REPORT

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Spatial Analysis of Sea Level Rise and Flooding in Ilwaco

CITY OF ILWACO

JUNE 2025

Prepared for:
City of Ilwaco
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Use Limitations: This report was prepared to evaluate the anticipated sea level rise and extreme flood extents for the City of Ilwaco based on the parameters requested by the City of Ilwaco. No one other than the City of Ilwaco staff and their agents should use this report for any purpose other than general information. The report is not considered to be comprehensive of all facilities or infrastructure and may exclude assets that were not included in the referenced databases. This report is intended to provide high-level information and general adaptation strategies. The conclusions and identified strategies were based on the best available science and mapping resources. It is noted that the projections mentioned in this report may change over time due to anthropogenic changes or future conditions.

Data Limitations: The information contained in this report is based on the application of technical guidelines currently accepted as the best available science and in conjunction with the manuals and criteria outlined in the methods section. All discussions, conclusions and recommendations reflect the best professional judgment of the author(s) and are based upon information available at the time the study was conducted. All work was completed within the constraints of budget, scope, and timing. The findings of this report are subject to verification and agreement by the appropriate local, state, and federal regulatory authorities. No other warranty, expressed or implied, is made.

The data acquired from the National Oceanic and Atmospheric Administration (NOAA) is utilized with the accompanying disclaimer: The data and maps in this tool illustrate the scale of potential flooding, not the exact location, and do not account for erosion, subsidence, or future construction. Water levels are relative to Mean Higher High Water (MHHW) (excludes wind driven tides). The data, maps, and information provided should be used only as a screening-level tool for management decisions. As with all remotely sensed data, all features should be verified with a site visit. The data and maps in this tool are provided "as is," without warranty to their performance, merchantable state, or fitness for any particular purpose. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference tool and not for navigation, permitting, or other legal purpose (NOAA Office for Coastal Management, 2021).

Executive Summary

The City of Ilwaco received a Shoreline Planning competitive grant from the Washington State Department of Ecology to complete a sea level rise vulnerability and risk assessment under contract with Facet, formerly DCG/Watershed. Based on Pacific County's recently completed sea level rise risk assessment (2023), the purpose of this assessment is to evaluate how surface stormwater and groundwater conditions will interact with future sea level rise and extreme flood events and potentially impact critical assets, including roads, drainage and stormwater, septic and sewer, drinking water and communications infrastructure. These assessments will be used to develop resiliency planning strategies, including draft policies and regulations, which can be considered for incorporation into the Shoreline Master Program, Critical Areas Ordinance, and emergency planning documents during future updates.

Five different types of flooding are discussed, including coastal, riverine, groundwater, stormwater and compound flooding. For coastal flooding, two scenarios were mapped that included the projected increase in the daily average high tide as well as what an extreme flood with a 20-year return frequency might look like by 2050 and 2100. Following the mapping exercises, several critical infrastructure assets or facilities that preserve public health and safety were evaluated to characterize the risks that may be associated with sea level rise or extreme flood events within the given timeframe. These areas were quantified and given a vulnerability score of low, medium, or high depending on exposure to inundation as well as the adaptive capacity of the asset type. Erosion, subsidence and wind-driven wave runup were not factored into inundation extent. Flooding and inundation may occur outside the areas mapped under different weather conditions. This report focuses on two (2) focus areas and may not capture the impacts of flooding in other areas and assets that may be facing challenges outside of those focus areas.

Adaptation strategies were then identified to assist the City and community in their planning efforts to protect and preserve critical facilities by mitigating the anticipated climate change impacts. Key findings included that, while the vulnerability of assets in downtown Ilwaco is mostly determined to be low, the Vandalia neighborhood has several asset types that may be highly vulnerable. A community plan may need to be prepared for the Vandalia neighborhood to implement strategies to reduce the risk of damage to vulnerable structures and infrastructure.

Acronyms and Abbreviations

AHRF	Area at High Risk of Flooding
API	Application Programming Interface
CMZ	Channel Migration Zone
CIP	Capital Improvement Plan
DEM	Digital Elevation Model
e.g.	For example
Ecology	Washington State Department of Ecology
FEMA	Federal Emergency Management Agency
FFRMS	Federal Flood Risk Management Standard
FIRMS	Flood Insurance Rates Maps
GIS	Geographic Information System
HMP	Hazard Mitigation Plan
i.e.	In other words
IMC	Ilwaco Municipal Code
LiDAR	Light Detection and Ranging
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
NAD	North American Datum
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OSS	On-site septic system
PUD	Public Utility District
QAPP	Quality Assurance Project Plan
REM	Relative Elevation Model
SLR	Sea Level Rise
TAC	Technical Advisory Committee
TIP	Transportation Improvement Plan
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington Department of Health
WDNR	Washington Department of Natural Resources
WSDOT	Washington State Department of Transportation
WWTP	Wastewater Treatment Plant
USACE	United States Army Corps of Engineers

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1. Introduction

DCG/Watershed, now Facet, conducted a Phase I assessment of risk and vulnerability to identify areas that are at risk of loss or damage, assess the extent of loss, and characterize the extent of vulnerability due to sea level rise (SLR) in Pacific County (DCG/Watershed, 2023). While this assessment was focused on unincorporated Pacific County, mapping was completed for incorporated cities, including the City of Ilwaco. The planning-level Phase I assessment identified several focus areas with increased risk and vulnerability to flooding and storm damage. In the Phase 1 Assessment, Pacific County chose to assess sea level rise and extreme coastal flooding for 2050 and 2100 at the 17%, 50% and 83% likelihood levels, and mapped scenarios specifically focused on the sea level rise assessed at the 83% likelihood level. These mapped scenarios from the previous assessment were utilized in this report. The Phase 1 Assessment assessed potential impacts to buildings (e.g., residences and community facilities), critical infrastructure (e.g., electrical substations, wastewater treatment facilities), transportation infrastructure (e.g., roads and airports) and wetlands. This City of Ilwaco specific report continues the planning-level assessment with more in-depth investigation of potential effects of SLR and flooding on groundwater and freshwater flooding in two geographic Focus Areas: the city center of Ilwaco and the Vandalia Neighborhood (Figure 4). The assessment uses Geographic Information System (GIS) spatial analysis and hydrologic studies to further define risk and vulnerability due to potential flooding in the focus areas. This information will aid the development of policies and plans to avoid or mitigate impacts. A similar study of Long Beach Peninsula, Naselle River near Naselle, Chinook, and Tokeland/North Beach Focus Areas are included in a separate report.

For this planning-level assessment, the City of Ilwaco chose to review SLR projections for a 50% likelihood in contrast to the original 83% likelihood used for the 2023 SLR County-wide report. However, the difference was approximately 0.2 feet higher at the 50% likelihood by 2050 which was still captured within the maps developed for the 2023 report due to the approximation/rounding requirements. For the purposes of this assessment the projected sea level rise for planning purposes continued with the inundation amount of one (1) foot by 2050 to four (4) feet by 2100 above current Mean Higher High Water (MHHW) established in the Phase 1 report for Pacific County (DCG/Watershed, 2023). These projections do not take into account storm surge caused by wind driven waves, erosion or subsidence, and use a conservative level of likelihood so impacts and flooding extents may exceed the projections used in this report under future conditions.

King Tides are incorporated into the extreme flooding projection of the scenarios because the extent of flooding was estimated using historical extreme water level patterns as a factor in projecting future trends. The lunar conditions that cause King Tides, the highest tides in the annual tidal cycle, have not changed. However, the intensity of winter storms that often coincide with the timing of King Tides has increased over time. Although sea level rise is contributing to increased flooding from these storms, the rise in sea levels in Pacific County and Willapa Bay has been relatively small compared to other parts of Washington State. The perception that the King Tides are getting worse may also be due to the fact that those newer to living on the shoreline do not have the benefit of a long-shared memory, so these events feel like nothing they’ve experienced before. The financial impact of these storm events is increasing, largely due to the higher value and greater density of residences now affected compared to a few decades ago (I. Miller, personal communication, November 21, 2024). Shoreline setbacks for structures and infrastructure may also not account for extreme flood events and rising sea levels, which will be addressed as recommendations in this report.

1.1 Types of Flooding

To determine the extent to which rising sea levels may be exacerbated by flood events, it is important to acknowledge that there are several types of flooding that may be experienced within the City of Ilwaco and other areas within the region. While these types of flooding may occur distinctly, flood events may experience multiple types of flooding and have cumulative impacts. The types of flooding considered in this report are further explained below.

1.1.1 Flooding in Streams and Rivers

Flooding in Streams and Rivers occurs when inflows exceed conveyance capacity and channel storage. Large Inflows may result from intense or prolonged rainfall, snowmelt, or a combination of rain on snow. Under these conditions, streams and rivers can overtop their banks and spread out into the adjacent floodplain. Flooding usually begins when river discharge exceeds bankfull flows. In Western Washington, bankfull flows generally occur with a 1.5-to-2-year recurrence interval (Castro, 2007).

Flooding in the City of Ilwaco often occurs during winter storms. Storms can bring high tides, wind waves, storm surges, sudden barometric changes and higher flows in coastal rivers and streams subject to tidal effects. Rainstorms covering a large area in Pacific County typically occur in December through February (FEMA, 2015). "*The most significant rain event in Pacific County occurred December 1-3, 2007*" (FEMA, ibid). "*This three-day severe storm event consisted of three separate storms that battered the County with snow, rain, and hurricane force winds. The first storm produced heavy snow throughout the state of Washington. On December 2nd, the snow changed to rain as the temperatures increased, accompanied by strong winds. On December 3rd, the most significant storm arrived; bringing hurricane force winds, record high temperatures, and record rainfall*".

Vulnerability to river and stream flooding depends on topography (particularly relative elevations in floodplain areas), watershed and runoff characteristics, and peak flows. Flood impacts depend on the type of land use and development within the floodplain, flood frequency (e.g., how many floods occur over time), flood magnitude (e.g., depth of water and area flooded), and flood duration (e.g., how long it lasts). Flood vulnerability is considered the exposure to potential flooding. Flood risk is the probability of potential losses from flooding.

1.1.2 Flooding in Coastal Areas

Coastal flooding often occurs when storm surges and high winds increase wave heights in coastal areas. Sudden changes in barometric pressure can cause higher than normal wave runup and flooding in nearshore areas.

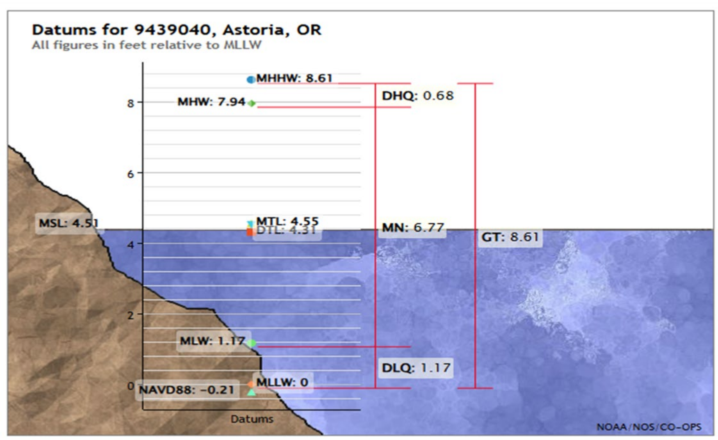
Coastal flooding in the City of Ilwaco occurs when high tides and winter storms cause storm surges and high wind waves onshore. The Mean Higher High Water (MHHW) tidal elevation at the nearest gauge in Astoria (OR) is 8.61 feet MLLW (8.40 feet NAVD88). Storm surges and high winds during winter storms can increase high tides by four (4) feet or more with additional wind waves of three (3) feet or more. The Beaufort Scale (Appendix E) is used to estimate wave heights and relative wind speeds based on observed open water conditions[1,2]. Wind wave heights are reduced over land as surges lose energy to over variable land surfaces. The seasonal variation of exceedance probability levels shows these high-water levels are more likely in November to February.

Storm tides in the past have flooded homes in the low area near the Holman Lake drainage slough on the west side of the downtown area of the City of Ilwaco (FEMA, 2015). "*Personal interviews, records, and newspaper accounts indicate that the worst wave conditions in Baker Bay were generated by a January 29, 1921, storm. Winds gusting to 150 mph from the southeast shifted to the southwest as the storm moved inland. The waves were about six feet high and caused damage along the waterfront and at the boat docks. The wave action on Baker Bay eroded the City of Ilwaco beachfront and washed-out roads east of the city*" (FEMA, 2015).

Tidal Datums

Tidal datums are references to measure water levels. The most common datums in Washington State are Mean Lower Low Water (MLLW), Mean Higher High Water (MHHW) and North American Vertical Datum of 1988 (NAVD88).

Unlike how feet and meters vary consistently (3.3 feet to 1.0 meter), datums vary in reference to each other in different locations. For example, in Cape Disappointment, 0 ft MLLW is equivalent to 8.07 ft MHHW and 8.05 ft NAVD88, while in Astoria, OR, 0ft MLLW is equivalent to 8.61 ft MHHW and 8.40 ft NAVD88.



(Source: https://tidesandcurrents.noaa.gov/datum_options.html)

[1] There is a tidal gauge at Cape Disappointment, but Extreme Water Level data is not available for that station. Astoria, OR is the closest tidal gauge to the project focus areas that report on Extreme Water Levels. https://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=9439040

[2] https://www.weather.gov/pqr/beaufort

Photo 1. Coastal flooding along Highway 101 in Pacific County

Vulnerability to coastal flooding depends on topography (relative elevations in shoreline floodplains), prevailing wind direction and fetch, and high tides. The impacts of coastal flooding depend on land use and development on the coast, storm frequency (how many storms occur over time), depth of flood water and area flooded, and flood duration (how long it takes for flood water to recede). These impacts are projected to increase with sea level rise.

1.1.3 Compound Flooding

Compound flooding occurs when high tides and storm surges block discharge from coastal rivers and streams and cause flooding until the tide turns. Compound flooding may also occur when log jams and gravel bars block tide gates and instream structures which may cause water to back up and slow draining. Vulnerability to compound flooding depends on high tides, upstream extent of tidal influences, and relative elevations in the floodplain. The impacts of flooding depend on land use and developments in the floodplain, flood frequency (including tidal cycles during riverine floods), resulting flood magnitude (depth of water and area flooded), and flood duration.

Structural or mechanical failure of flood control works, such as dams, levees, or pump plants, can cause sudden and serious flooding. Development of low-lying coastal land and areas within river floodplains has been deemed acceptable in some areas because of the protection provided by these man-made structures. However, flood damage may be severe in these vulnerable areas that were thought to be protected by structural or mechanical flood control devices should those devices fail. Maintenance of small, parcel-scale water control devices is usually the responsibility of a property owner. Maintenance of larger structures that span multiple lots or long reaches of coastline or river is often the responsibility of agencies or entities, such as the U.S. Army Corps of Engineers (USACE). Within the focus area, the USACE's "National Levees Database" identifies the Flood Control Zone District No. 1 levee at the Port of Ilwaco Airport (in Vandalia Neighborhood) as flood control works. [3]

1.1.4 Stormwater Flooding

Stormwater flooding occurs when intense rainfall generates high - runoff rates, particularly from impervious surfaces, exceeding storage and stormwater drainage capacities. Build-up of debris or trash on stormwater intakes, low gradients in discharge pipes, and tide gates blocking discharge culverts can reduce stormwater discharges and cause flooding upstream. Under these circumstances, stormwater will pond in low-lying areas until the drainage system can function normally again.

Vulnerability to stormwater flooding is primarily influenced by contributing factors such as the topography, including the relative elevations in runoff areas, the extent of impervious surfaces within the watershed, timing and duration of peak flow rates during heavy rainfall, and the capacity of storm drainage systems in the area. The impacts of stormwater flooding are determined by the duration of flooding in affected areas, the frequency of floods, including how often they occur during the winter, the magnitude of flooding, and the length of time the flooding persists.

[3] https://levees.sec.usace.army.mil/

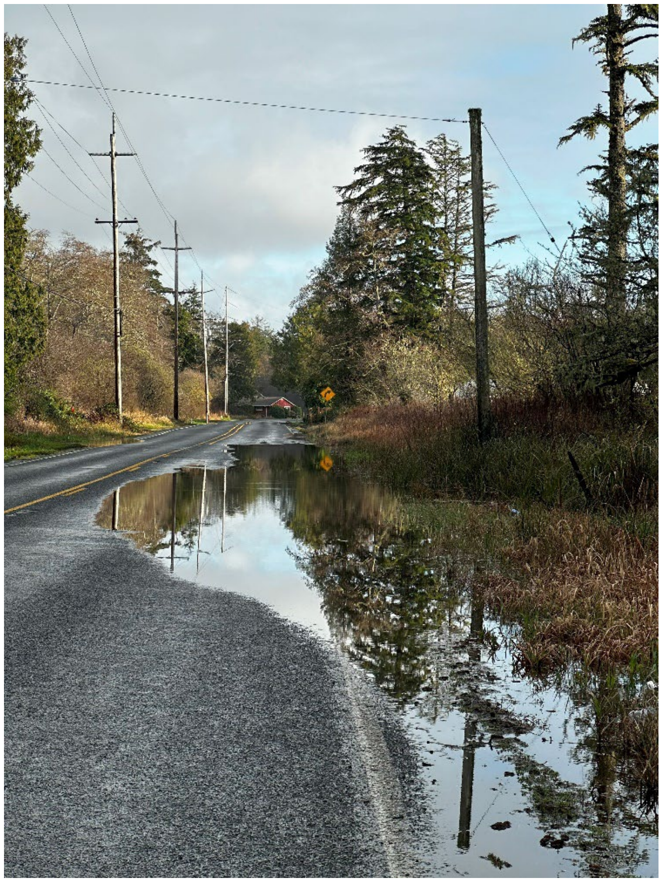


Photo 2. Flooding of impervious surfaces

1.1.5 Groundwater Flooding

Groundwater flooding occurs when precipitation and runoff exceeds infiltration rates and soil moisture storage capacity. Groundwater levels can increase slowly with increased groundwater recharge over several years. Vegetation and sediment build-up in drainage ditches and outlet pipes may also cause groundwater flooding in low-lying areas.

Vulnerability to groundwater flooding depends on topography of the surrounding area, watershed and runoff characteristics, and areas of low-permeability soils with shallow depths to the water table. Impacts of groundwater flooding depend on land use in low-lying areas, flood frequency, and the magnitude and duration of flooding.

Photo 3. Groundwater flooding near Port of Ilwaco Airport

Portions of the City of Ilwaco have a shallow groundwater table, particularly in the Vandalia Neighborhood. Groundwater can contribute to surface water flooding and cause impacts to existing buried infrastructure, particularly old or deteriorating systems. With rising sea levels, groundwater rises and subsequently increases the risk of flooding (Figure 1). Rising groundwater may expose buried infrastructure, building foundations, and low-elevation roads and structures to more frequent inundation or wetter conditions and cause damage to aging infrastructure.

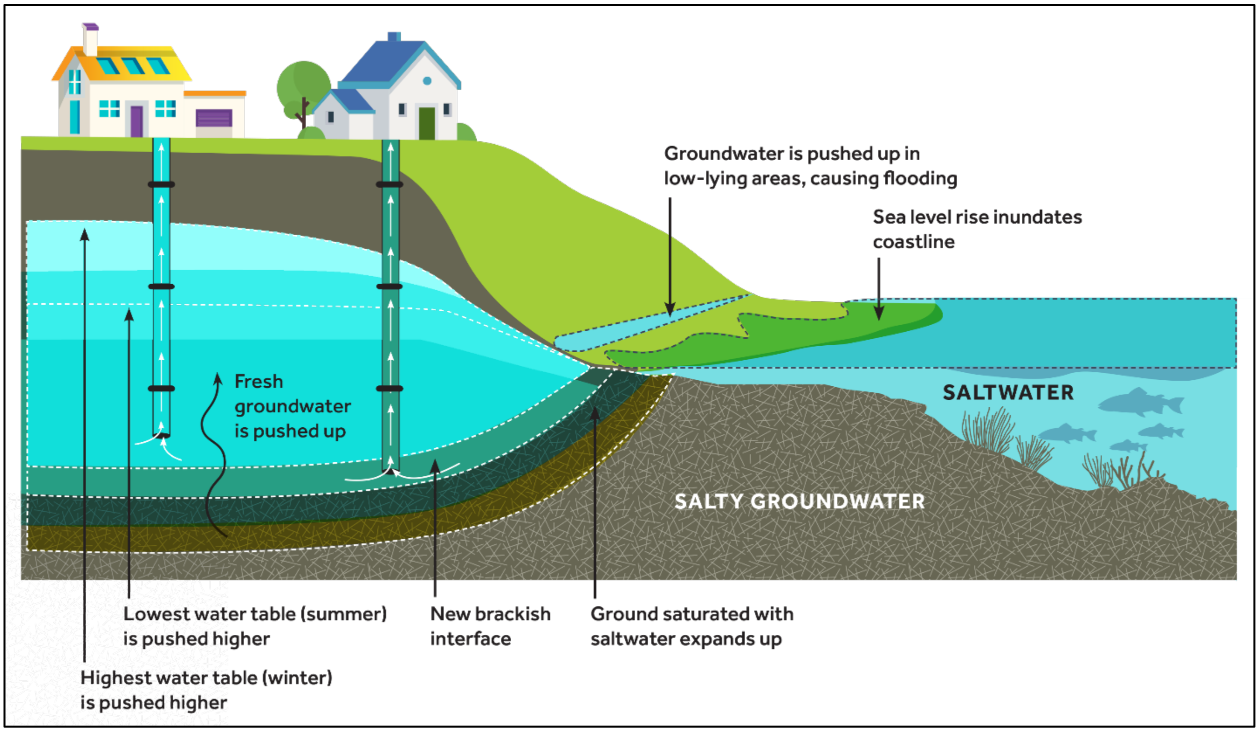


Figure 1. An illustration on how rising saltwater moves groundwater into new areas (Modified, based on source: A. Mohan, 2018).

1.1.6 Cumulative Impacts

Sea level rise increases vulnerability to coastal flooding through several mechanisms that often occur concurrently. The occurrence of higher tides, particularly King Tides in winter months and storm surges, driven by extreme winds and weather, on top of the increased average height of sea water, due to sea level rise and low atmospheric pressures, make for increasingly common extreme coastal flooding. Higher water elevations along the coastal areas increase the frequency and duration of compound flooding on rivers and streams with tidal influence and increases stormwater flooding in developed areas, due to tidal effects blocking drainage outlets and reducing low tide durations. Additionally, sea level rise can increase groundwater along the coastal areas because groundwater has less time to infiltrate and discharge out along seeps in the intertidal areas. This increase in groundwater reduces the land’s capacity to infiltrate surface runoff and flood waters which further exacerbate the duration and extent of flooding conditions (Befus et. al., 2020).

1.2 Soil Types

Soils with low permeability and high-water tables derived from the United States Department of Agricultural (USDA) Natural Resources Conservation Service (NRCS, 2025) are shown in Figure 2. These soils are important in assessment of exposure and sensitivity of assets to flooding. The soils that are low permeability and don’t facilitate infiltration of surface waters are prone to flooding from above ground flooding and pooling. These soil types include the Ocosta, Orcas, Seastrand, and Yaquina series. Alternatively, highly pervious soils allow water to rise easily from below the surface, which leads to elevated water tables. This reduces infiltration capacity and increases the risk of flooding and surface water pooling. These soil types include the Fluvaquents, Salzer, Seastrand Variant and Beaches series. While these eight (8) soil types are found within the region of Pacific County, only Yaquina, Ocosta and Fluvaquents are documented in the two (2) focus areas assessed in this report (Figure 3).

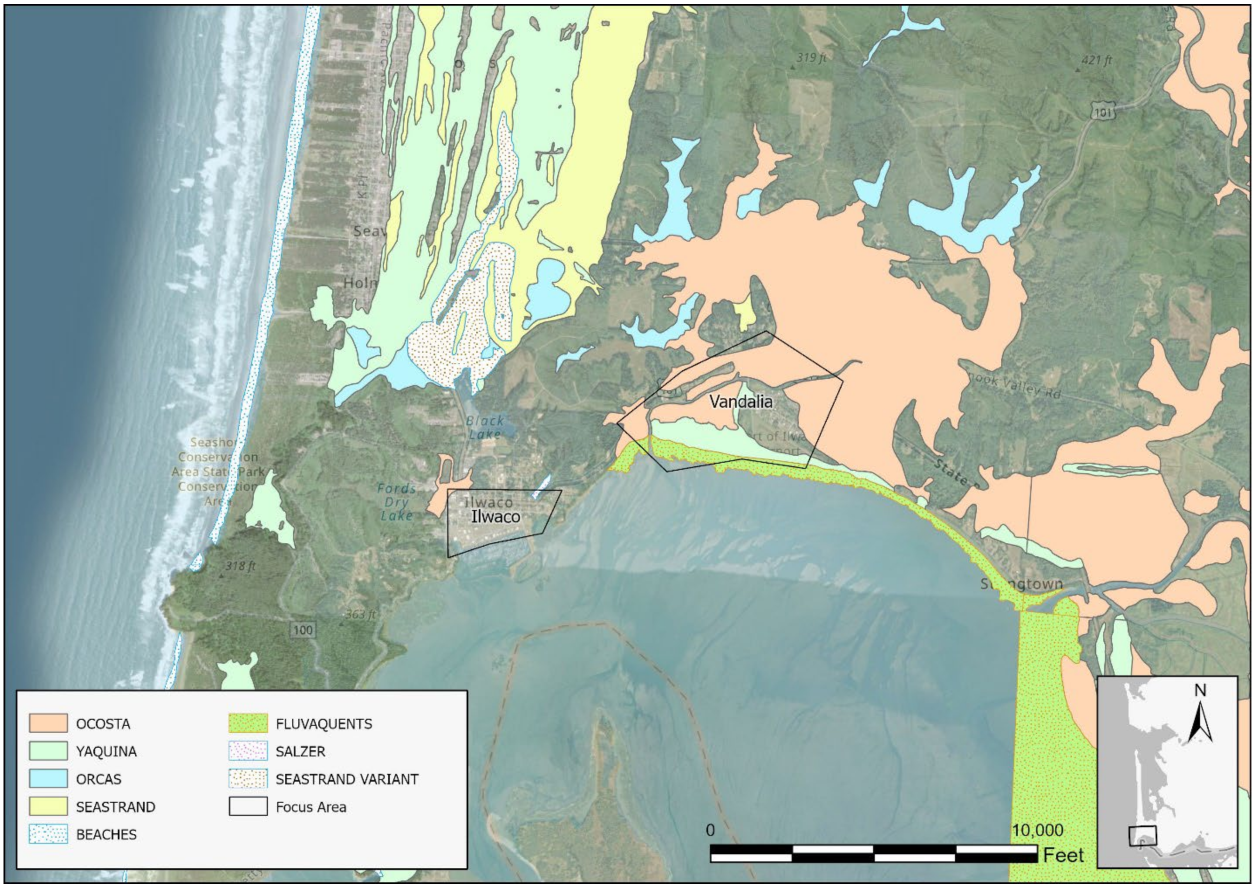


Figure 2. Presence of soil types in the region.

