

GUIDANCE FOR INCORPORATING SEA LEVEL RISE INTO CAPITAL PLANNING



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Introduction

Pinellas County, with nearly 590 miles of coastline and a million residents, is susceptible to the impacts of sea level rise (SLR). The county is vulnerable to coastal flooding from the Gulf of Mexico to the west, Tampa Bay to the south and east, and the Anclote River to the north. Our Gulf Beaches are subject to significant erosion from tropical and winter storms and waves; during extreme high tides water backs up into the stormwater system and seawalls are overtopped; and during significant rain events coupled with high tides, low lying areas experience flooding and property damage. Projected SLR will worsen these existing hazards by increasing the elevation and frequency of flooding, extending the

coastal high hazard zone further inland, and accelerating shoreline erosion. As a consequence of rising sea levels, areas that currently experience infrequent flooding will be inundated more often. Sea level rise poses a long-term and increasing threat for Pinellas County. As new infrastructure projects are planned, or existing assets are modified or improved, flooding and other impacts exacerbated by SLR must be considered in the decision making process.

This Guidance provides a framework for evaluating SLR within the capital improvement program process. The document also outlines key issues related to SLR adaptation measures; however, specific adaptation measures and approaches are not provided. The number of possible adaptation strategies is continuously changing and selecting the appropriate adaptation methods requires site and project specific information that will emerge at the technical committee level, informed by this Guidance, and coordinated through the capital planning process.

A resilient Tampa Bay, one that acknowledges and responds to coastal vulnerabilities, is one that can support the economic, environmental, and cultural prosperity of this unique and highly valuable region.
CSAP, 2015

This Guidance provides direction to all Divisions within the Public Works Department on how to incorporate SLR into capital improvement and maintenance projects. The Guidance identifies and describes four key steps for assessing and adapting to the effects of SLR in capital planning:

- 1. Climate Science:** What is the current science and what are the local projections for SLR?
- 2. Vulnerability Assessment:** Which assets are vulnerable to SLR?
- 3. Risk Assessment:** Which assets are at greatest risk to SLR?
- 4. Adaptation Measures:** What can we do to improve the asset's resiliency to impacts from SLR?

Finally, urban flooding that occurs when the stormwater system exceeds its capacity is not specifically addressed by this Guidance. Sea level rise will exacerbate urban flooding, particularly when significant rainfall events coincide with high tides; therefore, this Guidance document can be used to assess urban flooding events in light of SLR. Some projects may require consideration of additional climate change impacts such as changes in intensity and frequency of rainfall to fully quantify climate change related vulnerability and risk.



Capital Planning Program

This Guidance provides Division Directors, project managers, and technical staff with a step-by-step approach for considering SLR vulnerability, risk, and adaptation planning within their Division capital plans and projects. The Public Works Director will use this Guidance to determine if SLR vulnerabilities, risk, and adaptation have been adequately assessed. If all Divisions follow this Guidance when developing their projects and capital plans, the Public Works' capital program will improve the resilience of the county's public infrastructure to anticipated SLR.

It is recognized that some projects may need to address SLR on a larger scale rather than at the individual project level. An example would be a regional park. For those instances where SLR has been addressed at the larger scale, future individual projects within the area must satisfy the requirements of the regional project. An example would be a new picnic area or recreational facilities within a regional park. In these cases, the Guidance (as updated) should still be used to prepare capital plans and projects and applied as individual projects are implemented within the larger project area, but should remain consistent with the regional assessment (as updated).



While the primary responsibility for developing projects and capital plans resides within each Division, the Public Works Director and the County Administrator’s Office encourage and support collaborative planning across Divisions and County Departments. This Guidance facilitates the use of a common approach across all project types. Recommendations include using the same underlying science, tools, and methods, providing for seamless collaboration and integration. This collaboration is most critical where infrastructure, and the adaptation plans needed to address the vulnerabilities of that infrastructure, cross Departments such as Public Works, Utilities, Parks, and others.

Updates to the Guidance Document

All assessments should utilize the SLR scenarios set forth by the Tampa Bay Climate Science Advisory Panel (CSAP, 2015) as updated. CSAP will periodically update the regional SLR scenarios based on the latest climate science; and, as warranted, the Guidance will be amended accordingly.

