Sea Level Rise Vulnerability Assessment Framework

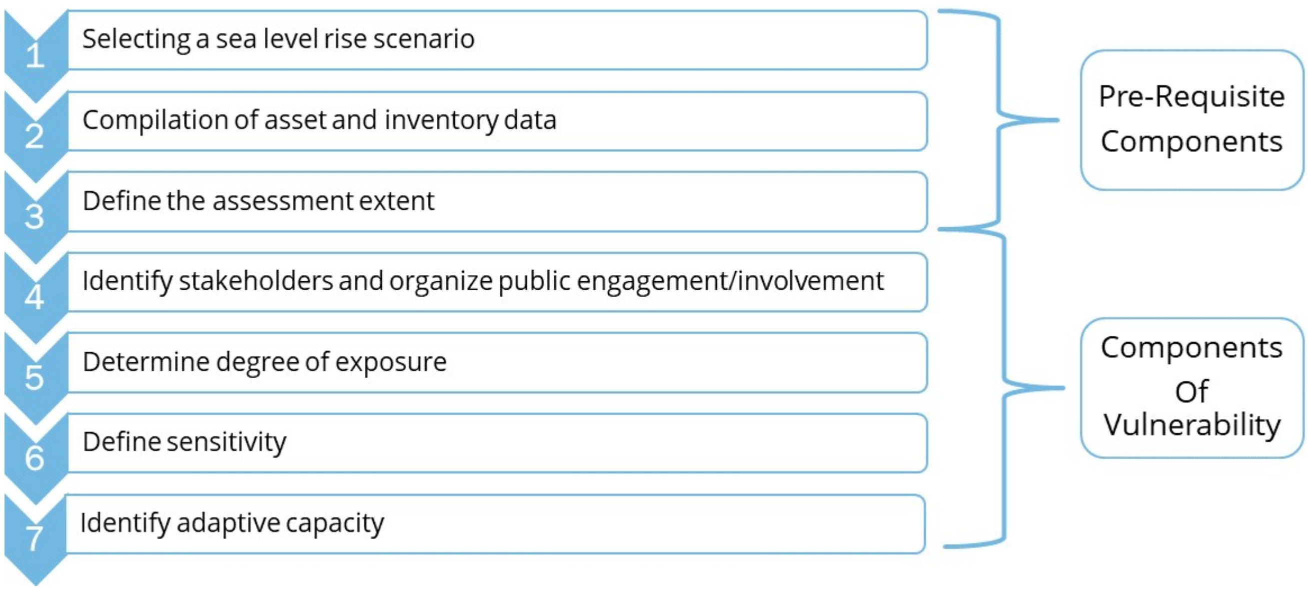
For

Bellingham's Shoreline Master Program

Executive Summary

This project is focused on creating a Sea Level Rise Vulnerability Assessment Framework to inform the Bellingham Shoreline Master Program update. The project has received guidance from Bellingham staff, The Port of Bellingham, USGS, the Department of Ecology and faculty from the University of Washington Masters Urban Planning program. This process has helped make sure that staff will be ready to move forward from a cohesive starting point once the project is complete.

This document is designed to provide a guide for professional planners to conduct a VA of SLR using the framework. This report discusses and details the seven key components of the SLR VA framework:

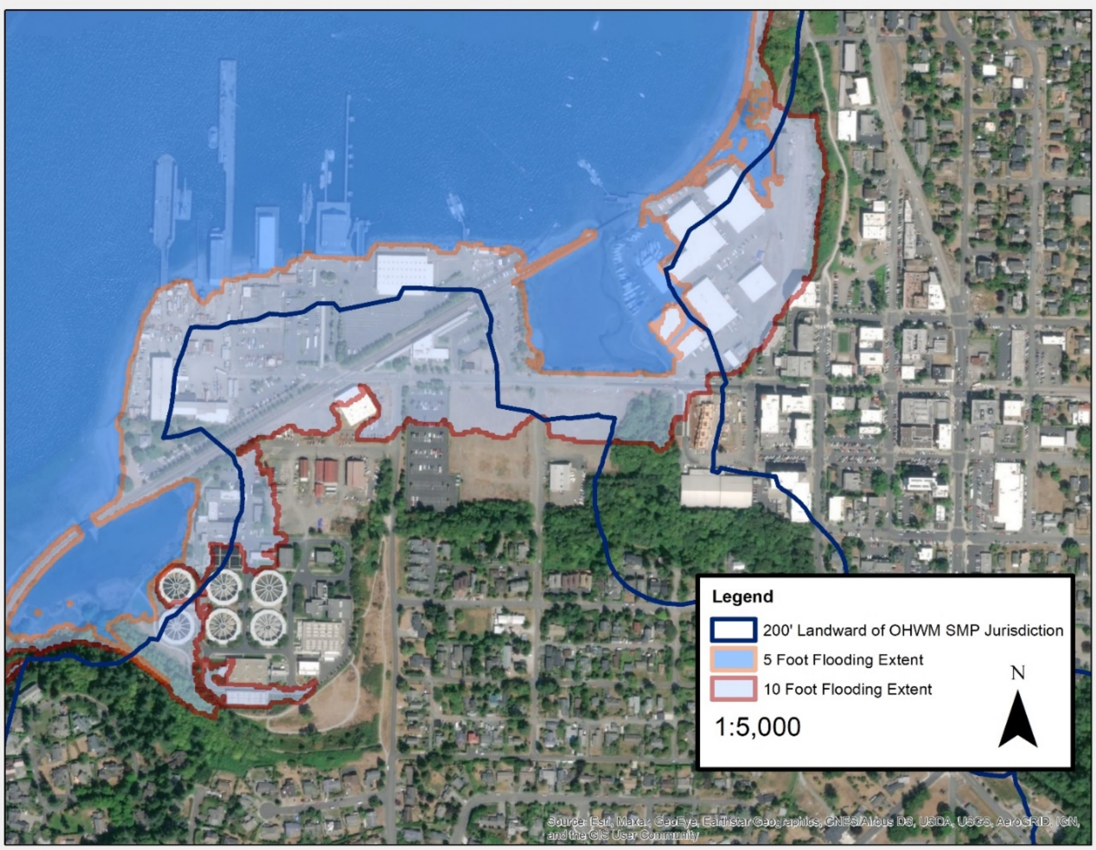


This Sea level rise Vulnerability Assessment Framework is unique in that it aims to inform the Shoreline Master program and is the first of its kind. The purpose of this effort is to create a vulnerability assessment framework which can be used to update the shoreline master program documents and to guide the analysis needed to adequately identify alternatives and incorporate appropriate management measures into shoreline master programs. The framework itself will act as a guide for staff to do a vulnerability assessment for sea level rise as part of the periodic updates for the shoreline master program. The vulnerability assessment which will result from the implementation of the framework could also be added as an amendment to the shoreline master program if the timing of the update and the assessment do not line up.

The results of an Assessment may be more broadly applicable and could help inform stormwater planning, hazard mitigation planning, adaptive planning, and other long-range planning and policy beyond just the Shoreline Master Program.

As part of The Vulnerability Assessment framework the area being assessed needs to be defined. This is the Assessment extent. The framework helps staff identify coastal hazards and include them in determining this extent. The Puget Sound Coastal Storm Modeling System (PS-CoSMoS) could be a very valuable tool for this and would provide detailed and granular information for coastal flooding beyond what is otherwise available. Selecting sea level rise probabilities and resources for where to gather the data and modeling information needed to create a sea level rise scenario are provided in the framework. The most recent sea level rise modeling and data for Washington is a 2018 assessment of sea level rise. This data along with the storm modeling can be used by Bellingham to create a scenario for coastal flooding.

As part of these scenarios, Sea level rise is projected over 50, 100, or more years and so the Vulnerability assessment should consider parallel timeframes for planning horizons. With a timeframe and all of the coastal flooding factors taken into account, a total landward flooding extent can be determined. This area could be used as the assessment extent, but some adjacent areas may need to be considered because of their significance to the community. The framework outlines the VA extent process and helps guide staff in providing elected officials with options for the assessment extent.



To illustrate why the assessment extent needs to be linked to more than just the shoreline master program's jurisdiction, the map above was create. The blue line is 200 foot landward of the Ordinary high-water mark (OHWM) and roughly represents the Shoreline master programs jurisdiction. The orange line shows the extent of landward flooding if water were 5 feet above the ordinary high-water mark and the red line shows landward flooding at 10 feet above the ordinary high-water mark. This is not a specific sea level rise scenario, rather it is just an illustration of how in both a 5- and 10-foot flooding condition, that the extent of the water goes beyond the 200' landward jurisdiction of the shoreline master program in some areas.

Vulnerability itself is comprised of three main components – exposure, sensitivity, and adaptive capacity. Exposure which is the degree to which an asset, population or system is exposed to flooding in a selected Sea Level Rise Scenario. Sensitivity which is the degree to which the assets populations or system's functionality or purpose is adversely affected by flooding in that scenario, and adaptive capacity which is their ability or inability to address the adverse impacts of that flooding. It is also worth mentioning that assets and systems include those that are both built and natural.

The first step in this sea level rise vulnerability assessment is to conduct an Exposure Analysis at the total water level and sea level rise associated with a scenario. The framework outlines the process of conducting this analysis which involves determining which assets, populations, and systems are exposed, to what degree, how often, and over what time period. The results can then be mapped and catalogued for use in conducting the sensitivity analysis.

The process of conducting the sensitivity Analysis involves evaluating the results from the exposure analysis and determining if, when, and to what degree is the functionality or purpose adversely affected. Additionally, consideration needs to be given to indirect and cascading impacts. An example of this may be an infrastructure network which is comprised of connected elements that are susceptible to disruption if individual elements are impacted, as with an electrical grid, or stormwater system, but it could also include an ecological system, especially if a keystone species is impacted or displaced by habitat disruption or loss as a result of the flooding. Recording the sensitivity analysis results may also need to take the form of a narrative when considering exposed populations or looking at complex systems.

The catalogued results from the previous analysis which are both exposed and have a sensitivity to the flooding will then need to be considered for their Adaptive Capacity. This process will help establish where and how further investment is needed. The initial analysis is aimed at evaluating whether the assets, systems, or populations can be characterized by their ability to adapt, relocate, elevate, or their redundancy in response to the impacts of flooding. These characterizations can then be used as an approach for adaptive planning.

The framework suggests that a cost benefit analysis be done to decide which if any approaches should be taken. All of the collected information can then be used to inform the policies, regulation, environmental designations, and other components of the shoreline master program as part of the update process.

While we can quantify the extent of landward flooding, and determine vulnerability, the primary focus is to help the community make the most informed decisions for the future. This is why public involvement is an integral component of the vulnerability assessment framework at all stages throughout the process. The framework is designed to help staff to identify stakeholders beyond those which may already be identified as part of the shoreline master program and outlines additional opportunities for public involvement as part of the existing shoreline master program public involvement process. Perhaps one of the most important elements of public involvement is engaging the community and stakeholders in determining the desired outcomes. Desired outcomes will range in scale from those which encompasses the entire waterfront, down to some which concern an individual asset. These outcomes of this involvement will help provide guidance for staff and elected officials for the adaptive planning process.

The report also includes recommendations and considerations for implementation, how to use the results of the VA in an SMP, and administrative considerations of timeframes, staff capacity and budgeting for a VA. The results of this project are designed to assist the city of Bellingham plan for SLR as part of its SMP. Planning for sea level rise needs to become a priority for shoreline communities throughout Washington as part of their shoreline master programs. The intention of this framework is that widespread adoption of planning for SLR is more achievable in the state of Washington.

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1.0 Introduction

Bellingham, Washington is currently starting their periodic update of their Shoreline Master Program (SMP). As part of this effort, they would like to address sea level rise. The city entered into a collaboration with Washington Sea Grant and the University of Washington Department of Urban Design and Planning to explore how sea level rise might be integrated into the Bellingham SMP. These conversations, which also included the Washington Department of Ecology (ECY), resulted in a recommendation to create a vulnerability assessment framework which can be used to update shoreline master program documents in the state of Washington. This framework provides a starting point to understand the analysis needed to adequately identify alternatives and incorporate appropriate management measures into SMPs. It is the first of its kind in Washington which focuses on creating a VA framework to be used within the SMP update process to address SLR.

For the Purposes of the SMP, the Bellingham shoreline is within the jurisdiction of Bellingham. Land use activities within the shoreline are subject to the Shoreline Management Act of Washington, administered through the locally adopted SMP. The Washington Department of Ecology (ECY) has authority to issue final approve of these local SMPs subject to the provisions of the Act. ECY establishes guidelines for developing the content of SMPs. SMPs are local land-use policies and regulations that guide use of Washington shorelines. SMPs apply to both public and private uses for Washington's more than 28,000 miles of lake, stream, wetland, and marine shorelines. They protect natural resources for future generations, provide for public access to public waters and shores, and plan for water-dependent uses. At present, the SMA and SMP guidelines contain no requirements for SMPs to address climate change or sea level rise. However, the guidelines require local governments use “the most current and accurate and complete scientific and technical information available.” [WAC 173-26-090(1)] (SMP Handbook Appendix A).

One way to accomplish this is to give the city of Bellingham the information necessary to create the opportunity to plan for SLR, by creating a Vulnerability Assessment (VA). As a result, this framework has been developed to guide the process which would address the needs and concerns of Bellingham while also being generalizable to other cities for future use. The SMP requires periodic updates, and Bellingham is interested in addressing SLR in its shoreline regulatory process. Creating the VA framework will help the City conduct a VA which will provide important information for determining how to address SLR in the SMP.

This document is meant to provide a guide for professional planners to conduct a VA of SLR using the framework as their guide and reference. The VA framework is supported by a literature review. This report discusses the seven key components of the SLR VA framework:

1. Selecting a SLR scenario
2. Compilation of assets and inventory data
3. Defining the extent
4. Identify stakeholders and organize public engagement/involvement
5. Determining the degree of exposure
6. Defining sensitivity
7. Identifying adaptive capacity

An overarching component is that of public involvement. At each stage of the process the public is recommended to be involved to best direct the efforts in establishing and accomplishing the desired outcomes of the community. The report also addresses some recommendations and considerations about implementation, how to use the results of the VA in an SMP, and administrative considerations of timeframes, staff capacity and budgeting for a VA.

2.0 Methodology

This section describes the overall process used to create this VA framework. A series of meetings with city staff, a scope and workplan were established which outline the primary focus and timeframe of this project. At each stage, the work was reviewed by the city to maintain the continuity of this focus. Staff from ECY also reviewed and commented on the scope of work. The project consisted of four main phases. While each phase built upon the previous one, some tasks were iterative, and feedback required that elements of an earlier phase filled in any gaps in knowledge or approach methodology of another phase. While the process of scoping a project may produce a linear timeline, in this case, creating feedback loops to provide the highest quality product made for a less linear approach than was outlined in the scope.