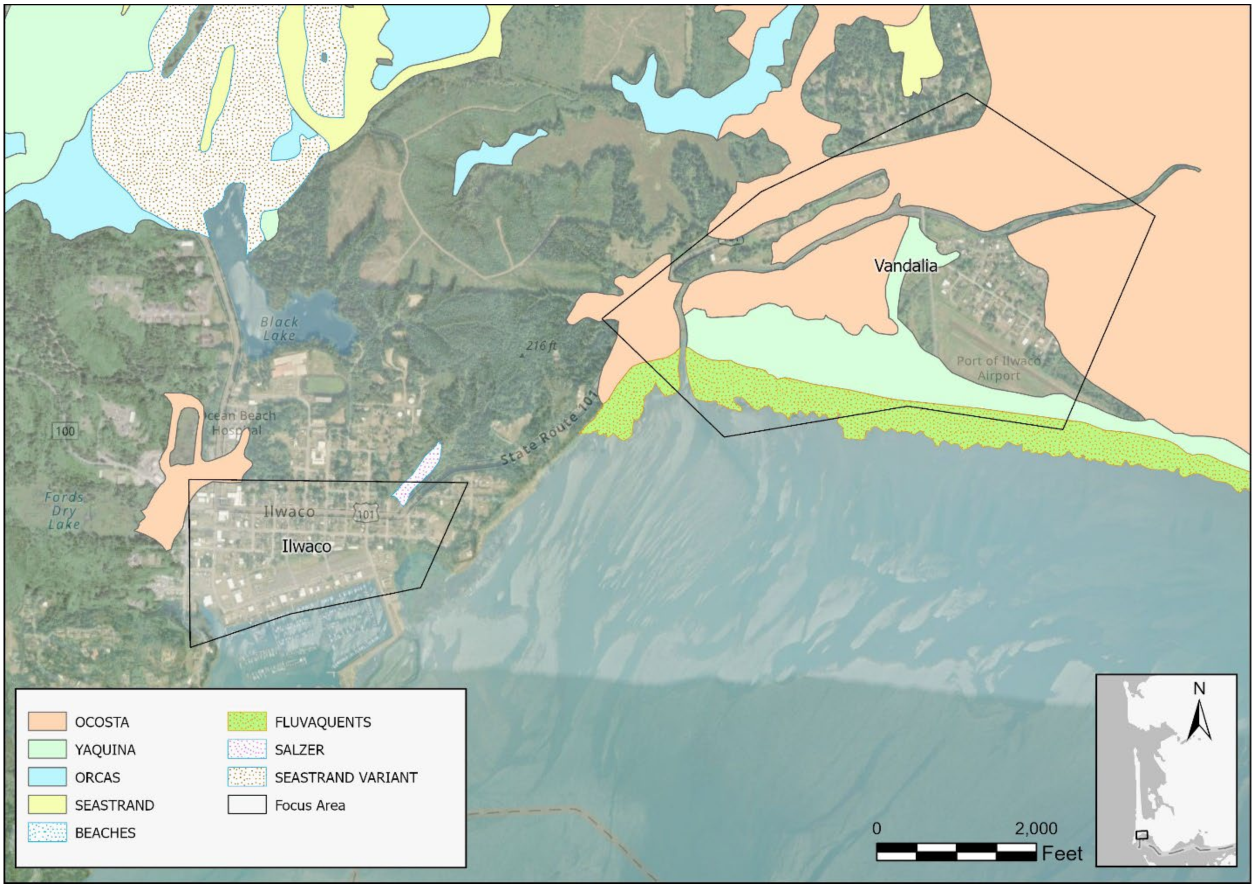


Figure 3. Presence of low-permeability soil types within the focus areas.

1.3 Sea Level Rise Scenario Projections

In the first phase of the Sea Level Rise Risk Assessment (DCG/Watershed, 2023), Pacific County chose to use SLR levels projected with an 83% likelihood for 2050 and 2100 and look at the potential extreme flooding. For this Countywide scale assessment, it was determined that it would be prudent to map sea surface increases in one-foot increments rather than the inches-differences documented in the previous section (Table 1). The rationale for this approach, in consultation with the primary author of the projections modeling (Miller et. al., 2018), was driven by the fact that when mapping at a County-wide scale (e.g., 1:50,000 or greater), the differences between inches of tidal elevation would not be visible. The +1-foot increment decision was also driven by the fact that half foot increments were not yet mapped by NOAA's Office for Coastal Management for these types of large-scale analyses (NOAA Office for Coastal Management, 2021). As a result of using these NOAA layers with the 1-foot increments, the assessment utilized a more extreme rise in the daily average high tide than is projected to occur with 83% likelihood by 2050 (e.g., zero (0) and five (5) inches). This 'overestimate' of daily average high tides is beneficial when planning expensive capital projects that will be on the landscape for decades and for emergency response planning. These higher levels would ensure that if sea levels

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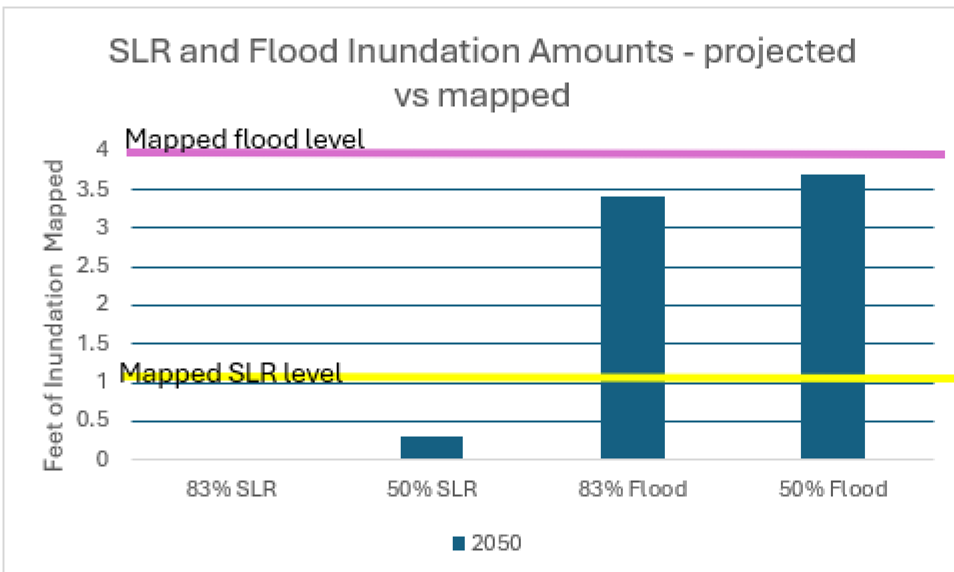
rise faster than predicted, or as predictive modeling improves, the results of this assessment would still apply.

The City of Ilwaco's Planning Commission (PC) chose to revise the scenarios used in the 2023 Pacific County Sea Level Rise Risk Assessment. The 2023 assessment mapped the 83% likelihood (8.5 RCP) SLR, plus a 20-year and 50-year return frequency flood. The PC chose to review the 50% likelihood amounts (Table 1). In January 2025, NOAA's Office of Coastal Management released new tidal inundation mapping layers in half-foot increments which enabled a reassessment of whether the mapping should be revised with a higher resolution and 50% likelihood. After reviewing the SLR projections for a 50% likelihood, it was found that the more conservative projections were still within the bounds of the rounded mapping tolerance. City staff agreed to not revise the mapping from the 2023 assessment as the mapping would still represent the more conservative 50% SLR projection amounts.

For this assessment, the +1 foot and +4-foot projections were used for the SLR component of the coastal flood factor, which are further described in Section 3.6 below.

Table 1. SLR and flood inundation comparison between 50% and 83% probability by 2050.



1.4 FEMA Flood Insurance Studies

The Federal Emergency Management Agency (FEMA) provides flood insurance studies to reduce flood hazards for jurisdictions and sells insurance policies to cover some of the cost incurred from damages to structures during flood events. Flood insurance studies address coastal and riverine flood hazards for communities in Washington State. FEMA published a Flood Insurance Study (FIS) for Pacific County that includes coastal flood elevations for shoreline properties and base flood elevations for floodplain areas along rivers (FEMA, 2015). The base flood elevation is a 1% probability of occurrence, also known as 100-year return period, flood based on a frequency analysis of historical flood records. Base flood elevations are derived from hydraulic models and current river channel topography (e.g., gradients, roughness, and cross-sections). The purpose of the flood maps is to provide flood risk calculations for the flood insurance program, particularly for selling flood insurance policies. FEMA requires the city to ensure that development activities in the flood hazard area are consistent with Flood Damage Prevention standards contained within Ilwaco Municipal Code Chapter (IMC) 15.16, Development in Flood Areas. These standards include structural measures to reduce flood damage to residential or commercial properties to promote public health, safety, and general welfare; reduce the annual cost of flood insurance; and minimize public and private losses due to flood conditions in specific areas. The FIS uses historical flood data available from other agencies. They do not include sea level rise projections, stormwater discharges from future developed areas, or changes in hydrology. The FIS studies use step-backwater hydraulic models for computation of water surface elevations based on current channel characteristics. This methodology calculates water depths for reaches of rivers to account for variations in channel geometry. These projections do not include flood effects due to channel migration, sediment build-up (gravel bars), or debris jams in alluvial rivers draining forested watersheds. FEMA Flood Insurance Rate Maps (FIRMs) for the Ilwaco City Center and the Vandalia Neighborhood are shown in Appendix B.[4]

2. Public Engagement

A public participation plan was developed at the outset of this project to provide a coordinated effort to determine the existing issues related to infrastructure and flooding to better understand the future impacts from a changing climate and how best to mitigate them. This effort included coordination with key contributors and Tribes to understand existing conditions and potential gaps in the hydrologic analysis and GIS modeling efforts, provide timely information on, and an understanding of the process of developing the hydrologic analysis and GIS modeling to establish low, medium, and high-risk classifications for assets in the focus areas, and opportunities to participate in the development of draft amendments to City Codes and plans.

A Technical Advisory Committee (TAC) was formed through a stakeholder mapping exercise. These contributors were identified to be individuals who can effect change, have relevant knowledge or skills, represent the interests of particular groups, and/or will be impacted by SLR. The Shoalwater Bay Indian Tribe and Chinook Indian Nation (Tribes) were consulted to determine how they would like to be involved and what support they require to participate. The Planning Commission and Tribes were consulted individually to obtain historical context and refine areas of concern and messaging strategies. The TAC included representatives from the following groups:

Table 2. TAC Representatives

Pacific County	Washington Sea Grant
Lead to Results	Washington Department of Fish and Wildlife
Willapa Erosion Control Action Network	City of Ilwaco Public Works

[4] https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd

Shoalwater Bay Tribe	City of Long Beach
Chinook Indian Nation	Port of Ilwaco/Port of Chinook
Joint Pacific County Housing Authority	Port of Peninsula
Pacific Conservation District (PCD)	Port of Willapa Harbor
Pacific County Department of Emergency Management	Pacific County Economic Development Council
Pacific County Public Works	Pacific County PUD #2
Pacific County Marine Resources Committee (MRC)	Seaview Sewer District
Washington State Department of Ecology	Representative from Surfside
Representative from Seaview	

The Technical Advisory Committee (TAC) met four (4) times to review and advise on methodologies, results, and strategies. The project was also presented to the City Council to receive feedback and guidance on directions. Two (2) public meetings were held to walk attendees through concerns and locations of existing flooding. An ArcGIS StoryMap was developed and included areas and infrastructure at risk to provide an accessible, interactive format for the public to view information. This StoryMap will explain how the assessment was conducted and provide recommended strategies and resources.

The public meetings helped to provide feedback on assets chosen to be evaluated, the boundaries of the focus areas, and existing areas of concern. As a result of the first public meeting, the initial boundaries of the Vandalia focus were revised to include the Port of Ilwaco Airport next to the neighborhood of Vandalia. The culverts at the base of the Discovery Trail were also noted as an area of concern after heavy rain events. However, these culverts are not included in the City's inventory and thus were not able to be included in this assessment. The second public meeting noted that the vulnerability ranking should consider the cost to retrofit, a Master Plan with a prioritization of infrastructure should be developed, and that definitive or absolute values are needed to provide bookends for updating regulations. It was discussed whether the increased standards are needed to ensure structures and infrastructure are protected and what planning horizons the City should be required to plan for. It was recommended that ground truthing data (verification of projections) be collected to inform future efforts. These high-level topics were similar to those discussed with the TAC.

Focused outreach includes meetings with Shoalwater Bay Tribe, Chinook Indian Nation, the City of Ilwaco Public Works Director, and the Pacific County Department of Emergency Management Director. Information was provided to the local newspaper team regarding all public meetings via press releases, published on the City's website and posted physically at the City's Post Office. Meetings were held in both virtual and hybrid formats to increase participation by the public. The project team also conducted an interview with the Daily Yonder, a small regional newspaper, to provide information on the project.

Check-ins were held with the Pacific Conservation District (PCD) to share information and coordinate efforts between the PCD projects (e.g., Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy and Lower Willapa River Resilience Project) and this assessment.

3. GIS Mapping Methods

3.1 Focus Areas

Two (2) focus areas were selected for this assessment (Figure 4) based on identification in the Phase 1 Sea Level Rise Vulnerability and Risk Assessment (2023) as areas of concern pertaining to groundwater and surface water flooding.

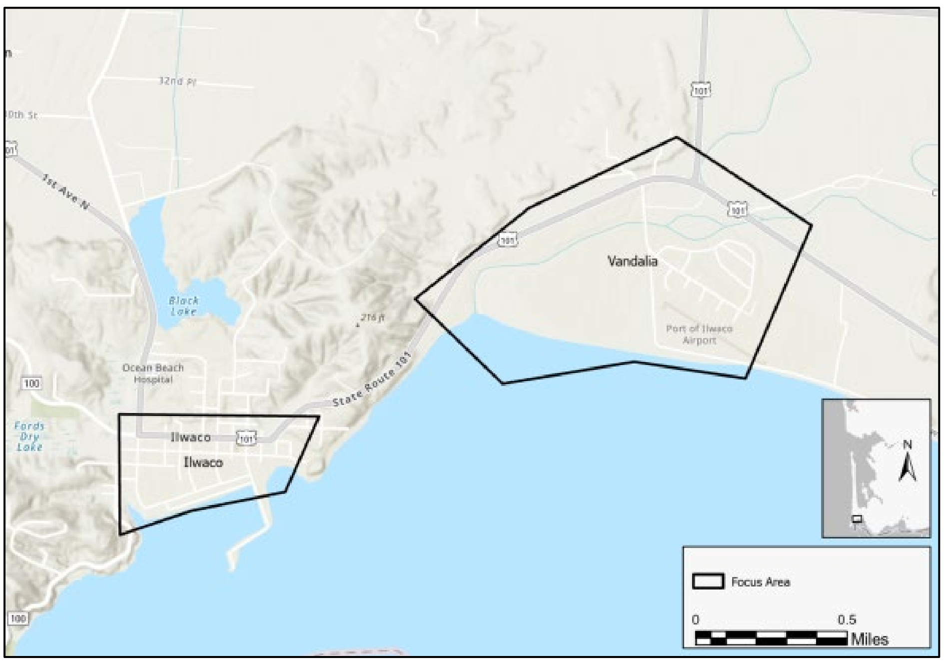


Figure 4. Focus Areas

3.2 Hydrologic Analysis (USGS Streamstats program[5])

Hydrologic analysis of basin characteristics and peak flow statistics for the Wallacut River near Vandalia is shown in Appendix A[6]. The statistics are based on regional analysis and regression equations for gauged streamflow stations. Basin characteristics include mean basin slope and watershed area. Peak flow statistics include flood frequency and bankfull width and depth calculations for rivers and streams.

[5] https://streamstats.usgs.gov/ss/
[6] https://modelmywatershed.org/

3.3 Relative Elevation Models

Relative Elevation Models (REMs) are floodplain visualization tools (Coe, 2016). REMs use digital terrain models to show fluvial surfaces, including off-channel areas, relative to surface water elevation in a river, lake, or other water bodies. REMs can show channel migration effects beyond the current channel alignment, including abandoned channels in the floodplain. The REMs for the focus areas are shown in Appendix C. A REM was not used for the analysis of Ilwaco's city center because there are no rivers or lakes to serve as reference points.

3.4 Vulnerability Assessment

Asset vulnerability is a characterization of how likely the asset will be exposed to a negative impact (risk of exposure and sensitivity of the asset) and the capacity of that asset to withstand and recover from that impact (adaptive capacity) (Figure 5). The US Climate Resilience Toolkit's "Steps to Resilience" provides an adaptable framework for assessing asset vulnerability (NOAA, 2025). The Technical Advisory Committee (TAC) vetted and recommended an adjusted framework that will apply rulesets developed for each type of asset. These rulesets include specific exposure/sensitivity criteria and adaptive capacity criteria for each type of asset. These two components were characterized using a vulnerability matrix (Figure 6).

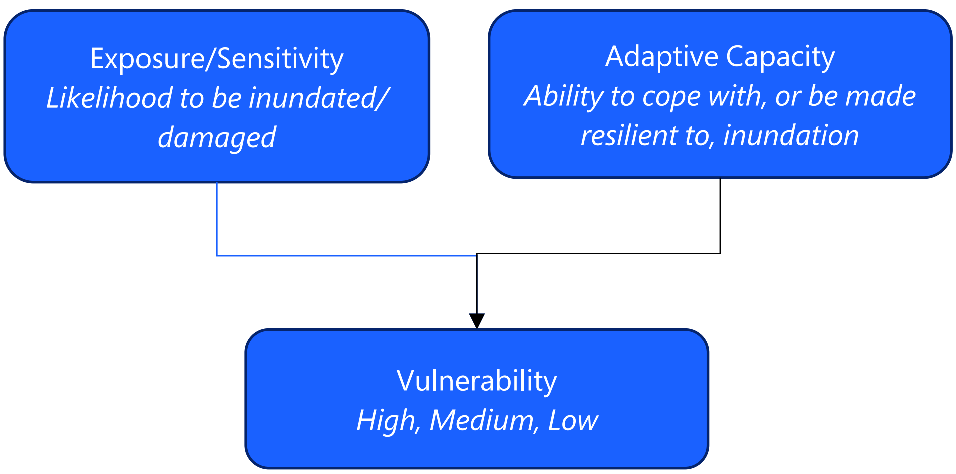


Figure 5. Vulnerability assessment model

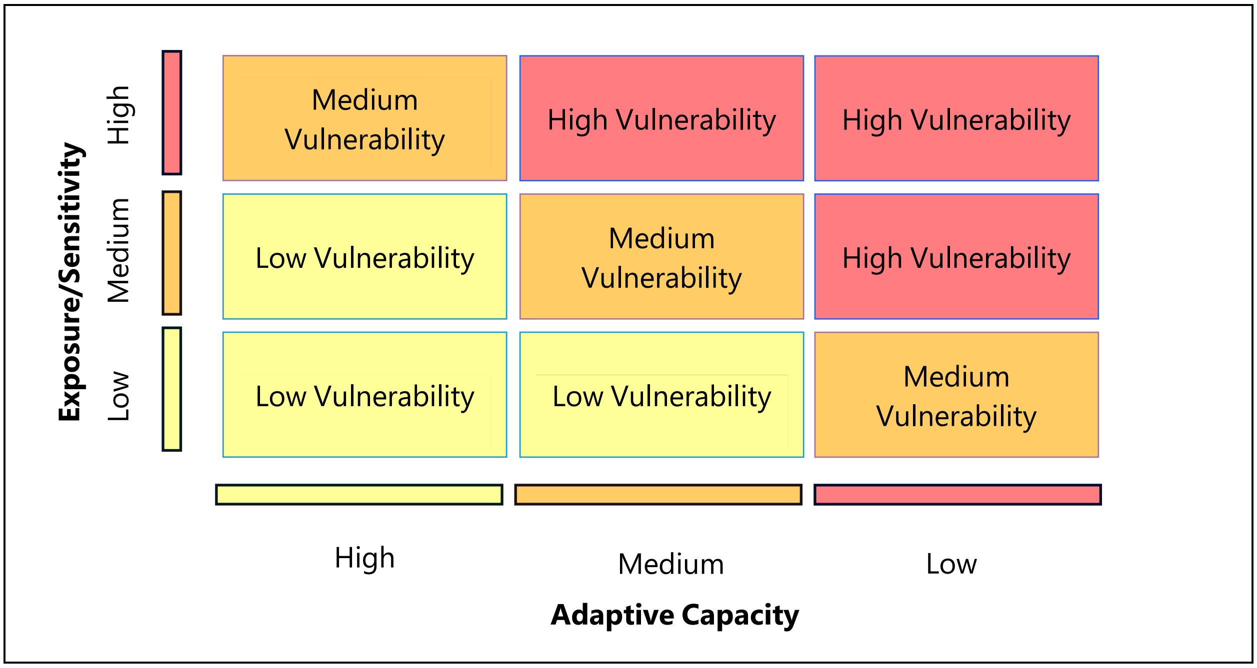


Figure 6. Vulnerability Matrix

The assessment of exposure evaluated assets that are located in areas with a high probability to flood due to the existence of one or several "flood factors". The flood factors used in this assessment include the following:

- Areas where sea level rise is projected to inundate areas inland because of extreme storm events or higher daily high tides (see Section 1.2 for additional details);
- Areas with low permeability soils, which are susceptible to increased flooding in the future due to inability to infiltrate surface water whether the source of the water is from coastal flood overwash, increased precipitation and stormwater that cannot drain through blocked outfalls or by river flooding due to river discharge backup when the tides are high;
- Areas with high permeability soils that permit groundwater to be driven up to the surface when pushed from below by advancing saltwater wedges from marine waters and hyporheic flooding from full rivers; or
- Areas within a designated FEMA Flood Zone A, AE, or VE.

The term "**Areas at High Risk of Flooding**" (AHRF) is used throughout this document to refer to areas that meet one of the Flood Factor" criteria, as described above. This is a term and process created for this assessment. Given the limited data available, this approach to quantifying flood exposure and asset sensitivity was reviewed and endorsed by the Technical Advisory Committee (TAC).

The AHRF layer was intersected, using GIS mapping software, with different kinds of assets to quantify the potential impact. Assets included structures, roads, drinking water infrastructure, wastewater infrastructure, stormwater infrastructure and public utility infrastructure (electrical and communications). These asset types were selected by the TAC during the outset of this project.

__Flood Factors__: Conditions that result in a location being at higher risk of flooding. For this assessment flood factors include impervious soils, FEMA Flood Zones A, AE and VE, and areas mapped as likely to be inundated by an extreme flood, with 83% likelihood by 2050.

__AHRF:__ Areas at High Risk of Flooding that have at least one of the flood factors.

Where data is insufficient and quantification of potential impacts cannot be produced, results are limited to more general discussion regarding potential impacts to the asset type given the site-specific conditions in that focus area. Data gaps are notes in Section 3.7, Gaps and Alterations.

Rule sets were developed to classify where assets may be at high, moderate, or low risk of exposure to flooding. It should be noted that assets that are not mapped as being a high, moderate or low risk are not considered to be at zero risk. This classification is based, in part, on a conservative confidence of likelihood for sea level rise projections. As such, assets that are not found to intersect an AHRF could be at risk if flooding exceeds the frequency, magnitude and projections that were subjectively selected for this assessment. It should also be noted that the state of the infrastructure was not evaluated as a part of this assessment. Aging infrastructure could result in increased risk of impacts or failure that may exacerbate impacts on assets.

More details about how these rule sets were applied, where data gaps prevented rule set application and potential impacts to assets and are discussed in the Results section below.

Table 3. Rule Set - Roads Exposure/Sensitivity

Exposure/Sensitivity	Description
High	Roads that intersect the AHRF and are a single ingress/egress from a community OR where the roadbed would be flooded at less than +1 feet of inundation (+1 ft was used for SLR MHHW mapping for 2050 for a conservative mapping projection)
Medium	Roads that intersect the AHRF and where the roadbed would be flooded at less than +4 feet of inundation. +4 ft is used because the 20-year return flood by 2050 may be +4 ft above current MHHW.

Exposure/Sensitivity	Description
Low	Roads that intersect the AHRF and aren't classified as High or Medium. **No roads are considered to have no risk of exposure. A different selection of SLR likelihood could alter the inundation extent and would alter the number and extent of roads exposed. Additionally, the capacity and state of stormwater infrastructure was not included in this assessment.*

Table 4. Rule Set –Exposure/Sensitivity: Stormwater and drainage (culverts, tide gates, storm catch basins, canals, ditches).

Exposure/Sensitivity	Description
High	Infrastructure that is within an AHRF with stormwater drainage systems and catch basins in need of repair or storm lines that are less than 10 inches in diameter that directly drain into an AHRF.
Medium	Infrastructure that is within an AHRF with a stormwater drainage system and catch basins designed for less than a 20-year return frequency storm.
Low	Infrastructure that is within an AHRF with stormwater drainage using infiltration ponds or injection methods, or catchment basins designed for a 50-year return frequency storm, or Infrastructure that is within an AHRF but is not designated as Medium or High. **No stormwater facilities are considered to have no risk of exposure. A different selection of SLR likelihood could alter the number and extent of infrastructure exposed. Additionally, the capacity and state of stormwater infrastructure was not included in this assessment.*

Table 5. Rule Set - Adaptive Capacity, applied to all asset types.

Adaptive Capacity Ranking	Description
Low Does *not easily* adapt, or is difficult to adapt, *to new conditions*	Impacts on assets may lead to significant operational disruptions or loss of functionality. Adaptative solutions may need to be innovative and require collaboration with agencies and representatives. High costs are likely associated and may require significant capital improvements to mitigate impacts
Medium	Impacts on assets may lead to temporary operational disruptions or loss of functionality. Impacts can be reduced or mitigated to some extent, but adaptive solutions may only be feasible for certain components of the assets. Some assets may face challenges regarding cost and implementation. .
High *More easily adapted*	Assets can adapt to impacts with minimal difficulty. Adaptive solutions are highly feasible for most assets with affordable costs

Rule sets for on-site septic/sewage and drinking water wells were not utilized for this report because both focus areas are serviced by a wastewater treatment facility and sewer lines, as well as drinking water sourced from the Indian Creek Reservoir, located east of the City limits. This is discussed further in the Results section below.

Coastal Wetlands that intersect with AHRFs will be quantified. Rule sets were not developed for coastal wetlands. Potential impacts to wetlands due to coastal, riverine, stormwater and compound flooding are discussed in the Results section below. Suggestions for potential mitigation and adaptation actions are offered in the Recommendations section below.

Projects listed in the City's Capital Improvement Plan (CIP) were cross-referenced with the AHRF areas to determine if the CIP projects were located within an area at higher risk of flooding and how many flood factors were involved.