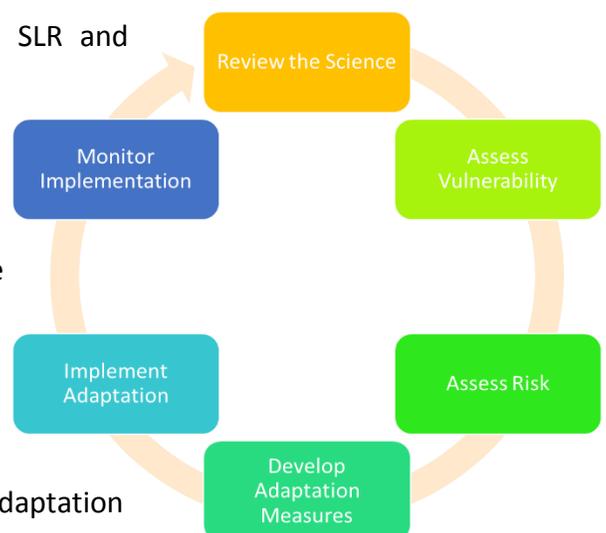
Early in 2018, the County is flying new LiDAR which will be used to create a new Digital Elevation Map (DEM). When the new DEM is available, the data will be used to update the County inundation maps and will be shared with other agencies including the U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), and the University of Florida (UF) for inclusion in their mapping and analysis.

Additionally, the County is undertaking an assessment of critical infrastructure to impacts of SLR and storm surge. Upon completion of this project, the Guidance and associated tools will be updated.

Lastly, any updates to the County mapping tools utilized in this Guidance will be updated in accordance with the data providers to ensure the best available science is utilized in the decision making process.

Guidance Outline

Many state and local governments are preparing for the impacts of SLR through adaptation or the practice of planning for anticipated changes in SLR and developing strategies to address potential impacts. Planning efforts must incorporate the latest climate science to determine how to protect and modify existing assets and design new assets to be more resilient to rising seas. Adaptation planning requires the consideration of uncertainty and risk, because the science supporting SLR and climate change projections has many underlying uncertainties. As such, a robust adaptation plan requires that potential adaptation strategies be revisited as the science progresses and projections are updated. While adaptation planning can take many forms, the process of assessing SLR vulnerability and risk follows some basic steps:



1. Review the Science

- a. Sea level rise estimates
- b. Sea level rise scenario selection
- c. Sea level rise inundation mapping

2. Vulnerability Assessment

- a. Exposure: degree to which an asset is unprotected or left in a vulnerable state (e.g., depth of flooding due to SLR)
- b. Sensitivity: degree to which an asset is impacted (e.g., temporary flooding causes minimal impact or results in complete loss of asset or shut-down)
- c. Adaptive Capacity: ability of an asset to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or cope with the consequences

3. Risk Assessment

Evaluate consequences to help set priorities for adaptation planning (i.e., cost of reconstruction or repair, economic impact of disruption, length of disruption, irreversibility of impact)

4. Adaptation Planning

Identify, prioritize, and incorporate means to reduce, mitigate, or protect from unacceptable risks.

- a. Identify adaptation strategies and approaches to protect assets and increase adaptive capacity
- b. Prioritize strategies based on risk levels, sequence of expected impacts, and adaptive capacity
- c. Timing of strategies: when do they need to be implemented?

The following sections provide an overview of each of the steps outlined above.

Section 1. Review the Science

Adaptation to SLR begins with an understanding of the current science on SLR. The science associated with SLR is continually being updated and improved. Although there is clear evidence that sea levels have risen and will continue to rise over the coming century, it is difficult to predict with certainty what amount of SLR will occur at any given time in the future. The uncertainty increases over time (e.g. the uncertainties associated with 2100 projections are greater than with 2050 projections) because of uncertainties in future greenhouse gas (GHG) emissions trends, the evolving understanding of the sensitivity of climate conditions to GHG concentrations, and the overall capabilities of climate models. Given these uncertainties, the SLR projections presented in this guidance draw on the best available science on the potential effects of SLR in the Tampa Bay area as of October 2015.

The Tampa Bay Climate Science Advisory Panel (CSAP), formed in spring 2014, is an ad hoc network of scientists and resource managers working in the Tampa Bay region (Pinellas, Hillsborough, Manatee, and Pasco counties). The advisory panel developed recommendations for local governments and regional agencies as they make decisions about responding to climate change and associated SLR. CSAP assessed the best available scientific data to develop a regional set of projection scenarios through 2100.

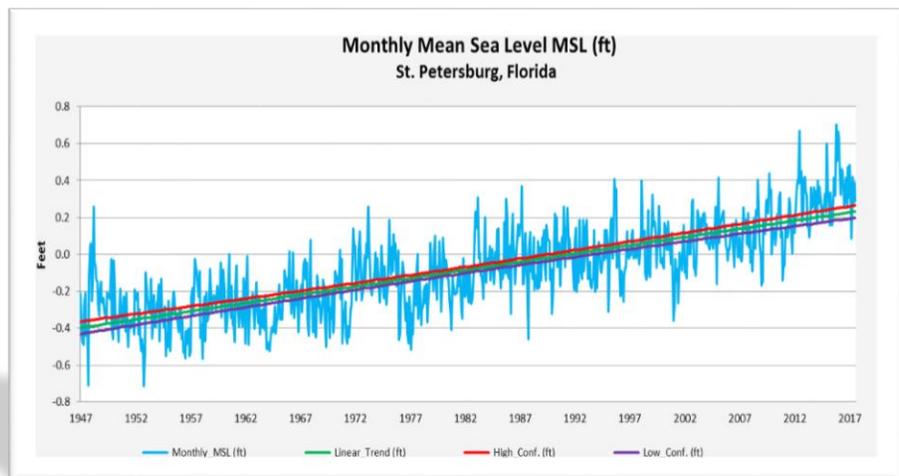
Technical Methods and Recommendations (CSAP, 2015)