Phase 1: The first phase established a process and coordination framework for the project. This included creating scope and timeline documents with a set of intermittent deliverables and touchpoints to keep Bellingham apprised of the progress. Because of the COVID-19 pandemic most all the work was conducted remotely. The remote nature of the work made it possible to meet every two weeks using the zoom online meetings platform to discuss progress, receive feedback, and share documents pertaining to the project with the client. This also included the scheduling of internal weekly meetings with the Washington Sea Grant liaison who took on an active and primary role in guiding and providing feedback throughout the project. Additionally, a review committee of 12 people from the Bellingham staff, The Port of Bellingham, USGS, and the Department of Ecology was created to review the project and provide feedback. This thorough approach to coordination and the review processes ensured the delivery of a functional and adequate work product.

Phase 2: The second phase consisted of information gathering. As part of the scoping process in the first phase, a set of research categories was established with the feedback of the city staff and review committee. The categories for information gathering include:

- Vulnerability Assessments
- Coastal Hazards
- Coastal data and mapping
- Sea Level Rise; Projections, Scenarios, and Modeling
- Policies & Regulations; Adaptive Planning
- Shoreline Master Programs

These categories served as the basis for the literature review portion of this document.

Vulnerability Assessment information was gathered by reviewing VAs from around the US, including: Olympia WA, Tacoma WA, King County WA, Marin County CA, Los Angeles County CA, Tampa Bay FL, Island County WA, and through several peer reviewed articles which looked at 65 other SLR VAs in the US. Additional resources included, reviewing the National Oceanic and Atmospheric Administration (NOAA) and The Intergovernmental Panel on Climate Change (IPCC) documents on vulnerability assessment.

The coastal hazard information was gathered by reviewing information from the Washington Coastal Hazards Resilience Network (CHRN), The Bellingham Natural Hazards Mitigation Plan, and the City of Bellingham Comprehensive Emergency Management Plan (CEMP). Additional information on Coastal Hazards was drawn from the Whatcom County Natural Hazards Mitigation plan, and from the USGS Coastal Storm Modeling System (CoSMoS) and its Puget Sound Component (PS-CoSMoS), along with marine coastal flooding information from the Federal Emergency Management Agency (FEMA).

Coastal data and mapping information was gathered by reviewing the Sea level rise in Washington - A 2018 assessment, the NOAA SLR data and visualization tools, the CoSMoS and PS-CoSMoS programs, and the FEMA coastal flooding maps. This involved finding existing visualization tools like the NOAA SLR viewer, CIG visualization tools, and the USGS Hazard Exposure and Reporting Analytics (HERA) tool.

Sea level rise projections, scenarios, and modeling information was gathered by reviewing the available information from NOAA, USGS, CoSMoS, PS-CoSMoS, CHRN, and the Washington Climate Impacts Group (CIG). In addition, various SLR adaptation plans and VAs were reviewed, including those for Olympia WA, LA County CA, Marin County CA, and peer reviewed articles which considered SLR projections, scenarios, and modeling.

Policies & regulations; adaptive planning information was gathered by reviewing several elements in the Washington Administrative Code (WAC) and the Revised Code of Washington (RCW). Broader context for implementation was established by reviewing SLR response plans in Washington, Florida, and California. Additional information was gathered by reviewing the Whatcom County Comprehensive Emergency Management Plan, the DHS National Mitigation Framework, parts of the IPCC AR5 Climate Change 2014: Impacts, Adaptation and Vulnerability report, and several peer reviewed articles on adaptive planning and dynamic adaptive planning pathways which focused on “crafting robust decisions for a deeply uncertain world” (Haasnoot et al).

Shoreline Master Program information was gathered by reviewing the Bellingham SMP, the Washington Shoreline Management Act, and the ECY SMP Handbook, with special attention paid to the SMP Handbook Appendix A: Addressing Sea Level Rise in Shoreline Master Programs.

To gain a better understanding of the planning context, a site visit was conducted. The site visit consisted of a coastal bike tour with two local experts, one from the city and one from the port. Because this project was conducted during the COVID-19 global pandemic, social distancing, masking regulations, and best health practices were followed during the site visit.

In addition to the research and site visits, interviews with subject matter experts and technical professionals were conducted to provide supplemental information, additional resources, expert opinions, and feedback on specific components of the project. These interviews were held remotely.

The literature review was conducted primarily during this phase, but as research is an inherently iterative process, additional information was incorporated and considered for review throughout the entire project. The literature review was then given to the city for review and comment. The feedback was then incorporated into the final literature review document. At end of this phase, a presentation of the completed work and findings was given to the client, and the timeline was updated to accommodate the agreed upon review cycle.

Phase 3: The third phase of the project consisted of analyzing the collected and reviewed information for the purpose of creating the Vulnerability Assessment (VA) Framework for the City of Bellingham. The draft VA framework was outlined and reviewed by the City Staff, ECY, and faculty from the UW Department of Urban Planning and Design (URBDP) overseeing this project. The feedback from this review was then taken and incorporated into the outline. Any gaps in reviewed literature and supporting documentation were reviewed, and additional examples and articles were incorporated as needed. The framework was then drafted for preliminary review by the City. Once reviewed, the feedback was incorporated into the framework.

Phase 4: The fourth and final phase of this project was to create the VA Framework, and deliver the finalized document to the City for future implementation. This phase was primarily focused on iterative revisions of the framework draft created in the previous phase. As part of the ongoing review process the full document was sent to a review committee of 12 people from the Bellingham staff, Bellingham port, USGS, and the Department of Ecology. As well as UW URBDP faculty overseeing the project, and the WA Sea Grant Liaison. The Final version of the document was then prepared and given to the city at the end of this phase for future implementation. As part of this phase, an overview was presented to the Bellingham City Council.

The methods and approach to this project aims to give professionals the tools which they need for conducting a SLR VA and then communicating the results and their recommendations to elected officials and decision makers.

3.0 Literature Review

3.1 Literature Review Introduction

The purpose of this literature review is to provide a background and direction for how to conduct a vulnerability assessment and their use in planning for sea level rise. The literature review is intended to give an overview of the best practices, and foundational components needed to establish a process for creating a vulnerability assessment that is tailored and specific to a location but can be implemented in other jurisdictions. The focus of this research is not just Vulnerability Assessment (VA) as a whole, but specifically those related to SLR. Even more specifically, the aim is to look at VAs in the context of the Washington Shoreline Master Programs. It is also important to make the distinction that the goal is to create a VA framework which will act as a general guide for Bellingham and other cities in conducting their VA, not as rigid step by step process which is narrowly applicable to only one municipality. Rather the framework will help planners choose the best available resources and approach the VA process as one which will help update their SMP and may help inform other planning practices in their city, such as stormwater management, and land use. The focus and direction of this review has also been guided by input from the WA Department of Ecology, the city of Bellingham, various subject matter experts and professionals.

3.2 Background

To develop and maintain a long range and sustainable approach to shoreline planning, it has become increasingly apparent that planning for sea level rise is both fundamental and essential. The SMP requires periodic updates, and Bellingham is interested in addressing SLR in its shoreline regulatory process. And a fundamental starting point for conducting this planning is the preparation of a vulnerability assessment. The vulnerability assessment provides the scientific foundation for the development of regulations and policies to address sea level rise. This report provides the framework for Bellingham and other communities to understand how to develop a vulnerability assessment.

To provide a cohesive approach for a vulnerability assessment framework, literature pertaining to six major topics was evaluated and will be used to support the decisions made in establishing the framework. These six topics in no particular order are:

- Vulnerability Assessments
- Coastal Hazards
- Coastal Mapping and Data
- Sea Level Rise; Projections, Scenarios, and Modeling
- Policies & Regulations; Adaptive Planning
- Shoreline Master Programs

With each of these subject areas the pertinent literature was selected to help discern which approaches have been taken by other communities planning for sea level rise, and to establish a baseline for informed decision making in creating a vulnerability assessment framework for the city of Bellingham. To ensure that the literature is locally pertinent and has adequate jurisdictional specificity, much of the referenced literature pertains to the west coast and a large portion are from the state of Washington. Some case studies from other parts of the US were used to evaluate alternative approaches and parallels which could be generalized or applied in Bellingham. No literature review was done on approaches taken outside of the US because of the difference in laws and policy, which would make all but the most general approach components inapplicable.

3.3 Vulnerability Assessments

3.3.1 What is a Vulnerability Assessment?

The USGS defines A Vulnerability Assessment (VA) as the result of synthesizing the exposure analysis, sensitivity analysis, and adaptive capacity (Staudinger et al, 2015). Similarly, the Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as three distinct components: (1) exposure: magnitude and rate of climate change a resource is likely to experience, (2) sensitivity: characteristics that mediate tolerance to climate change of a particular resource, and (3) adaptive capacity: the inherent ability of the target to moderate the impacts of climate change (IPCC 2007, P 883)**.** "The simultaneous assessment of all three vulnerability components provides a comprehensive and rigorous framework for climate adaptation planning" (Staudinger et al, 2015). T

A recent analysis done by Fu, et al, of 64 SLR VAs in the United States was conducted to evaluate the effectiveness and to identify gaps which may be addressed in future VAs (Fu, et al. 2019). The quality of VAs and their results are typically correlated with the amount of funding spent on the project and the degree of public involvement in those communities during the planning process (Fu, et al. 2019, P 16). While there was a wide range of approaches taken in VAs, elements from many of them could be combined to create a more effective VA structure and approach which would include adaptation planning as part of the outcome and implementation (Fu, et al. 2019, P 15). Therefore, stakeholder identification would need to be an important and critical component of a vulnerability assessment.

3.3.2 Vulnerability Assessment Components

From a review of SLR vulnerability assessments (VA) and relevant literature reviewing other VAs, seven primary components were identified. The first four components are preliminary required steps in a vulnerability assessment framework to ensure that the components comprising vulnerability can be addressed effectively to inform policy decisions. The remaining three components, which comprise vulnerability are: Determine degree of exposure, defining sensitivity, and Identifying adaptive capacity.

The preliminary components are: Selecting a sea level rise scenario, the Compilation of asset and inventory data, Defining the SLR vulnerability assessment extent, and Identifying stakeholders and organize public engagement/involvement which are implemented before the three components of vulnerability.

NOAA (2010) provides a general guideline for climate change vulnerability assessments and incorporates six components in their list: Identify the climate change phenomena, identify the climate change impacts and consequences, assess physical characteristics and exposure, consider adaptive capacities, develop scenarios, and simulate change, and summarize vulnerability and identify focus areas. Because the focus of this report is SLR in the context of an SMP, and not just climate change more generally, the review below will include the broader group of seven components. These components are briefly described here. More details on how to apply each of these in the context of Bellingham are found in the remainder of this report.

The first component is *Selecting a sea level rise scenario* (NOAA, 2010, P 28). Before moving on to any other components it is worth mentioning that all the reviewed vulnerability assessments relied on a scenario which was determined by the jurisdiction using available data and modeling with the input of stakeholders and the community not just staff and specialist inputs.

The second component is to *compile asset and inventory data* along with the characterizations of coastal landforms (NOAA, 2010, P 30). More details on what a scenario is comprised of and the process of selecting them is detailed in a later section. Each jurisdiction whose vulnerability assessment was reviewed varied greatly with the depth and breadth of data used, but all incorporated existing built infrastructure and assets within the jurisdictional boundary (Fu, Et al., 2019, P 3). The City of Olympia provides a good example of how this was done, by including each asset in categorized inventories by owner and by levels of exposure (City of Olympia, 2018, P 47).

The third component is to *define the SLR vulnerability assessment extent*. The SLR VA extent is not a defined in the law. Establishing such an extent then falls on the city to determine. The city must then identify the areas which may be vulnerable or exposed to SLR (NOAA, 2010, P 40).

The fourth component is to *identify stakeholders and organize public engagement/involvement*. While most stakeholders can be identified using tax records for parcels inside of the jurisdictional area, some stakeholders described in other VAs were identified because of their special interests, whether environmental protection, development, or an otherwise engaged party/agency (Point Blue Conservation Science, 2019, P 6). A systematic approach may be the best way to determine the stakeholders, and such an approach would need to comply with the state planning and public engagement laws. NOAA has created a set of engagement tools and worksheets which can aid planners in determining the stakeholders and then engaging them on the specific topics at hand (National Oceanic and Atmospheric Administration NOAA. (n.d.-c).

The fifth component is to *determine the degree of exposure*; this relates to assets, populations, or systems as identified earlier in this process, which are exposed to SLR. Quantifying exposure will depend greatly on the selected scenarios for SLR, and the incorporated amplifications as mentioned in the coastal hazards section. "Exposure is an inventory of the "assets"—people, property, systems, and functions—that could be lost, injured, or damaged due to an impact of climate change. (National Oceanic and Atmospheric Administration NOAA, 2010 P. 31). Approaching the process of gathering the information for exposure could start with the existing inventory and characterization which the city has already compiled for the purposes of their SMP, and then further surveying the area to determine if additional elements need to be added to the Inventory.

The sixth component is to *determine the sensitivity* of those same assets, populations, or systems. Sensitivity is determined by considering a range of variables for each component of the inventory; buildings for example may be evaluated for structural integrity, age, construction methods, and flood resilience. A detailed sensitivity assessment will also be conducted for all elements of the inventory and characterized coastal landforms. When completed the sensitivity assessment paired with the exposure analysis will help to inform the adaptive capacity analysis (Fu, et al., 2019, P. 3).

The seventh component is to Identify Adaptive capacity. The "capacity can be described in terms of the ability of your state's governments and their populations to prepare for, respond to, and recover from the impacts of climate change" (NOAA, 2010 P. 35). "Adaptive capacity is the ability of an asset to accommodate or adjust to an impact to maintain its primary function. In general, assets with high sensitivity and low adaptive capacity are more susceptible to impacts and therefore have a higher overall vulnerability. Alternatively, assets with high adaptive capacity and low sensitivity can tolerate impacts to a greater degree, and therefore have a lower overall vulnerability" (San Francisco Bay Conservation and Development Commission, 2012, P. 2). An example of an adaptive capacity analysis applied to assets is applied by the city of Olympia in their 2010 sea level rise response planning document on Vulnerability and Risk Assessment. They used the following four categories: Redundancy, Ability to relocate, Ability to adapt, and Ability to elevate.

Redundancy can be defined by the asset in this context e.g., a storage facility may have an alternative or backup location, while a road may have alternative routes (City of Olympia, 2019, P. 14). Broadly applied this could include wildlife populations, or ecological systems.

The ability to relocate is largely focused on inventory for which the use or purpose can be relocated, but in some instances the physical asset itself can be moved outside of the impacted area. This also applies to populations and systems (NOAA, 2010 P. 80).

The ability to adapt is a specific assets ability to handle an event and to be resilient and operational afterwards. This is evaluated by looking at frequency, intensity, and duration of an event and then determining the operational capacity of the asset over time (City of Olympia, 2019, P. 40). The ability to adapt is also applicable to populations and natural systems which should be considered as part of this component (IPCC, 2014, 778).

The ability to elevate is focused on changing the asset to become adaptable and resilient through applied changes such as the raising of a building or element of infrastructure to preserve the use or function of that given asset. This category is sometimes broadened to include re-enforcement or retrofitting actions which allow the asset or system to maintain function, such as creating a sea wall, anchoring structures to foundations or implementing other flood proofing approaches which vary depending on the asset or system in question (NOAA, 2010 P. 76).