Elevation profiles were generated within each of the focus areas as a representation of the elevations relative to sea levels. The transects were chosen to be representative of the focus area in general. The elevation profile tool was used over the most recent digital elevation model for the area. Locations of roads were used to provide a sense of place to the elevation profile.

3.5 Data

Data utilized to conduct this report was primarily from state agencies with assumed established quality management systems. The data sources were reviewed with the TAC, City staff and the public to ensure that local knowledge was reflected in the assessment. Data sources included, but not limited to, the following:

Table 6. Data Sources

Data Parameter	Attributes available	Source
Aquifer and surficial geology coverage	Soil Data Series characteristics, extents, depths, transmissivity, storativity, relative discharge	U.S. Natural Resources Conservation Service
Bare-earth, LiDAR based topography	2017-2019 Flights, three (3) ft resolution, NAVD 88	NOAA, WA Dept. Of Natural Resources LiDAR Portal
River Statistics	Flow rate trends and records	USGS Stream Stats Model My Watershed,
Precipitation	Frequency, Probable Maximum	NOAA Hydrometeorological Design Studies Center
Marine Water	Datums, Exceedance trends and amounts	NOAA
Existing Infrastructure (culverts, tide gates, outflow pipes and retention pond locations, component sizing and condition)	*See below*	City of Ilwaco Public Works staff and/or Pacific County Public Works, WSDOT
Roads	Name, Type, Pavement Type, Lane Width, Direction, Length	Pacific County
Roads	.jpg of points (2-3 per focus area) with heights. Assumed NAVD88	WSDOT
Culverts	Length, Height/Width, Access, Feature Type/Description, Fish Use/Passage, Owner, Problem Notes, Comments, Inspection Date (pre-2013)	Pacific County
Culverts	ID Number, Region	WSDOT
Storm Lines	Diameter	City of Ilwaco
Water Lines	Size, Material, Length, Type, Name	City of Ilwaco
Catch Basins	ID Number, Region	WSDOT
Tide gates	Length, Height/Width, Access, Feature Type/Description, Fish Use/Passage, Owner, Problem Notes, Comments, Inspection Date (pre-2013)	Pacific County
Sewer Lines	Length, Diameter, Sewer Type (Gravity, Fm, PFM, Outfall, Service), Material	City of Ilwaco

Data Parameter	Attributes available	Source
Mapped sea level rise and extreme flood inundation used in Phase 1	Feet above MHHW	Pacific County, NOAA Tidal Vectors
Flood coverage maps	Flood zone extent and type	FEMA, Pacific County
Areas of flooding concern	Location, dates, areas, and local knowledge	Public feedback during meetings, Interviews with City Public Works staff Pacific Conservation District
Subsurface communication infrastructure	Location, Type ("Core", "Distribution")	Public Utility Districts, City of Ilwaco
Planned development activities	Type, Location, Timeline estimate	City of Ilwaco, Pacific County Capital Improvement Plan
Projections of atmospheric river changes and modeling of future conditions	Feet of SLR by likelihood, year	University of Washington's Climate Impact Group, Northwest Hydraulics

3.5.1 Local knowledge

The consultant team met individually with several groups or departments to gather local knowledge on existing conditions, including the Pacific County Department of Emergency Management and the City's Public Works staff. Local knowledge was also obtained through public engagement events and through the Pacific County Phase 1 SLR Assessment.

3.6 Gaps and Alterations

This section documents where variances from the scope of work and methods detailed in the Quality Assurance and Protection Plan (QAPP) occurred. The section also notes some assets this assessment didn't assess, the reasons and makes recommendations as appropriate to address these at a later time.

Cultural assets were not reviewed in this assessment. Historical buildings were assessed for exposure to SLR and extreme coastal flooding in the Pacific County Phase 1 assessment (Source). Assessing potential impacts to cultural resources will require close partnership with, and direction from, the Shoalwater Bay Tribe and Chinook Indian Nation. It should also involve a subject matter expert, such as an archeologist, who can identify the sensitivity and adaptive capacity of specific types or resources. The team convened for this assessment did not include that particular expertise. The mapped AHRFs detailed in this report, could be used by experts with access to sensitive cultural resources to determine if flooding exposure is possible and develop appropriate mitigation strategies.

The Flood Simulation Model did not provide the results expected. The model did not produce flow rates as stated in the project's Quality Assurance Project Plan (QAPP). The model did not produce data that could be used in a statistical assessment. The limitations of the model meant that it was potentially useful as a scoping tool but not precise enough to compare asset sizes and functions in a real-life situation. Site-specific, field-based hydraulic engineering is likely necessary in areas such as this where differences in slope between the land surfaces and the tidal surfaces are flat.

Data for certain above-ground components of subsurface infrastructure was unavailable, preventing the implementation of rulesets designed to assess exposure based on flood heights. This limitation affected the evaluation of specific components for telecom, electrical and internet infrastructure. Additionally, incomplete data for culverts and outfalls impacted the accuracy of the quantification results.

The drinking water and wastewater rule sets approved by the TAC were not able to be applied to the City of Ilwaco and the Vandalia Neighborhood because the rule sets were built around wells and septic systems, not reservoirs and sewer systems. An adhoc vulnerability assessment was performed with rationale described in the summary tables.

4. Results

4.1 Results Overview

Asset types assessed included:

- Structures
- Roads
- Drainage/Stormwater infrastructure
    - Culverts/Tide gates
    - Catch basins/stormwater tracts
    - Stormwater lines
    - Drainage ditches/canals
- Drinking water infrastructure
- Wastewater infrastructure

ELECTRICAL, INTERNET AND TELECOMMUNICATIONS

The Public Utility District No. 2 of Pacific County (Pacific PUD) provides electric and telecommunication (and water) services within the County. Across both focus areas, there was insufficient publicly available data for telecommunications, internet and electrical services to enable quantification by exposure/sensitivity ranking. Pursuant to discussions with Public Utility District No. 2 (PUD) during the outset of the project, utility transmissions and distribution lines in Pacific County are primarily subsurface and have been built to withstand flooding and groundwater conditions. Exact location of services was withheld due to safety concerns (PUD No. 2, Personal Communication, April 9, 2024). The exposure of above-ground substations was assessed with Phase 1 (DCG/Watershed, 2023). Pacific PUD also provided the location data of fiber conduit. If data for above-ground equipment components could be made in the future, a vulnerability assessment could be conducted. The Pacific PUD's Strategic Plan states "*Design and construction of the system will follow proven and tested engineering standards and criteria in order to assure maximum reliability into the future while maintaining prudent financial responsibility. Future construction objectives will be considered in the design and applied to all aspects of construction from individual services to transmission facilities…Pacific PUD will continuously seek ways of improving system efficiency and reliability. By monitoring system loads and tracking outage locations, Pacific PUD can prioritize projects*." Among the Plans goals is to continue the overhead to underground conversion program, require new/revised services be underground and to implement a redundant/loop design and construction (Pacific PUD, 2025).

During a field visit, above ground components for electrical and telecommunication facilities were observed to be inundated in some areas (Photo 4). It is recommended that Pacific PUD include in their monitoring program the condition and duration of inundation for above-ground equipment located in AHRFs. Without information regarding the ability to withstand temporary or permanent inundation, no exposure/sensitivity, adaptive capacity or vulnerability ratings were applied.

Photo 4. Inundated above ground infrastructure for electrical and telecommunication facilities in Pacific County, WA.

4.2 City of Ilwaco Focus Area.

The Ilwaco City Center Focus Area is shown below in Figure 7.

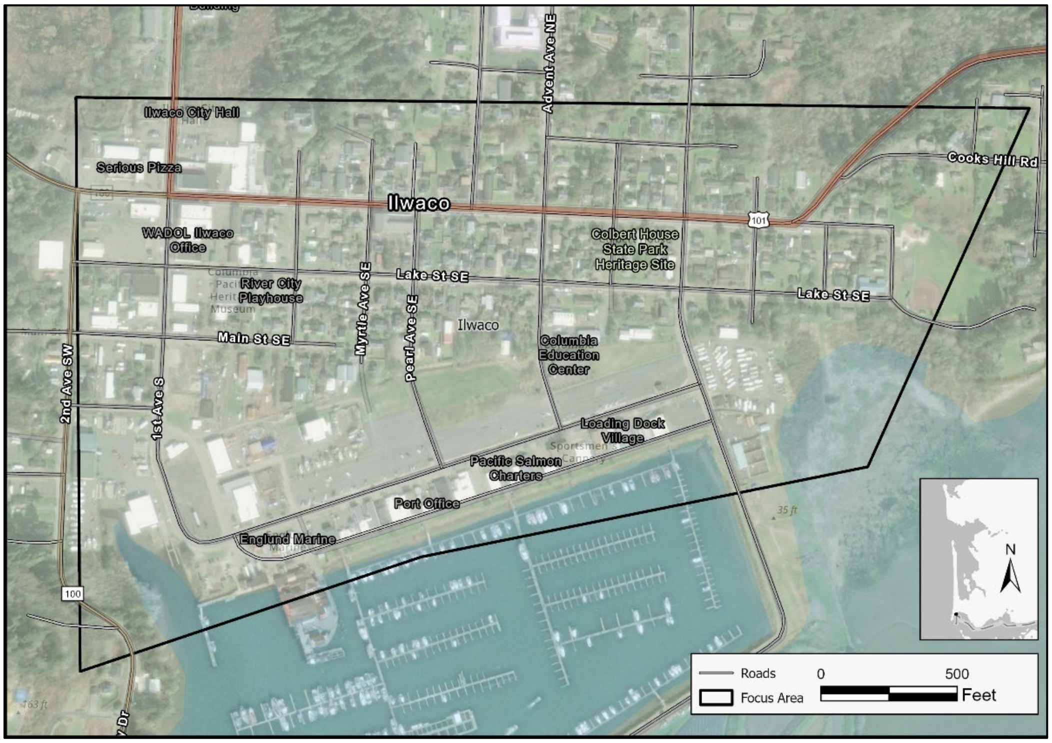


Figure 7. City of Ilwaco focus area.

The focus area lies in a hydrogeomorphic reach of the Columbia River Estuary with tidal influences on the Columbia River, Baker Bay, and several tributary rivers and streams.

Flooding in Ilwaco results from coastal flooding from storms on Baker Bay and the lower Columbia River, compound flooding when high tides and storm conditions combine with flood discharges from rivers and streams, stormwater flooding on roads and residential areas with insufficient drainage, and groundwater flooding in low-lying areas with low permeability soils and high-water tables. Surface elevations in the city vary from 7.35 feet NAVD88 near the marina to greater than 43 feet in uphill areas. Spot elevations near the shoreline are typically less than 17 feet NAVD88. The FEMA AE coastal base flood elevation (0.01 probability of occurrence) is 11 feet NAVD88 (Appendix B).

Table 7. Cross-reference of the different datums for the same locations[7].

Location	NGVD (ft)	MHHW (ft)	MLLW (ft)	NAVD 88 (ft)
Marina (46.3066, -124.03914)	4	-0.4	7.5	7.4
East Ilwaco (46.3072, -124.03243)	14	9.6	17.5	17.3
North Ilwaco (46.3100, -124.0396)	40	35.5	43.5	43.4
FEMA AE Base Flood	7.7	3.2	11.1	11

Compound flooding in Ilwaco occurs when flooding from the Wallacut, Chinook, and Columbia Rivers emptying into Baker Bay combined with high tides, storm surges, and wind waves. High tides during winter storms with high flows in and from coastal rivers and streams can block storm discharges. Under these conditions, and particularly if they have tide gates, rivers, streams and drainages back up and increase flooding upstream. When tides recede during the storm, floodwaters from the rivers and streams increase water levels in Baker Bay.

Frequently flooded areas in the downtown area of the City of Ilwaco may be due to stormwater flooding during rainstorms. Flooding may occur when high tides block drainage culverts along the bay causing runoff from impervious areas to flood roads and low-lying areas until the tide recedes. Flooding north of Highway 101 has been observed during king tides when outfalls are backwatered (S. Corsi, personal communication, February 24, 2025).

Groundwater flooding occurs in the northeast of the city around Black Lake and other drainages in depressional areas with low permeability soils and a high-water table. Detailed soil descriptions are included in Appendix D. Soils considered to have low permeability and associated with high water table hazards include the soil series Beaches, Fluvaquents, Ocosta, Orcas, Salzer, Seastrand, Seastrand-Variant and Yaquina. The only occurrences of these soil types are present in the northwest corner of the City boundary and north of Highway 101 northeast of the downtown area. Figure 8 below illustrates these areas of low permeability. The areas may experience elevated levels of flooding due to the reduced permeability and adjacent infrastructure and assets may be impacted.

[7] https://www.vdatum.noaa.gov/vdatumweb/vdatumweb?a=113900820250130

Figure 8. The presence of low-permeability soils in the City of Ilwaco focus area. Flooding is observed at the marker during King Tides due to backflow effect up outfall pipe.

Projected sea level rise and extreme flooding is mapped below in Figure 9. Projections represent the extent of daily high tides (MHHW) by 2050 with 83% likelihood (yellow). The extent of an extreme flood with a 20-year return frequency by 2050 is mapped in pink (DCG/Watershed, 2023). The majority of the City is at an elevation that appears to be above extreme flooding and daily high tides. It is possible for coastal storms driven by wind wave runup to exceed these mapped projections. Tsunamis are not considered in this projection mapping. Figure 10, below, shows the elevation profile along a transect from the marina upland. While the possibility of coastal flooding inundating the City with wind driven waves pushing water up is present, it may not be a common direct cause of flooding due to the overall elevation of the City landward from the marine environment.

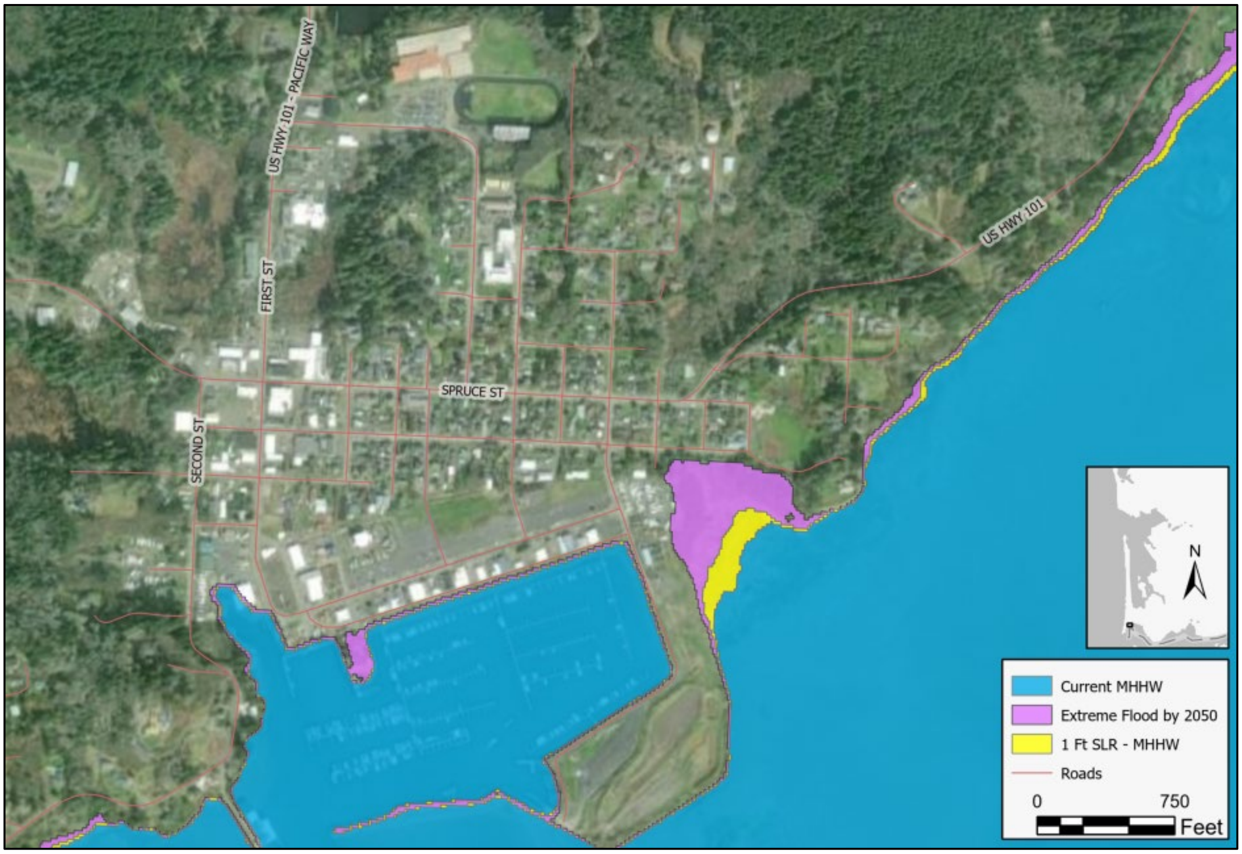


Figure 9. Projected inundation due to sea level rise and 20-year return frequency flooding by 2050 with 50% likelihood.

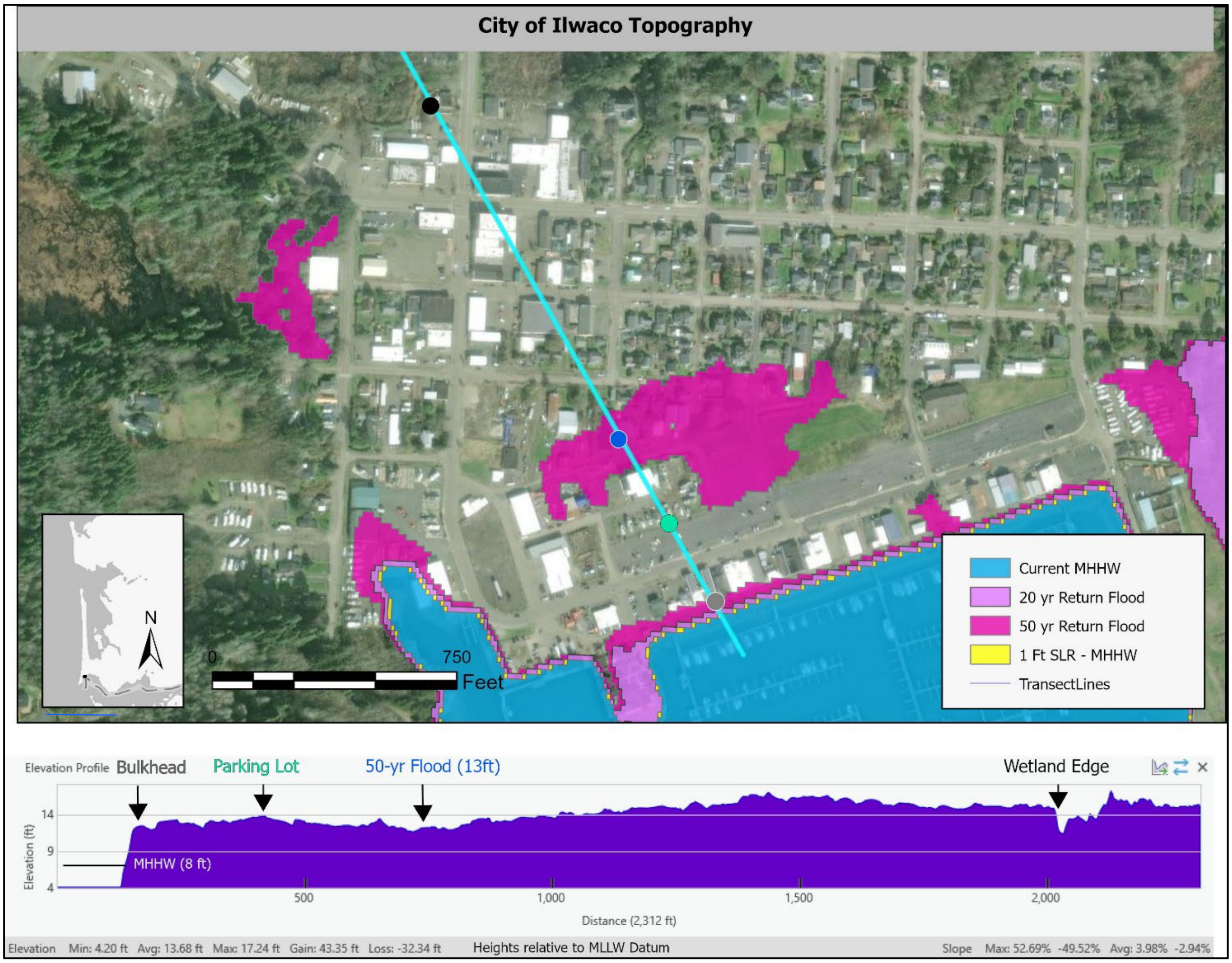


Figure 10. Elevation profile along a transect (blue line) from the marina to North Ilwaco (left to right on profile).[8]

4.2.1 Assets Vulnerability Assessment

The purpose of the assessment is to identify and quantify the level of impact that assets experience from surface flooding. Groundwater flooding is a concern because of soil saturation that impacts infiltration or rainfall, which can lead to surface water flooding. The City of Ilwaco is serviced with water and sewer. Therefore, groundwater impacts on-site septic systems or individual drinking water wells are not a concern. The City's drinking water comes from a reservoir in the mountains to the East and is not susceptible to groundwater hazards or the flooding impacts discussed here. Assessing the reservoirs' susceptibility to other climate-driven changes, such as droughts or forest fires, is out of scope for this project.

[8] The yellow color represents 1ft of sea level rise above MHHW. The light pink color represents a 20-yr return flood in 2050. The darker pink color represents a 50-yr return flood in 2050. The 50-yr return flood was not used in the rest of this assessment and is included here to show an extreme scenario. Elevation is MLLW Datum. (0 ft MLLW = -0.11 ft NAVD88)

FACET

Table 8. Summary of the asset vulnerability assessment for the City of Ilwaco.[9]

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Structures	Two (2) structures are located less than a foot above the current MHHW and would be impacted by 1' increase in sea level rise. **(Exposure/Sensitivity = High)**	Mitigation measures for commercial buildings would require significant improvements to increase resilience from SLR and flooding impacts. Adaptations are possible, but cost is a challenge. **(Adaptive Capacity = Low)**	**High**
	Three (3) structures are between 1-4 ft above current MHHW. Flooding impacts are expected to be temporary but may increase in frequency overtime. **(Exposure/Sensitivity = Medium)**	One commercial building, which is expensive to elevate and difficult to relocate, is at risk. Two (2) residences are less complicated to elevate or relocate, but costly. Mitigation measures for buildings may require improvements to increase resilience from temporary flooding impacts. Adaptations are possible, but cost is a challenge. **(Adaptive Capacity = Low)**	**High**

[9] Please see Sea Level Rise Risk Assessment- Pacific County, Phase 1 for additional asset assessments (DCG/Watershed, 2023).

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Roads	No roads are less than +4 ft above MHHW or intersect an AHRF. **(Exposure/Sensitivity = Low)** *As described in the AHRF rule set, no roads are considered to have no risk of exposure because the flood factors chosen are subjective in nature. A different decision of SLR likelihood would alter the number and extent of roads exposed. Additionally, the capacity and state of stormwater infrastructure was not included in this assessment. .*	Temporary impacts due to flooding of transportation routes or facilities may impact the accessibility of residents. Impacts can be reduced or mitigated to a certain extent. Cost and implementation to retrofit, relocate or expand capacity of stormwater systems is a significant investment. However, roadways that are at a low risk of exposure will likely not be impacted during the short-term planning horizon **(Adaptive Capacity = Medium)**	**Low**
Culverts	Insufficient data to determine quantitative impacts. However, local flooding has been observed as a result of undersized or aging infrastructure throughout the city center. Impacts on current infrastructure are also dependent on the condition and age, design standards, and redundancy in the system. Older assets or those built to older design standards are likely to be more affected by temporary or permanent inundation. **(Exposure/Sensitivity = Medium)**	Cost and implementation to retrofit, relocate or expand capacity of stormwater or drainage systems is a significant investment. Significant operational disruptions will result from overwhelmed facilities. Adaptive solutions will likely have to be innovative and involve collaborative partnerships. **(Adaptive Capacity = Low)**	**High**

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Stormwater	Insufficient information to quantify but localized flooding is periodically observed. However, the city center experiences occasional flooding due to inadequate stormwater infrastructure that will likely be exacerbated by changing climate conditions. Impacts on current infrastructure are also dependent on the condition and age, design standards, and redundancy in the system. Older assets or those built to older design standards are likely to be more affected by temporary or permanent inundation**. (Exposure/Sensitivity = Medium)**	Cost and implementation to retrofit, relocate or expand capacity of stormwater systems is a significant investment. Significant operational disruptions will result from overwhelmed stormwater facilities. Adaptive solutions will likely have to be innovative and involve collaborative partnerships. **(Adaptive Capacity = Low)**	**High**
Drinking Water	Drinking water lines are buried infrastructure that are not likely to be impacted if inundated periodically. However, above ground infrastructure, such as pump stations or pipes at bridge crossings, may be at risk during temporary flooding events **(Exposure/Sensitivity =Medium)**	Buried infrastructure related to the municipal water service are likely to be resilient to periodic inundation. Material improvements may be required if infrastructure is permanently inundated in the future. Above-ground infrastructure improvements may be required for periodic or permanent inundation but could be planned for through Capital Improvement Funds. **(Adaptive Capacity = Medium)**	**Medium**

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Sewer	Sewer lines are buried infrastructure that are not likely to be impacted if inundated periodically. However, above ground infrastructure, such as lift stations or pipes at bridge crossings, may be at risk during temporary flooding events. **(Exposure/Sensitivity = High)**	Buried infrastructure related to the municipal sewer service are likely to be resilient to periodic or permanent inundation. Material improvements may be required if infrastructure is permanently inundated in the future. Above-ground infrastructure improvements may be required for periodic or permanent inundation but could be planned for through Capital Improvement Funds. **(Adaptive Capacity = Medium)**	**Medium**

STRUCTURES

The number of structures, including critical facilities, was assessed in 2023 as part of the Phase 1 Assessment (DCG/Watershed, 2023). There are five (5) structures that are within an AHRF in the focus area (Figure 11). Safe Coast Seafoods is located in an area that is projected to be inundated by a 20-year return extreme storm by 2050. However, resiliency measures are currently being implemented, including raising the bulkhead to incorporate future SLR projections, to reduce the risk of impacts from coastal flooding. Several Port of Ilwaco facilities are also in an area of higher exposure risk. The vulnerability ranking for the structures within this focus area is classified as 'High' due to their large size, which makes elevation challenging, and their water-dependent functions, which limits relocation options (Table 8).