Estimates of future SLR are generally expressed by plotting or tabulating a quadratic function. This function is used because it is the simplest function that can effectively capture a wide range of possible SLR scenarios, including constant increasing, rapidly increasing, or decreasing sea levels. Defining a specific SLR scenario requires three numbers: a datum, the point in time 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.

Both the datum and the rate of change are defined using present day observations from a local tide gauge. Local rates of sea level change reflect a variety of factors, including vertical land motion (subsidence or uplift), changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns, and hydrologic cycles. So, while global measurements and projections are important for estimating SLR, local measurements and projections are needed for representative local planning efforts. For communities in the Tampa Bay region, CSAP recommends using data collected from the tide station located near downtown St. Petersburg as the basis for adjusting the first two parameters that are needed to predict regional SLR. The St. Petersburg tide station has the longest reliable period of record (1946 to present) in the region and is consistent with other nearby tide stations, including one located in the Gulf of Mexico in Clearwater.

Data measured at the St. Petersburg tide station shows that water levels in Tampa Bay have increased approximately 6.6 inches or approximately 1 inch/decade.



The final parameter, projections of how much sea level will change globally over the next 100 years, is derived from climate science experts. Currently, there are two primary sources of information regarding SLR projections: the Intergovernmental Panel on Climate Change (IPCC) and the US National Climate Assessment (NCA). Although these assessments employ different methods (IPCC relies upon numerical process models; the NCA uses semi-empirical models), both produce estimates of SLR that are consistent with the other. 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 2012 NOAA Technical Report, *Global Sea Level Rise Scenarios for the United States National Climate Assessment*, was a collaborative interagency effort to identify nationally agreed upon estimates for global SLR. The projections included in the report are reviewed every five years in concert with the NCA and the projections use the most current science available. For these reasons, CSAP recommends that local governments and regional agencies use the set of four global SLR scenarios included in the NCA (hereinafter the NOAA SLR projections), adjusted to local conditions, to inform adaptation and infrastructure planning efforts in the Tampa Bay region.

Future SLR estimates can be calculated for the Tampa Bay region, integrating data from the local St. Petersburg tide gauge, using a tool developed by the United States Army Corps of Engineers (USACE). The tool takes the three parameters discussed above (datum, rate of change, and projection) and produces the plots or tables that show how sea level may change in the future, such as those included as Table 1.

In January 2017, NOAA published *Global and Regional Sea Level Rise Scenarios for the United States*. This technical report was used to inform the *Draft 2018 National Climate Assessment* (NCA). It is anticipated that the NCA will be finalized by the end of 2018. At that time, CSAP will review the revised science and develop a recommendation for revisions to the regional SLR projections for the Tampa Bay area. The full CSAP report is available in Appendix A.

a. Sea Level Rise Estimates

Table 1. Relative (to 1992) Sea Level Change Scenarios for St. Petersburg, Florida in Feet above Local Mean Sea Level (CSAP, 2015)

YEAR	NOAA LOW (FT)	NOAA INT LOW (FT)	NOAA INT HIGH (FT)	NOAA HIGH (FT)
2025	0.28	0.38	0.60	0.84
2035	0.37	0.53	0.90	1.31
2050	0.50	0.80	1.46	2.22
2065	0.63	1.10	2.15	3.35
2075	0.71	1.33	2.68	4.23
2100	0.93	1.97	4.26	6.89

b. Sea level rise scenario selection

The selection of the appropriate SLR scenario(s) for the vulnerability and risk assessment of a particular asset or set of assets can be challenging. There are several factors that should be used to guide scenario selection (See Section 1 in Tab 1 in the spreadsheet tool):

- **Functional Lifespan:** How long will the project be in use at this location (Including O&M)?
- **Location:** Is the project located in a [vulnerability zone](#) during its lifespan
- **Planning Horizon:** The date construction is complete + the functional lifespan.

Capital planning efforts should consider both the lifespan and the location of their project as they evaluate SLR vulnerabilities and risks and plan to accommodate or adapt to future SLR. Typically, a planning horizon is aligned with a project’s design life. The design life is the period of time during which the asset or facility is expected to perform within specified parameters; in other words, the life expectancy as constructed. However, most structures and facilities are in service far beyond their design life. An asset might have a design life of 50 years, but in reality may be in service for 65 or more years with routine operation and maintenance (O&M).