Once assets, systems, and populations have been evaluated using these components, stakeholders and the public can be engaged once again to determine community priorities. The importance of various assets to the community can be weighed across time and with consideration of adaptive use and overall costs. This process can help inform a more formal cost-benefit analysis which would be conducted as a more formal budgetary process.

3.4 Coastal Hazards

To discuss exposure and risk as part of a Vulnerability Assessment, it is first necessary to identify and define which coastal hazards play a role in a community. Bellingham hazards, both coastal and otherwise are detailed in the Bellingham Comprehensive Emergency Management Plan (City of Bellingham, 2018a, P 15). While this gives a list of what Bellingham may face, the definitions are narrowly tailored to emergency management within the city. The Washington Coastal Hazards Resilience Network (CHRN) has created both a list of the coastal hazards and a set of definitions to give some continuity to the way in which the terms are used and discussed throughout the state (CHRN, Overview). The use of consistent terminology and clear definitions is generally important but becomes essential when the terms have a complex set of underlying variables and specific regional or local context which needs to be considered.

While a comprehensive list of hazards for Bellingham may be longer, this review focused on coastal hazards with specific emphasis on those which interact with sea level rise, coastal flooding, and could compound or amplify the exposure or risk in Bellingham. There are seven hazards identified as being primary coastal hazards, three of these hazards constitute a secondary risk or may acting as an amplification factor for the others. The seven primary hazards are:

- Sea level rise
- Storm surge
- Riverine flooding
- Landslides
- Earthquakes
- Erosion/Deposition
- Tsunamis

For the purposes of continuity and industry consistency this report will rely on the definitions set out by the CHRN (Washington Coastal Hazards Resilience Network – CHRN, Overview). To plan for SLR, Bellingham will need to consider the total landward flooding extent as it results from a combination of the total water level and their selected SLR scenario. "The total water level is the maximum coastal water elevation on the shoreline, including waves and wave run-up" (CHRN, 2018, P. 4). Selecting a SLR scenario will be detailed in 3.6 Sea Level Rise; Projections, Scenarios, and Modeling.

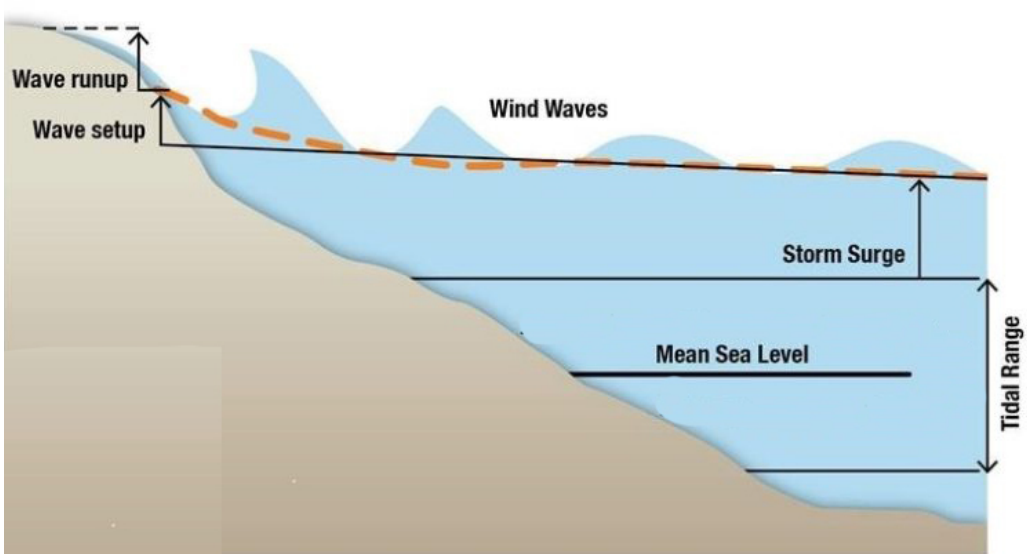


Figure 1 Total Water Level (CSIRO, 2017)

In determining exposure, the compounding of sea level rise, storm surge, and tidal stages will inform the decision-making process for determining which elements of the city's inventory is at risk. Bellingham does not have its own standalone Natural hazards Mitigation Plan, and while the preparation and mitigation of impacts for hazards is addressed in the Whatcom County comprehensive Emergency Management plan, this document does not address sea level rise, or the approaches needed in planning for it (Whatcom County, 2017).

3.5 Coastal Data and Mapping

In Washington, an assessment of SLR was conducted in 2018 which created relative sea level rise projections for 171 locations along Washington's coasts (Miller et al, 2018, P 9). This regionally specific data also provides uplift and subsidence modeling which is essential in determining the total landward flooding extent (Miller et al, 2018, P 19). Planners in Washington have two primary sources of data which are readily available to them, first is the NOAA SLR viewer with its associated data, and second is the Washington specific 2018 SLR assessment (National Oceanic and Atmospheric Administration NOAA. (n.d.-b).

The Coastal Storm Modeling System (CoSMoS) has been used to create detailed models for coastal flooding and incorporates storm systems, shoreline change, cliff retreat, and various sea level rise projections. At this time CoSMoS has only been rolled out in limited regions of California (United States Geological Survey - USGS. (n.d.-a). The two primary data sets necessary for SLR vulnerability assessments are those included in CoSMoS and the Washington 2018 Assessment of SLR.

The USGS is now working to partner with communities and organizations in the Puget Sound region to expand the CoSMoS system, aptly named the PS-CoSMoS: Puget Sound Coastal Storm Modeling System (United States Geological Survey - USGS. (n.d.-b). The PS-CoSMoS is currently working to create models for Whatcom County which would be directly applicable and usable in a Bellingham SLR VA for their SMP. Additional consideration should be given to adding data for sites designated under the Model Toxics Control Act (MOTCA), and the Environmental Protection Agency's (EPA) Superfund sites. An example which combines the various aforementioned data and tools is the USGS Hazard Exposure Reporting and Analytics (HERA) interactive map (Jones et al., 2017). This detailed tool incorporates CoSMoS map modeling with demographic, economic, development land cover, and infrastructure elements to create a comprehensive analysis tool which would be ideal for conducting vulnerability assessments.

Coastal mapping serves as a tool for evaluating the spatial relationships and risk exposure of assets in a given jurisdiction (Marin County, 2017, P 21). To develop a baseline of the working components of coastal mapping a range of sources were consulted for this review. Vulnerability assessments in other jurisdictions such as LA and Marin Counties in California, and King County along with Olympia in Washington, and the Florida Department of Environmental Protection covering a variety of jurisdictions, outlined key components to be considered (Marin County, 2017) (King County, 2019) (Fleming et al, 2020) (Florida Department of Environmental Protection, 2015).

First and foremost is the resolution or granularity of the maps and data (Fu, et al., 2019, p. 3). The scale and specific regional attributes must be accounted for on a near human scale to give enough resolution for assessing exposure and potential impact to the various assets (Marin County, 2017, p 37). The creation of mapping layers that illustrate one or more selected sea level rise scenarios can be combined with layers that depict known coastal hazard extents and used to determine the exposure and risk levels to various assets. As demonstrated in vulnerability assessments done in Marin and LA Counties in California, the creation of such layers is essential, and requires that highly granular and location specific GIS modeling is done (Fleming et al., 2020, P 37-38).

3.6 Sea Level Rise; Projections, Scenarios, and Modeling

Sea level rise is most commonly modeled using a bathtub model which does not consider changing shorelines, erosion, deposition, or subsidence (Miller et Al., 2018, P 13). While this modeling does not take into account many factors, it is widely used because more complex modeling is not widespread at this time and is both time consuming to develop and expensive to undertake. Sea level rise projections are most commonly expressed as a probability of a given rise in sea level at a set time increment (Fleming et al., 2020, P 37). Several examples of scenarios are:

Set Risk Scenarios	Term	Risk Aversion	Sea Level Rise Projection (ft)			Storm Event
			Santa Monica	Los Angeles	CoSMoS Option	
Near Term-Low Risk	2040	Low - 67% probability	0.8	0.7	0.8	Annual Storm
Medium Term-Medium Risk	2070	Medium - 5% probability	2.3	2.2	2.5	20 yr Storm
Long Term-High Risk	2100	High - 0.5% probability	6.8	6.7	6.6	100 yr Storm

Table 1 LA County CA Coastal Flooding Risk Scenarios (Fleming et al., 2020 P. 37).

Year	Most Likely (inches)	High-Range (inches)
2020	3	7
2030	**5 to 7**	**11 to 13**
2040	8 to 10	16 to 18
2050	**11 to 13**	**23 to 25**
2060	15 to 17	30 to 32
2070	18 to 20	37 to 39
2080	22 to 25	46 to 49
2090	27 to 31	54 to 58
2100	**32 to 36**	**64 to 68**

Table 2 City of Olympia Sea Level Rise Projections (City of Olympia, 2019, P 31).

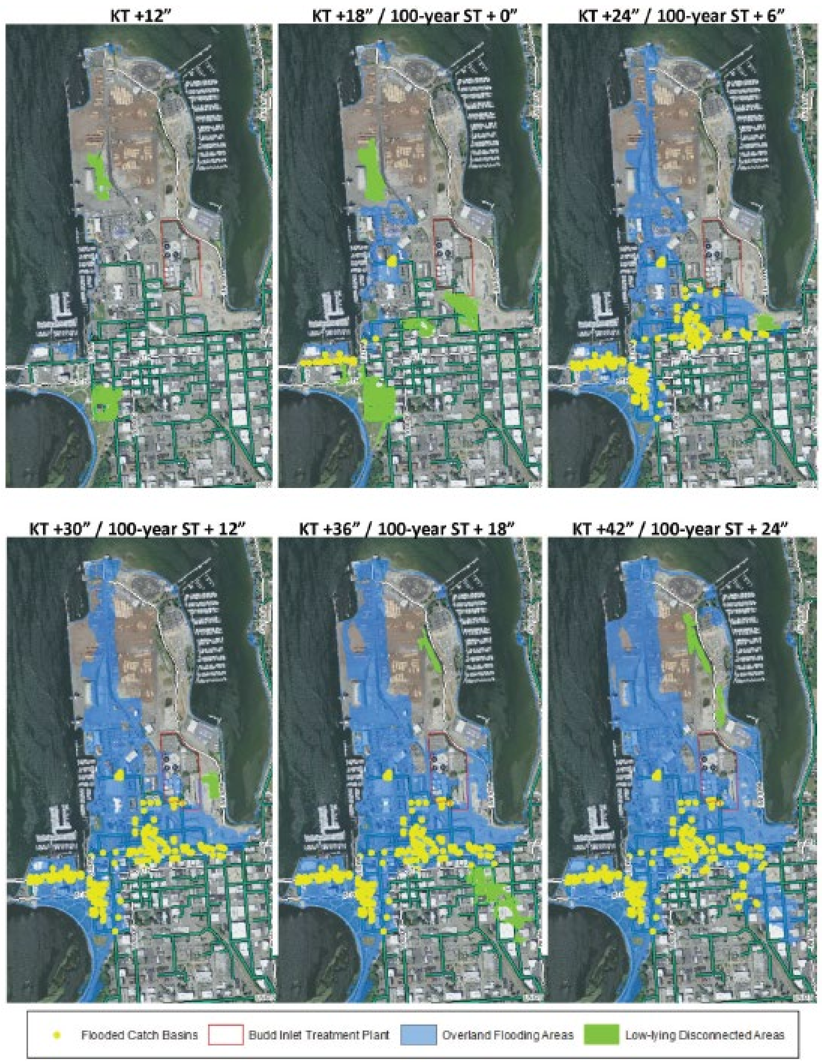
Mapping Scenario	Reference Water Level	Applicable Range for Mapping Scenario (Reference ± 3 inches)
Scenario 1	MHHW + 12"	MHHW + 9 to 15"
Scenario 2	MHHW + 24"	MHHW + 21 to 27"
Scenario 3	MHHW + 36"	MHHW + 33 to 39"
Scenario 4	MHHW + 48"	MHHW + 45 to 51"
Scenario 5	MHHW + 52"	MHHW + 49 to 55"
Scenario 6	MHHW + 66"	MHHW + 63 to 69"
Scenario 7	MHHW + 77"	MHHW + 74 to 80"
Scenario 8	MHHW + 84"	MHHW + 81 to 87"
Scenario 9	MHHW + 96"	MHHW + 93 to 99"
Scenario 10	MHHW + 108"	MHHW + 105 to 111"

MHHW = Mean Higher High Water
" = inches

Table 3 Bay Area SLR Scenario (Bay Area Metropolitan Transportation Commission, 2017, P28).

The CHRN and CIG have compiled a document which walks through the process of selecting the data location from the 2018 WA SLR assessment, selecting the timeframes, selecting probabilities, and greenhouse gas emissions scenario (Raymond et al, 2020, P 6). Vulnerability assessments typically selected two or three projections and probabilities and incorporated them into a map which expresses these scenarios over several time increments (NOAA, 2010 P 39).

A good example of a Washington jurisdiction which created such a map and multiple scenarios is the City of Olympia (City of Olympia, 2019, P 49).



Locations of Stormwater Catch Basins that Drain to the Budd Inlet Treatment Plant Note: KT = king tide and ST = 100-year storm tide in figure legend.

Figure 2 City of Olympia SLR Scenario Maps (City of Olympia, 2019, P 49).

To increase legibility the selected probabilities were often labeled using “most likely” for a highly probable outcomes and “high range” for low probability outcomes (City of Olympia, 2018, P 7). In selecting scenarios which include the projections, probabilities, and modeling of sea level rise, the exposure level of assets is the primary focus. When determining the models best suited for vulnerability assessments all reviewed cases chose the most granular and specific data available to their respective jurisdiction and evaluated both high and low probability scenarios to maximize the scope of potentially impacted assets (Marin County, 2017, P 50). In the State of Washington, the most detailed modeling and data available for SLR is currently the Washington 2018 Assessment of SLR (Miller et al, 2018, P 5).

3.7 Policies & Regulations; Adaptive Planning

The purpose of this analysis is to understand what rules and regulations govern the body of work related to SLR and coastal flooding and determine where specific agencies have jurisdiction with respect to sea level rise and coastal hazards. This section focuses on the existing the background and understanding of how different regulatory bodies regulate or provide guidance on sea level rise, how those different regulations or policies intersect, and how adaptive planning is or can be applied.

There are a variety of regulations and policies relating to shorelines and flooding at various levels of government. At the federal level, the Federal Emergency Management Agency (FEMA) does not directly regulate or manage local coastal areas. However, local jurisdictions which want to participate in the National Flood Insurance Program (NFIP) are required to adequately plan for flooding to participate in the program. The details of minimum compliance with flood plain management criteria are outlined in the Code of Federal Regulations (CFR) Title 44, Chapter I, Subchapter B, Part 60.2.