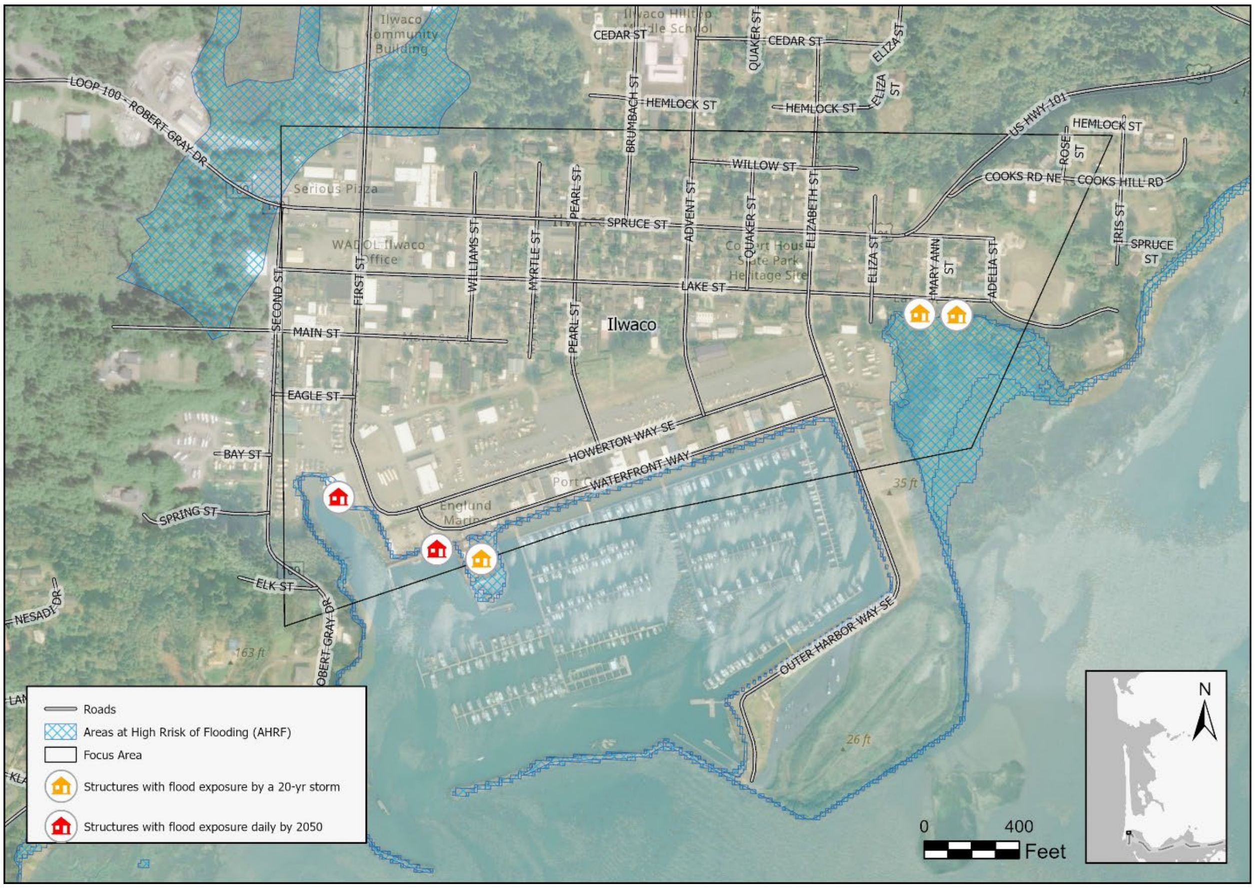


Figure 11. Map of structures with an exposure risk in the City of Ilwaco focus area.

ROADS

Although there were not any roads within the focus area that are considered as having an exposure risk, based on the rule sets developed, no roads are considered at 'no risk of exposure'. The rule set for roads considers coastal flooding more heavily than stormwater or compound flooding. Because the roads in the City of Ilwaco are higher than the MHHW plus 4 ft of sea level rise, they are less susceptible to coastal flooding. However, wind driven waves may drive seawater up and onto roads and flood coastal roads temporarily during storms.

When roads were assessed for their potential intersection with areas that contain flood factors (e.g., soils, SLR, FEMA Flood Zones), only two (2) roads, totaling 750 feet in length, were found to cross areas that are at high risk of flooding in the vicinity, but not within, the focus area. Spruce Street and First Street, on the west side of the City, are constructed through Ocosta soils which have low permeability and are more susceptible to flooding. These roadways are shown on the top left of the map below (Figure 12).

The exposure/sensitivity rating for roads within the focus area is considered low. Additionally, the adaptive capacity is considered high because storm-induced overwash, while disruptive, is typically temporary and less damaging than wave-driven flooding. As a result, minimal road modifications are required to mitigate this impact. Overwash effects are expected to be confined to the waterfront, and multiple routes to higher ground provide sufficient egress. Therefore, vulnerability is considered low (Table 8). Drainage is considered separately in the next subsection.

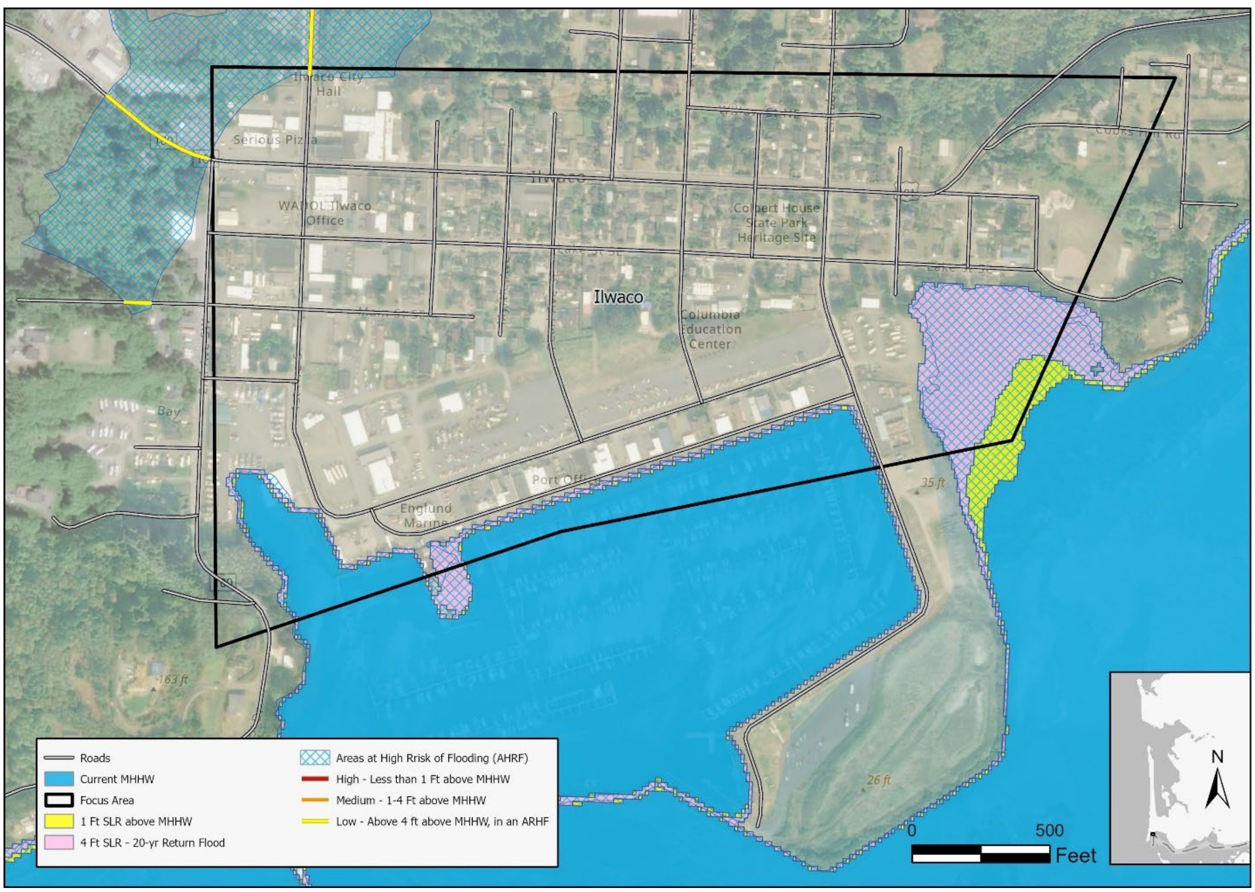


Figure 12. Roads near the City of Ilwaco with an exposure risk.

DRAINAGE INFRASTRUCTURE

There has been observed flooding along Willow St. during heavy rain events based on local reports (S. Corsi, personal communication, February 24, 2025). The grass-lined swale adjacent to the roadway collects water (Photo 5). The GIS data states there is a stormwater line but with a diameter of zero (0) inches along Willow St. that leads to eight (8) inch and 12-inch stormwater lines on either end or at the midpoint. The GIS data does not show low permeability soils or any culverts in this area, despite one shown in the photo. Updated drainage infrastructure data would be helpful in diagnosing drainage issues and is a recommended next step included later in this report.

Photo 5. Photo of ditch drainage along Willow St.

Backup of stormwater has also been observed north of Highway 101 at Cooks Rd (S. Corsi, personal communication, February 24, 2025). The GIS data shows a ten (10) inch WSDOT culvert and an 18-inch City stormwater line under Highway 101 in this area of backup (highlighted stormwater line in Figure 13). The stormwater line outfalls into the wetland that is mapped as being inundated with a one (1) to four (4) feet of SLR.

The drainage capacity of the structures may be impeded as sea levels rise increasing the low tide elevation and reducing the time upland water must drain to the offshore. High amounts of precipitation and increased river outputs exacerbate outfall drainage in Baker Bay, as noted in the flooding descriptions in Section 1. Pursuant to discussions with City staff, this is particularly an issue this outlet into Baker Bay Rd (S. Corsi, personal communication, February 24, 2025).

The City's stormlines are predominately aging terracotta infrastructure. Ongoing efforts are under way to determine the condition of these lines, including dye testing and engaging in Washington State Department of Commerce funded project to identify opportunities to install green stormwater infrastructure and retrofits to improve water quality conditions and thus salmon habitat. Further stormwater mitigation is discussed below in the Recommendations section (Section 5).

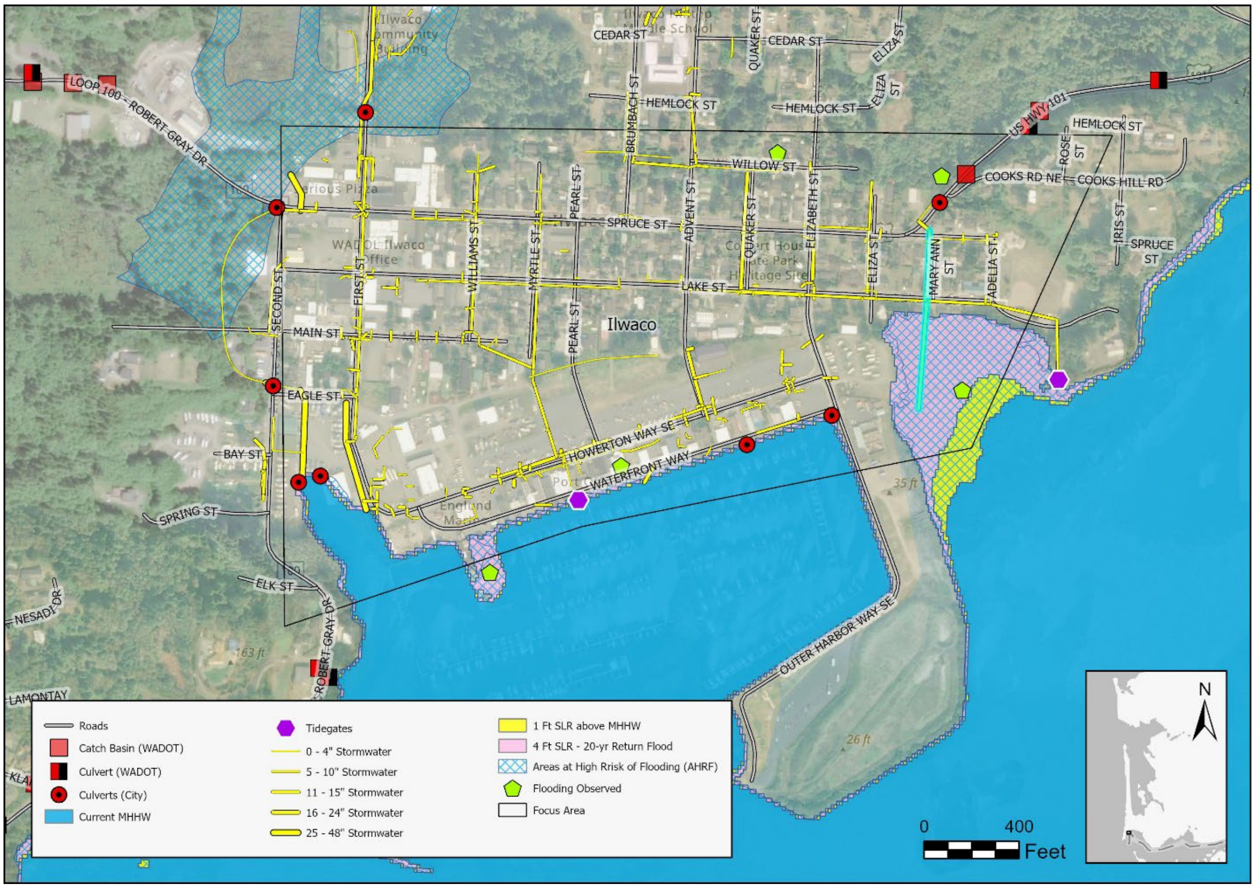


Figure 13. Map of drainage structures within the City of Ilwaco focus area. The 18" storm line between the wetland north of Highway 101 and the Bay, mentioned in text above, is highlighted in blue.

There is little information available on the existing tide gate sizing or condition. It is noted that the tide gate on the East side of the City is in a manhole.

FACET

Ditch flooding and backup have been observed on Highway 101 by Black Lake, north of the City. The outfall that runs from the ditch, under Highway 101 to the Lake is more often below the level of the lake (S. Corsi, personal communication, February 24, 2025). Increasing precipitation events will likely exacerbate this condition. The overall vulnerability assessment for stormwater and culvert infrastructure is 'high' due to the uncertainty around data and that flooding is currently observed in a few areas that is likely to be exacerbated under future conditions (Table 8).

OTHER INFRASTRUCTURE

In the City of Ilwaco services are delivered primarily through subsurface infrastructure, including drinking water lines, sewer lines, stormwater conveyance and utility services, including electrical and internet. Pursuant to discussions with Public Utility District No. 2 (PUD) during the outset of the project, electrical transmissions and distribution lines in Pacific County are primarily subsurface and have been built to withstand flooding and groundwater conditions (PUD No. 2, Personal Communication, April 9, 2024). Approximately 5,200 feet of distribution line exists within the Ilwaco focus area. Telecommunication services are provided by several different providers and details on technical specifications on buried conduit are difficult to find so were not able to be included in this assessment.

The available sewer line GIS data includes pipe diameter, material, and type. It does not include data on other components within this focus area. The City's wastewater treatment plant (WWTP) is located along Elizabeth Ave S.E. on the jetty and is at 13 – 14 feet NAVD88. The associated treatment ponds are at a 6-foot NAVD88 elevation, which is lower than MHHW. This has not been field verified and maybe a LIDAR reflection error. Due to its proximity to the nearshore, wind driven waves may push saltwater up and over the levels above stillwater SLR projection levels. This overwash may come into contact with the WWTP. The currently listed WWTP Facility Plan is dated 2001[10] and does not include climate change considerations. Updates to the WWTP Facility Plan should address climate change to improve the resilience of the critical infrastructure.

According to the City's Water System Plan (2011), drinking water for the City of Ilwaco is diverted from Indian Creek where it is collected in a reservoir behind a dam, treated and then delivered to reservoir tanks in the City with the assistance of booster pump stations. One of the booster pump stations is located in the Vandalia focus area within an area that is likely to be inundated with one (1) to four (4) feet of sea level rise or riverine flooding. Above ground components that are within areas that may be temporarily or permanently inundated may be at risk of damage or failure, depending on the magnitude and duration of the event. The plan states that flooding can affect water quality as a result of damage to water system facilities. The emergency procedure for the transmission and distribution system is more frequent testing and preparing for pipes that may get washed out at bridges, like Highway 101 over the Wallacut River. There are no recommended actions listed for storage facilities or booster stations. Given the vulnerabilities mentioned above, it is recommended that emergency procedures be evaluated in the event that storage facilities or booster stations become periodically inundated or damaged during a flood event.

[10] https://storage.googleapis.com/juniper-media-library/120/2024/08/2001-Wastewater-Facility-Plan.pdf

4.3 Vandalia Focus Area

The Vandalia Neighborhood Focus Area is shown below in Figure 14.

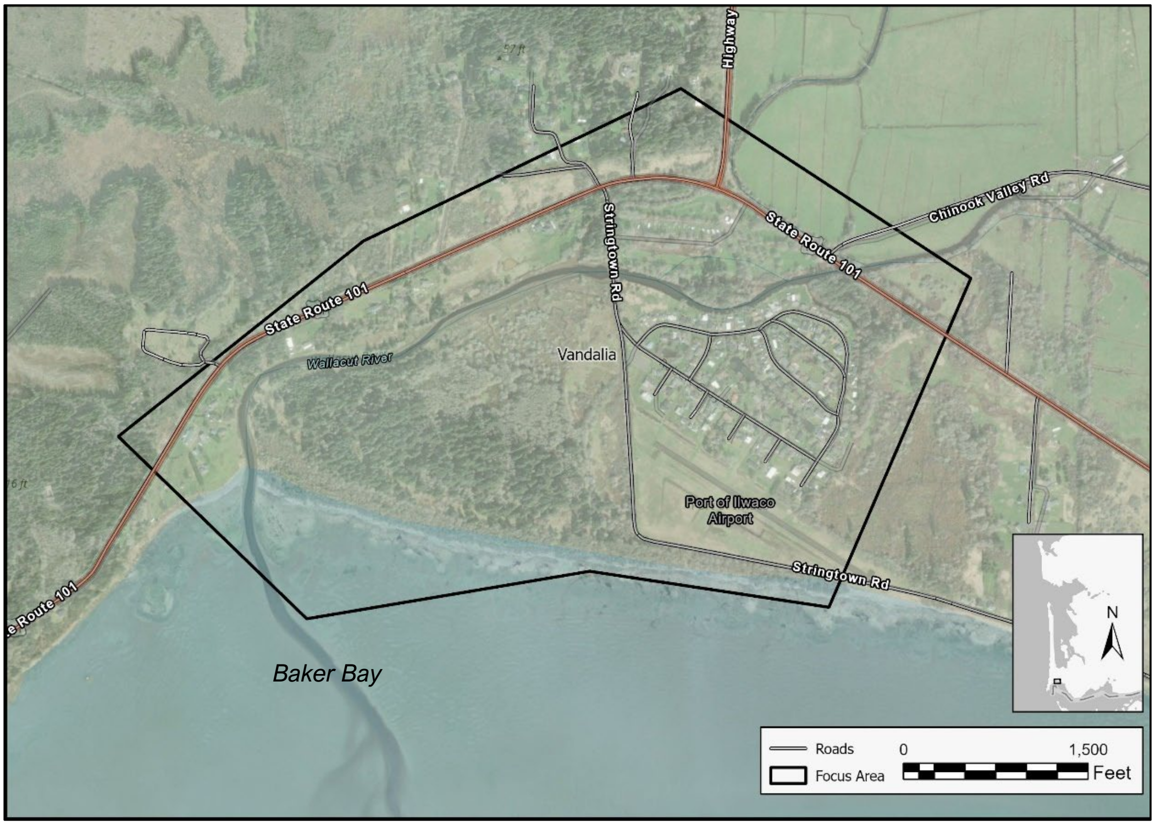


Figure 14. The Vandalia Neighborhood focus area.

The Vandalia area is impacted by several flood factors. Flooding in the focus area includes:

- riverine flooding from the Wallacut River,
- coastal flooding from Baker Bay,
- compound flooding due to tidal effects on the Wallacut River,
- potential flooding from failure of flood control levees,
- stormwater flooding from developed areas with impervious surfaces, and
- groundwater flooding in areas with low permeability soils and a high-water table.

The Wallacut River is the source for riverine flooding in and around the Vandalia focus area. The Wallacut River drainage area is about 5.6 square miles and discharges into Baker Bay. Tidal effects extend 0.8 miles upstream of the mouth to tide gates under Highway 101. Bankfull depth is 1.3 feet, and the 50% probability of occurrence peak flow is 274 cubic feet per second (cfs) (Appendix A). The 1% probability of occurrence peak flow is 916 cfs. When the Wallacut River overflows, particularly when tide gates block the lower reach, it can flood a large area of the drainage (Figure 15). According to

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NOAA's High Tide Flooding tool, the minor level of flooding would inundate the same areas that would be inundated by +4 Ft of SLR.

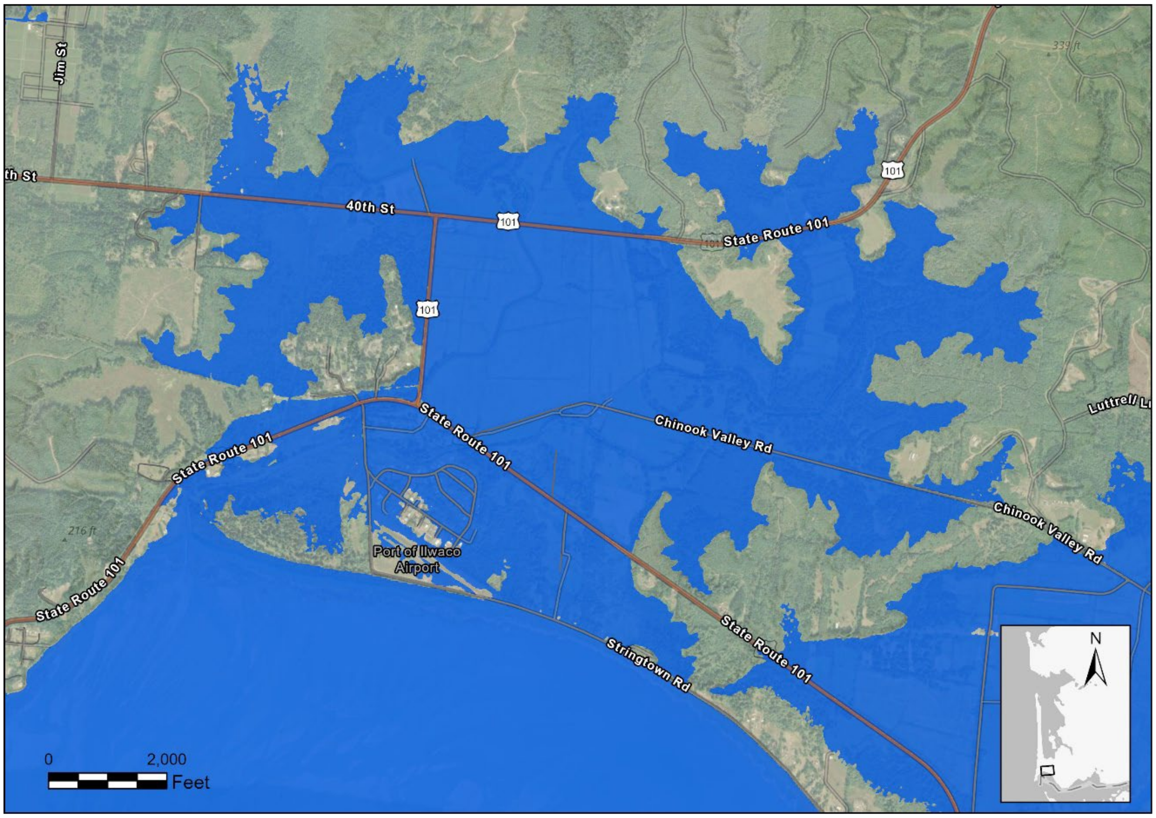

Figure 15. Areas near the Wallacut River currently subject to tidal flooding, often called "recurrent or nuisance flooding"[11].

The focus area experiences coastal flooding from storms and high tide on Baker Bay. There is about a mile of waterfront on the bay with spot elevations of eight (8) to 10 feet NAVD88 on the shoreline and 10 to 14 feet elsewhere. A cross section reveals the flat terrain of the area and relatively low elevation relative to current MHHW (Figure 16).

[11] https://coast.noaa.gov/slr/#/layer/fld/1/-

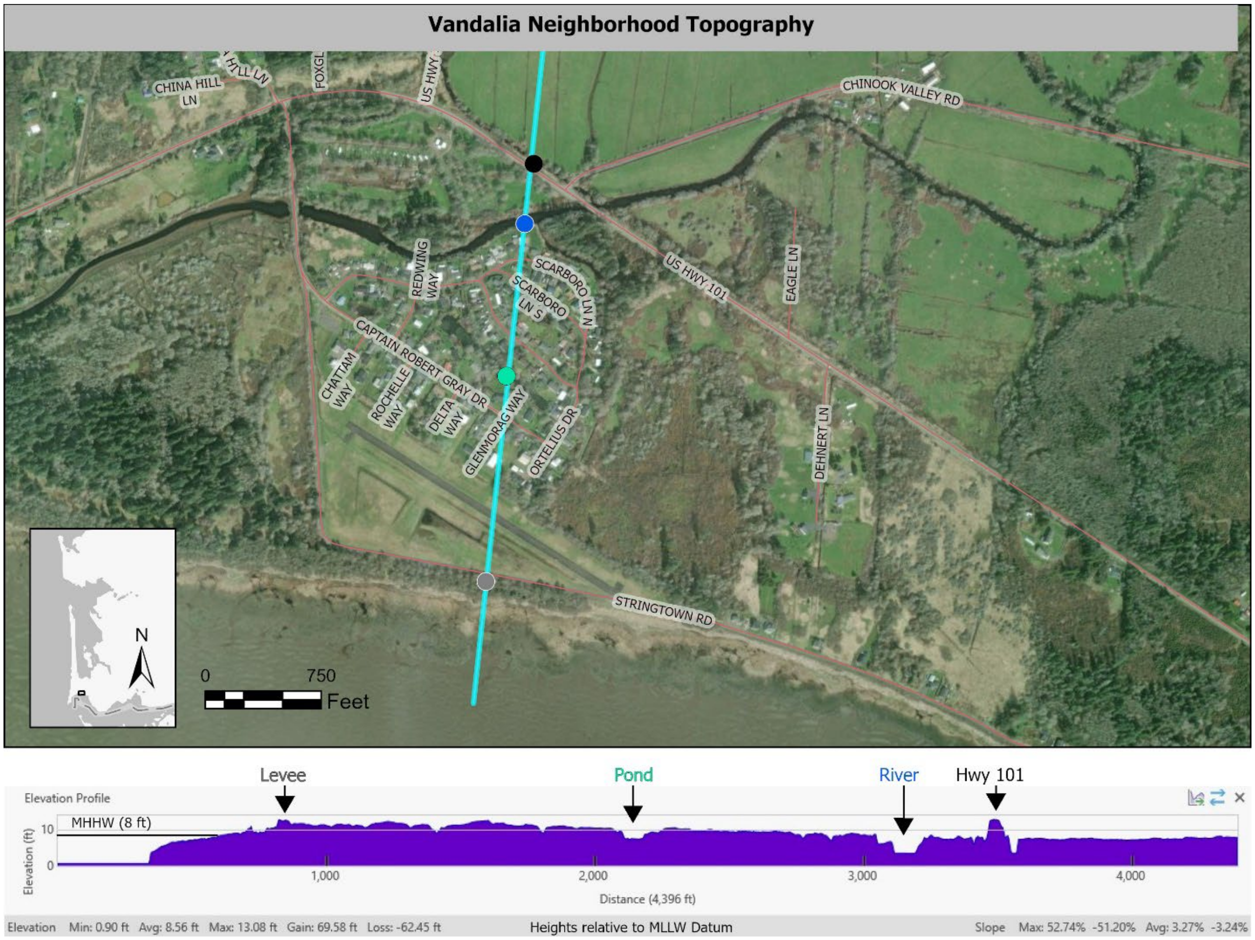

Figure 16. Elevation profile for the Vandalia neighborhood MHHW is 8.4 feet NAVD88.