The functional lifespan, rather than design life, is needed for assessment of vulnerability to SLR. To distinguish between engineering design life and the true, reasonable life expectancy of the asset, and the timeframe for assessment, this Guidance uses the term functional lifespan to refer to the period an asset will likely remain in place through multiple O&M cycles.

Projects should adopt a planning horizon based on the functional lifespan of the project. To determine the projected functional lifespan, consider how long the project will be in use at this location, factoring in regular repair and maintenance. For example, a seawall may have a 30-year design life; however, it may be projected to be in service at the selected location for 50 or more years, although the wall may undergo significant rehabilitation during that timeframe. In this case, the functional lifespan would be 50 years; therefore, the planning horizon would be $2020 + 50 = 2070$ (assuming 2020 is year construction is complete).

If the asset is an existing asset, to calculate the planning horizon, use the year the asset was constructed. For example, if the seawall was originally constructed in 2000 and it has a functional lifespan of 50 years the project planning horizon would be $2000 + 50 = 2050$.

Project managers may choose to plan now for the high end of the range (6.89 feet by 2100) particularly for assets that must maintain their functionality if inundated. Alternatively, it may be appropriate to plan for a lesser scenario (e.g. 1.97 feet by 2100) while completing the assessment and developing appropriate adaptation strategies that could be implemented in the future to accommodate higher SLR estimates (e.g. for projects that have adaptive capacity see [Section 2.c. for the discussion on adaptive capacity](#)). This latter approach allows for uncertainty in the science and flexibility should the higher end of the SLR projections become more likely.

- Choose the NOAA Int-High and High scenarios if the project is sensitive to inundation and flooding and it has low adaptive capacity (i.e., the project cannot be easily adapted to accommodate the upper range SLR estimates in the future if it is designed and constructed to the likely SLR estimate today).

- Choose the NOAA Int-Low and Int-High scenarios if the project is not sensitive to inundation or flooding, or if adaptive capacity can be included in project design for later modifications if SLR rates exceed the likely projections.
- Using the appropriate scenarios, assess potential SLR impacts at multiple time steps throughout the planning horizon to determine when SLR impacts would occur, when adaptation measures would need to be implemented, when the asset would experience significant inundation affecting service levels, and other critical decision points.

Although the SLR estimates presented in Table 1 are presented relative to specific time horizons (e.g., 2035, 2065, and 2100), these estimates can be interpolated for alternate time horizons (e.g., 2050) to consider different project planning horizons utilizing the [USACE Sea Level Change Curve Calculator](#). Start by selecting the St. Petersburg, FL gauge, then choose “NOAA et al. 2012” as Scenario Source, and factor the projected SLC rate as “Regional.” To adjust the time horizon enter project start year, interval year, and project end year. Note the tool now includes an option for NOAA 2017; however, until the regional projections are updated, this Guidance utilizes the 2012 rates.

c. Sea Level Rise Inundation Mapping

Inundation maps are a valuable tool for evaluating the asset’s location in reference to potential exposure to future SLR and the most up-to-date maps should be referenced during project planning and design. The maps are typically used to evaluate when (under what amount of SLR) and by how much (what depth of inundation) an asset will be exposed. A variety of inundation maps exist today for evaluating potential future SLR exposure. At the time of publication of this Guidance, the following inundation maps represent the best available information:

- Internal County [WebGIS](#) Layers: Sea Level Rise Projections, FEMA flood maps, Flood Prone Areas, Storm Surge, Stormwater Hot Spots, and other data pertinent to the project.

- [University of Florida Sea Level Scenario Sketch Planning Tool](#)
- [NOAA Sea Level Rise Viewer](#)