The Washington Growth Management Act (GMA) establishes the requirements and legal grounds for comprehensive planning at the local level (Washington State Legislature, Chapter 36.70A RCW). The Shoreline Management Act (SMA) which was its own planning process has now been incorporated into the GMA planning Process (Washington State Legislature, RCW 36.70A.480.). As a component of a comprehensive plan, jurisdictions are required to create shoreline master programs (SMP). Both Counties and Cities create comprehensive plans and shoreline master (or management for counties) programs. Neither the Bellingham Comprehensive Plan nor the Bellingham SMP currently address SLR. Bellingham’s Surface and Stormwater Comprehensive Plan addresses SLR in a limited policy approach which accounts for minimal impact to existing systems using the existing model from 2018 (City of Bellingham - SSCP, 2020, P 72). Saltwater intrusion into infrastructure and water tables which may result in surface inundation is not addressed in the stormwater plan (City of Bellingham - SSCP, 2020).

To plan for such uncertainties and create effective policies, it is possible to implement a system of monitoring and triggers for specific thresholds which result in the implementation of a previously created alternative policy (McInerney et al. 2012, P 549). A more comprehensive approach which includes both adaptive policymaking and adaptation pathways for implementation is called the Dynamic Adaptive Policy Pathways or DAPP (Haasnoot et al, 2013, P 489). The DAPP process involves creating a problem analysis which in this case would be the VA framework, then identifying possible actions and determining possible pathways which can become an iterative process. The possible pathways are filtered down to those which are preferred and evaluated for robustness.

These pathways are then incorporated into an adaptive planning structure which can then be implemented, and monitoring can be setup to include triggers which would alter the pathways used for the specific implementation of policy (Haasnoot et al, 2013, P 489-91). An example of this for SLR, could be to track landward water extents and to adopt the aforementioned policy approach when a set threshold is crossed. Setting these thresholds can be done based on a specific assets sensitivity or as determined by the community for a more qualitative and narrative based approach (Raso et al. 2019, P 5).

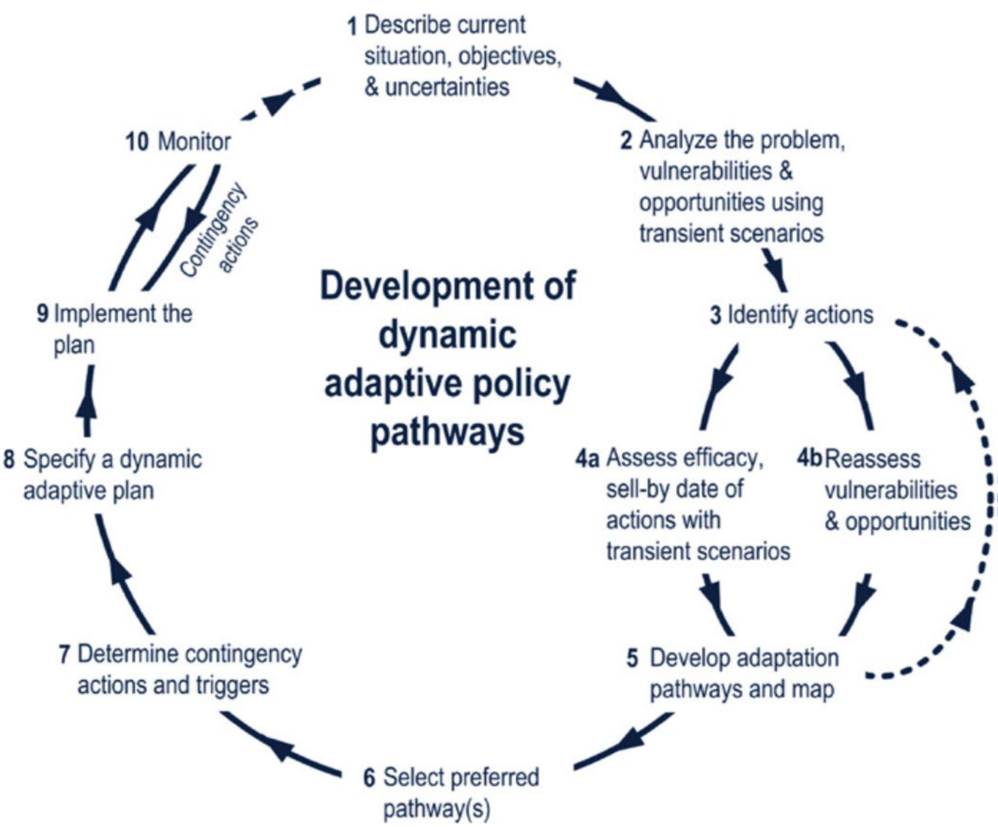


Figure 3 Developing Dynamic Adaptive Policy Pathways (Haasnoot et. al, 2012,P. 5)

3.8 Shoreline Master Programs

The Shoreline Management Act requires the creation and systematic update of a planning document produced by each community which has a shoreline. The state of Washington has 260 cities with Shoreline Master Programs (Washington State Department of Ecology, Shoreline management, 2020). The jurisdiction of the SMP is 200' directly inland from the ordinary high-water mark (Washington State Legislature, RCW 90.58.030 (2)(c)). State law regulating the contents of shoreline master programs does not contain any requirements to address sea level rise (WAC 273-36-191).

Appendix A of the SMP guidebook, while limited, does outline how sea level rise should be addressed. The jurisdictional boundary will maintain the 200' jurisdictional area which will shift over time as the sea level rises (Washington State Department of Ecology, Appendix A, P 5). This shift will also require a re-evaluation of inventory and may alter the characterization of some areas as they are inundated or changed by erosion or deposition. Additionally, an inventory of assets is necessary and required as part of the SMP planning process (Washington State Department of Ecology Appendix A, 2017, P 6). Characterization of coastal landforms is projected to change, but there is no requirement to account for this change before it occurs.

The Washington Department of Ecology which has approval authority over local SMPs, has outlined an approach with a wide range of SMP policies including no net loss strategies in its SMP handbook. The policies include guidance on climate change preparation, shoreline use, flood hazards, shoreline modification, development regulation, environmental buffers, and adaptive use approaches. The Appendix A of the SMP guidebook offers an overview of how a jurisdiction can and should approach SLR but does not provide a framework for assessing vulnerabilities which SLR causes. The current Bellingham shoreline master program does not address the vulnerabilities caused by SLR. The 2013 Bellingham SMP has an objective to incorporate SLR relating to development as new science becomes available (City of Bellingham, 2013, P. 32).

3.9 Literature Review Conclusion

The current laws and guidance in Washington State do not speak to how Cities should plan for SLR. To establish a starting point for Bellingham to adequately identify alternatives and incorporate appropriate management measures into SMPs a SLR VA is needed. Before a vulnerability assessment can be done and used for updating the SMP, a framework which details and guides the process should be created. The format for creating the framework will be based on the seven components identified in the literature:

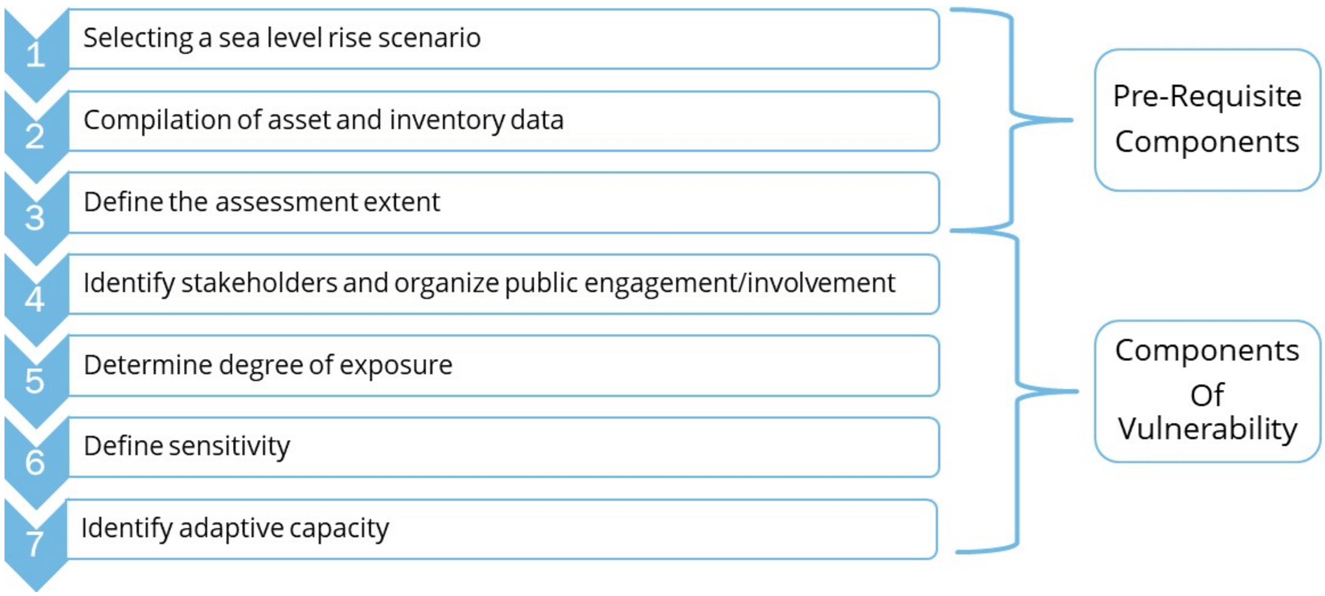
1. Selecting a sea level rise scenario
2. Compilation of asset and inventory data
3. Define the assessment extent
4. Identify stakeholders and organize public engagement/involvement
5. Determine degree of exposure
6. Define sensitivity
7. Identify adaptive capacity

While some components of the framework will be tailored for Bellingham, many will have interjurisdictional relevance and applicability because of their generalizable nature of the resources. The sources for modeling and data will need to be tailored to each jurisdiction. In the literature, this was the most varied component in other vulnerability assessments. While the overarching structure and approach of the VA can be made to suit a wide range of Washington jurisdictions the goal is to establish a specific VA for SLR in Bellingham to be used in updating the SMP. For each component, examples, worksheets and/or resources are provided to guide the reader on how to proceed.

4.0 Vulnerability Assessment Framework

4.1 Vulnerability Assessment Framework Introduction

The following document aims to create a framework to assess the vulnerability of Bellingham to Sea level rise and to provide the opportunity for the community to plan for it. The various sections below outline the primary components of the process, and the subsections provide an approach along with resources where relevant. These seven components are:



The overarching goal is to give Bellingham the ability to plan for sea level rise and to incorporate it as part of the Shoreline Master Program as well as other relevant planning documents mentioned in the below subsections.

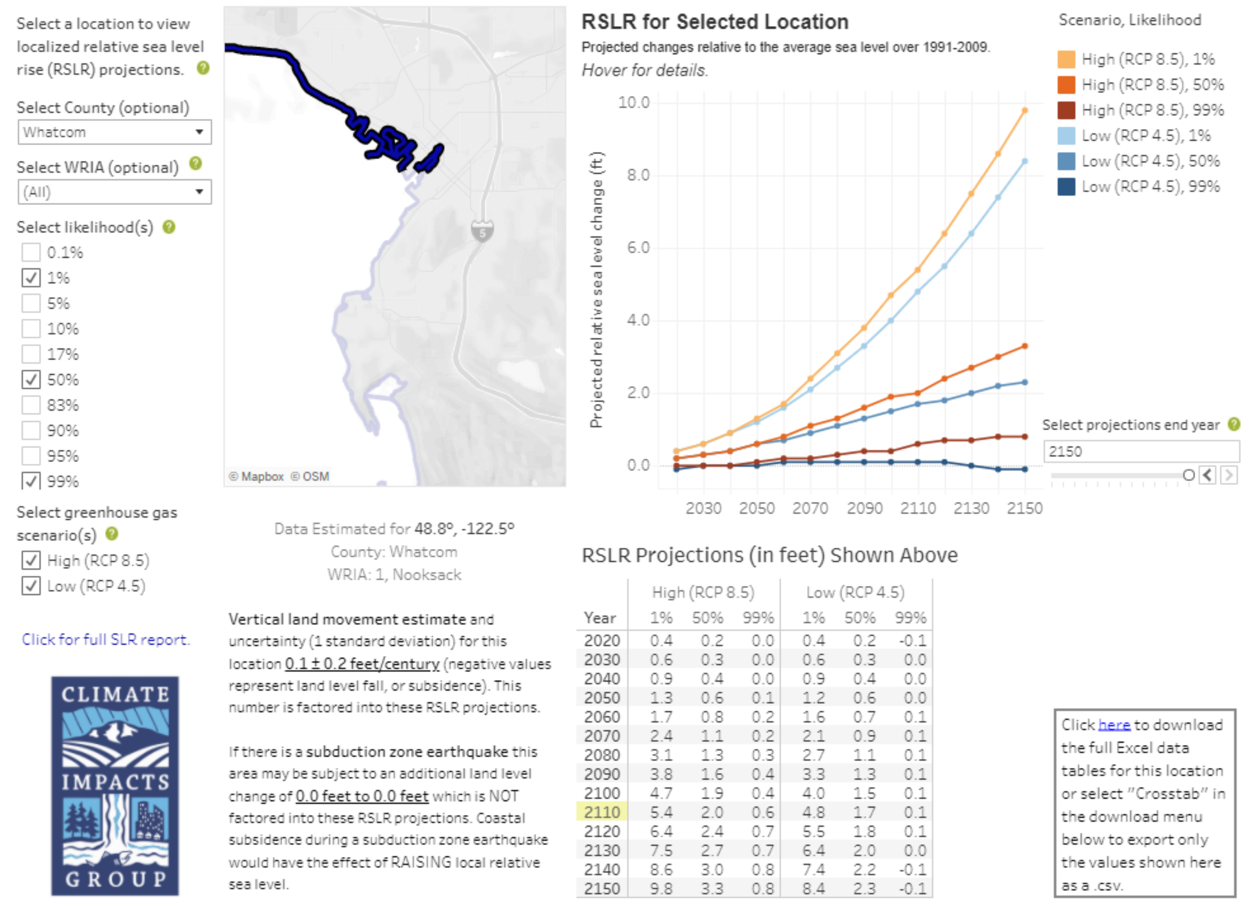
4.2 Selecting A Sea level Rise Scenario

This section focuses on selecting a Sea level rise (SLR) scenario which is comprised of the sources of data and modeling for SLR, the specific probability of SLR, coastal hazards, and changes to the geomorphology which may impact the landward extend of marine flooding. The result of this selection process will be a scenario which is expressed as a total water level (TWL).

4.2.1 Data and Modeling Selection

As part of deciding on an overall scenario it is important to use the best available science and most current data sets. As an example, the most current SLR projection data for Washington is from 2018 and is available to the public for incorporation into planning documents. The selection of best available data is important in order to provide the most accurate combined scenario of sea level rise for your community. A combined scenario is one which incorporates the various components of total water as described by the components in this Sea level Rise Scenario section. In Washington we have public access to two primary sources of SLR data. The most general is the NOAA SLR viewer, using data from the NOAA SLR database linked below in the resources. This provides a model visualizer and a simple sliding scale for water elevations. The second source is the 2018 sea level rise assessment completed for Washington. Links to this data and visualizations of it are in the resources below. This data is more specific to our region and has a higher resolution for evaluating the extent of landward water. The data also incorporates projections of subsidence and uplift which are important to consider, especially in regions which were previously glaciated which may result in rebound, or areas which have active tectonic plate movement, which could raise or lower the relative elevation. The University of Washington Climate Impacts Group also create a set of Visualizer tools for this data which can be helpful in communicating the data to the public and elected decision makers.