FEMA coastal flood elevations for the 1% probability of occurrence are 11 feet (Appendix B). Coastal flood conditions are similar to those in Ilwaco where the Mean Higher High Water (MHHW) tidal elevation at the nearest gauge in Astoria,OR is 8.40 feet NAVD88. Storm surges and high winds during storms can increase high tides by four (4) feet or more with wind waves of three (3) feet or more according to the Beaufort scale (Appendix E). The seasonal variation of exceedance probability levels shows high water levels are likely to occur from November to February according to NOAA[12]. A flood control levee has been constructed around the airport. The area within the levee is mapped by FEMA as protected from the 1% probability of flood occurrence (Figure 17).

[12] https://tidesandcurrents.noaa.gov/est/curves.shtml?stnid=9439040

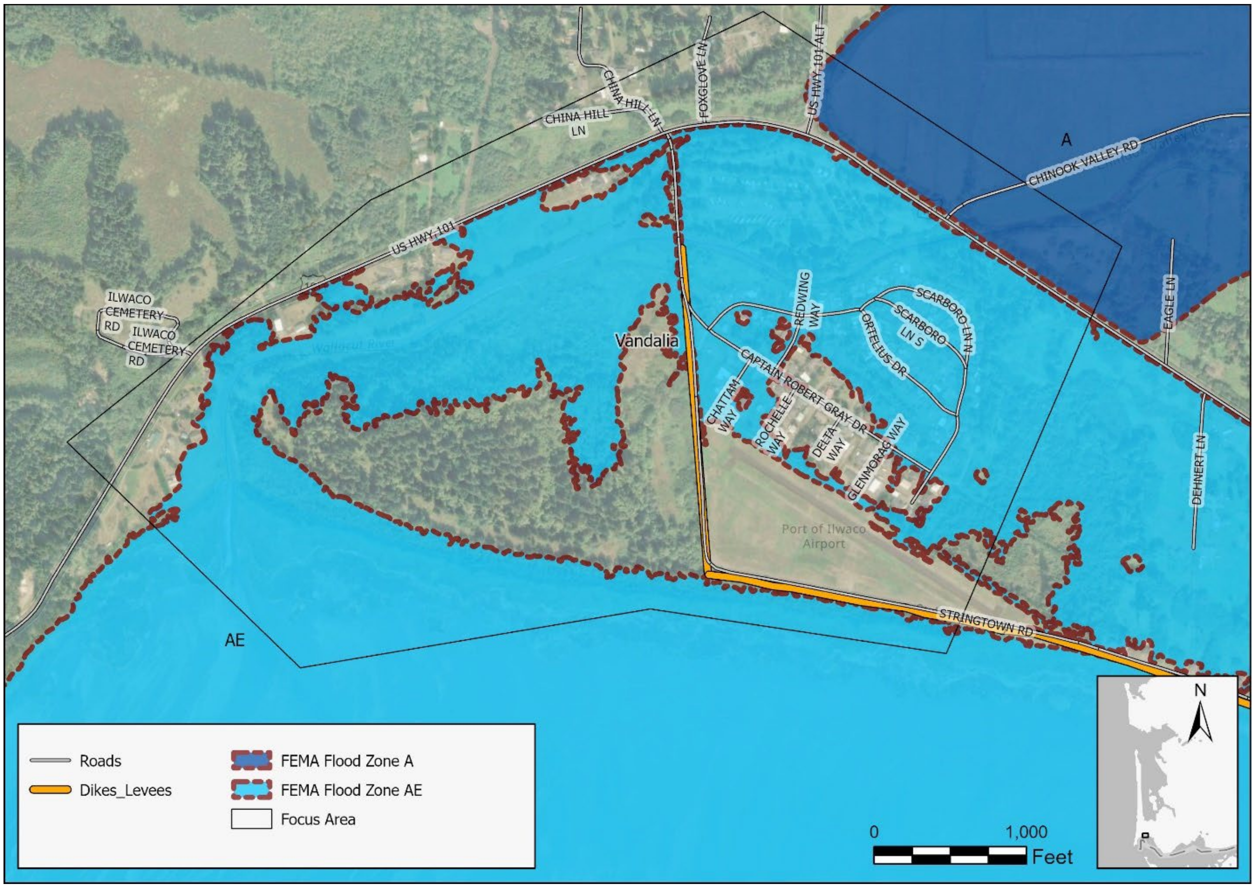

Figure 17. Map of FEMA Flood Zones and Levees in the Vandalia Focus Area

A sea level rise of one (1) foot above Mean Higher High Water (MHHW) will increase the frequency of flooding, area impacted, and duration of flooding, as shown in yellow below in Figure 18. The area projected to flood with a 20-year return frequency storm by 2050, with 83% likelihood is also shown. Most of the focus area is expected to be impacted.

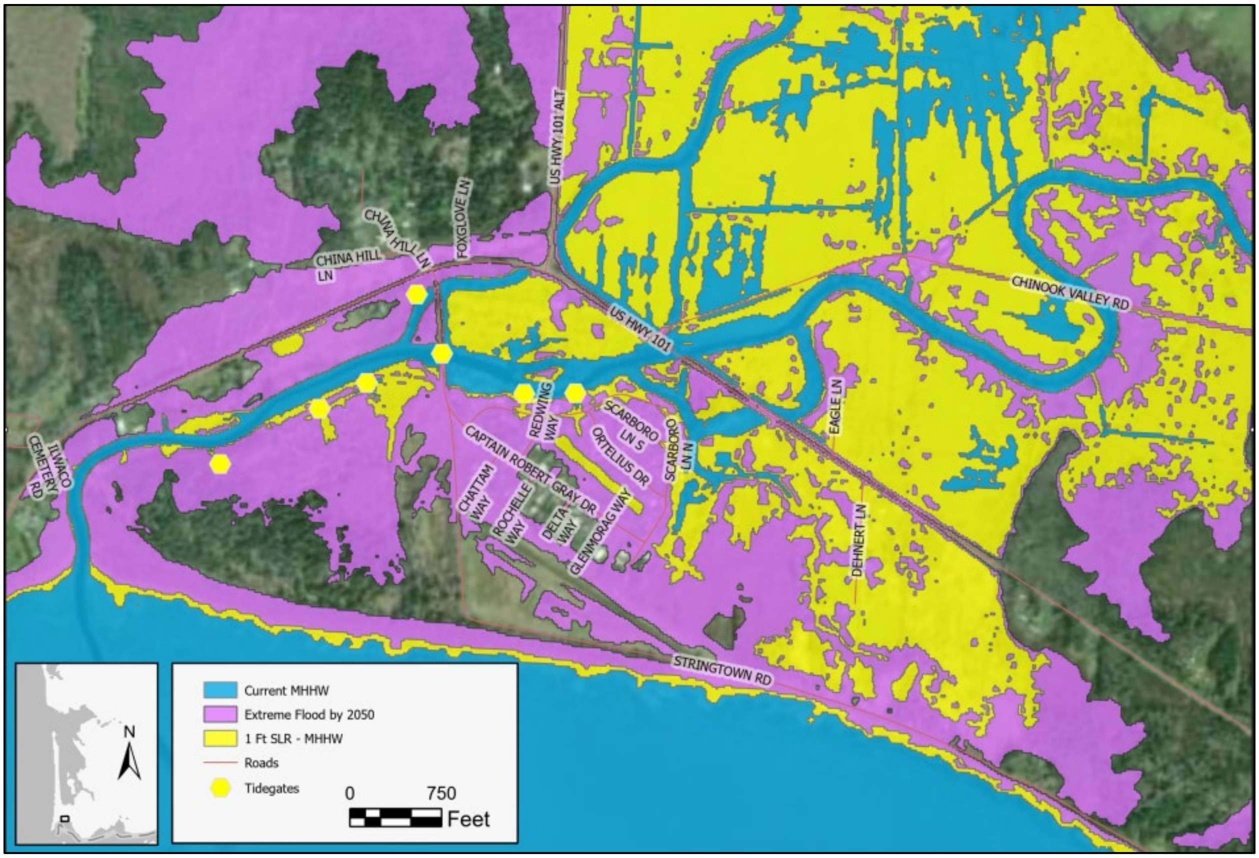

Figure 18. Projected inundation due to sea level rise and extreme flooding by 2050 with 83% likelihood.

<u>Compound flooding</u> in the focus area occurs when the Wallacut River is in flood stage and high tide blocks the tide gates in the lower reach, causing greater overbank flows upstream. Flood depths increase around the Vandalia Neighborhood until the tide recedes, and the river can be discharged into Baker Bay. Flooding in the area within the levee around the airport is possible if the levee is overtopped or fails because of structural weakness. The engineering qualities of the levee materials and foundation are not known at this time.

<u>Stormwater flooding</u> in the focus area occurs when runoff from developed areas with impervious surfaces collects in low-lying areas. Stormwater may also back up when high tide blocks discharge from stormwater outlets.

<u>Groundwater flooding</u> in the focus area occurs when rainfall and local runoff collects in low-lying areas with low permeability soils and high-water tables. The REMs for this focus area show the relative elevation of the water table based on the water surface elevation in the Wallacut River (Appendix C). The REM with a soil type overlay shows the areas of low permeability with relatively high-water tables. Many of these areas are wetlands or have been ditched and drained for pastures and hay fields. They are subject to shallow flooding, usually in winter months, during intense rainstorms or when the river overflows.

4.3.2 Vulnerability Assessment of Assets

Most of the Vandalia area intersects with areas that are designated as high risk of flooding (AHRF). The land uses in this focus area consists of a large coastal wetland parcel owned by the Columbia Land Trust and a residential neighborhood with an airstrip that is owned by the Port of Ilwaco. Several of the homes adjacent to the airstrip are able to take advantage of the flat topography to house their own private aircraft with direct access to the airstrip. There is also a RV park and campground between the Wallacut River and U.S. Highway 101. While the types of assets will be assessed individually, the impacts across the asset types, when considered together, may have a compounding impact on the livability of the area. For example, while structures and roads may be considered to have a medium ranking of vulnerability, having a home that is flooding, during a time when all the roads are also flooding, may make a community member highly vulnerable.

Table 9. Summary of Asset Vulnerability Assessment for the Vandalia focus area.

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Structures	26 structures are less than a foot above the current MHHW and would be impacted by 1' increase in sea level rise. **(Exposure/Sensitivity = High)**	Mitigation measures for buildings would require significant improvements to increase resilience from SLR and flooding impacts. Adaptations are possible, but cost is a challenge. **(Adaptive Capacity = Low)**	**High**
	117 structures are located between 1-4 ft above current MHHW. Flooding impacts are expected to be temporary but may increase in frequency overtime. **(Exposure/Sensitivity = Medium)**	Mitigation measures for buildings may require improvements to increase resilience from temporary flooding impacts. Adaptations are possible, but cost is a challenge. Lower cost alternatives, such an improved stormwater management or on-site ditches/berms, could be implemented to reduce impacts. **(Adaptive Capacity = Medium)**	**Medium**

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Roads	1.1 mile of roadway within the Vandalia Neighborhood is expected to be inundated by 1 ft increase in sea level rise or riverine flooding including: - Scarboro Ln N - Ortelius Dr -Chinook Valley Rd Most of Stringtown Road is located between 1-4 feet above the current MHHW and may be temporarily inundated by coastal or riverine flooding. However, this roadway is considered a lifeline access route for the community and thus is ranked as high exposure/sensitivity. **(Extensive/Sensitivity = High)**	Temporary or permanent impacts due to flooding of transportation routes or facilities may impact the accessibility of residents. Impacts can be reduced or mitigated to a certain extent. However, the cost and implementation to retrofit, relocate or expand capacity of stormwater systems is a significant investment. Certain roadways may need to be elevated or relocated to improve resilience to flood events. **(Adaptive Capacity = Low)**	**High**
	2.2 miles of roads are located between 1-4 ft above current MHHW. Flooding impacts are expected to be temporary but may increase in frequency overtime. **(Exposure/Sensitivity = Medium)**	Temporary or permanent impacts due to flooding of transportation routes or facilities may impact the accessibility of residents. Impacts can be reduced or mitigated to a certain extent. However, the cost and implementation to retrofit, relocate or expand capacity of stormwater systems is a significant investment. Certain roadways may need to be elevated or relocated to improve resilience to flood events. **(Adaptive Capacity = Low)**	**High**

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
	0.5 miles of roads intersect the AHRF and aren't classified as High or Medium. **(Exposure/Sensitivity = Low)** *As described in the AHRF rule set, no roads are considered to have no risk of exposure because the flood factors chosen are subjective in nature. A different decision of SLR likelihood would alter the number and extent of roads exposed. Additionally, the capacity and state of stormwater infrastructure was not included in this assessment.*	Temporary impacts due to flooding of transportation routes or facilities may impact the accessibility of residents. Impacts can be reduced or mitigated to a certain extent. Cost and implementation to retrofit, relocate or expand capacity of stormwater systems is a significant investment. However, roadways that are at a low risk of exposure will likely not be impacted during the short-term planning horizon **(Adaptive Capacity = Medium)**	**Low**
Culverts	10 tide gates and three culverts are likely to be impacted by 1' increase in SLR or riverine flooding. This number may be an underrepresentation of current conditions, particularly for the number of culverts impacted due to data gaps. Impacts on current infrastructure are also dependent on the condition and age, design standards, and redundancy in the system. Older assets or those built to older design standards are likely to be more affected by temporary or permanent inundation. **(Exposure/Sensitivity = High)**	Cost and implementation to retrofit, relocate or expand capacity of stormwater or drainage systems is a significant investment. Significant operational disruptions are expected to result from overwhelmed facilities. Adaptive solutions will likely have to be innovative and involve collaborative partnerships. **(Adaptive Capacity = Low)**	**High**

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
	Four culverts are likely to be impacted by 1-4' increase from the current MHHW or riverine flooding. This number may be an underrepresentation of current conditions due to data gaps. Impacts on current infrastructure are also dependent on the condition and age, design standards, and redundancy in the system. Older assets or those built to older design standards are likely to be more affected by temporary or permanent inundation. **(Exposure/Sensitivity = Medium)**	Cost and implementation to retrofit, relocate or expand capacity of stormwater or drainage systems is a significant investment. Significant operational disruptions are expected to result from overwhelmed facilities. Adaptive solutions will likely have to be innovative and involve collaborative partnerships. **(Adaptive Capacity = Low)**	**High**
Stormwater	Insufficient information to quantify but flooding is frequently observed. Vandalia experiences flooding due to inadequate stormwater infrastructure that will likely be exacerbated by changing climate conditions. Impacts on current infrastructure are also dependent on the condition and age, design standards, and redundancy in the system. Older assets or those built to older design standards are likely to be more affected by temporary or permanent inundation**.** **(Exposure/Sensitivity = High)**	Cost and implementation to retrofit, relocate or expand capacity of stormwater systems is a significant investment. Significant operational disruptions will result from overwhelmed stormwater facilities. Adaptive solutions will likely have to be innovative and involve collaborative partnerships. **(Adaptive Capacity = Low)**	**High**

	Exposure/Sensitivity	Adaptive capacity	Vulnerability
Drinking Water	Drinking water lines are buried infrastructure that are not likely to be impacted. However, above ground infrastructure such as pump stations, or pipes at bridge crossings, may be at risk. The Baker Bay Pump Station at the corner of Highway 101 and Stringtown Rd may be at risk of periodic inundation during flood events (Figure 21). **(Exposure/Sensitivity =High)**	Buried infrastructure related to the municipal water service are likely to be resilient to periodic inundation. Material improvements may be required if infrastructure is permanently inundated in the future. Above-ground infrastructure improvements may be required for periodic or permanent inundation but could be planned for through Capital Improvement Funds. **(Adaptive Capacity = Medium)**	**High**
Sewer	Sewer lines are buried infrastructure that are not likely to be impacted if inundated periodically. However, above ground infrastructure such as lift stations or pipes at bridge crossings, may be at risk. Both of the lift stations in Vandalia may be at risk of permanent or temporary inundation during extreme flood events by 2050 (Figure 21). **(Exposure/Sensitivity = High)**	Buried infrastructure related to the municipal sewer service are likely to be resilient to periodic inundation. Material improvements may be required if infrastructure is permanently inundated in the future. Above-ground infrastructure improvements may be required for periodic or permanent inundation but could be planned for through Capital Improvement Funds. **(Adaptive Capacity = Medium)**	**High**

STRUCTURES

The GIS data used to identify structures does not distinguish between residences, garages or other ancillary structures. Nor does the available data distinguish between primary residences and second homes. However, it does provide a sense of the magnitude of impact to the built environment for these scenarios. Of the 179 structures within the focus area, 147 structures are located in an area that is at high risk of flooding due to at least one of the flood factors (Figure 19). Either they are located in an area that has soils known to not drain well, in areas within the current FEMA Flood Zone (A, AE or VE) or in an area projected to be inundated by SLR or extreme coastal floods by 2050 with 83% likelihood. Twenty-six (26) structures are in areas projected to be potentially inundated by high tides every day by 2050 (1 foot above current MHHW) while 117 structures are in areas projected to be inundated by a flood with a 20-year recurrence interval by 2050. However, these numbers may be exaggerated as the assessment uses land elevation and soil composition only and does not account for the mitigating effects of existing levees.

The vulnerability ranking for structures are below one (1) foot elevation above current MHHW is considered 'high' and 'medium' for those that are between one (1) and four (4) feet elevation about current MHHW.

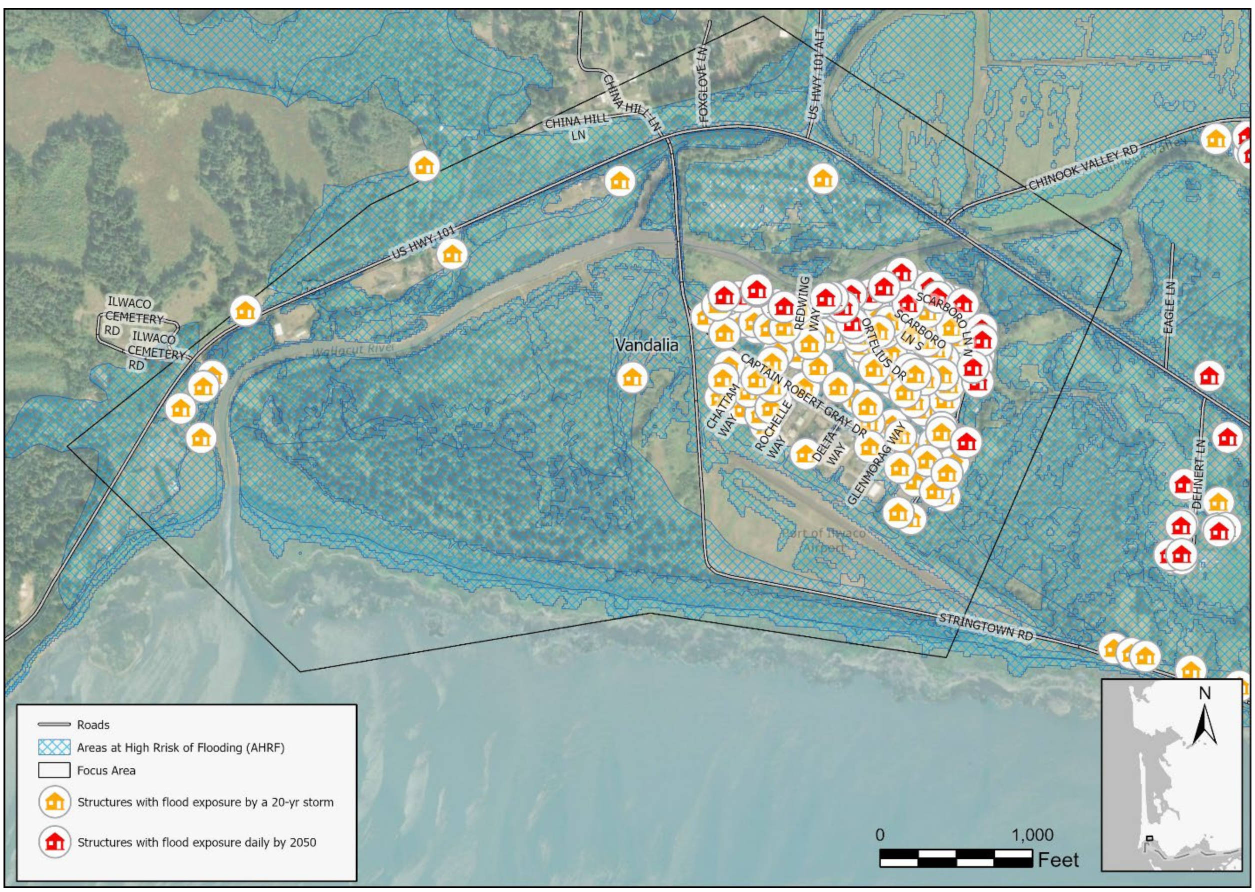

Figure 19. Map of structures with an exposure risk in the Vandalia focus area.

ROADS

Throughout the Vandalia focus area, Highway 101 is situated at an elevation above the projected 50-year return period flood level by 2050 (more than 4 feet above the current MHHW and is therefore considered to have a 'low' exposure rating). However, Chinook Valley Rd, Scarboro Lane and the northeast portion of Ortelius Drive are lower than one (1) foot above current MHHW and as such, are at 'high' exposure risk. While Stringtown Road is mapped as between one (1) – four (4) feet above MHHW benchmark, it is ranked as 'high' exposure because it is the single egress for the community. The remaining roads are within the four (4) ft, 50-yr return flood height and are therefore assigned a 'medium' exposure rating according to the rule set (Figure 20).

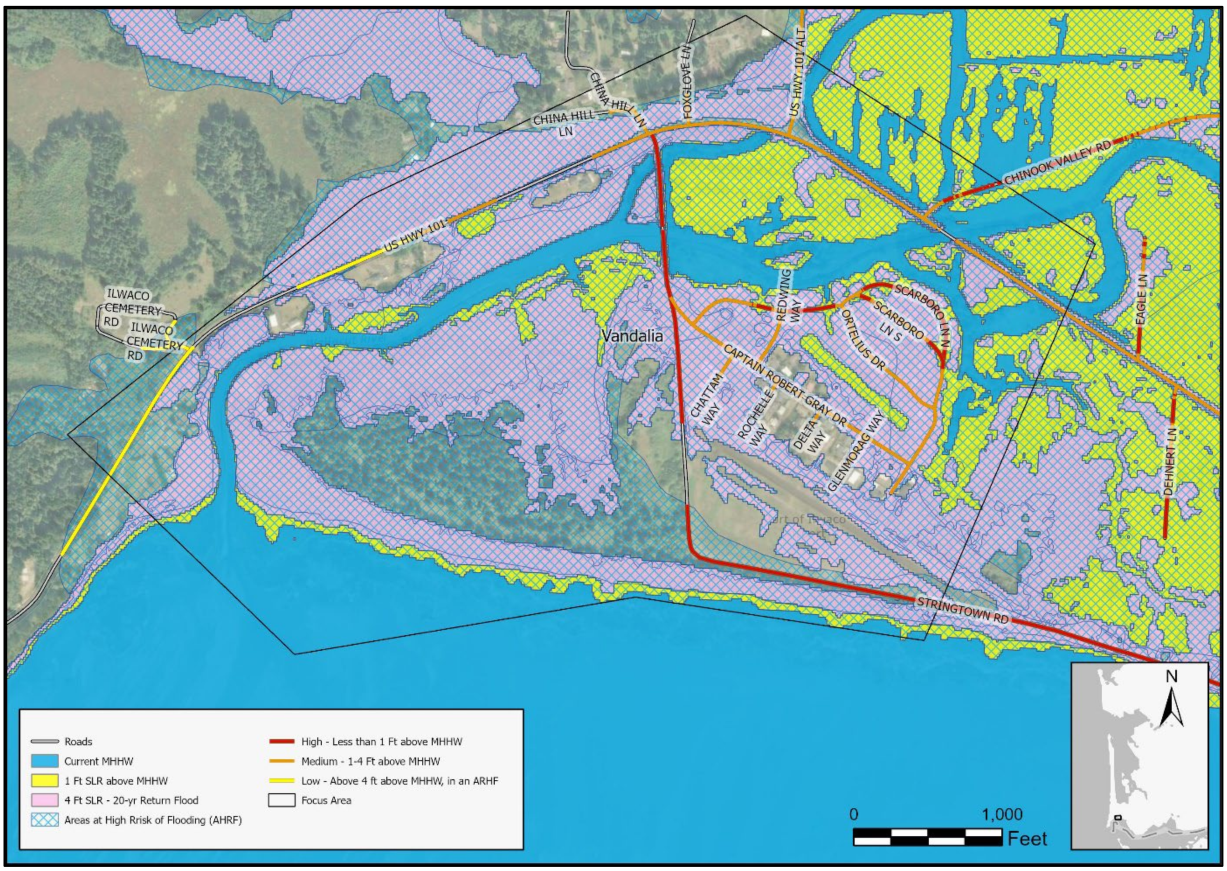

Figure 20. Roads in areas that are at high risk of flooding.

DRAINAGE INFRASTRUCTURE

Vandalia has experienced longstanding challenges related to drainage and stormwater management (H. Beller, personal communication, February 24, 2025). Drainage infrastructure in the focus area consists of tide gates, culverts, stormwater tracts (catch basins) and roadside ditches. Unlike the City of Ilwaco's downtown focus area, there are no documented subsurface stormwater lines or WSDOT catch basins in the Vandalia focus area. Nor are there any pumps in use at the time of this writing.

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There are several tide gates in the focus area along the sides of the Wallacut River. (Figure 21). There are also three flap tide gates across the mainstem of the Wallacut River under Stringtown Road. There are active efforts to determine how to replace these tide gates, while meeting fish passage requirements (L. Bauernschmidt, personal communication, March 12, 2025). The goal is to allow sufficient downstream flow to reduce backwater effects in the upstream reaches of the Wallacut River, limit tidal exchange from moving upstream, and ensure fish passage in both directions. This project is discussed further in Recommendations (Section 5).