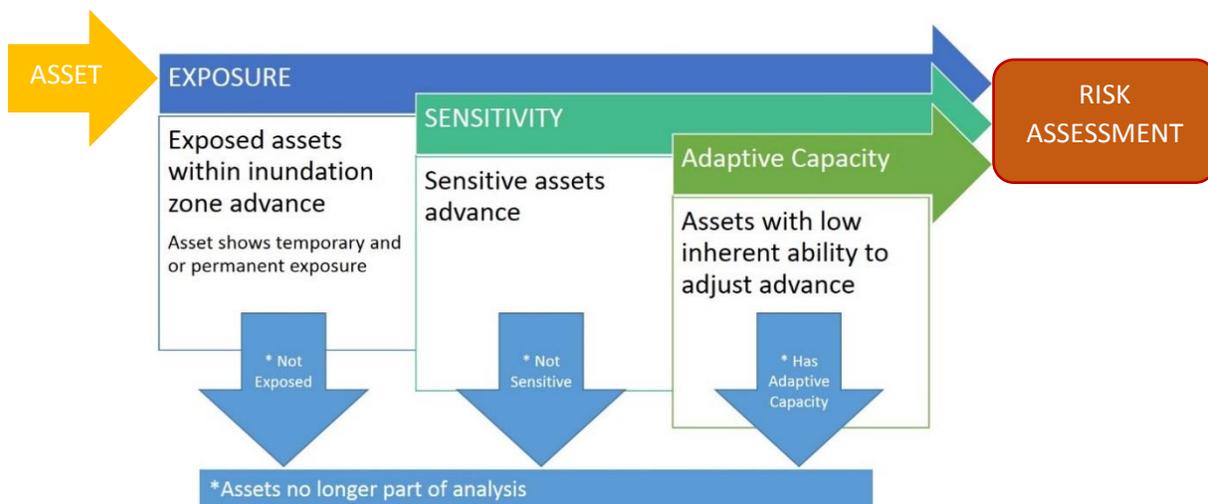
(Note that these maps, however, do not consider rainfall or tidal driven flooding. The County Web GIS and the University of Florida tool do include storm surge data)

All inundation maps have caveats and uncertainties. Inundation maps and the supporting analyses are intended to be used as planning-level tools that illustrate the potential for inundation under future SLR scenarios. Although this information is appropriate for conducting vulnerability and risk assessments, more detailed modeling and information may be needed for engineering design and implementation particularly for projects located near the coast. The maps depict possible future inundation that could occur if nothing is done to adapt or prepare for SLR over the next century. The above referenced maps relied on a digital elevation model created from 2007 LiDAR data (flown in 2006). If development or changes occurred along the shoreline after 2006, these changes are not captured within the inundation maps. In addition, the maps are based on model outputs and do not account for all of the coastal and bay processes, or future conditions such as erosion, subsidence, future construction, nourishment projects, and other changes that may occur.

[Section 2. Vulnerability Assessment](#)

The vulnerability assessment phase utilizes the results of the science review and SLR scenario selection ([See Section 2, Tab 2 in the spreadsheet tool](#)), including inundation mapping, to help guide identification of the exposure, sensitivity, and adaptive capacity of an asset in order to understand that asset's vulnerability to SLR. By screening for vulnerability, the groundwork is laid for adaptation planning. Assets found to be vulnerable move on to the risk assessment and adaptation planning phases, while the analysis is complete in this phase for assets found not to be vulnerable. Development and adoption of a standardized approach for performing a vulnerability assessment for both existing and future projects is critical to ensure that vulnerabilities are assessed consistently. As part of this assessment, project managers should

consider the tailwater conditions and floodplain management requirements in the County code of ordinances which may influence the sensitivity and adaptive capacity of the asset.



Vulnerability Assessment Process

Each asset or project in a capital plan should be evaluated to identify these factors:

a. Exposure

The exposure of an asset is the degree to which an asset is susceptible to hazards (e.g., depth of flooding due to SLR or inundation from storm surge). Exposure can be evaluated based on the type, magnitude and duration of flooding by either selecting readily available inundation mapping at an appropriate scale and resolution, or by completing site-specific modeling and mapping of an accepted range of current and future SLR projections and storm surge. Exposure can be evaluated by overlying the asset footprint with the storm surge and inundation mapping and extracting the necessary information, such as depth of inundation, area inundated, and percent of area inundated. In addition, evaluation of multiple scenarios for static SLR and storm surge can help determine asset vulnerability under a variety of future conditions. Projects west of the Coastal Construction Control Line or CCCL are more exposed to potential hazards such as storm surge and SLR. The CCCL is defined as the line established pursuant to the provisions of [Section 161.053, F.S.](#) and recorded in the official records of the county, which defines that portion of the beach-dune system subject to severe fluctuations based on a 100-year storm surge, storm

waves, or other predictable weather conditions. Construction west of the CCCL is governed by the [Florida Department of Environmental Protection](#). The CCCL map viewer can be accessed [here](#). Impacts from coastal flooding and storm surge are documented on Tab 4 of the spreadsheet tool. Assets that are not exposed do not need to be evaluated further in the vulnerability assessment.

b. Sensitivity

Assets that are exposed should progress to the next step: evaluating the sensitivity of the asset to SLR. Sensitivity is the degree to which an asset is affected (i.e., temporary flooding causes minimal impact, or results in complete loss of asset or shut-down of operation). For example, a roadway may be