VISUALIZATION #1: Projected sea level change by year



	High (RCP 8.5)			Low (RCP 4.5)		
Year	1%	50%	99%	1%	50%	99%
2020	0.4	0.2	0.0	0.4	0.2	-0.1
2030	0.6	0.3	0.0	0.6	0.3	0.0
2040	0.9	0.4	0.0	0.9	0.4	0.0
2050	1.3	0.6	0.1	1.2	0.6	0.0
2060	1.7	0.8	0.2	1.6	0.7	0.1
2070	2.4	1.1	0.2	2.1	0.9	0.1
2080	3.1	1.3	0.3	2.7	1.1	0.1
2090	3.8	1.6	0.4	3.3	1.3	0.1
2100	4.7	1.9	0.4	4.0	1.5	0.1
2110	5.4	2.0	0.6	4.8	1.7	0.1
2120	6.4	2.4	0.7	5.5	1.8	0.1
2130	7.5	2.7	0.7	6.4	2.0	0.0
2140	8.6	3.0	0.8	7.4	2.2	-0.1
2150	9.8	3.3	0.8	8.4	2.3	-0.1

Figure 4 Climate Impacts Group SLR Visualizer (Lavin P et. al, 2019)

Where available, the Coastal Storm Modeling System (CoSMoS) provides an additional level of detail, including storm surge, erosion, and tidal fluctuation data, among others. CoSMoS has expanded and is now in the process of modeling parts of Puget Sound as the program partners with communities to do the modeling work.

Resources:

NOAA Sea Level Rise Viewer

NOAA Sea Level Rise Database (Download By State and County)

Sea Level Rise in Washington State – A 2018 Assessment

Interactive Sea Level Rise Data Visualizations (WA 2018 Assessment)(CIG Website)

PS-CoSMoS: Puget Sound Coastal Storm Modeling System

4.2.2 How to Choose

To begin the process of selecting a sea level rise (SLR) scenario it is important to begin by understanding the existing literature and best science. A document which helps to break down the various elements and decisions to aid in the decision-making process has already been written. "How to Choose – A Primer for Selecting Sea Level Rise Projections for Washington State" is an essential read for the staff involved in creating the SLR scenarios for elected officials to choose. The primer acts as a guide to selecting three primary elements; the timeframe, probabilities, and choosing greenhouse gas emission levels. While the sections of this document help walk through the various steps of a SLR scenario selection, the primer can help bring essential staff quickly up to speed on the reasoning and background for the decisions needing to be made.

Resources:

How to Choose: A Primer For Selecting Sea Level Rise Projections for Washington State

4.2.3 Sea Level Rise Probability

Determining which probability to use is directly related to the city's acceptance of risk. Choosing to go with a high probability scenario will be easier to justify to constituents but may result in a scenario being selected which does not accurately account for actual SLR, resulting in areas being impacted which were not accounted for in the selected scenario. While selecting a low probability SLR scenario will cover even unlikely outcomes but will allow for a maximum level of mitigation and preparedness on the part of all affected entities. The How to Choose report assists in understanding this issue as well as use of the Interactive data visualization tools.

Resources:

Interactive Sea Level Rise Data Visualizations (WA 2018 Assessment) (CHRN Website)

4.2.4 Coastal Hazards

In addition to considering sea level, consideration should be given to coastal hazards which may further impact the extend and degree of flooding. Whether considering erosion or deposition patterns, or storm modeling, it is important to layer this information with the sea level rise to determine the maximum flooding extent. Modeling for these factors has been started by the USGS CoSMoS program. At the time of writing this report the modeling extent is limited in Washington state but expanding to include new regions. If available, this data and modeling can be used to represent the net impacts more accurately and in determining extreme water levels.

Where this data is not yet available, the Washington Coastal Resilience Project has created the "Extreme Coastal Water Level in Washington State: Guidelines to Support Sea Level Rise Planning" document. In determining total water levels, the most current and best science available should be utilized to ensure that the decision-making process is well informed. The purpose of a vulnerability assessment is to look at the maximum landward extent of probable flooding as it results from SLR and the presence of amplification factors from coastal hazards such storm surge. The specific storm probability and extent should be selected based on the risk acceptance level that the community has. As an example, the city of Olympia has chosen to use a 100-year storm in conjunction with a king tide for their scenario.

Resources:

Coastal Hazards: An Overview (CHRN)

Extreme Coastal Water Level in Washington State

4.2.5 Planning Horizons

As part of the process to select a sea level rise scenario which comprises the total water level, the planning horizon must be established. While the Growth management Act (GMA) in Washington requires periodic comprehensive plan updates on an 8-year schedule with a planning horizon of 20 years, sea level rise is often projected out more than 50 or even 100 years. Creating a set of scenarios at intervals of 50 years spanning a 150-year period would give an adequate temporal scale for evaluating changes and accounting for both ecological and development trends. The speed and levels of re-development and ecological change should be accounted for when considering the planning horizon to account for the timelines required by various mitigation approaches the city may take. As with the periodic planning updates for comprehensive plan and the Shoreline Master Program (SMP), the horizon should be shifted with each subsequent update to maintain the same interval. Examples of tables which show scenarios and incorporate a temporal scale can be found in section *3.6 Sea Level Rise; Projections, Scenarios, and Modeling* of this document.

4.3 Compilation of Asset and Inventory Data

The compilation of asset and inventory data should be done in the same manner as the inventory and characterization is done for the SMP. The primary difference is that the VA asset and inventory data will cover an area which may exceed the jurisdictional boundary of the SMP. For efficiency, the data may be compiled in the same manner in which the SMP inventory and characterization data is collected. Defining the area which will be considered is detailed in the following section (Section 4.5).

4.4 Define the Assessment Extent

Before conducting the VA, it is necessary to determine the area which is being considered. While the Shoreline Master Program (SMP) jurisdiction is explicitly defined and codified, the Vulnerability Assessment (VA) boundary extent is not. The following sub-sections differentiate between the existing jurisdictions and review the elements which should be considered for being part of the VA extent, ultimately a community can decide to include as much as their urban growth area boundary, or as little as the current SMP jurisdiction, but the primary focus here is on using the total landward flooding extent and any potentially impact to set an extent which will help the community in its planning.

4.4.1 Current SMP Jurisdiction

The Shoreline Master Program has a jurisdictional boundary which is defined as being two hundred feet landward of the OHWM. The jurisdiction may include (at the city's discretion) additional areas which are part of a contiguous floodplain beyond the OHWM, and the boundary may be two hundred feet inland of that area as measured along a horizontal plane. RCW 90.58.030 (c & d)

4.4.2 SLR SMP Jurisdiction

As the sea level rises the OHWM will shift, and the jurisdiction will need to be updated to maintain the two-hundred-foot landward boundary. This jurisdictional adjustment is done as the OHWM changes and may incorporate the resulting adjusted floodplain as set out by the Washington State Legislature.

4.4.3 SLR VA Extent Selection

After having selected a SLR scenario, the selection of a VA extent can be done by identifying the most landward extent of flooding as expressed by the total water level (TWL) and the selected SLR scenario. This is the minimum extent for the VA. It is also pertinent to consider adding a buffer which would include adjacent parcels or tracts which may be subject to primary or secondary impacts of the total landward flooding extend. Where relevant built and natural systems should be evaluated for impacts beyond the projected flooding extent. This may include storm water systems, pocket estuaries, or other ecological or built systems which may be impacted by saltwater intrusion or inundation. Consideration should be given to the entire system and its components which may suffer direct or secondary effects of the projected total landward flooding extent. Primary or direct effects are those which result from direct contact with the floodwaters. Secondary effects may include long term disruption of ecosystems or services, such as the contamination of an aquifer from runoff or the loss of transportation routes over time. The final VA extent should be a combination of the above elements and any buffers determined to be necessary through public engagement.

4.5 Identify Stakeholders and Organize Public Engagement/Involvement

4.5.1 Desired Outcomes (Big Picture)

To determine the desired outcomes, the community first needs to be given the opportunity to understand the maximum landward extent of marine flooding an area may experience in the future. As part of the VA process, it is important to establish a set of desired outcomes for the community which are iteratively decided upon during the implementation of the other six VA framework components. Determining the community's priorities and desired outcomes will ensure that the assets (either built, natural, or social) are preserved, maintained, or decommissioned in a manner which is most congruent with the communities wants and needs. The desired outcomes will drive the decision making throughout the planning process, which is why it is vitally important to involve the public in the iterative process of determining them at all stages of implementing the VA framework.

4.5.2 SMP Public Involvement

The Shoreline Master Program has a well-defined public engagement practice. The addition of the SLR VA will require that additional public engagement be done at each stage of the process to ensure that the community priorities are considered when selecting scenarios and conducting the assessment. Public engagement in the VA process should begin with the selection of the SLR scenario, especially with regards to determining the desired outcomes. Because the public engagement process is detailed in the SMP guidebook, these suggestions are only meant to highlight additional opportunities for public engagement during the VA process. Where plausible the existing schedule for public engagement should be amended to include discussion on the VA elements being conducted or planned for at that time.

4.5.3 Identifying Stakeholders

The list categories of stakeholders identified by the SMP guidebook is in most cases adequate. In addition to the existing lists of identified stakeholders it is important to include those individuals or groups who may be directly impacted by the projected TWL. This may or may not be entirely covered by the existing list of stakeholders and as such any parties not currently in the original SMP stakeholders' group should be added to it so that they may be apprised of the process and given the opportunity to engage with the process.

Resources:

NOAA Participants Checklist for Risk and Vulnerability Assessment

NOAA Stakeholder Analysis Worksheet

Community Asset Mapping Meeting Engagement Tool

4.6 Determine Degree of Exposure

Once the VA extent has been selected the next step is to conduct the exposure analysis. This section is focused on identifying what is exposed to the TWL. This is primarily an exercise in mapping the VA extent and identifying the assets, populations, and systems which are within that area. The output from this step should be a table of exposed assets, systems, and populations which are geolocated and then mapped with the selected SLR scenario, and coastal hazard data per section *4.3 Selecting A Sea level Rise Scenario* of this document. The degree of exposure and timeframes should also be recorded for each of the three elements.

4.6.1 Assets

In the context of the VA, assets shall include both natural and built elements. All assets within the VA extent should be evaluated to determine the degree and timeframe of exposure to flooding. Each asset should be categorized based on the extent of exposure to flooding. The degrees of exposure can be grouped for assets of similar exposure levels. Such groupings could be created by using incremental flooding and inundation groups which relate to a specific timeframe, e.g.: 1” to 2”, 2.1” to 3”, 3.1” to 4” of projected flooding for the year 2100. The increment of flooding and the timeframe should be determined by the city’s acceptance of risk and community input. Each asset should be identified and mapped.

4.6.2 Populations

The City should identify population groups that utilize assets which have been determined to have an exposure to the total landward flooding extent. These groups are not limited to the stakeholders but may also include at risk populations such as the homeless population which may rely on assets impacted by the flooding. Identifying these populations may require directly surveying the area and determining which individuals or groups are impacted.

4.6.3 Systems

While the assets may include directly exposed elements of a system, it is necessary to consider if the entire system is impacted by the exposure of individual components. If the whole system has a dependency on exposed components, then the entire system should be documented as part of the exposed assets. To determine this, it may be necessary to contact the department or agency in charge of the given system. An example of an exposed system element may be an infrastructure network which is comprised of connected elements that are susceptible to disruption if individual elements are impacted, this may include common infrastructure such as an electrical grid, or stormwater system, but may also include ecological systems especially if a keystone species or component is impacted.

Resources:

Marin Shoreline Sea Level Rise Vulnerability Assessment.

(Pg. 58 Asset Profiles: Transportation Exposure Tables)

4.7 Define Sensitivity

The next step is to determine which of them are sensitive to the impacts of the flooding. Sensitivity is the degree to which the condition or functionality is affected as a result of the total landward flooding extent. Determining sensitivity is done by assessing the adverse effects of the flooding or inundation which results from the selected scenario, these affects will vary by asset, and by the extent and frequency of exposure which was determined in the previous section.

4.7.1 Assets

Sensitivity of an asset is determined by the degree to which the condition or functionality of said asset is adversely impacted by the total landward flooding extent. The determination of sensitivity can be somewhat subjective when evaluating certain assets. For such cases, a qualitative description of the sensitivity should serve as the analysis of the asset. Where sensitivity can be easily determined as with assets that have binary outcomes from flooding exposure the sensitivity analysis can be a more quantitative narrative. For example, an electrical panel which is not rated for marine environments would need to be replaced or moved outside of the affected area or elevation. On the other hand, an asset such as park land may have a more complex interaction with flooding which is adverse and requires a more qualitative description. There may also be assets which do have exposure to flooding but do not have sensitivity. Assets which are not sensitive to flooding do not need to be evaluated for adaptive capacity. All assets should be placed into categories for both organization and ease of reference. Categories may include: Buildings, Utilities, Park Lands, etc. Each category may have several characteristics which make it sensitive to flooding. For example, older buildings may be more susceptible to damage from flooding, and vegetation in parks may be intolerant to salt water. Once established these categories and sensitivity characteristics can then be added to the overall data collection. An example of how a table of this data might look is included below, and a link to the full table and document is linked in the resources.

VULNERABILITY (SENSITIVITY AND ADAPTIVE CAPACITY) AND QUALITATIVE CONSEQUENCE INFORMATION

Note: Assets that are greyed out are not located in the SLR vulnerability zone (100-year storm tide + 68-inches SLR). Asset exposure listed as ">24 inches" indicates flood impacts occur between 24-inches and 68-inches of SLR.