Photo 6. Photo of tide gates under Stringtown Rd on the mainstem of the Wallacut River.

Culverts are documented along Highway 101, Chinook Valley Road and Ortelius Road. There are several other culverts known or suspected of existing but are not documented in GIS currently and paper records were not available at the time of this writing. There are two culverts on the north side of Ortelius Road that convey water out of the Vandalia neighborhood, through two tide gates into the Wallacut River. During discussions with City staff, it has been determined that the culvert at the intersection of Robert Gray Drive and Chattam Way has collapsed and is need of repair (S. Corsi, personal communication, February 24, 2025) (Photo 7).

Photo 7. Collapsed culvert at Robert Gray Drive and Chattam Way

The adjacent roadside ditches are likely undersized and would benefit from more detailed analysis or maintenance (Photo 8).

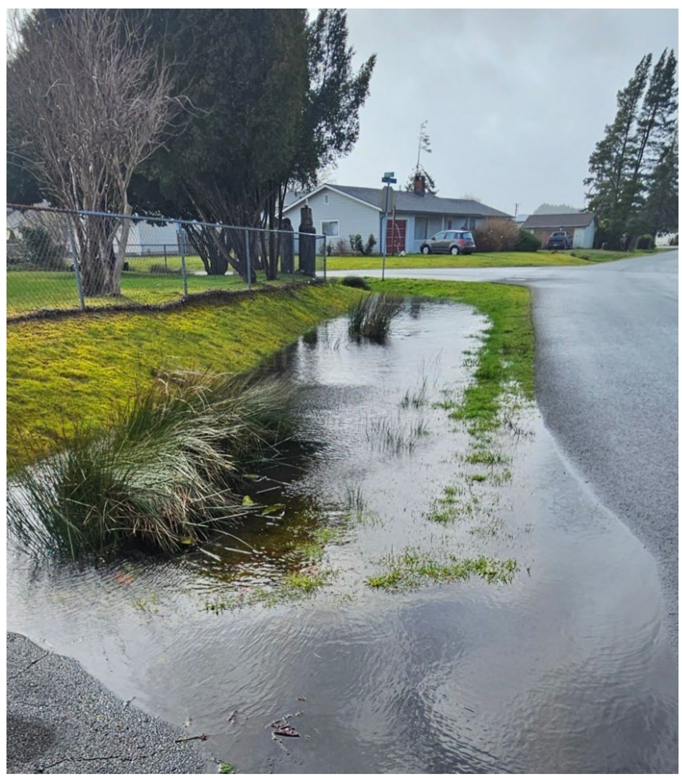

Photo 8. Roadside ditch along Redwing Way and Ortelius Drive

The original plat of Vandalia included several stormwater detention ponds in dedicated tracts to manage runoff (Photo 9). However, these facilities are in need of maintenance or repair, and it is unknown if they have overflow capacity in the event of heavy precipitation. Pursuant to conversations with the City's Public Works staff, the stormwater ponds outlet to the Wallacut River. The outlets are maintained by the City, but the facilities are periodically maintained by the property owners. Lack of maintenance or undersized facilities may exacerbate the impacts of sea level rise and extreme flood events.

Photo 9. Stormwater Tract in the Vandalia Neighborhood near Port of Ilwaco Airport

The drainage infrastructure in this area could be considered to be critical infrastructure. Due to the location, extent of current flooding and high probability of future flooding from several different flood factors, the exposure ranking is considered 'high'. The adaptive capacity of these structures and to facilitate drainage in this flat topography, will likely require innovative solutions and those are generally expensive. Therefore, the adaptive capacity ranking is considered 'low'. The overall vulnerability ranking for stormwater facilities is considered 'high'.

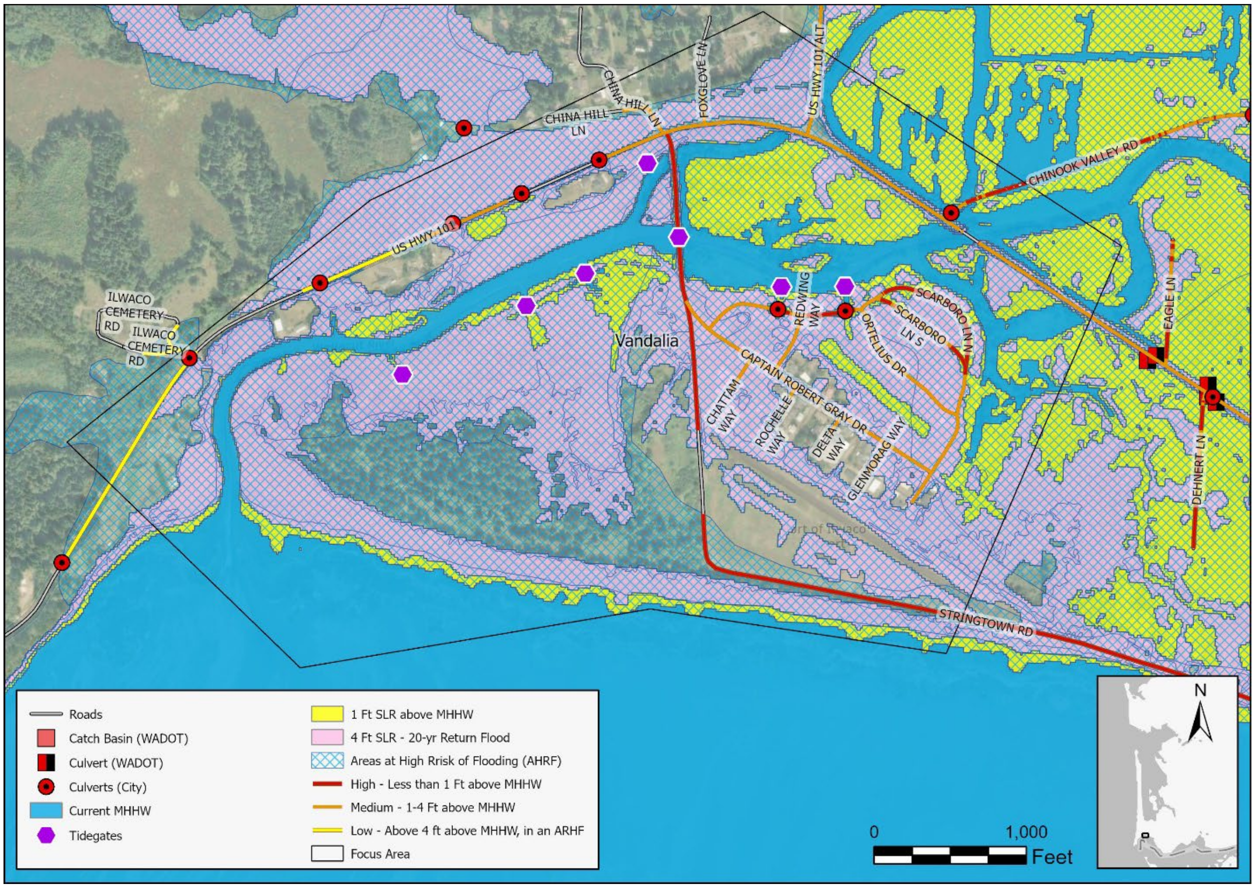

Figure 21. Map of tide gates and culverts in and near the Vandalia focus area.

OTHER INFRASTRUCTURE

Utility services in this focus area are delivered through subsurface infrastructure, including drinking water lines, sewer lines, telecommunications, internet and electrical. Pursuant to discussions with Public Utility District No. 2 (PUD) during the outset of the project, electrical transmissions and distribution lines in Pacific County are primarily subsurface and have been built to withstand flooding and groundwater conditions (PUD No. 2, Personal Communication, April 9, 2024). Approximately 2,500 feet of fiber distribution line exists within the Vandalia focus area. Telecommunication and internet services are provided by a number of different providers and details on technical specifications on buried conduit are difficult to find so were not able to be included in this assessment. Should sufficient data become available as to the locations, elevations and sensitivity to flooding of above and below ground equipment components, a vulnerability and risk assessment could be performed.

Sewer line GIS data includes pipe diameter, material and type. It does not include data on the other components in this focus area. According to the City of Ilwaco's 2001 Wastewater Facility Plan, there are two lift stations, one of which has a force main to a manhole within the Vandalia Plat. These may be at risk depending on the actual elevation of the above ground components and how well sealed they are. The lift station on the west side of the Vandalia Plat is located in an area that is likely to be inundated

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with one (1) to four (4) feet of sea level rise or riverine flooding. The second lift station on the east side of the plat is located in an area likely to be inundated with one (1) foot of sea level rise or riverine flooding. This pump is already flooded when the Wallacut River exceeds its banks. It has been replaced several times due to failure from continuous running and burning out (H. Beller, personal communication, April 14, 2025). There is no further information on the manhole. If the electric supply to run the pump stations is located on site with the pumps, then there may be an exposure risk and potential disruption. A long-term solution should be evaluated for these components, as conditions are expected to worsen and become more frequent over time.

Drinking water for Vandalia is supplied by the City of Ilwaco. According to the City's Water System Plan (2011), the City's water source is Indian Creek where it is collected in a reservoir behind a dam, treated and then delivered to reservoir tanks in the City with the assistance of booster pump stations. One of the booster pump stations is located in the Vandalia focus area (Figure 22). The station contains three (3) electrical centrifugal pumps. The station is located in an area that is likely to be inundated with one (1) to four (4) feet of sea level rise or riverine flooding. The plan states that flooding can affect water quality as a result of damage to water system facilities. The emergency procedure for the transmission and distribution system is more frequent testing and preparing for pipes that may get washed out at bridges, like Highway 101 over the Wallacut River. There are no recommended actions listed for storage facilities or booster stations. Given the vulnerabilities mentioned above, it is recommended that emergency procedures be evaluated in the event storage facilities or booster stations become periodically inundated or damaged during a flood event.

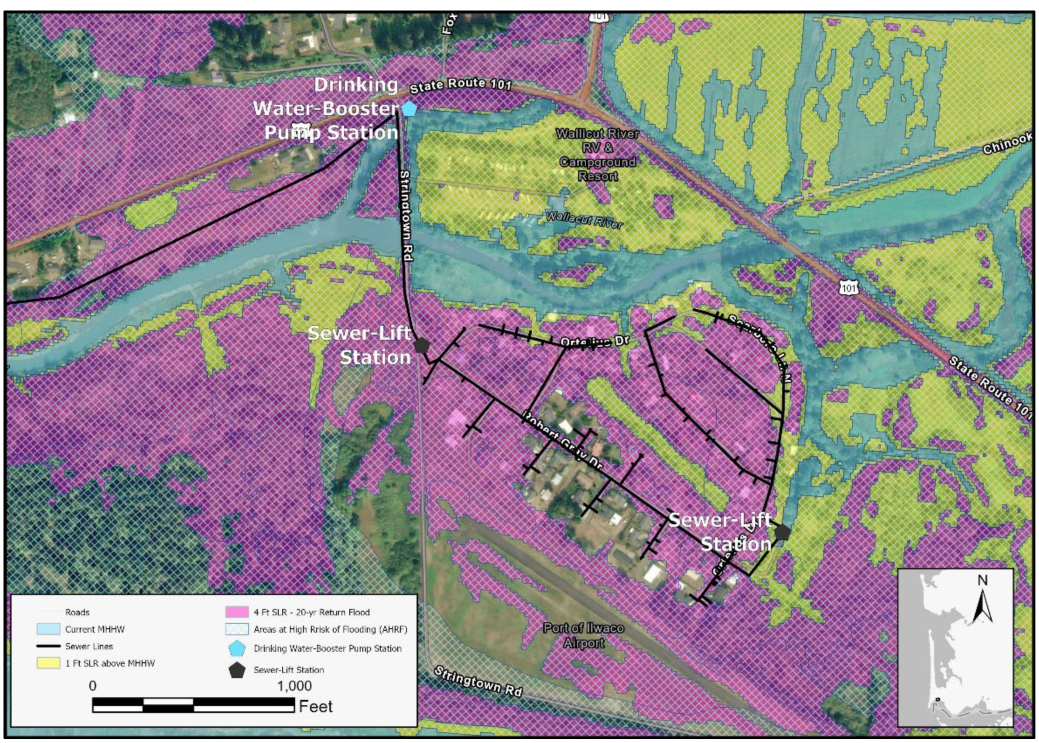

Figure 22. Locations of Lift Stations and Pump Station in Vandalia.

4.3.3 Flood Simulation

Using ESRI's ArcGIS Flood Simulation[13] tool, scenarios were modeled to simulate the potential impact of wider culverts on surface flooding, as well as the influence of backwater effects resulting from high tide conditions (Table 10).

The tool is a coarse level planning tool that has several features that can be adjusted such as barriers (i.e. placed to simulate dams, sandbags, closed tide gates, backwater pressure), channels (i.e. culverts, open tide gates), water source (i.e. river flow) and rainfall rates. The tool uses a LiDAR-derived digital elevation model (DEM) for water flow calculations. A limitation of the tool is that the area involved in the simulation is finite, which means it is only calculating rain accumulation from within the simulation area and not the entire watershed. Infiltration rates can be selected but are applied universally across the simulation area.

The scenarios selected below are for demonstration purposes only. The infrastructure referenced is not being proposed or considered by the City of Ilwaco. For the Vandalia scenarios, the rainfall rate (4 mm/hour to simulate 4 inches/day), water source and barriers were all held constant, but the channelization was altered for each scenario. A water depth raster was created to simulate a full river and adjacent low areas. The model results are captured in the Figures below. Darker shades of blue on the map indicate greater modeled water depths. The model was run to simulate a 2-hour time frame during a four (4)-inch/day rain event. This simulation would be considered an extreme precipitation event.

Table 10. ArcGIS Flood Simulation Scenarios

Scenario	Figure	Culverts
1	Figure 23	3 @ 3 ft each under Stringtown
2	Figure 24	120 ft channel under Stringtown Rd
3	Figure 25	15 ft channel under Stringtown to the Columbia Land Trust[14] property, 15 ft channel out of the Columbia Land Trust property to the Wallacut River* 2 – 3 ft culverts from retention ponds to the Wallacut River

[13] https://pro.arcgis.com/en/pro-app/latest/help/mapping/simulation/simulation-in-arcgis-pro.htm

[14] Important note: creating a drainage facility through the Columbia Land Trust property is <u>not</u> being proposed. This was proposed in the model only to simulate removing excess water from behind the levee and Vandalia neighborhood. The model is not able to simulate a pump station, which is the more likely scenario.

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Figure 23. Flooding in the Vandalia Focus Area in a back water situation with 3-10ft culverts under Stringtown Rd.

Figure 24. Flooding in the Vandalia Focus Area in a back water situation with a 120-foot bridge Stringtown Rd.

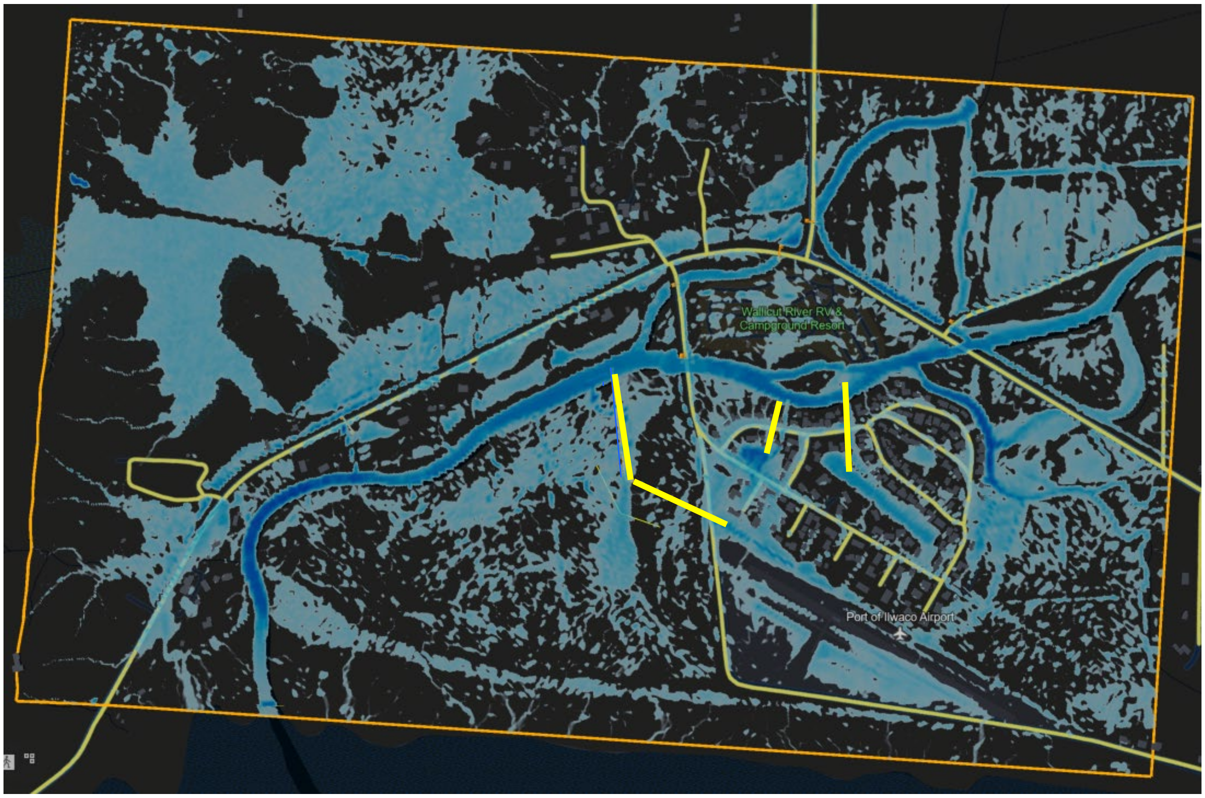

Figure 25. Flooding in the Vandalia Focus Area in a back water situation with a 120-foot bridge Stringtown Rd and an additional culvert under Stringtown Rd and channels to facilitate drainage to the Wallacut downriver from the road crossing.[15]

The results showing no reduction in the amount of surface flooding in the community, despite modeling additional drainage in the river mainstem and through culverts, could be attributed to, but is not limited to, the following:

1. An artifact of the model having troubles establishing flow directions on such a flat surface;
2. The underlying digital elevation model resolution isn't adequate;
3. The model is too limited to adequately model the complexities when larger watersheds, rivers and tidal influence are involved; or
4. The possible fact that relying on gravity to drain a rainfall will not work in this area.

Site-specific, field-based hydraulic engineering is likely necessary in areas such as this where differences in slope between the land surfaces and the tidal surfaces are so flat.

[15] Important note: This is only for demonstration purposes to evaluate what flooding extents would look like with additional culverts constructed in west wetland (bright yellow lines). Creating a drainage through the Columbia Land Trust property is NOT being proposed. This was proposed in the model only to simulate removing extra water from behind the levee and Vandalia neighborhood. The model is not able to simulate a pump station, which is the more likely scenario.

4.4 Coastal Wetlands

Coastal Wetlands are at heightened risk from changing flooding conditions because of the complexity of ecological interactions that are necessary to develop these types of wetlands. Since SLR and coastal flooding may accelerate coastal erosion and increase saltwater intrusion and wetland migration opportunities, habitat for birds, amphibians and fish may be compromised or may shift to different assemblages.

Coastal wetlands are experiencing intensifying vulnerability due to the convergence of multiple flooding mechanisms such as those described in Section 1.1. SLR, altered precipitation patterns and snowmelt timing in the Olympic Mountains has resulted in a complex flooding dynamic where coastal inundation, riverine overflow, and stormwater runoff increasingly coincide in compound flooding events (Mauger et al., 2015). These hydrological stressors exceed the natural adaptive capacity of many wetland ecosystems, disrupting established hydroperiods and introducing new saltwater inundation patterns (subsurface groundwater composition and salty floodwater and ocean spray on the surface).

Wetland vegetation communities face compositional shifts as salinity gradients change, and sediment deposition patterns are altered. Beyond biodiversity impacts, these wetland transformations compromise essential ecosystem services including carbon sequestration, water filtration, and coastal buffering against storm events.

Wetland Impacts were not assessed through the Vulnerability framework that was developed for infrastructure assets. The Shoalwater Bay Tribe conducted a vulnerability assessment that included coastal wetlands, and the authors of this assessment recommend that the Shoalwater Bay Tribe's vulnerability assessment be considered the authoritative source for coastal wetlands in Pacific County (Shoalwater Bay Indian Tribe, 2021).

The wetlands within the focus areas for this assessment that may be impacted are quantified in Table 11. With one (1) foot of SLR, 126 acres will be inundated twice daily by saltwater. By 2050, a 50-year return flood may periodically inundate 157 acres (modeled with +5 feet of increase above current MHHW) (Figure 26). The nature of this flooding is much more temporally temporary and rare than daily inundation and is likely to have a much more subtle impact on the vegetative communities. The majority of potentially impacted wetlands are found in the Vandalia focus area (131.5 acres) where there is a significant amount of soil with low permeability (Figure 28). Surface flooding is a larger threat than an increase in groundwater elevations because of the existing soil composition.

It is important to note that the source of wetland data is from the National Wetland Inventory (USFWS) and may underestimate the actual number of wetlands present due to the national-scale level of modeling used to develop the dataset. Until on-site delineations are added to the City's data source, it remains to be the best available source of data.

Table 11. Acres of coastal wetland potentially impacted by wetland type and by flood factor within the focus areas.

Wetland Types	+1 Ft SLR	Extreme Flooding	Low Permeability Soils	Groundwater Hazard Soils
Estuarine and Marine Wetland	6.1	6.5	1.6	0.7
Freshwater Emergent Wetland	32.3	45.6	36.2	0
Freshwater Forested/Shrub Wetland	87.6	104.3	93.2	1.1
Freshwater Pond	0.3	0.8	0.5	0
Total	**126.3**	**157.2**	**131.5**	**1.8**

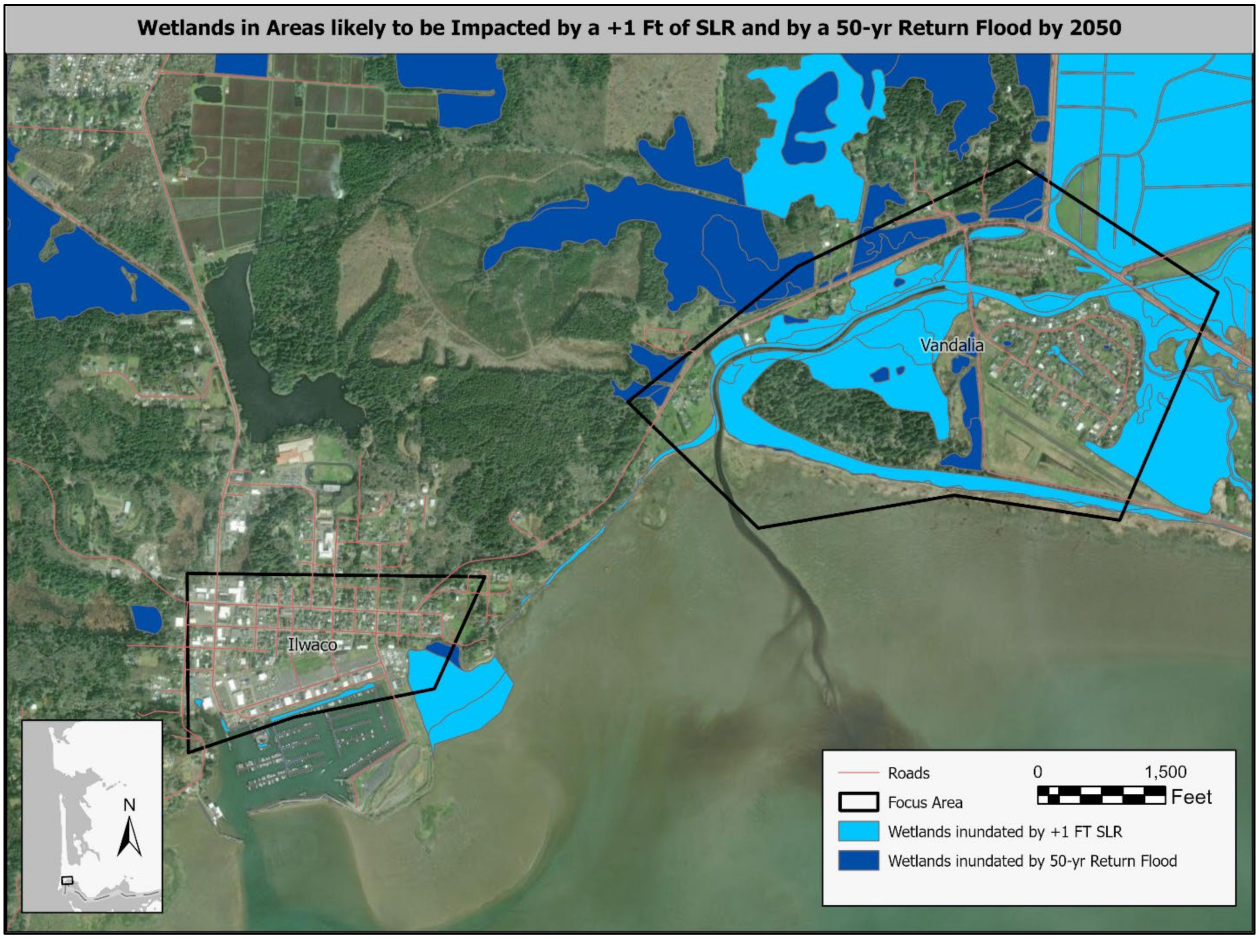

Figure 26. Map of wetland areas likely to be impacted by a +1 Ft of SLR and by a 50-yr return flood. Table 11 quantifies the area within the black polygons only.

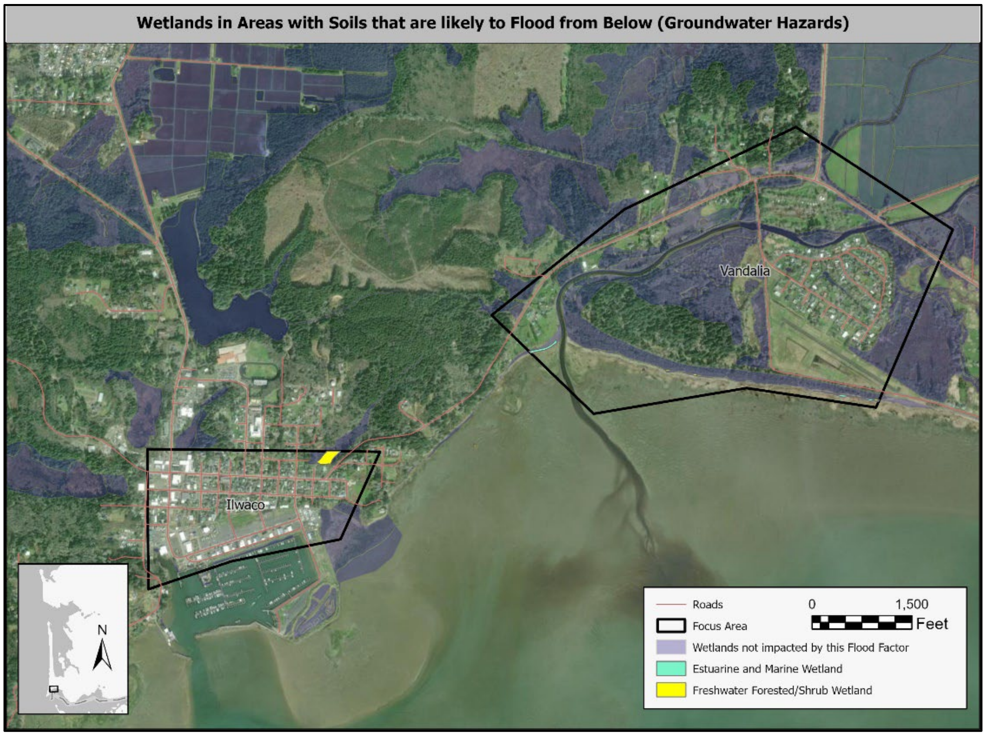

Figure 27. Map of type of wetlands in areas with soils often associated with high groundwater tables. Table 11 quantifies the area within the black polygons only.