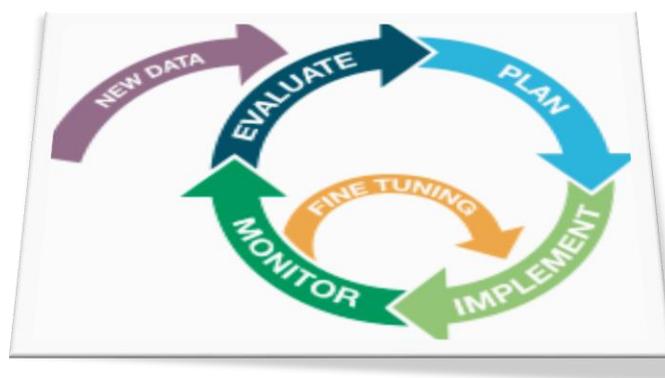
temporarily inundated under a storm surge scenario, but once the floodwaters recede, the roadway can resume useful service without the need for major repairs. Such a roadway would have a low sensitivity to periodic flooding; therefore, it may not need to be carried further in the process. Assets with low sensitivity may still benefit from adaptation measures, such as infrastructure improvements and/or operational adjustments; therefore, the inclusion or exclusion of exposed assets with low sensitivity should be considered on a case by case basis. On the other hand, a traffic control infrastructure may be taken completely out of service if it experiences even minor temporary inundation, requiring either major repairs or complete replacement. This asset would be considered highly sensitive to flood impacts and would be the subject of more detailed analysis. (See Section 2, Tab 3 in the spreadsheet tool),

c. Adaptive Capacity

Assets that are both exposed and sensitive continue to the last phase: evaluation of adaptive capacity. Adaptive capacity is defined as the asset's inherent ability to adjust to SLR impacts

without the need for significant intervention or modification. An asset with adaptive capacity is less vulnerable to SLR impacts. For example, a boardwalk may have been designed with an ability to be easily raised in the future, or a retaining wall may have been designed to accommodate future increases in height without the need for significant modifications. These assets are said to have adaptive capacity. (For new assets or assets with low adaptive capacity, enhancing or building in adaptive capacity will be an objective in the Adaptation Planning phase described below). The presence of redundancy in the system can also increase its adaptive capacity. If one section of roadway, for example, is impacted by flooding, but another section could provide at least a portion of the impacted level of service, the system is able to take advantage of existing opportunities to minimize impacts, and therefore might score higher for adaptive capacity.

Evaluating adaptive capacity is the most important step in assessing the nature of immediate or short-term adaptation planning. As explained in Section 1 and displayed in Table 1, for any given timeframe sea levels could rise by a relatively moderate amount, by a less likely but possible, upper range amount, or by some amount in between. The decision of what SLR scenario to adapt to for a given capital project or suite of capital projects is determined to a great degree by the adaptive capacity of the asset(s) being considered. If an asset location can be adapted today for most likely SLR and can relatively easily be adapted again in future decades for an upper range SLR condition, then it may be acceptable to plan for the most likely scenario today, and to incorporate adaptation strategies for future modification. This approach conserves scarce resources (e.g., funding). Providing for future adaptation in this manner is consistent with an adaptive management approach.



If an asset location does NOT lend itself to subsequent adaptation, if subsequent adaptation actions will be impossible or relatively expensive, then prudence suggests that adaptation measures for the upper ranges of SLR projections should be considered for project planning and implementation today. In this instance,

adapting now to long-term worse case scenarios represents may be the most efficient use of resources, protecting valuable public assets against the full range of SLR possibilities without the need to re-adapt at great expense in the future.

At the completion of the vulnerability assessment phase, each vulnerable asset, or project component, will have an associated rating (i.e., low, medium or high) for exposure, sensitivity, and adaptive capacity. The ratings are useful in the risk assessment phase for assessing the consequence of the vulnerabilities, and ultimately, in setting priorities for adaptation planning. (See Section 2, Tab 3 in the spreadsheet tool),

Table 2. Example of a vulnerability assessment matrix for one sea level rise scenario (Adapted from Guidance, 2015).

Asset	Exposure to NOAA Int-High 2050 Sea Level Rise		Sensitivity		Adaptive Capacity		Total Score
	SLR	Storm Surge	SLR	Storm Surge	SLR	Storm Surge	
#1	None	None	n/a	n/a	n/a	n/a	0
#2	None	Low (1)	n/a	Low(1)	n/a	High (1)	3
#3	Low (1)	Low (1)	Low (1)	Med (2)	Med (2)	Med (2)	9
#4	Med (2)	Med (2)	Med (2)	High (3)	Low (3)	Med (2)	14
#5	High (3)	High (3)	High (3)	Med (2)	Low (3)	Low (3)	17

As part of the vulnerability assessment phase, the low, medium and high ratings must be defined using thresholds appropriate for the asset(s). No single, simple definition of low, medium, and high exists that is applicable for all assets and projects: each Division should be consistent internally in defining these ratings to produce supportable criteria for each step in the process. For example, exposure thresholds for low, medium, and high can be defined using inundated depth or inundation duration. This kind of subjective but consistent approach is also appropriate for subsequent phases of this Guidance as each Division prepares its capital plan.