			Notes			
Asset ID	**Asset Name**	**Initial Exposure to 100-Year Storm Tide (100-Year + SLR)**	**Sensitivity** Definition: the degree to which the physical condition and functionality of an asset, population, or system is affected by a climate hazard) Example: A pump station or traffic signal is exposed to flooding and has sensitive electrical components contained within a panel at ground level. *Note: Olympia responses based on a 1 percent tidal event*	**Adaptive Capacity** Definition: the degree to which an asset, population, or system is able (or unable) to cope with adverse impacts of a climate hazard) Example: Sensitive electrical panels could be elevated above flood waters. Panels could be retrofitted to be watertight.	**Qualitative Consequences**	**Consequence Rating (Low/Medium/High)**
City Assets						
1	Percival Landing Moorage	0-inches	Extreme high tides that raise the gangplanks above horizontal may result in closure of the floating docks.	The shoreline will need to be elevated to maintain dry access to the marinas.	Guest moorages are used during community festivals such as Harbor Days and Wooden Boat Festival. Flooding could disrupt festivals and impact associated economic activity.	Low
2	Downtown Welcome Center	>24-inches	Access limited at 24-inches SLR. Potential structural damage at 27-inches SLR. Finished floor elevation is 16.2 feet NAVD88.	Potential to protect doors with flood barriers for a limited time. It is assumed that the ultimate adaptation will be a regional solution (levee, wall, raised roadway, etc.)	Home of the Olympia Downtown Ambassadors, a team that cleans and patrols downtown.	Low
3	Olympia Center	0-inches	Access limited at 0-inches SLR. Potential structural damage at 5-inches SLR. Finished floor elevation is 14.41 feet NAVD88.	Installation of stormwater valve in the parking lot in the next year will protect parking lot against flooding. Flood barriers could be installed on the doors to extend structural resilience to approximately 12-inches SLR. It is assumed that the ultimate adaptation will be a regional solution (levee, wall, raised roadway, etc.).	Olympia's only community center, therefore it is considered to be a critical facility. Flooding would impact meals served to low income seniors. Potential loss of revenue from inability to rent event space.	Medium
4	Hands on Children's Museum & Plaza	12-inches	Access limited at 12-inches SLR. Potential structural damage at 24-inches SLR. Finished floor elevation is 16.01 feet NAVD88. Outdoor play area elevations vary from approximately 15.8 to 17.0 feet NAVD88.	Adaptability beyond 24-inches SLR is uncertain. It is assumed that the ultimate adaptation will be a regional solution (levee, wall, raised roadway, etc.).	The HOCM attracts more than 300,000 visitors per year. Loss of operation would impact Olympia tourism.	Medium

Table 4 Sensitivity and Adaptive Capacity Qualitative Data (Olympia, 2018, P. 56)

4.7.2 Populations

Those population groups identified by the exposure analysis should now be evaluated for their sensitivity to flooding. The determination of sensitivity for a population is more easily quantifiable where displacement or loss of personal possessions is plausible and documentable. The sensitivity of a population group may be difficult to express in a quantitative manner and in those cases, it is advisable to write a qualitative narrative assessment.

4.7.3 Systems

The sensitivity of a system whether natural or built to flooding should be evaluated for not only the directly impacted elements of a system, but for those elements which may be impacted by the reduced functionality of the other elements. When considering systems such as an aquifer, it may be relevant to call out the sensitivity of other systems such as wells which rely on this aquifer, or habitat which may be degraded or destroyed by changes to it. While in some instances there may be system wide sensitivity to the exposure of just one component, in other cases that component may not have such an impact. In evaluating a system's sensitivity, contacting a subject matter expert, or those responsible for the continued operation or functionality of the system may be the best approach to identify specific strengths or weaknesses as part of the sensitivity analysis.

Resources:

[Olympia SLR Vulnerability and Risk Assessment]

(Pg. 56 Sensitivity and Adaptive Capacity Tables)

4.8 Identify Adaptive Capacity

The purpose of conducting the adaptive capacity analysis is to establish which assets and systems need further investment and when. This section is broken out into four categories and a fifth category which gives an opportunity to quantify and filter the approaches for prioritization and fiscal purposes. The four categories are:

- System redundancy
- Ability to relocate
- Adaptive Learning
- Ability to elevate

The initial analysis is aimed at characterizing the natural built or social systems by their ability to develop functional redundancy, relocate, elevate and adaptive learning given a selected SLR scenario and the resulting total landward flooding extent. After the assets, populations and systems have been characterized, the four categories can be considered again as an approach which could be applied. For example, a street which is the only service route to an area may be adaptable in that it can flood intermittently and still serve its purpose, or be retrofitted to function during flooding events, but after this characterization the approach may be to relocate the road or add a second access route which would serve as a redundancy. This approach evaluates the assets, systems, and populations regarding their existing adaptive capacities, and for plausible future approaches in addressing deficiencies.

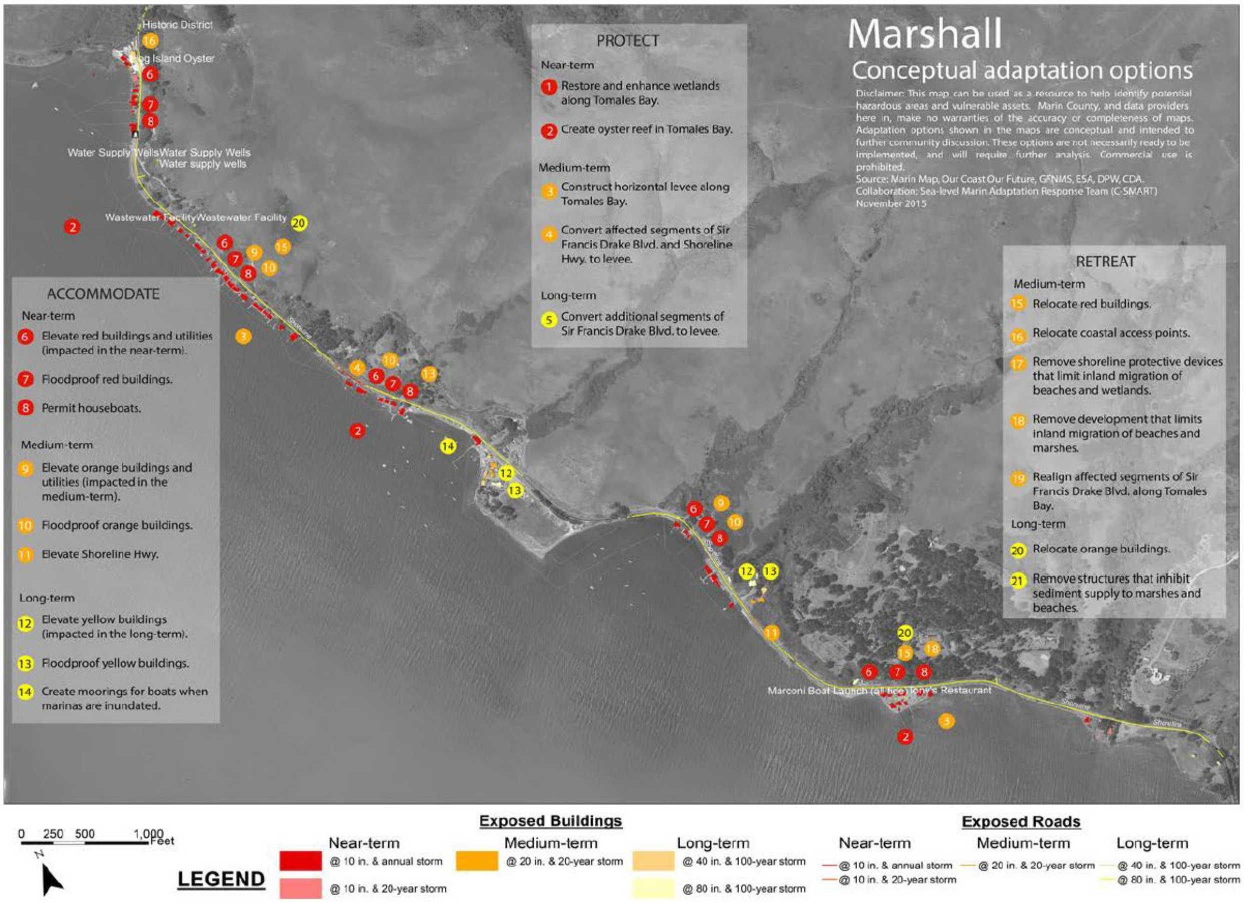


Figure 5 Conceptual Adaptation Options (Marin County, 2018. P. 190)

4.8.1 System Redundancy

Each asset should be evaluated for system redundancy. An asset may be considered redundant when a direct substitute or duplicate is available in either form or function and will not be impacted by flooding. Redundancy will be expressed differently for different assets, for example a road or path may have an alternative route which serves the same purpose, or a storage facility may have an alternative location which could be utilized. In the case of natural assets, the redundancy would be expressed by way of abundance as it relates to necessity or demand. A shoreline habitat may be unique or may share similar characteristics with an adjacent area which will not be impacted.

4.8.2 Ability to Relocate

This adaptive characteristic is more typically coupled with built assets and is characterized by the ability to move the asset outside of the VA extent and beyond the sensitivity threshold of the given asset. In terms of natural assets, it is possible to relocate trees, vegetation, or animal populations but this has limitations coupled to the habitat and survivability of relocation for living organisms. The relocatability of a function for an asset is also at question, not just the physical asset.

4.8.3 Adaptive Learning

An assets adaptive learning is determined by its resilience to the adverse impacts of the total landward flooding. Assets may be entirely adaptable to flooding or only to a degree. For example, emergency response vehicles may be able to drive in 6" of standing water but not in 10". The level of adaptability is dependent on the asset and characterized by the degree of TWL exposure and sensitivity. It is also important to consider frequency of flooding or if the area is inundated as the specific ability to adapt may depend on this. Determining degree of exposure as detailed in section 4.6 will provide the necessary information for evaluating this aspect of an assets ability to adapt. The findings of adaptability can be given as a narrative which describes their adaptability bounds and limitations in the context of the selected SLR scenario and a given timeframe.

4.8.4 Ability to Elevate

Elevating is an option which may extend the useful life of a built element, but generally does not apply to natural environments or their components. For this reason, the ability to elevate also includes retrofitting which may be applied to both the built and natural environments. A more detailed definition can be found in section 3.3.2. Retrofitting can include elevating a building to an extent where the occupiable space is above the flooding or re-purposing the lower floor(s) for uses which are not sensitive to temporary or permanent inundation depending on the flooding impacts at that given location. Retrofitting may also include the structural hardening of sites to prevent flooding, inundation, erosion, or any other adverse impacts to sensitive assets. In the case of non-built assets, retrofitting includes measures such as securing a bluff with a variety of erosion control methods or creating an estuary where a field may have been. The range of solutions depends greatly on the specific asset. Each asset will need to have details added to the VA data set.

4.8.5 Cost- Benefit Analysis

To aid in decision making, a cost - benefit analysis can be done when considering specific assets or systems and the approaches to be taken. No matter which of the above four approaches are considered, the cost of each relative to the benefit for the community is important to quantify. As part of the VA this analysis would focus on a qualitative evaluation, while other mechanisms within the city may be used to consider the quantitative costs of the above approaches. Examples from Olympia Washington and Marin County California illustrate the ways in which this can be incorporated as a narrative for decision makers and specialists to take next steps in determining the fiscal components associated with the outcomes of this analysis.

Strategy Type / ID	Strategy	Lead Agency	Resources	Time-frame
Physical Strategies				
Capitol Lake / Lower Deschutes Watershed				
Near-Term Strategies (up to 6 inches of sea level rise)				
CL-1	Install backflow prevention on stormwater outfalls and other key pipes	City of Olympia Public Works	Existing Staff $50K	2019-2024
CL-2	Minor landscaping at key locations to raise ground elevations	DES	$250K	2019-2024
Mid-Term Strategies (up to 24 inches of sea level rise)				
CL-3a	Construct new wall: Construct a new flood-wall at elevation 17 feet and elevate Capitol Lake path along the shoreline	DES	$4M - $6M	2025-2050
CL-3b	Construct new berm: Construct a berm at elevation 17 feet within Heritage Park and relocate Capitol Lake path inland to a higher elevation	DES	$3M - $5M	2025-2050
CL-4	Install flood gate across railroad and Pow-erhouse Road (required with wall and berm options)	City of Olympia Public Works	$200K - $300K	2025-2050
Long-Term Strategies (up to 68 inches of sea level rise)				
CL-5a	Raise floodwall: Raise floodwall and path along shoreline to 21 feet	DES	$2M - $2.5M	2050-2075
CL-5b	Raise berm: Raise berm and path in Heri-tage Park to 21 feet	DES	$8M - $10M	2050-2075
CL-5c	Raise floodwall and berm: Hybrid strategy that would raise floodwall and landscaping within Heritage Park	DES	$14M - $17M	2050-2075
CL-6	Replace flood gate across railroad and Powerhouse Road	City of Olympia Public Works	$300K - $400K	2050-2075
CL-7	Raise 5th Ave and Columbia Street (optional)	City of Olympia Public Works	$80M - $100M	2050-2075
CL-8	Consolidate stormwater outfalls	City of Olympia Public Works	TBD	2050-2075
CL-9	Construct stormwater discharge pump station	City of Olympia Public Works	$300K - $400K	2050-2075
CL-10	Protect Percival Drinking Water Pump Station	City of Olympia Public Works	$0.5M - $1M	2050-2075

Table 5 Adaptation Strategies with Costs (City of Olympia, 2019. P. 114)

Resources:

Olympia SLR Vulnerability and Risk Assessment

(Pg. 56 Sensitivity and Adaptive Capacity Tables)

Marin Shoreline Sea Level Rise Vulnerability Assessment:

(Pg. 24 Appendix A. Adaptation and Vulnerability Evaluation Tool)

Island County Sea Level Rise Strategy Study

(Pg. 160 Worksheet 4A Adaptation Strategy Development)

4.9 Implementation

4.9.1 SMP Update

As part of the SMP update process there is an opportunity to incorporate new elements such as this VA for SLR. To plan for SLR the first step is to determine the vulnerability of the city and create a foundation of information which would also include the adverse impacts of SLR. While updating the SMP with a SLR VA, the best available science should be used to inform the research and information gathering process. As the literature, scientific research, data, and modeling evolve and improve, subsequent SMP updates should incorporate them to ensure best plausible outcomes can be achieved.

4.9.2 Vulnerability Assessment Data

The Data collected from the Exposure Analysis, Sensitivity Analysis, Adaptive Capacity Analysis should be compiled as a table which would serve to give an overview of the information gathered and provide a starting point for addressing the impacts of SLR. The data should also include the address or latitude-longitude location for the assets in a consistent format so that the entire data set may be mapped. See table below for reference. In creating such a table, additional fields may be added to give further details or specific characteristic details to an asset which are deemed significant by the city which may not have been included in the example.