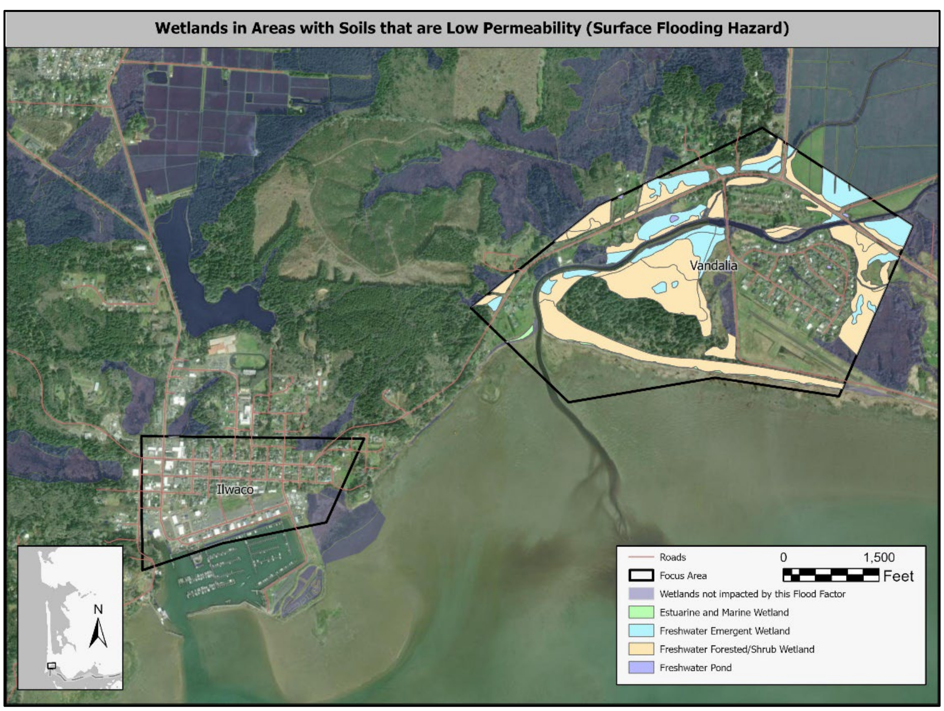

Figure 28. Map of type of wetlands in areas with soils with low permeability and susceptible to surface water flooding. Table 11 quantifies the area within the black polygons only.

4.5 Capital Improvement Plan

The current City of Ilwaco Capital Improvement Plan (CIP) was reviewed to determine which projects have a nexus with information provided in this report.

Table 12. City of Ilwaco Capital Improvement Plan (CIP)

Priority / Year	Street	Project Description	Class	Estimated Cost	Funding Sources	Status
1 2019	Captain Gray Drive	Chip seal Capt. Gray Dr. from beginning at Stringtown Rd to the 7200 block of Ortelius Drive. Also incorporate the cul-de-sac's of Chattam Way, Rochelle Way, Delta Way, Glenmorag Way, and Ortelius 7200 block. Finally, finish with Scarboro Lane N and S. Add storm drains at all possible locations.	Local	$446,000	TIB, local	Expected 2025
2 2020	Cooks Road NE	Rebuild hazardous intersection with SR 101	Local	$523,000	TIB, local	TBD
3 2019	Quaker Avenue N	N Cedar Street to Whealdon Street. Chip Seal access road to City Center Reservoir	Local	$354,000	TIB, local	Complete
4 2020	Hilltop School Route, Advent Avenue N	Pave and add sidewalks to Advent Ave. beginning at Spruce Street North to Fir Street.	Local	$506,000	TIB, local	Paving only 2025. Sidewalks TBD
5 2022	Adelia Avenue	Begin paving at SR 101 cutoff (Spruce Street E) to Adelia Ave. From Adelia Ave to Lake Street E	Local	$832,200	TIB, local	Paving on Adelia complete
6 2023	Pearl & Myrtle Avenues	Pave Pearl Ave from Spruce to Howerton & pave Myrtle Ave from Spruce to Lake. Chip Seal Myrtle Ave from Spruce end to Main	Local	$389,000	TIB, local	Expected 2025
7 2022	Miscellaneous chip seal	Advent, Myrtle, Ash, Eagle, Main SE, & Pearl	Local	$26,064	Local	Expected 2025
9 2023	Discovery Trail Extension	Extend the Discovery Trail from Main Street to Cooks Hill	Pedestrian/ Bicycle	$2,074,000	State Ped/ Bike	TBD
10 2024	Main St. SW	Repair sloughing street and connect to Discovery Trail	Local	$53,100	TIB, local	Street repair 2025

Priority / Year	Street	Project Description	Class	Estimated Cost	Funding Sources	Status
11 2022	Sidewalk improvements	Repair various city sidewalks	Various	$20,000	TIB	TBD
12 2020	Howerton Avenue	Resurface Howerton Avenue, First Avenue S to Elizabeth Ave SE	Local	615,800	State/Local	TBD

Project 1 of the CIP includes work within the Vandalia Neighborhood and references that storm drains will be added wherever possible. The outfall that any new stormwater drainage would be directed to goes out to the Wallacut River. However, this outfall is often covered by water in heavy rainfall events and may also be impacted by high tides. The extent of work for the CIP Project 1 is intended to be clearing/replacing the existing culverts and any related infrastructure that leads to the retention ponds. This project scope may also include additional stormwater collection pipes to increase the retention pond collection. The implementation of this project may improve the capacity of stormwater collection within the Vandalia neighborhood compared to existing conditions. However, additional improvements will be necessary to mitigate the impacts from sea level rise and increased frequency, duration and magnitude of flood events.

4.6 Summary of Flood Exposure and Potential Impact

Risk and vulnerability to different types of flooding are considered separately. **Risk** may be low, moderate, or high depending on topographic position, elevation, and depth to water table. **Potential Impact** may be low, when flooding causes inconvenience, moderate when flooding impacts buried infrastructure, water wells, or on-site septic systems, and high when flooding threatens personal safety or significant property loss.

Table 13. Potential Impact of each type of flooding in each focus areas

Focus Area	Flooding	Exposure	Potential Impact
Ilwaco City Center	Coastal	High	Moderate
	Stormwater	High	Moderate to High[1]
Vandalia Neighborhood	Riverine	High	Moderate to High[2]
	Compound	High	Moderate to High[2]

[1] Sea level rise will increase stormwater flooding along Baker Bay frontage due to loss of gravity drainage during high tides and winter storms.
[2] Sea level rise will increase depth and duration of riverine flooding in the Wallacut River floodplain, with compound flooding in Vandalia neighborhood closer to Baker Bay.

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5. Recommendations

5.1 General Recommendations

In general terms, increasing resiliency from stormwater and groundwater flooding primarily involves managing the water while increasing resiliency from coastal, riverine, and compound flooding primarily involves managing the at-risk structures and infrastructure. A variety of flood resilient strategies will likely be necessary to reduce impacts to specific assets.

Coastal flooding mitigation priorities include protecting low-lying infrastructure from erosion, elevating structures above potential flood or inundation levels, and ensuring that floodwaters are able to drain back to the sea as tides recede.

The objective of this "General Recommendations" section is to recommend strategies and actions that can be chosen and applied based on on-site characteristics. The recommendations below are based on the limited data available and are not intended to be inclusive of all strategies that may be necessary to increase resiliency. As additional data becomes available, strategies may need to be revised and/or expanded upon.

5.1.1 Stormwater flooding mitigation priorities:

- Update GIS data for existing drainage infrastructure, including culvert size and condition (if possible), tide gate type, size and condition, elevation and location of stormwater components that are above ground, and outfall elevations.
- Repair and maintain infrastructure to improve drainage and water quality.
    - Conceptual plan development is underway to encourage green stormwater infrastructure and low impact development techniques (See Section 5.2.2).
    - Collect heights in NAVD88 of infrastructure outlets (tide gates, outfalls, culverts).
- Install catch basins to hold water until it can be infiltrated or drained in areas that are designated at risk.
- Designate locations where pumps could be installed in catch basins to push water out at low tide.
- Reroute or redirect stormwater to catch basins or preferred routes, allowing some emergency routes to remain unflooded.
- Identify infrastructure that is most at risk during the dye test and prioritize replacement or repair to protect stormwater conveyance capacity.
- Identify funding opportunities to replace collapsed culverts in Vandalia and evaluate ditch capacity for conveying expected increased precipitation.

5.1.2 Riverine flooding mitigation priorities:

- Regularly maintain and repair levees, as needed. This effort may include long-term management plans to ensure adequate protection under changing climate conditions.
- Create wetlands and off channel habitat areas to route water upstream of communities.
- Assess and prioritize bridge repairs and height adjustment to incorporate future conveyance requirements due to SLR and flooding impacts.
- Work with jurisdictions upstream to increase flood storage capacity using off channel habitat.

5.1.3 Groundwater flooding mitigation priorities:

- Create lower catch basins to route groundwater and stormwater to hold for infiltration.
- Reroute or redirect stormwater to catch basins or preferred routes, allowing priority emergency routes to remain unflooded.
- Reduce or convert impervious surface area to increase spatial opportunities for infiltration.

5.1.4 Compound flooding mitigation priorities.

- Reroute or redirect stormwater to catch basins or preferred routes, allowing priority emergency routes to remain unflooded.
- Repair and maintain infrastructure to improve drainage, including replacing tide gates.
- Install catch basins to hold water until it can be infiltrated or drained in areas most at risk.
- Designate locations where pumps in catch basins could be installed to push water out at low tide.
- Consider developing new stormwater retention areas to increase flood storage capacity.

5.1.5 Overarching strategies

- The 2022 Pacific County Hazard Mitigation Plan (HMP) notes flooding is one of the major potential hazards for Pacific County. The HMP focusses heavily on tsunami flooding rather than the types of flooding mentioned in this document. The work in this assessment is supplemental to that existing information. Severity of the emergencies may vary and require different strategies. Evacuation processes apply no matter how severe the flooding event.
- Update the Wastewater Treatment Plant (WWTP) Facility Management Plan to address equipment location, maintenance and operations in response to climate changes, such as potential coastal flooding, including saltwater spray and overwash.
- Encourage pre-planning and pre-staging instead of emergency response. Given the limited capacity of emergency response efforts within the City and throughout Pacific County, pre-planning may reduce impacts to structures and infrastructure and improve overall health and safety of the community during flooding events.

- Welcome packages for new residents to the City of Ilwaco could be created and offered in community gathering areas or by real estate agents or title offices. These packages could include information on flooding and what may be experienced. Further, these packets could provide information on how to prepare for emergencies and times when water levels may be high enough to prevent travelling anywhere. Normalizing high water levels to a degree, may be necessary, given the low topography of the land and limitations for relocation.
- Develop community groups and leaders to advocate for community groups where vulnerabilities are identified. Creating and supporting collaborations that work together, across silos, to identify and implement projects through a resilience lens. The Pacific Conservation District has proposed a collaborative effort to acquire upland areas for housing to allow for community relocation in the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy (Blalock et. al., 2024). The efforts in the Willapa Bay National Wildlife Refuge to protect and restore coastal wetlands, such as the Bear River Estuary efforts[16]. The Shoalwater Bay Tribe has identified several proposals to increase resiliency for coastal infrastructure (Shoalwater Bay Indian Tribe, 2021). The North Willapa Shoreline Erosion Mitigation Master Plan[17] provides an example of what a community can do to develop a resiliency plan with a specific objective. Though not limited to the City of Ilwaco, these are just a few examples. A web-based clearing house would be helpful to gather these types of efforts into one searchable library.

5.2 Specific Recommendations

5.2.6 City of Ilwaco

Overall, the City would benefit from evaluating building standards for development within designated floodplains. It is recommended to extend these standards to areas identified by SLR and areas outside the FEMA Floodplain maps (e.g., 500-year floodplain), particularly for critical facilities or structures within a long-term planning horizon. The Department of Ecology recommends adopting a minimum of two (2) feet above BFE (FEMA Flood Zone AE) as a building standard. The FFRM is a federal rule and policy, effective September 2024, that states that development using federal funding must meet a new standard in order to protect projects, property and taxpayer investments from current and future flood risks. The requirement currently applicable in Washington State states that development of non-critical actions or development are required to build the lowest floor 2 feet above the BFE for development freeboard. Critical actions or facilities, as defined in § 55.2(b)(3)(i), are those activities *for which even a slight chance of flooding would be too great,* because such flooding might result in loss of life, injury to persons, or damage to property. Critical actions are required to build the lowest floor 3 feet above BFE. Critical actions include police stations, fire stations, roads providing sole egress from flood-prone areas, hospitals, and nursing homes (Ecology, 2024). The City could consider requiring shoreline structures to incorporate two (2) feet of freeboard into designs to increase resilience in alignment with the Federal Flood Risk Management Standards, particularly in vulnerable areas. Additionally, the City could consider requiring the lowest floor of residential properties in the Special Flood Hazard Area (SFHA) or

[16] Partnership Conserves New Lands for Wildlife and People | U.S. Fish & Wildlife Service
[17] Willapa-Erosion-Mitigation-Master-Plan-Final-Final.pdf

areas at high risk of exposure to be at least two (2) feet above base flood elevation (BFE) or be floodproofed to that extent.

Further, it is recommended that the City coordinate with Pacific County Department of Emergency Management to update the Pacific County Hazard Mitigation Plan (HMP), which includes the City of Ilwaco. It is recommended to identify evacuation routes for flood events for areas designated to be most at risk. The existing HMP only includes tsunami evacuation routes for the entire County. Particularly in the Vandalia Neighborhood, there is a concern about emergency access in the event of temporary or permanent flooding conditions along single ingress/egress roadways.

5.2.7 Ilwaco City Center

The Pacific Conservation District (PCD), along with the Lower Columbia Estuary Partnership and Washington Sea Grant, worked with the community on a three-year long project about how to best respond to current and SLR-driven flooding in the Baker Bay and Grays Bay nearshore areas. They used scientific information and community visioning to address how best to respond to current and future possible flooding events. This resulted in several resilience strategies and conceptual designs for projects, including a few in the City and Vandalia focus areas (Blalock et al., 2024). One of the projects recommended in the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy, the Ilwaco Stormwater Management concept, is being addressed in a project that is currently underway as of the writing of this assessment. The City is conducting an integrated stormwater planning and outreach project under the Washington State Department of Commerce's Salmon Recovery Through Local Planning grant program which is intended to update goals, policies, and development regulations with the overarching goals of advancing salmon recovery, improving climate resiliency, and promoting regenerative stormwater management.

The City of Ilwaco could consider pursuing flood protection strategies along the Port of Ilwaco and the adjacent marsh to aid in the protection of the City. As identified in the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy, the City could consider raising the shoreline along the Port of Ilwaco or exploring the feasibility of placing dredged materials from the Port within the adjacent marsh as a beneficial use site (Figure 29).

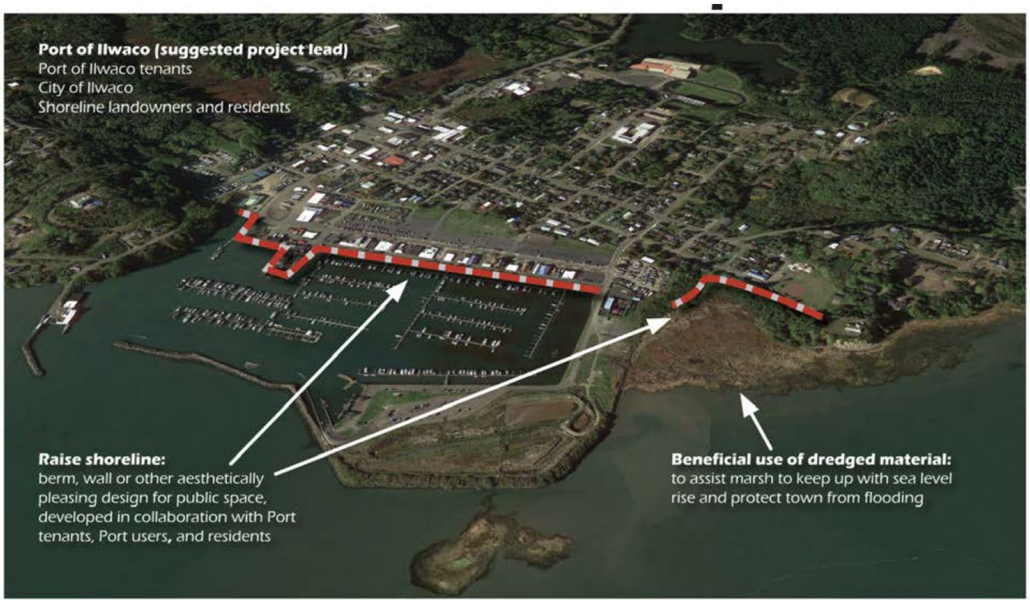

Figure 29. Potential Flooding Mitigation Strategies Identified in the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy (Blalock et. al., 2024)

5.2.8 Vandalia Neighborhood

Both municipal sewer lift stations, along with the drinking water pump station, should be prioritized in future Capital Improvement Planning to improve resiliency and protective measures. Disruptions to these facilities could have widespread effects on the community.

The Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy (Blalock et. al., 2024) suggests a strategy to address long-term resilience for increased flooding is to redirect new housing growth to upland areas through cooperative acquisition and planning strategies. This would increase opportunities for residents to relocate up out of the floodplain.

Further, the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy suggests replacing the three failing culverts along Stringtown Road with a muted tidal regulator to support some level of fish passage (Figure 30). A standard tide gate would reduce flooding impacts but inherently does not provide fish passage and thus would not comply with state requirements. Specific resiliency strategies for the Vandalia neighborhood should be evaluated to determine feasibility, including the assessment of overall stormwater management of the area, by submitting for competitive funding opportunities. Community engagement should be incorporated to evaluate alternatives and specific design components.

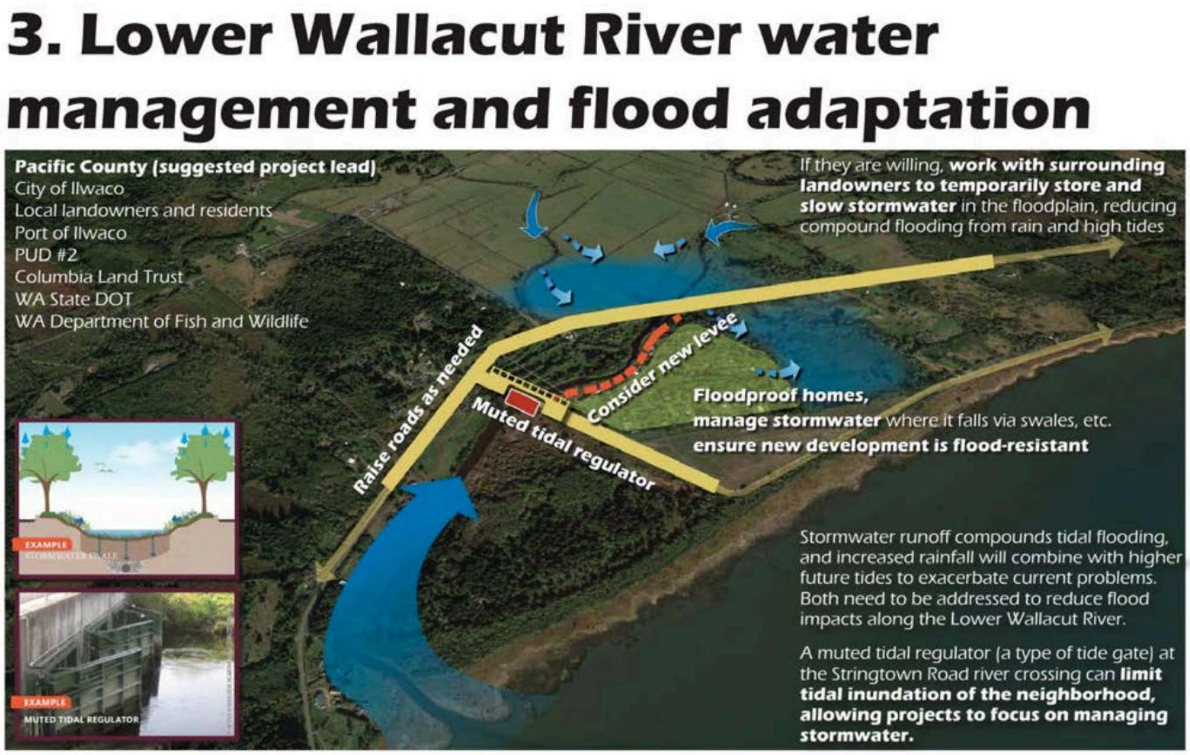

Figure 30. Water Management and Flood Adaptation Strategies from the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy (Blalock et. al., 2024)

The Vandalia neighborhood could benefit from converting the currently undeveloped community tract to include detention and water quality improvement facility if groundwater conditions are suitable. This effort could include adding a bioretention facility to provide removal of many stormwater pollutants and provide reductions in surface runoff flow rates. A bioretention facility could include a layer of bioretention soil mix (BSM) to treat stormwater runoff as well as can be designed to address flow control requirements. The existing tracts may be improved to provide better outlets, facilities, and water quality, particularly Tract "C" near between Ortelius Drive and Captain Robert Gray Drive (Figure 31).

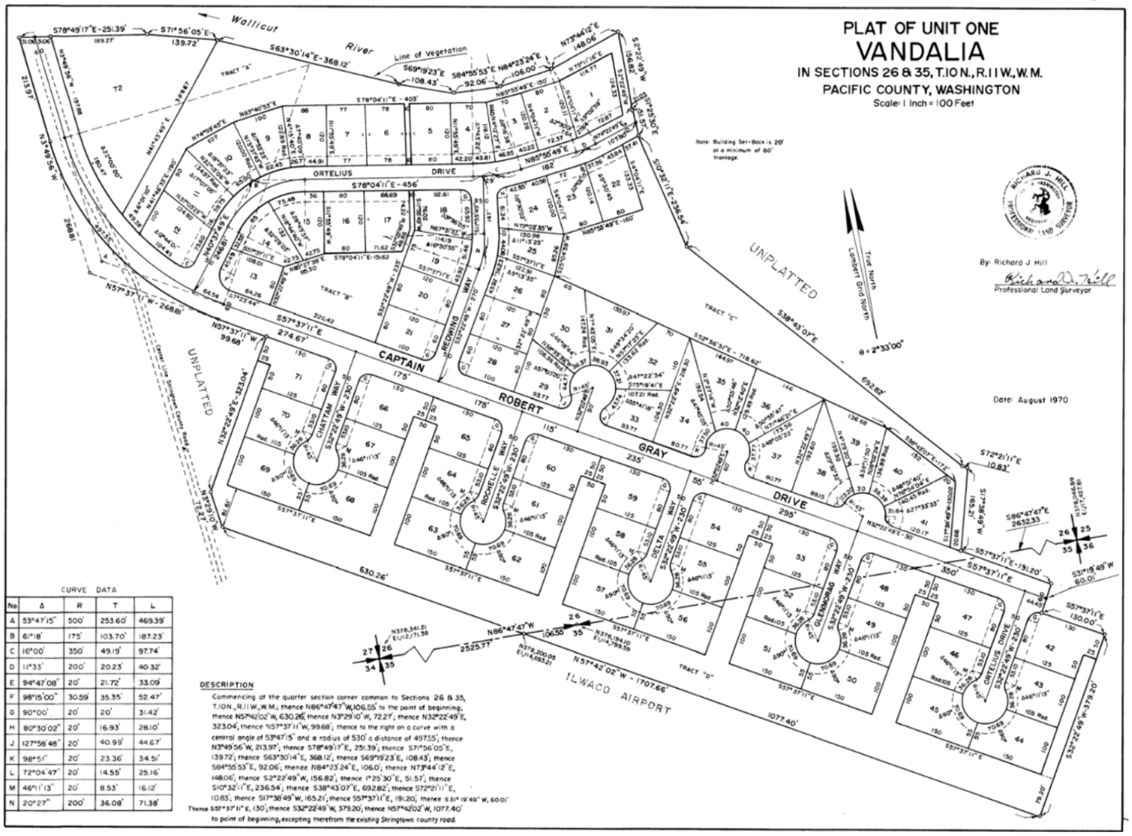

Figure 31. Plat of Vandalia – Unit One

The City could also consider partnering with the Columbia Land Trust to treat stormwater from Vandalia and route it under Stringtown Rd to the property owned by the Columbia Land Trust to improve habitat functions and increase flood storage capacity for the community. However, this discussion has not yet been initiated with the Land Trust and should be pursued further to assess their interest and the feasibility of the idea.