The rating scale presented in Table 2 was developed so that a low score (1) is associated with limited exposure, minimal sensitivity, and high adaptive capacity to SLR. A low score for all three characteristics would result in an asset with very low overall vulnerability. A high score (3) would represent an asset that is significantly exposed, highly sensitive, or with limited adaptive capacity to SLR. A high score for all three characteristics would result in a highly vulnerable asset. Thresholds for the ratings may vary based on different asset types and their tolerance for inundation. [The Vulnerability Assessment Matrix is found in Tab 5 of the spreadsheet tool.](#)

As stated above, assets that are not exposed to SLR or storm surge do not need to be considered further as they are not impacted by the SLR stressors. Assets that score low for sensitivity or high for adaptive capacity may not warrant further consideration at the risk assessment phase as these assets are either not sensitive to the SLR impacts or they have a high ability to adapt without the need for the identification, design, and implementation of new adaptation strategies (see example Asset #2). On the other hand, Assets #4 and #5 in Table 2 are exposed, sensitive to some degree, and have moderate to low adaptive capacity to SLR. Because they are at risk, these assets must be considered in the risk assessment phase, during which the consequence determination is made. In sum, the vulnerability assessment will produce a final list of assets, or project components, that warrant further evaluation in the risk assessment phase.

Note that an evaluation of multiple SLR scenarios to accommodate different time scales or different assumptions about SLR may be needed to adequately assess overall vulnerability and to provide useful information to inform the consequence rankings and adaptation planning. Table 2 and 3 in this Guidance, therefore, are provided as relatively simple examples of the kind of matrix that should be used.

[Section 3. Risk Assessment](#)

Risk is typically evaluated by comparing the probability that impacts would occur (or likelihood) to the consequence of these impacts. However, likelihood can be difficult to quantify when

considering SLR related impacts, as most current scientific studies cannot calculate the probability of a SLR projection occurring in any given year or at any particular level. Therefore, when assessing the risk associated with SLR vulnerabilities identified through the vulnerability assessment, the most important component of classical risk assessment methods is the evaluation of consequence.

Calculating the consequence of failing to address SLR for a particular asset or project is useful in prioritizing assets for adaptation planning. Consequence considers the magnitude of the impact that would occur under the selected SLR and storm surge scenarios. Information about the asset, such as its age, condition, and materials are often informative when considering the consequences. The questions below can be useful in framing the consequence of SLR related impacts ([See Section 3, Tab 5 in the spreadsheet tool](#)),

- **Damage:**
 - What is the level of damage to the asset?
 - Can the asset be repaired, or would the asset require complete replacement?
- **Disruption:**
 - Is there a disruption in service?
 - If yes, what is the length of that disruption, i.e., hours, days, weeks? Does the disruption threaten public health and safety?
- **Cost:**
 - What is the cost to repair or replace the asset?
 - What are the economic costs associated with the disruption in service?
 - What are the public health and safety costs of the service disruption?
 - Are there secondary impacts that need to be considered (i.e., costs to the environment or recreational activities)?

Table 3. Example of a consequence matrix for one sea level rise scenario (Adapted from Guidance, 2015).

Asset	Damage		Cost (Repair/Replace)		Disruption		Total Score
	SLR	Storm Surge	SLR	Storm Surge	SLR	Storm Surge	
#1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
#2	n/a	Low (1)	n/a	Med (2)	n/a	High (3)	6
#3	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	Low (1)	6
#4	Med (2)	High (3)	Med (2)	High (3)	Med (2)	High (3)	15
#5	High (3)	High (3)	Low (1)	Med (2)	Low (1)	Low (1)	11

The best questions for framing consequence may vary depending upon asset function or the type of service the asset provides (i.e., essential infrastructure, flood protection, health and safety, recreation, evacuation route). The intent of the consequence determination is to develop a means to prioritize assets for adaptation plan development. Table 3 presents a simple example of a consequence matrix for one SLR scenario (same hypothetical assets as presented in Table 2); however, additional consequence factors may also be considered in practice, such as factors that consider economics, secondary impacts, or interdependencies. As noted in Table 2, Asset #1 was not considered vulnerable, so it was not evaluated in the risk assessment phase. For this selection of assets, Asset #4 is associated with the highest consequence rating; therefore the development of an adaptation plan for Asset #4 may be a high priority. As part of the risk assessment phase, the low, medium, and high ratings must be defined using thresholds that are appropriate for the asset type. [The Consequence Matrix is Tab 6 of the spreadsheet tool.](#)

To adequately assess consequences and to develop a prioritized list of short- and long-term adaptation planning needs, an evaluation of multiple SLR scenarios to accommodate different time scales or different assumptions about SLR may be needed.