			Notes			
Asset ID	**Asset Name**	**Initial Exposure to 100-Year Storm Tide (100-Year + SLR)**	**Sensitivity** Definition: the degree to which the physical condition and functionality of an asset, population, or system is affected by a climate hazard) Example: A pump station or traffic signal is exposed to flooding and has sensitive electrical components contained within a panel at ground level. *Note: Olympia responses based on a 1 percent tidal event*	**Adaptive Capacity** Definition: the degree to which an asset, population, or system is able (or unable) to cope with adverse impacts of a climate hazard) Example: Sensitive electrical panels could be elevated above flood waters. Panels could be retrofitted to be watertight.	**Qualitative Consequences**	**Consequence Rating (Low/Medium/High)**
30	State Archives Building	80-feet	Underground		Little consequence within this plan's time horizon.	
31	Natural Resources Building	50-feet			Little consequence within this plan's time horizon.	
32	Governor's Mansion	130-feet			Little consequence within this plan's time horizon.	
33	Insurance Building	>100-feet			Little consequence within this plan's time horizon.	
34	State Capitol Building	>100-feet			Little consequence within this plan's time horizon.	
35	Visitor Center	>110-feet			Little consequence within this plan's time horizon.	
36	Licenses Building	>50-feet			Little consequence within this plan's time horizon.	
37	Powerhouse	18-inches	Access and parking exposed at 18-inches SLR. Building is elevated and is not exposed to flooding.			
38	Capitol Lake Dam	>24-inches	High tides may affect operation of dam and water level management within Capitol Lake.			
39	Intercity Transit Center	6-inches	Bus routes accessing the transit center are effected at 0-inches SLR. The finished floor elevation is 14.54 feet NAVD88, therefore structural damage at 7-inches SLR could occur.	Door flood barriers may protect to 18-inches SLR. It is assumed that the ultimate adaptation will be a regional solution (levee, wall, raised roadway, etc.).	Approximately 7,000 trips daily (3,800 outbound, 3,200 inbound). The Transit Center is the regional hub for public transportation in Thurston County with routes connecting to Mason, Grays Harbor and Pierce counties.	High
40	Federal Building	-				
41	Downtown Post Office	-				
42	Heritage Park	0-inches	Significant portions of the park will flood under current (0-inches SLR) scenario.	Raise landscape and pathways. Replumb drainage system including tide gates.	Loss of recreational opportunities. Potential loss of a location for festival events. Potential loss of revenues generated during festival events.	Low
43	Sylvester Park	-	Inundation begins at 8-feet SLR.	It is assumed that the ultimate adaptation will be a regional solution (levee, wall, raised roadway, etc.).	Little consequence within this plan's time horizon.	Low
LOTT Clean Water Alliance Assets						
44	Budd Inlet Treatment Plant	12-inches	Biological treatment processes are sensitive to high salinity inflow. Brown and Caldwell vulnerability study identified 12 locations within Budd Inlet Treatment Plant where overland flooding could flood facilities.	Could bypass flows around the biological treatment process if had advanced warning of expected high tides. Could use sandbags or install watertight door/entryway protection.	Flooding through combined sewer system would convey saltwater to Budd Inlet Treatment Plant. Significant inflows of saltwater could impact treatment biological processes. High salinity inflow could kill microorganisms used in treatment process.	High

Table 6 VA Assets, Sensitivity, and Adaptive Capacity (Olympia, 2018, P. 60)

4.9.3 Prioritization - Monitoring and Triggers

The city should establish a system by which to prioritize assets and associated projects. This is also an opportunity for community feedback on which projects have the support of the public. In some cases, policies and approaches may be proposed to address the impacts of SLR, but the timeframe and current vulnerability could make it difficult to adopt them. In these cases, it is important to create a system of monitoring the real-world conditions, and to establish triggers which would activate the process for adopting new policies and approaches to address SLR. This would give the city an opportunity to create policies and develop approached ahead of time and keep them at the ready for when a given factor triggers their activation. In the case of SLR this may be a particular TWL being reached a single time, or perhaps at a set frequency, after which the policy will be implemented. This is an important element to include because SLR scenarios are probabilistic, and in the event a lower probability scenario becomes true than the selected one, this allows the city to address it as events in the real world unfold. These recommendations may require additional research and review by staff to develop a functioning system. Some resources are included in this document to help with this process.

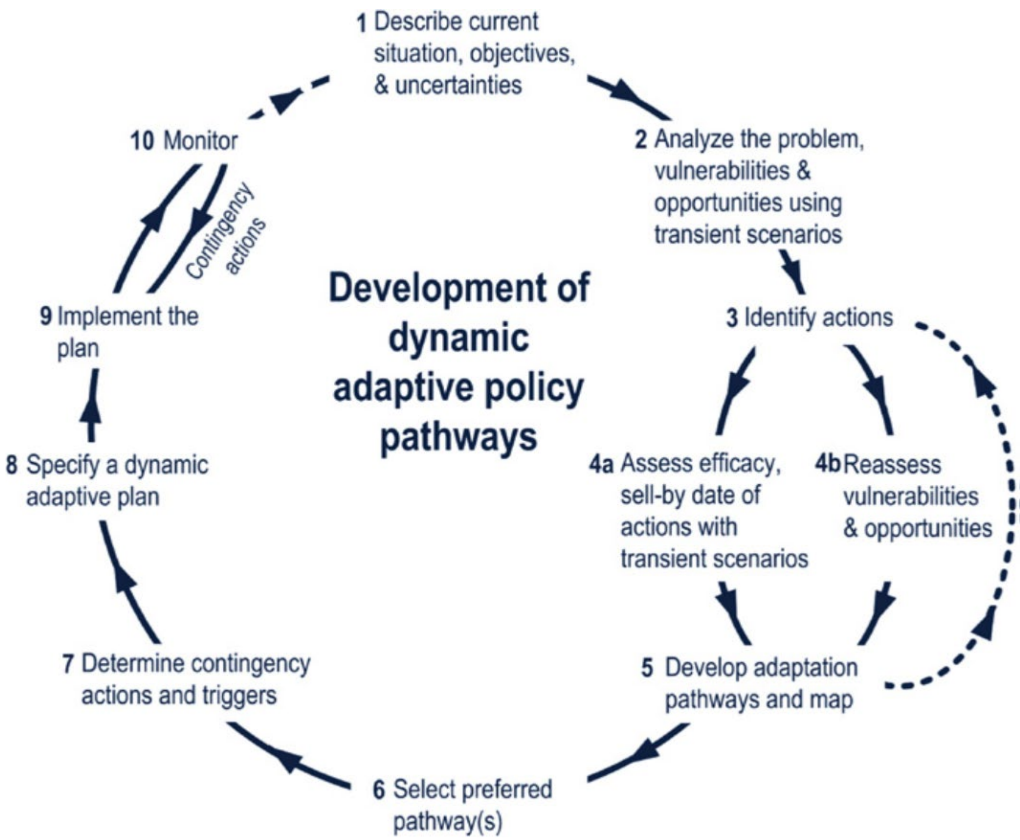


Figure 6 Developing Dynamic Adaptive Policy Pathways (Haasnoot et. al, 2012,P. 5)

4.9.4 Policy and Code

When the VA is completed the collected data and results can be used to draft new policy and update codes to address the projected impacts. As with prioritization, the policy and codes can be implemented using and approached called the dynamic adaptive policy pathways method or DAPP. See figure 4 above for example. This approach focuses on creating policies and approaches to uncertain or difficult to predict outcomes. Because SLR scenarios are probabilistic models there is a degree of uncertainty and margin of error, creating a system similar to monitoring and triggers which uses an adaptive approach to updating or implementing new policies and codes will give the city the best outcomes.

4.9.5 Desired outcomes by asset

While at an early stage it was important to establish the overall desired outcomes for the community, at this point with the detailed collection of data it is possible to develop specific desired outcomes by asset. It is important to note that while the city can create detailed and specific desired outcomes for the assets they control, that some of these assets are privately held or controlled by various entities. While this will prevent the city from carrying out a specific remedy in some cases, this is an opportunity to engage with the stakeholders who own or control the assets and determine which outcomes best serve the community and to create recommendations for those assets in a joint manner.

4.9.6 Other Vulnerability Assessments

The various entities whether public or private which are within or adjacent to the VA extent may have conducted their own VA at some point which could have some overlapping data or information. Entities such as the Port, County, State, or WSDOT are a few examples of entities which may have done independent VAs. Using the earlier created stakeholder list is a good way to identify possible entities which may have done so. Utilizing available data from those VAs and collaborating with those entities to create a combined data set would help reduce the amount of time required to conduct the assessment, it is important to make sure that the existing data to be included is up to date and relevant to the SLR VA. Entities such as the port may have a VA which is more detailed in some aspects and less in others than the city, those gaps will need to be addressed as the data is incorporated into the SLR VA.

4.10 Additional Considerations:

4.10.1 Asset and Extent Mapping

As part of the SLR VA a large amount of data will be collected and compiled. It will be helpful to create a set of maps which show the selected SLR scenario and various layers that comprise the TWL. These GIS layers may include the selected SLR, storm surge, king tide levels, and any other layers which comprise the TWL as decided upon when selecting the SLR scenario for the VA. The impacted systems could also be added and mapped, and the assets which will be geolocated as part of the assessment process can be added as points, shapes, or lines to the database. The attributes of the assets can be included in this geo database to give the opportunity for further integration and study of SLR impacts, and to facilitate future updates to the VA and other documents. Additionally, the Jurisdictional boundary for the SMP can be added as it stands today, and as it is projected to shift over time, giving context to the VA extent and its goals.

Resources:

Marin County Adapting to Rising Tides (ART) Sea Level Rise Maps

4.10.3 Inventory & Characterization Categories

With the creation of a SLR VA, there is an opportunity to add an element to the Inventory and Characterization which would be vulnerability. This would allow the already established document to incorporate the VA and give necessary information in an easy to access format for a given asset.

4.10.4 Consideration of Contaminated Sites

Contaminated sites in Washington are typically well documented and monitored. To ensure that sites identified under MTCA, CERCLA or other Federal, State, or local lists are given special consideration and attention it is recommended that a GIS layer be created which contains these sites and that it is overlaid with the Asset Mapping and Extent Layers. While contaminated sites are addressed in other planning and policy documents, it is important to give special consideration to them with regards to SLR as the extent of contamination may be expanded by inundation or flooding, and that the secondary impacts from such an outcome are exceedingly detrimental to the social, built, and natural environment.

4.10.5 Broader VA applicability

The SLR VA is a process that should be undertaken as part of the SMP update process. The goal is to provide a factual basis for developing policies and regulations to address sea level rise. It is important to note that there is broader applicability of the VA results, which can and should be discussed, referenced, and applied in other planning documents. The SLR VA can be used for long range planning and policy writing beyond the SMP. More broadly the VA can be applied to hazard mitigation planning, stormwater planning, and adaptive zoning practices. As SLR occurs the directly and indirectly impacted areas grow, and the planning for those impacts is beyond just the jurisdictional area of the SMP and coastal planning areas. The specific implications, planning extents, and horizons will depend on the results of the exposure, sensitivity, and adaptive capacity analysis.

4.10.6 Timeframe

The focus of this framework is on WA SMPs and the update schedule for the SMP. The update schedule may not always coincide with the timing of new data or modeling becoming available, the inclusion of updated information may have to wait until the next update cycle unless the city wants to propose an extension on this basis. The total amount of time required to conduct the VA should be estimated and the update timeline for the SMP may need adjustments or an SMP amendment may be needed. Timelines should also consider the necessary time needed to apply for grants, hire staff or consultants, and develop agreements with other jurisdictions or institutions which the city may want to involve in the process.

4.10.7 Staffing Capacity

Not all cities will have the necessary capacity or available staff hours to conduct or complete the SLR VA process in a timely manner within the SMP update cycle. Addressing this gap in resources may require the services of a consultant or consulting firm which has prior experience conducting and/or implementing SLR VAs. The process also requires that both built and natural assets be evaluated in greater depth than an existing inventory and characterization within the SMP Jurisdiction may have already done, which will require even more staff and work capacity. For jurisdictions where additional resources may not be available the approaches in this document can be applied to existing inventory and characterization documents. It should be noted that institutions of higher education can provide researchers and resources to conduct some elements of a VA and the collaboration with such entities on a SLR VA could help offset some of the staffing shortages. In some instances, cities could also form inter-jurisdictional agreements to conducts some of the work together with neighboring jurisdictions. These cost saving approaches aim do reduce the costs, but not the quality of work by utilizing available high-quality resources.

4.10.8 Budget

The process of creating the SLR VA will require work beyond what is currently being done in most Washington cities with marine shorelines. Because this VA aims to give the city a better footing for addressing SLR and its impacts it is worth weighing the long-term benefits with the short-term costs associated with conducting this VA. It may also be possible to apply for grants or other sources of funding, and to partner with institutions of higher education to assist in conducting these assessments.

5.0 Conclusion

This sea level rise vulnerability assessment framework will provide a guide from which the city of Bellingham and potentially other jurisdictions can conduct their vulnerability assessments. This report is meant to serve as a starting point for adaptive planning and policy making for coastal communities looking to update their Shoreline Master programs. As the framework is implemented it will be modified and adapted as each community creates customized approached which are tailored to address their specific needs, wants, and planning capabilities. The VA framework created here is meant to be a living document which is updated and revised over time so that the best planning practices, and best available science is incorporated.

While some vulnerability assessment of SLR have been done in Washington, this is the first framework meant to help a broad audience of communities to update their SMPs to include SLR. For many smaller communities developing a complex planning document is challenging and having an adaptable framework with which they can approach the process should lower the barrier to doing so. Giving those communities a path forward where they can interface with the WA Department of Ecology and create a plan which will address the requirements of our state and help to address the needs and desired outcomes of their residents. Additionally, the adaptive and dynamic planning approaches will help communities address various outcomes with policies which can be implemented at a specific threshold. Planning for sea level rise needs to become a priority for communities throughout Washington as part of their shoreline master programs. The intention of this framework is that wide adoption of planning for SLR is more achievable in the state of Washington.

6.0 Definitions

Resource:

Washington Coastal Hazard Resilience Network (CHRN) SLR Glossary

Adaptive Capacity: The degree to which an asset, population, or system is able (or unable) to address the adverse impacts of SLR given the selected SLR scenario.

Base Flood Elevation (BFE): The elevation of the "100-year flood," used as the national standard by federal agencies for requiring flood insurance and regulating new development.

Bathtub mapping of sea-level rise: Sea-level rise mapping using a single value of water level rise in all locations. This method does not take into account storm tide, waves or wind.

Coastal erosion: The wearing away of land, or the removal of beach or dune sediments by wave action, tidal currents, wave currents or drainage. A combination of episodic inundation events and relative sea-level rise will serve to accelerate coastal erosion.

Exposure: the degree to which an asset, population, or system is exposed to SLR given the selected SLR scenario.

Greenhouse gas: The gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds.

Mean Higher High Water (MHHW): Coastal Washington State experiences a mixed semi-diurnal tidal pattern, with two unequal low and high tides per day. Mean higher high water is the average of the highest water level observed in each day over a period interest. An official MHHW tidal datum is established by NOAA for each tide station by averaging over a designated 19.6-year "tidal epoch" period.

Ordinary High Water Mark (OHWM): "Ordinary high water mark" on all lakes, streams, and tidal water is that mark that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation as that condition exists on June 1, 1971, as it may naturally change thereafter, or as it may change thereafter in accordance with permits issued by a local government or the department: PROVIDED, That in any area where the ordinary high water mark cannot be found, the ordinary high water mark adjoining salt water shall be the line of mean higher high tide and the ordinary high water mark adjoining fresh water shall be the line of mean high water

Resilience: The capacity of a system, community, or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Risk: The probability of harmful consequences or expected losses (death and injury, losses of property and livelihood, economic disruption, or environmental damage) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Sea-level rise (SLR): The upward trend in average sea-level height. The upward trend in average sea-level height linked to three primary factors: 1) thermal expansion of the ocean, 2) melting glaciers and 3) loss of Greenland and Antarctica's ice sheets.

