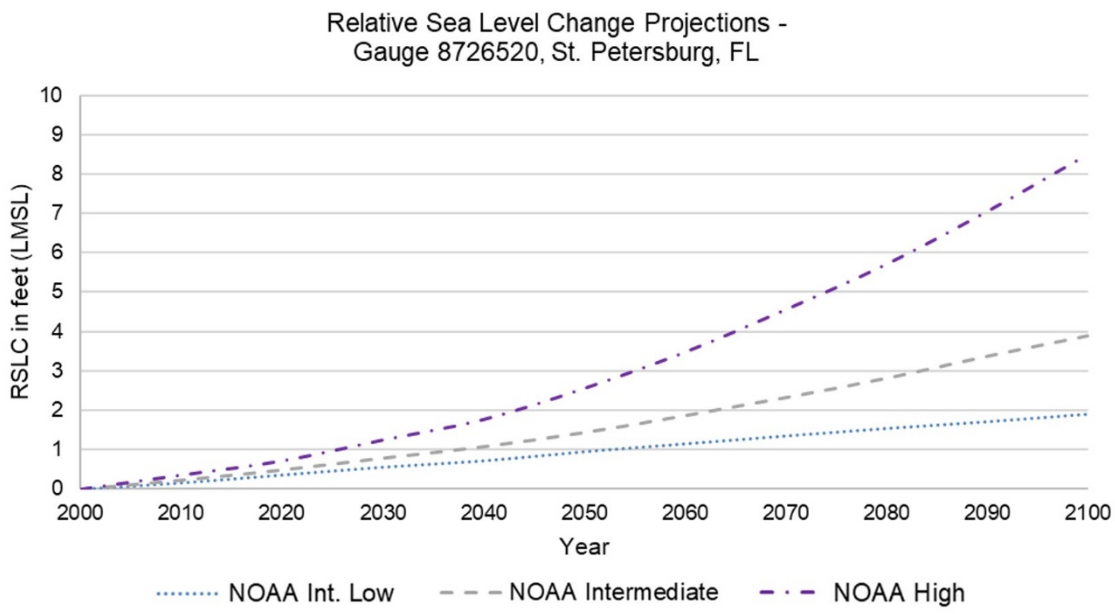

Figure 3*. Graphic Relative Sea Level Change (RSLC) Scenarios for St. Petersburg, Florida, as calculated using the regionally corrected NOAA 2017 curves. (USACE 2019)*

The regionally adjusted NOAA SLR projections (Table 1 and Figure 3) can be summarized as follows:

[2] When using the USACE Sea Level Change Curve Calculator Tool, first select the "St. Petersburg, FL" gauge, then choose "NOAA 2017" as the output agency. Although the CSAP recommends using the USACE Sea Level Change Curve Calculator Tool, this should not be confused with a recommendation of the USACE SLR projections. Although the USACE SLR projections produce results that are similar to that of the IPCC and NCA, they are based on equations developed in 1987 for the National Research Council (NRC) report, *Responding to Changes in Sea Level; Engineering Implications* and do not represent the best available science.

- *NOAA Intermediate Low (1.9 feet by 2100)*: This scenario represents a slight increase in the rate of SLR. The low end of the *very likely* range if greenhouse gas emissions continue current trends (RCP8.5).
- *NOAA Intermediate (3.9 feet by 2100)*: This scenario represents a moderate increase in the rate of SLR. The high end of *likely* range if greenhouse gas emissions continue current trends (RCP8.5).
- *NOAA High (8.5 feet by 2100)*: This scenario represents a significant increase in the rate of SLR. The high end of the *very likely* range if greenhouse gas emissions continue current trends (RCP8.5) and when accounting for possible ice sheet instabilities.

Year	**NOAA Int-Low** (feet)	**NOAA Intermediate** (feet)	**NOAA High** (feet)
2000[3]	0	0	0
2030	0.56	0.79	1.25
2040	0.72	1.08	1.77
2050	0.95	1.44	2.56
2060	1.15	1.87	3.48
2070	1.35	2.33	4.56
2080	1.54	2.82	5.71
2090	1.71	3.38	7.05
2100	1.90	3.90	8.50

Table 1. *Sea Level Change Relative to the Year 2000 for St. Petersburg, FL in Feet above Local Mean Sea Level (LMSL).*

Future sea level estimates are provided in tabular form to help planners and policymakers apply the CSAP recommendations in everyday practice; however, additional clarification is necessary to ensure that the projections are used appropriately. SLR projections should only be used to determine the change in sea level between any two given time periods. For example, Table 1 shows sea level change in 2100 under the NOAA High scenario as 8.50 feet. This means that the sea level height at any location is projected to be 8.50 feet higher on average than it was at that site in the year 2000.

[3] For the purposes of projecting sea level change, the year 2000 is the starting point for the recommended SLR scenarios. Although this represents a point in time the sea level is defined to be zero, it does not mean that sea level change has not occurred prior to that time.

Similarly, consider a hypothetical situation where a government constructs an infrastructure project in 2030. The costs and risk tolerance associated with the project are moderate. Elected officials have requested that the project withstand at least 30 years of likely SLR. Staff needs to calculate how much additional elevation to incorporate into a modified project design. The appropriate calculation to determine the necessary modifications would be as follows:

1. Select an appropriate SLR projection scenario. (NOAA Intermediate)
2. Determine the sea level at time zero. (0.79 feet)
3. Determine the projected sea level at a known point in the future. (1.87 feet)
4. Calculate the difference between projected SLR at a known point in the future and SLR at time zero. (1.08 feet)

In this example, an additional 1.08 feet above the observed sea level in 2030 would be needed to make the infrastructure project more resilient to future conditions in 2060.