Section 4. Adaptation Plan Development

During this phase, potential adaptation strategies are developed for assets or projects that are identified as vulnerable. The adaptation plan may focus on those assets or projects that also have a high consequence rating. Together, the vulnerability and consequence ratings can help a department develop a prioritized list of assets for adaptation strategy development and implementation. Given that the science is evolving and SLR projections have a wide range of values, projects should adopt a planning horizon based on functional lifespan (see SLR scenario selection discussion) and include appropriate adaptation strategies to accommodate anticipated SLR.

In many instances, it is not feasible or cost effective to design and build for long-term potential SLR scenarios of a highly uncertain nature, such as the NOAA High for the year 2100 (6.89 feet of SLR). In this case, a project could be designed and constructed to account for 2.2 feet of SLR (NOAA high in 2050) with the capacity to adapt to more severe SLR scenarios over time. An alternate approach would be to build resilience to likely SLR by 2100 (NOAA Int Low-Int High) now while identifying the adaptive capacity of the asset to the NOAA High estimate for 2100 in case future projections indicate that level has become likely.

This approach seeks to create or enhance the adaptive capacity of the asset or asset location, thereby making that asset resilient. As defined in the Vulnerability Assessment phase description, adaptive capacity defines a project's ability to adapt in a modular or step-wise fashion over time. The adaptation plan for the asset or project should include the level of SLR appropriate for near-term project planning and implementation, and the adaptation strategies that can be implemented over time if SLR exceeds or is anticipated to exceed the original estimate. The adaptation plan should clearly identify the triggers or time horizons for implementation of the identified adaptation strategies and the plan should include a process to monitor and respond to changes in the science or the condition of the asset. This approach can reduce the near term cost

of project implementation, while providing for future flexibility and adaptation potential. Further, the project's adaptation plan should consider the funding mechanism needed for future adaptation measures.

In evaluating the adaptive capacity of a project, these questions are often asked: Does the project, project footprint, or adaptation feature(s) have the ability to be modified or changed to accommodate higher SLR as new data and science emerges? In other words, can project resilience be secured for some logical period of time (e.g., through 2050) and also accommodate further adaptation measures based on new developments and science in subsequent years? And what are those triggers or time horizons for implementation of adaptation strategies (which make the project resilient now) and adaptive management approaches (which allow response to future trends with further measures)?

If, due to site or project constraints, it is determined that the adaptive capacity of a project is low (i.e. the ability to implement future adaptation strategies in response to new projections of additional SLR is low), using the NOAA High projections in initial adaptation plan development may be merited.

For example, if an existing flood protection feature was designed and constructed in such a way that its height, location, or operation can be easily adjusted in the future to accommodate SLR, the project would have some inherent adaptive capacity as its ability to accommodate future SLR is higher than a project that would require substantial reconstruction to increase its level of protection.



Adaptation plans should include clear accountability and thresholds for bringing approved strategies online. SLR science is subject to change as new information and studies become available. A well-defined process should be developed within each Division to ensure that milestones are achieved, the latest science is being considered, and vulnerability assessments are being completed as part of the capital planning process. [Document Adaptation Strategies in Section 4, Tab 8 of the spreadsheet tool.](#)

[Section 5. Project Production Team](#)

The process of identifying risks to public infrastructure is a team effort. Each project production team (PPT) member is encouraged to bring their expertise to the evaluation to ensure the best outcome. [Section 5, Tab 9 of the spreadsheet tool is the PPT certification page.](#) Add sufficient notes as needed to explain the PPT's recommended response. The PPT lead is to sign the form electronically once complete.

[Section 6. Departmental Certification](#)

Upon completion of the assessment, the PPT recommendation, and PPT signoff, the form is to be submitted to the Public Works Department Director for review. [See Section 6, Tab 10 of the spreadsheet tool.](#) Once a project evaluation is approved, the signed form is to be placed in the project folder on the server.

References

Adapting to Rising Tides, Transportation Vulnerability and Risk Assessment Pilot Project [PDF]. (2011, November). Caltrans, Adapting to Rising Tides sub-region working group, the Transportation Asset Subcommittee, and the Shoreline Asset Subcommittee.

Recommended Projection of Sea Level Rise in the Tampa Bay Region [PDF]. (2015, August). Tampa Bay Climate Science Advisory Panel.

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Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco: Assessing Vulnerability and Risk to Support Adaptation [PDF]. (2015, December 14). City and County of San Francisco.

Impacts of Climate Change Variability on Transportation Systems and Infrastructure: Gulf Coast Study. (2008, March). Retrieved from https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/gulf_coast_study/index.cfm

State of Maryland Climate Change and Coast Smart Construction Infrastructure Siting and Design Guidelines [PDF]. (2014, January). Maryland Department of Natural Resources.

APPENDIX A

[Climate Science Advisory Panel \(2015, August\). Recommended Projection of Sea Level Rise in the Tampa Bay Region.](#)