Sensitivity: The degree to which an asset, population, or system's functionality or purpose is adversely affected by SLR given the selected SLR scenario

Still water level: Coastal water elevation due to everything except waves: tides, storm surge, seasonal and annual water level cycles, as well as the long-term average sea level trend. This is the water level measured by tide gauges, which are specifically designed to remove any water level components related to waves.

Storm surge: Water that is pushed toward the shore by the force of the winds swirling around the storm.

Subsidence: A decrease in the elevation of the land surface. This can occur gradually or suddenly, and can be driven by a variety of processes, including earthquakes, GIA, groundwater extraction and sediment compaction.

Thermal Expansion: When the ocean warms, seawater becomes less dense and expands, raising sea-level.

Total Water Level (TWL): The maximum coastal water elevation on the shoreline, including waves and wave run-up. Where waves are present, the TWL will be higher than the SWL measured at a nearby tide gauge.

Uplift: Same as subsidence but describing an increase in land elevation.

Note: The definitions listed in this section are primarily from the CHRN SLR Glossary, which is linked at the top of the section, and includes additional terms which may help contextualize or interpret the literature.

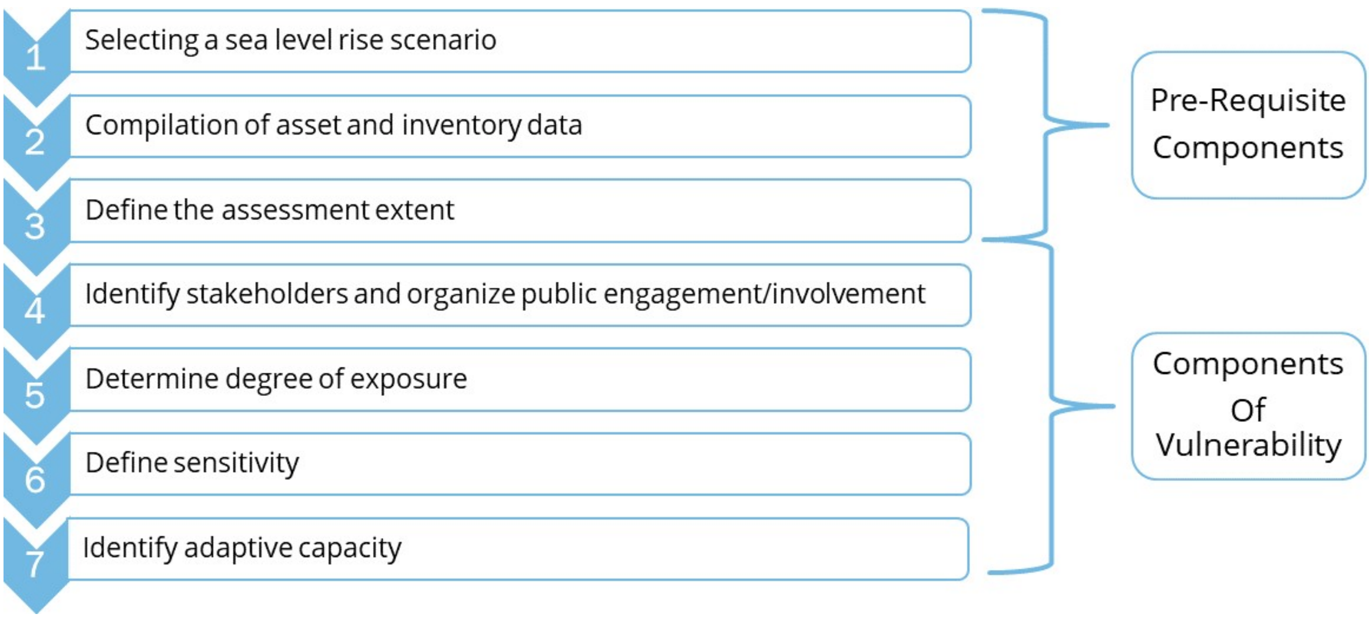
7.0 List of Acronyms

BFE	Base Flood Elevation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHRN	Washington Coastal Hazards Resilience Network
CIG	Climate Impacts Group
COB	City of Bellingham
ECY	Washington Department of Ecology
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GMA	Growth Management Act
IPCC	Intergovernmental Panel on Climate Change
MHHW	Mean Higher High Water
MTCA	Model Toxics Control Act
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
OHWM	Ordinary High-Water Mark
SLR	Sea Level Rise
SMP	Shoreline Master Program
TWL	Total Water Level
UGA	Urban Growth Area
URBDP	Urban Design & Planning
UW	University of Washington
VA	Vulnerability Assessment

8.0 Vulnerability Assessment Checklist

This checklist is meant to assist planning and city staff in conducting a sea level rise (SLR) vulnerability assessment (VA). The checklist is a component of the "Sea Level Rise Vulnerability Assessment Framework For Bellingham's Shoreline Master Program" and should be implemented using the information and guidance of the framework document.

These are the seven steps which comprise the checklist:



Step 1: Selecting A Sea level Rise Scenario (Framework Section 4.2)

- ☐ Data and Modeling Selection
  - ☐ Identify Latest WA specific SLR Assessment (The 2018 Assessment was most current when this document was written)
  - ☐ Check if Visualization tools have been updated to include latest data
    - ☐ Climate Impacts Group (CIG) Visualizer
    - ☐ NOAA Visualizer
  - ☐ Planning Horizons
    - ☐ Define the temporal scale for the SLR Projections and Future Planning
    - ☐ Consider adding useful/functional life timeline for assets where plausible or useful
  - ☐ Sea Level Rise Probability
    - ☐ Review the CHRN How to Choose Document
    - ☐ Identify a range of scenarios to propose to elected officials
      - ☐ Include at least a Low, Medium and High probability scenario
    - ☐ Consider whether using 1 or multiple temporal scales is helpful
    - ☐ Create SLR scenario set
  - ☐ Coastal Hazards
    - ☐ If Available incorporate CoSMoS (PS-CoSMoS) data
    - ☐ Incorporate best storm modeling data and approach available, review Extreme Coastal Water Level in WA state Document. In order of priority:
    - ○ CoSMoS
    - ○ NOAA Coastal Flood Exposure Mapper
    - ○ FEMA
      - ☐ Has FEMA incorporated SLR into their NFHL or FIRM Panels for your region?
        - ☐ If Yes see if this data can be incorporated
        - ☐ If No, Move on to other data sources
    - ☐ Identify and incorporate which coastal hazards will be included based on available data

Step 2: Compilation of Asset and Inventory Data (Framework Section 4.3)

- ☐ Refer to the SMP Handbook Chapter 7 for methods on collecting and compiling data
- ☐ All Assets need to be geo-located for future mapping
- ☐ Record elevation above grade of asset if not located at grade
- ☐ Create tables for Data (Example: Framework Section 4.9.2)

Step 3: Define Assessment Extent (Framework Section 4.4)

- ☐ Current SMP Jurisdiction
  - ☐ Create a Map which shows the current SMP Jurisdiction as adopted by Bellingham
- ☐ SLR SMP Jurisdiction
  - ☐ Has the SMP Jurisdiction shifted from SLR or other reasons? Update Map and Note Change area and time.
- ☐ SLR VA Extent Selection
  - ☐ Determine which flooding factors will be considered
  - ☐ Combine the SLR Scenario using decided upon data set and incorporate Coastal hazards
  - ☐ Include the SMP Jurisdictional Area
  - ☐ Resulting area can be increased using community input
  - ☐ Potentially impacted area should not be decreased from community input
  - ☐ Create a Map which shows the VA Extent
  - ☐ Use the VA Extent Map to determine if additional assets need to be documented.
  - ☐ Document Which Populations are in the VA Extent
  - ☐ Document which systems (Natural and built) are in the VA Extent
    - ☐ Consult with System Managers or Experts to see if data has already been compiled and can be readily incorporated.
    - ☐ Determine if System related staff and funding will take point on documentation, if so, provide them with a table to fill out
  - ☐ Incorporate data from new area into tables (Example: Framework Section 4.9.2)
  - ☐ Note which assets are currently in SMP Jurisdiction and which are just in the VA Extent

Step 4: Identify Stakeholders and Organize Public Engagement/Involvement (Framework Section 4.5)

- ☐ Public Involvement
  - ☐ Use the SMP Handbook Chapter 6 for Public Participation criteria
  - ☐ Build on the SMP Handbook by considering additional stakeholders and engagement processes using existing worksheets (Examples: Framework Section 4.5.3)
  - ☐ Incorporate additional meetings to discuss SLR into the planning process where feasible
  - ☐ Incorporate SLR VA discussion into existing public involvement practices
- ☐ Identifying Stakeholders
  - ☐ Use the SMP Handbook Chapter 6 for Public Participation criteria
  - ☐ Use VA Extent Map and Assets in that area to determine if additional stakeholders should be included in the process
- ☐ Desired Outcomes (Big Picture)
  - ☐ Use the SMP Handbook Chapter 10 for Community Visioning criteria
  - ☐ Use the New VA Extent Map and SLR Projections to engage with public on desired outcomes
  - ☐ Desired outcomes process should be iterative and may require engaging public at various stages
  - ☐ Ask the questions:
    - ☐ What areas are a community priority?
    - ☐ Are there specific landmarks or elements which should be given additional consideration?
    - ☐ Who and/or What is most impacted?
    - ☐ What do we want to do about it?
- ☐ Document meetings
- ☐ Incorporate feedback into maps as “feedback layers” to allow for differentiation between scientifically based extent and community driven amendments

Step 5: Determine degree and/or intensity of Exposure (Framework Section 4.6)

- ☐ Add Step 5 Data into table, and organize the vulnerability assessment by asset and category (Example: Framework Section 4.9.2)
- ☐ Assets
  - ☐ Who is the organization, business, or entity which owns and/or maintains the asset?
  - ☐ What is the level of exposure? (Inches of immersion)
  - ☐ What is the frequency of exposure? (Measured in hours, days, weeks, etc.)
  - ☐ What is the duration of exposure? (Measured in hours, days, weeks, etc.)
  - ☐ Note any hazardous materials
  - ☐ Record the specific SLR Scenario and Coastal Hazards used for determining exposure. Note the timeframe for the scenario.
  - ☐ Multiple exposure data sets may be created on one table to express the exposure under the different selected Scenarios.
- ☐ Populations
  - ☐ Are there populations which may be exposed to floodwaters in a given scenario?
  - ☐ Document their locations
  - ☐ Document their personal assets and characterize them as fixed or portable.
  - ☐ Note any hazardous materials
  - ☐ What is the degree of exposure? (Inches of immersion)
  - ☐ What is the frequency of exposure? (Measured in hours, days, weeks, etc.)
  - ☐ What is the duration of exposure? (Measured in hours, days, weeks, etc.)
  - ☐ Record the specific SLR Scenario and Coastal Hazards used for determining exposure. Note the timeframe for the Scenario as well.
  - ☐ Multiple exposure data sets may be created on one table to express the exposure under the different selected Scenarios.

☐ Systems
  - ☐ Who is the organization, business, or entity which owns and/or maintains the system?
  - ☐ For components of a system
    - ☐ What is the level of exposure? (Inches of immersion)
    - ☐ What is the frequency of exposure? (Measured in hours, days, weeks, etc.)
    - ☐ What is the duration of exposure? (Measured in hours, days, weeks, etc.)

        - ☐ Note any hazardous materials
    - ☐ If Feasible Incorporate entire system in Map
        - ☐ Differentiate between exposed elements and those which are just connected as part of the system
    - ☐ Consult with system experts and managers to gather existing data

Step 6: Define Sensitivity (Framework Section 4.7)

- ☐ Assets
    - ☐ Is the asset adversely affected by the exposure documented in Step 5?
    - ☐ To what degree is the condition of the asset impacted?
    - ☐ To what degree is the functionality of the asset impacted?
    - ☐ What is the quantifiable reduction in condition or functionality?
        - ☐ If the impact is quantitative, use values or specific terms used in the associated industry with that asset to document the impacts
        - ☐ If the impact is qualitative, create a narrative which describes the impacts.
- ☐ Populations
    - ☐ List both human and natural populations which may be impacted by the exposure documented in Step 5
    - ☐ Are the populations vulnerable, or endangered in the case of flora/fauna?
    - ☐ Write a brief and descriptive narrative describing the impacts to each population, Include:
        - ☐ Change in Access
        - ☐ Disruption of critical environment or services
        - ☐ Displacement
        - ☐ Ability of population to relocate safely
- ☐ Systems
    - ☐ Is the entire system or just a component affected?
        - ☐ If just a component, how critical is its function to the system?
    - ☐ Is the system adversely affected by the exposure documented in Step 5?
    - ☐ To what degree is the condition of the system impacted?
    - ☐ To what degree is the functionality of the system impacted?
    - ☐ What is the quantifiable reduction in condition or functionality?

        - [ ] If the impact is quantitative, use values or specific terms used in the associated industry with that system to document the impacts
        - [ ] If the impact is qualitative, create a narrative which describes the impacts.

Step 7: Identify Adaptive Capacity for assets and systems (and populations where applicable) (Framework Section 4.8)

"Element" shall be used in this section to describe an asset, system, or population which was documented in earlier steps and is now part of the dataset being reviewed for adaptive capacity.

- [ ] Redundancy
    - [ ] Is the element redundant?
    - [ ] Is the function of the element redundant?
    - [ ] How many redundancies does the element have?
    - [ ] Can the element be made redundant?
        - [ ] If yes, what is the estimated timeframe for creating a redundancy?
        - [ ] If yes, what is the estimated cost of creating redundancy for this element (if cost estimation is available or feasible)?
- [ ] Ability to Relocate
    - [ ] Can the element be relocated?
    - [ ] What is the estimated timeframe for relocation?
    - [ ] What is the estimated cost of relocating (if cost estimation is available or feasible)?
- [ ] Ability to Elevate
    - [ ] Can the element be elevated?
    - [ ] To what degree can the element be elevated?
        - [ ] Is functionality or purpose compromised at a given amount of elevation?
    - [ ] What is the estimated timeframe for elevation?
    - [ ] What is the estimated cost of elevating (if cost estimation is available or feasible)?
    - [ ] During what time period is elevation intended to maintain functionality of the element?
- [ ] Ability to Protect
    - [ ] Can the element be protected?
    - [ ] To what degree can the element be protected?

- ☐ Is functionality or purpose compromised at a given degree of protection??
- ☐ What is the estimated timeframe for installing protection?
- ☐ What is the estimated cost of protecting (if cost estimation is available or feasible)?
- ☐ During what time period is protection intended to maintain functionality of the element?

Step 8: Prepare a VA draft for local review and public adoption

- ☐ Compile Data
- ☐ Create Maps
  - ☐ Static PDF Maps showing various scenarios & datasets
  - ☐ Dynamic and Interactive Maps if feasible
  - ☐ Create a community facing Story Map if feasible
- ☐ Create a Report
  - ☐ Summary of findings
  - ☐ VA approach/methodology
  - ☐ Data
  - ☐ Maps
  - ☐ Next Steps (Refer to Framework Section 4.9 and Section 4.10 for implementation details and additional considerations as a place to start from)
- ☐ Conduct a Public meeting to review the VA results

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