SUMMARY

Based upon a thorough assessment of scientific data and literature on SLR, the Tampa Bay region can expect to see approximately 1 to 2.5 feet SLR by 2050 and between 2 to 8.5 feet by 2100.

Wastewater Treatment Plant
Source: Manatee County

Given this range of uncertainty in future SLR, the CSAP recommends that local governments and other agencies consider a variety of factors, including the expected lifespan of the project, project cost, and criticality of function when developing adaptation strategies. Scenario planning offers opportunities to initiate actions now by balancing the costs of inaction against reasonable returns on investments made to reduce future impacts on the built environment (Figure 4).

For example, decision-makers may decide to plan for less SLR (using the NOAA Intermediate Low) when implementing projects with greater risk tolerance such as infrastructure projects with a relatively short life cycle or those with high adaptive capacity (e.g. a waterfront park or parking lot), while they may choose to plan for more extreme SLR (using the NOAA High) in situations where there is little tolerance for risk (e.g. new infrastructure with a long-anticipated life cycle such as a power plant) (NOAA 2012). The level of adaptation planning necessary will be up to the planning entity and based on the acceptable level of risk and vulnerability. The CSAP anticipates working with the Tampa Bay Regional Resiliency Coalition to develop detailed guidance on the appropriate application of each scenario in various risk contexts.

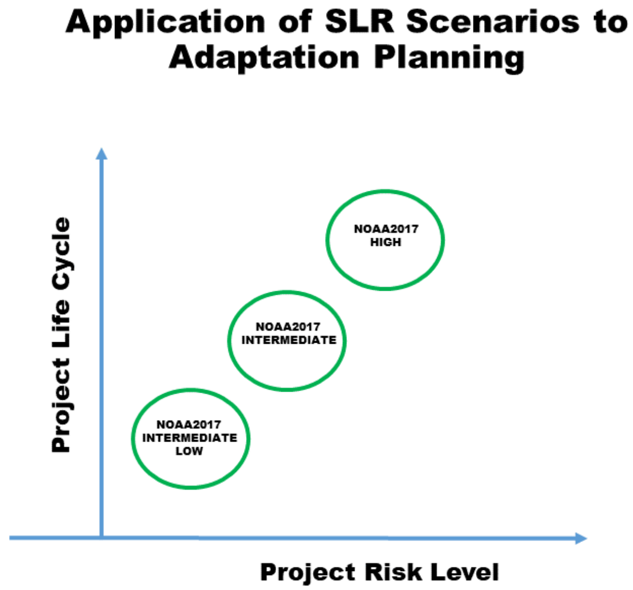

Figure 4. *Conceptual diagram demonstrating how to apply SLR scenarios to risk-based decision-making.*

Selecting a common set of SLR projections throughout the Tampa Bay region will advance the objectives of the newly-established Tampa Bay Regional Resiliency Coalition, supporting the efficient development and intergovernmental sharing of vulnerability assessment information and related policies. Furthermore, use of a regional set of projections of SLR will enable other entities to develop decision support tools, best practices, and planning documents to inform adaptation strategies for those charged with managing public infrastructure and natural resources. The CSAP recommendation is intended to further these goals, but it is important to acknowledge that scientific research advances as a continuous process. New data and technologies require refinements and reevaluation over time. In order to keep up with the best available science, the CSAP commits to revisit this recommendation in five (5) years, at a minimum, or sooner if significant new scientific information on future SLR becomes available.

Mangroves growing into road
Source: Dave Tomasko

Local governments and other agencies planning for SLR in the Tampa Bay region should incorporate three key findings of the CSAP recommendation:

- Projections of SLR should be consistent with present and future National Climate Assessment estimates and methods. The NOAA Low scenario should not be used for planning purposes.
- Projections of SLR should be regionally corrected using the St. Petersburg tide gauge data[4].
- Adaptation planning should employ a scenario-based approach that, at minimum, considers location, time horizon, and risk tolerance.

A resilient Tampa Bay region – one that acknowledges and responds to coastal vulnerabilities – is one that can support continued economic, environmental, and cultural prosperity for many years to come.

Weedon Island Preserve
Source: Pinellas County

[4] The Cedar Key tide gauge should be used for Citrus and Hernando counties, which are part of the Tampa Bay Regional Resiliency Coalition.

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LIST OF ACRONYMS

CSAP	Tampa Bay Climate Science Advisory Panel
IPCC	United Nations Intergovernmental Panel on Climate Change
LMSL	Lower Mean Sea Level (average tidal measurement)
NCA	U.S. National Climate Assessment
NCA3	3rd National Climate Assessment
NCA4	4th National Climate Assessment
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
RCP	Representative Concentration Pathway
RSLC	Relative Sea Level Change
SLR	Sea Level Rise
USACE	United States Army Corps of Engineers

DEFINITION OF TERMS

Datum	The base elevation used as a reference from which to reckon heights or depths; the point in time that sea level is defined to be zero.
Projection	The numerical value of sea level change between time zero and some point in the future.
Rate of Change	How rapidly sea level is changing (increasing or decreasing) at time zero.
Scenario	The quadratic function that shows possible sea levels at any point along the curve, between time zero and some point in the future.
Tool	Processes the datum, rate of change and projection to produce the plots or tables that describe how sea level will change in the future (e.g. USACE Sea Level Change Curve Calculator).

GROUP COMPOSITION

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