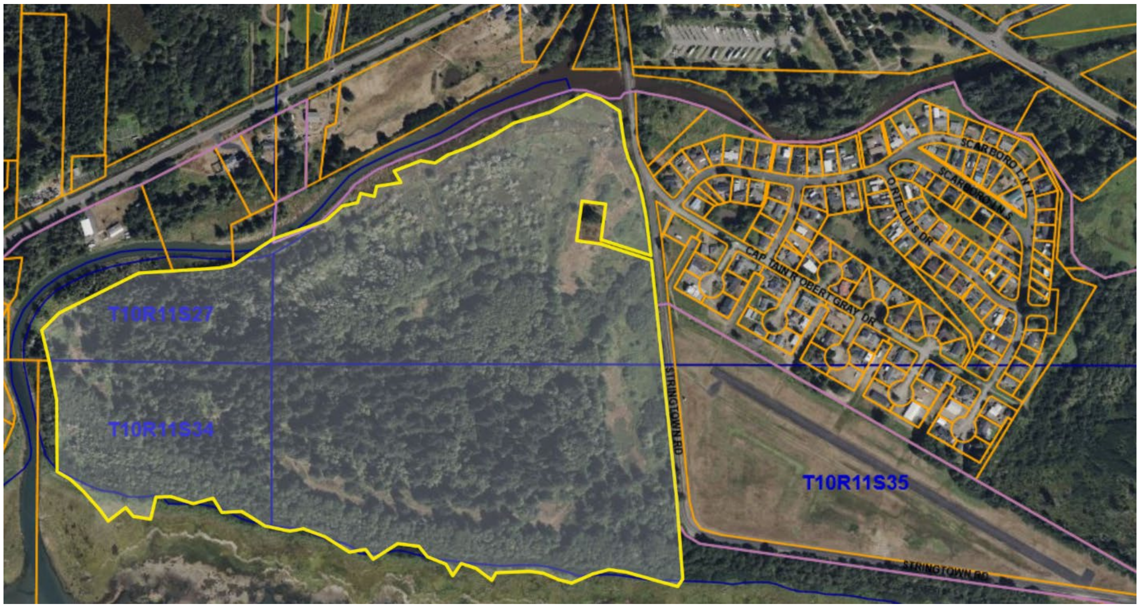

Figure 32. Aerial Imagery of Plat of Vandalia *(Source: Pacific County MapSifter*)

Additionally, a community plan could be developed to detain and pump water during regular or extreme events. To fund this type of development, a local improvement district could be developed to fund pump facilities and infrastructure improvement within the Plat, or grant opportunities could be explored.

To improve water quality, plants with saltwater tolerances could be planted along the banks of the Wallacut River and Compost Amended Vegetated Filter Strips (CAVFS) could be constructed along roadways. Additionally, low impact development (LID) features such as rain gardens, bioretention facilities, enhanced swales, etc. could be placed to aid in stormwater management.

6. Code and Plan Audit

The project team conducted an audit of the most recent version of the City of Ilwaco's Comprehensive Plan, Shoreline Master Program, and Ilwaco Municipal Code (IMC) Chapter 15.18, Critical Areas, to identify opportunities to amend policies and regulations to mitigate the risk of damage or loss from sea level rise and extreme flood events. The following recommendations include many approaches that are policy-based, or best practice, as well as some that may be regulatory. These recommendations are intended to provide a range of options for the City to consider in the near, medium, and long term. The Washington State Department of Ecology is currently working on the state rulemaking process to amend Chapters under the Shoreline Management Act (SMA) to address frequently flooded areas, sea level rise and shoreline permits. As the proposed rulemaking language was not available at the time of this report, these recommended revisions to City Codes and Plans should be considered subject to change as additional information becomes available. Recommendations are included, but are not limited to, the following:

City of Ilwaco Comprehensive Plan:

- Include a goal to establish land use patterns that increase resilience of the built environment, ecosystems and communities to climate change.
- Develop a policy to review land use maps and identify opportunities or barriers to responding to rapid population growth or decline, rebuilding housing, infrastructure and services after disasters, and other extreme climate impact scenarios.
- Implement a policy to establish development regulations that incorporate best practices for reducing the risk of sea level rise, extreme heat, flooding, wildfires and other climate exacerbated hazards.
- Recommend developing regulations for elevating or setting back new and substantially improved structures to reduce the risk of damage caused by sea level rise.
- Develop a policy to consider climate change, including sea-level rise, extreme precipitation, increased streamflow, and other impacts, in land use and floodplain management planning.
- Recommend developing, implementing and periodically updating a plan to mitigate and adapt to climate change impacts to the coastline.
- Implement a policy to factor sea level rise impacts for development proposals near the waterfront and require development to incorporate measures that will reduce risks and avoid future costs to the community by avoiding maladaptive interventions.
- Provide educations materials to encourage soft-shore approaches to managing shoreline erosion and discourage armoring to the extent practicable.
- Address rising sea water by planning for relocation of hazardous industries, siting and planning for relocation of other industry types and essential public services away from the 500-year floodplain.
- Develop a goal to protect and restore coastal ecosystems to increase the resilience of species, habitats, and communities to climate change.
- Implement a policy to identify and quantify the ecosystem services benefits of natural systems and include these natural capital assets in cost-benefit assessment for community and development planning.
- Recommend considering sea level rise in coastal and nearshore habitat restoration projects.
- Ensure no net loss of ecosystem composition, structure, and functions, especially in Priority habitats and Critical Areas, and strive for ecological gain to enhance climate resilience.
- Develop a Historic Preservation and Cultural resources section of the Comprehensive Plan

- Develop a goal to ensure that cultural resources and practices – including significant historic sites and culturally important traditions and natural resources – are resilient to the impacts of extreme weather and other natural hazards worsened by sea level rise and climate change.
- Establish and maintain government to government relations with Native American tribes for the preservation of archaeological sites, traditional cultural properties, and treaty resources that are vulnerable to climate impacts.
- Include a policy to protect significant historic sites prone to floods or other hazards worsened by climate change.
- Recommend establishing regulations that require the location of new lots and structures outside of sea-level rise hazard areas.
- Identify and plan for climate and sea level rise impacts to valued community assets such as parks and recreation facilities, trails and roadways, including relocation or replacement.
- Develop a policy to consider climate conditions during siting and design of capital facilities, including changes in temperature, rainfall, and sea level, to help ensure they function as intended over their planned life cycle.
- Address rising sea water by siting and planning for relocation of essential public facilities away from the 500-year floodplain.
- Develop a goal to ensure the local transportation system – including infrastructure, routes, and travel modes – is able to withstand and recover quickly from the impacts of extreme weather events and other hazards exacerbated by climate change.
- Enhance the resilience of the local transportation system by assessing climate hazards and impacts and developing local Hazard Mitigation Plan.

Shoreline Master Program:

- Incorporate a definition for "Life of a Structure" to provide a specific timeframe that will be evaluated.
- Include a policy to monitor sea level rise and accordingly adjust development standards and building setbacks to minimize flooding potential.
- Include a policy to encourage enhanced construction standards in areas that are vulnerable to flooding both now and in the future based on historical flooding events and future flooding predictions. The County should facilitate sharing of information related to coastal vulnerability to sea level rise with developers and residents.
- Include a policy that redevelopment activities that increase resilience from sea level rise or extreme flood events, such as raising structures or relocating, should be expedited to the extent feasible.
- Include a policy to limit the expansion of impervious surfaces within the shoreline environment and encourage conversion to pervious surfaces, where possible.

- Require that new development on steep slopes or bluffs consider sea level rise, increased storm intensity, and changes to coastal erosion and sediment supply in their geotechnical analysis to evaluate building setbacks.
- Provide a policy that encourages redevelopment of non-conforming structures to consider resilience strategies to mitigate risks associated with a changing climate, including sea level rise and extreme flood events.
- Provide a policy that encourages new development on marine shorelines to locate the bottom of the structure's foundation higher than the level of expected future sea level rise for the life of the structure.
- Develop a policy that sea level rise and increased frequency and magnitude of extreme storm events as a result of climate change should be taken into account when considering and evaluating shoreline uses.
- Require that new plats or subdivisions demonstrate that the residential development and all related infrastructure will not be impacted by sea level rise within 50 years.
- Provide a policy to locate utility facilities outside of areas that may be subject to inundation from sea level rise or extreme flood events, or design facilities to withstand temporary or permanent water inundation, or other natural hazards.
- Include a policy that public stormwater facilities should account for sea level rise, as well as the potential for increased storm frequency and intensity, when planning for future conveyance capacity.
- Provide a policy to identify and implement strategies to increase the resilience of the shoreline environment to sea-level rise and other climate hazards, while also protecting shoreline ecological functions, allowing water-dependent uses, and providing public access.
- Require that a preexisting residential or appurtenant structure that is nonconforming with respect to dimensional standards may be enlarged provided that such enlargement does not increase the extent of the nonconformity and does not increase the risk of damage from sea level rise for the life of the structure.
- Require that shoreline restoration and enhancement projects be designed using the most current, accurate, and complete scientific and technical information available, and implemented using best management practices, including consideration of sea level rise and other climate related impacts. Applicants should consult applicable guidance documents, such as the most current version of the Washington Department of Fish and Wildlife's Stream Habitat Restoration Guidelines, state noxious weed listings, and agricultural pest management guidance documents, promulgated by state or federal agencies.

Ilwaco Municipal Code Chapter 15.18, Critical Areas

- Incorporate a definition of "Channel Migration Zone (CMZ)"
- Add CMZs as a designated erosion hazard area.

- Require new subdivisions to be located outside of designated CMZs or have adequate buildable areas outside of the CMZ.
- Require geotechnical reports for alterations of shoreline erosion hazard areas to evaluate coastal erosion rates with consideration of sea level rise and increased storm frequency and intensity for a minimum of 50 years.
- Encourage floodproofing or elevation of structures for areas near special flood hazard areas or areas that may be inundated by sea level rise within the life expectancy of the structure.

7. Next Steps

This assessment included an evaluation of assets identified by the Technical Advisory Committee and city staff within the limits of existing data. Future efforts should consider re-evaluating assets as updated mapping of culverts, tide gates, outfalls, lift station and pump stations are completed to better establish overall vulnerability and risk. Given the limited staff capacity and funding, the City should consider seeking grant opportunities for financial support to obtain the necessary machinery and related resources to regularly maintain or replace aging infrastructure. The City could utilize the results of the recent stormwater dye test to determine infrastructure that is most at risk and prioritize replacement. Lift and pump stations located in the Vandalia neighborhood should also be prioritized to determine resiliency strategies to retrofit or relocate components outside of the areas expected to be impacted by future flood events. Once resiliency strategies are identified, these improvements should be included in Capital Improvement Planning efforts during the next periodic update cycle. The City should also consider working with the Pacific Conservation District and Washington Sea Grant to identify funding opportunities in alignment with the recommendations of the Baker Bay and Grays Bay: 2024 Sea Level Rise Resilience Strategy to begin the necessary steps to implement construction projects and enhance resiliency.

The Integrated Stormwater Management and Outreach Project will include an in-depth discussion and prioritization of public projects to improve water quality. These projects could also be expanded to include implementation of resiliency measures for flooding impacts. Future revisions to plans or development regulations, such as those recommended in Section 6.0, could be incorporated to improve the resilience of new or redeveloped properties and reduce the risk of damage or loss. The recommendations included in Section 5.0 could be evaluated on a project-specific basis to establish where improvements could be made to reduce future impacts on structures or infrastructure.

Coastal flooding mitigation priorities include protecting low-lying infrastructure from erosion, elevating structures above potential flood or inundation levels, and ensuring that floodwaters are able to drain back to the sea as tides recede. Since the Vandalia neighborhood is most at risk from sea level rise and extreme flood events, a community plan should be developed to identify the most beneficial resilience strategies along with their associated costs. This plan should be reviewed with residents and include clear steps for implementation with potential funding sources. As this area is predominately within the delineated FEMA floodplain, measures should be taken to ensure new, or redevelopment is adequately protected from rising sea levels and future flood events.

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APPENDIX A: Hydrologic Analysis

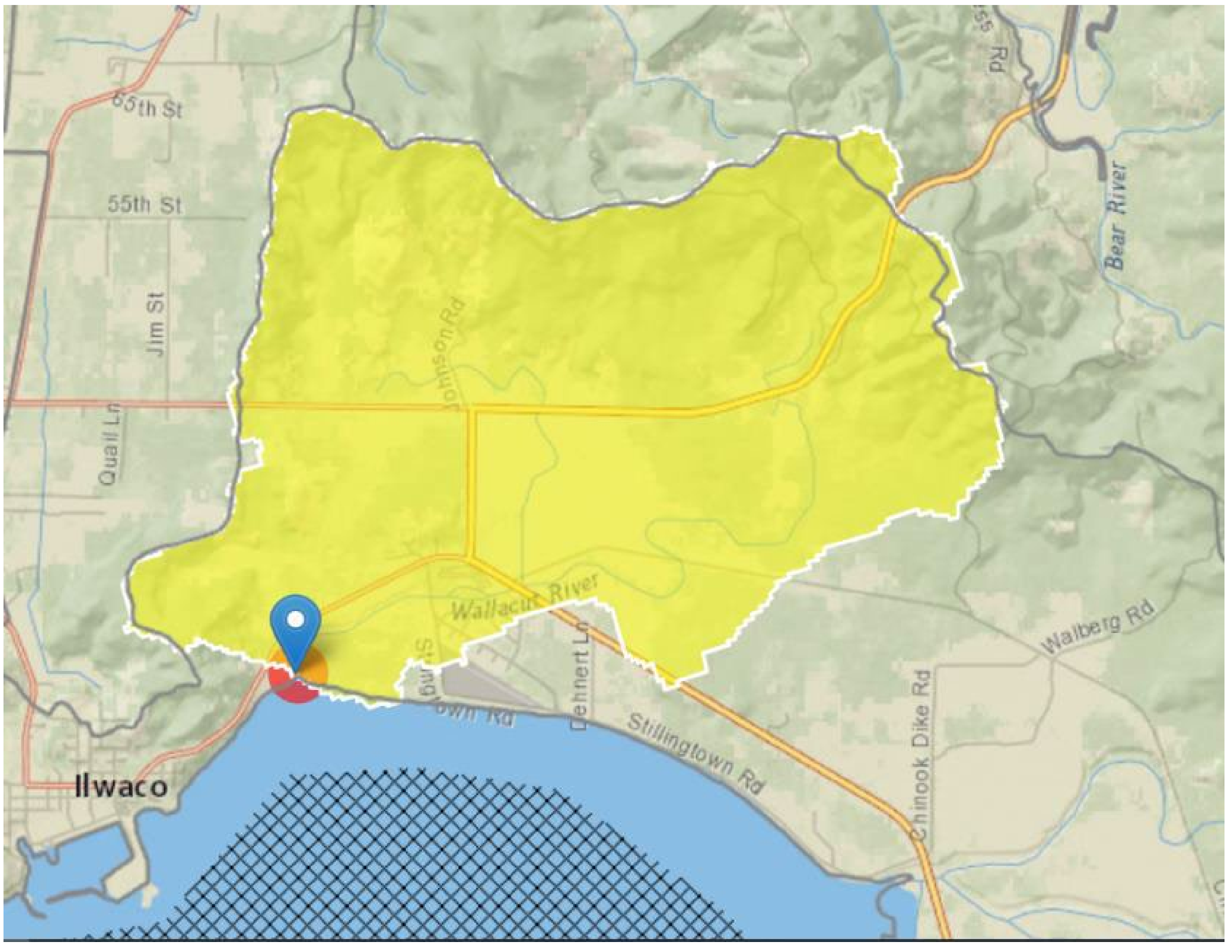

Figure 33. Drainage Area Boundary for the point selected around the Wallacut River.

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Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BSLDEM30M	Mean basin slope computed from 30 m DEM	6.5	percent
DRNAREA	Area that drains to a point on a stream	5.57	square miles
MINBELEV	Minimum basin elevation	0	feet
PRECPRIS10	Basin average mean annual precipitation for 1981 to 2010 from PRISM	78.5	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Peak Region 4 2016 5118]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.57	square miles	0.18	2230
PRECPRIS10	Mean Annual Precip PRISM 1981 2010	78.5	inches	11.9	187

Peak-Flow Statistics Flow Report [Peak Region 4 2016 5118]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

Statistic	Value	Unit	PIL	PIU	ASEp
50-percent AEP flood	274	ft^3/s	50.1	1500	52.5
20-percent AEP flood	423	ft^3/s	79.2	2260	50.6
10-percent AEP flood	537	ft^3/s	98.3	2930	50.5
4-percent AEP flood	680	ft^3/s	116	3990	51.7
2-percent AEP flood	794	ft^3/s	127	4950	52.9
1-percent AEP flood	916	ft^3/s	138	6060	54.2

Bankfull Statistics Flow Report [Area-Averaged]

Statistic	Value	Unit
Bieger_D_channel_width	26.3	ft
Bieger_D_channel_depth	1.65	ft
Bieger_D_channel_cross_sectional_area	53.3	ft^2
Bieger_P_channel_width	23.4	ft
Bieger_P_channel_cross_sectional_area	50.8	ft^2
Bieger_P_channel_depth	1.66	ft
Bieger_USA_channel_width	22.7	ft
Bieger_USA_channel_depth	1.74	ft
Bieger_USA_channel_cross_sectional_area	43.2	ft^2
Bankfull Width	25.9	ft
Bankfull Depth	1.29	ft
Bankfull Area	50.7	ft^2
Bankfull Streamflow	288	ft^3/s

APPENDIX B: FEMA AE Zones. Flood Elevations

Figure 34. Ilwaco, WA. AE Zone Coastal Flooding.

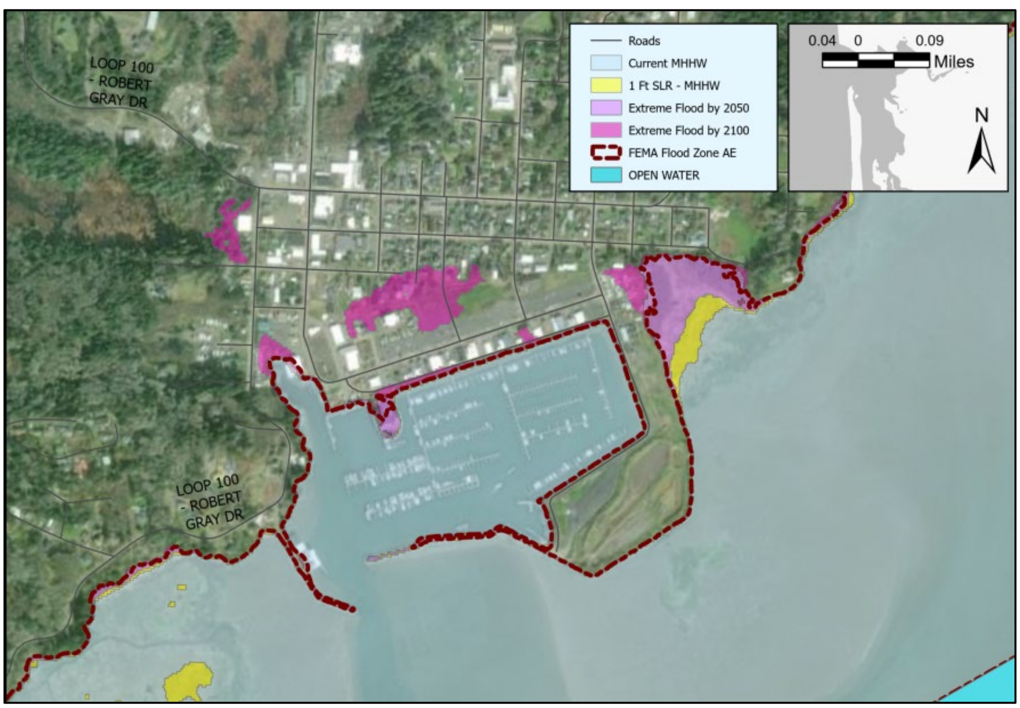

Figure 35. Projected SLR and extreme flooding in 2050 compared to FEMA Flood Zones for the City of Ilwaco.

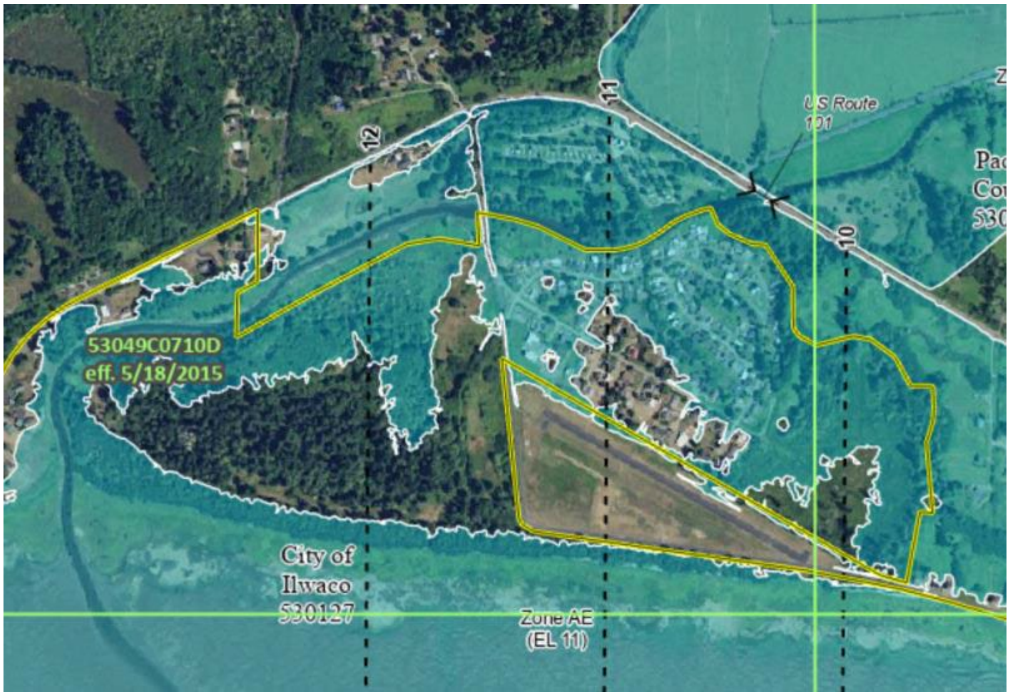

Figure 36. Vandalia Neighborhood in Ilwaco, WA. AE Zone Coastal flooding.

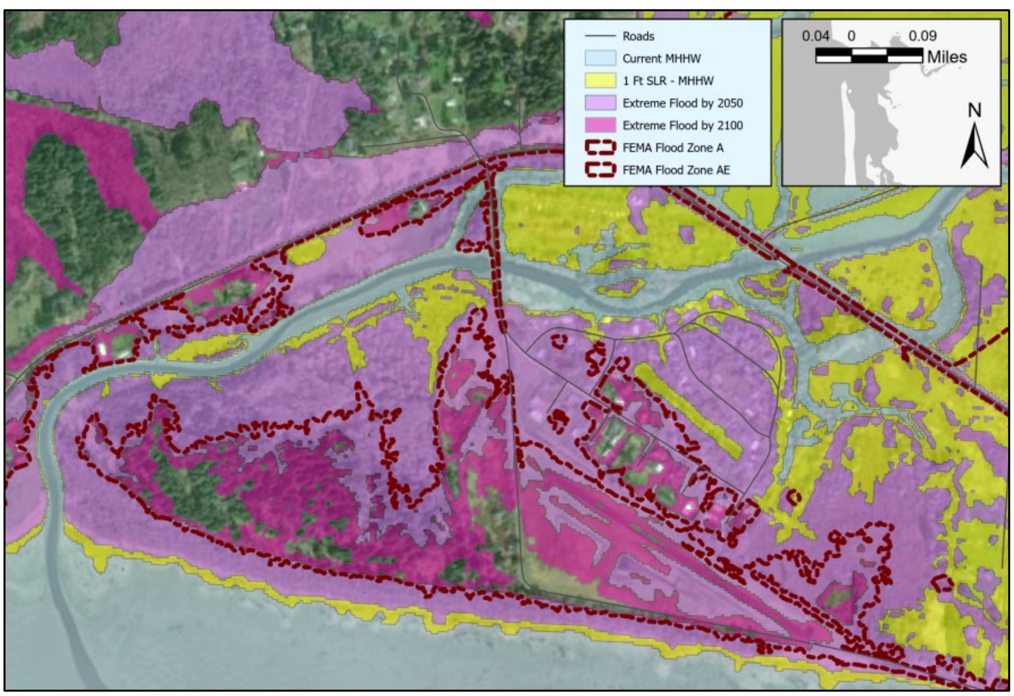

Figure 37. Projected SLR and extreme flooding in 2050 compared to FEMA Flood Zones for the Vandalia Neighborhood.

APPENDIX C: Relative Elevation Models for Vandalia Focus Area

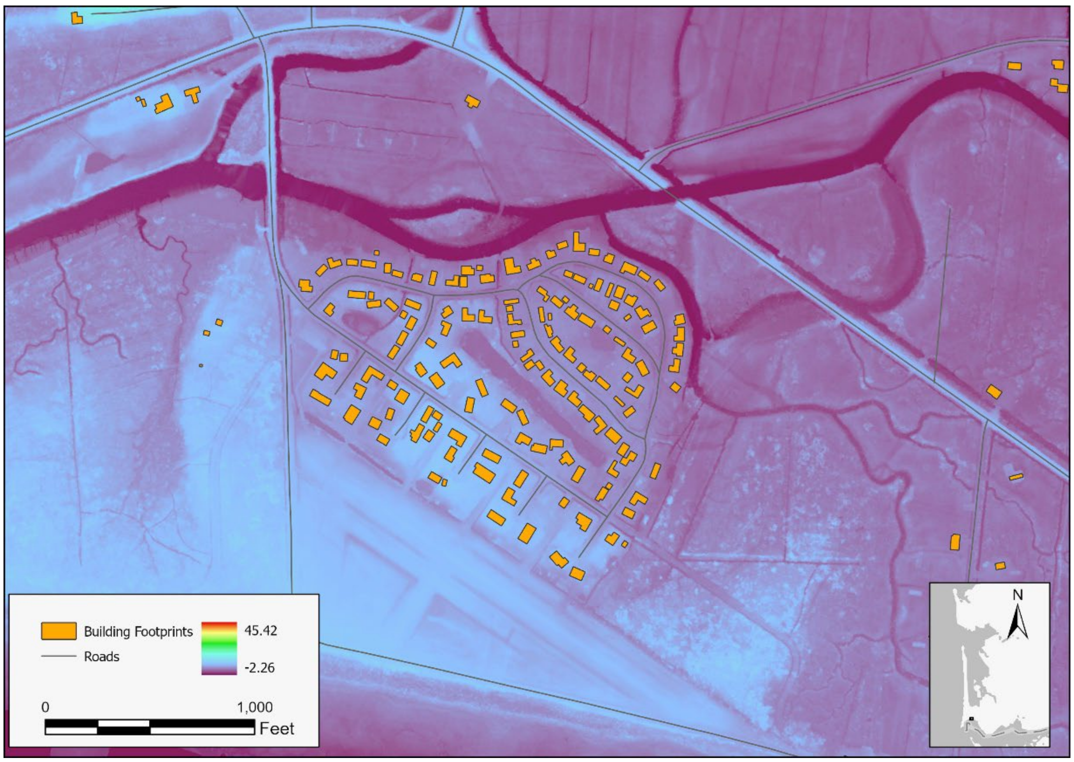

Figure 38. Vandalia Neighborhood in Ilwaco, WA REM. Color ramp units are feet (NAVD88).

APPENDIX D: Pacific County, Washington. Soil Series Descriptions (NRCS 2025)

OCOSTA SERIES

The Ocosta series consists of very deep, poorly drained soils that formed in alluvium deposited in coastal bays. Ocosta soils are in flat or depressed areas and are subject to total overflow unless protected. The mean annual precipitation is about 85 inches, and the mean annual air temperature is about 50 degrees F.

TAXONOMIC CLASS: Fine, mixed, super active, acid, isomesic Sulfic Endoaquepts

TYPICAL PEDON: Ocosta silty clay loam, cultivated pasture. (Colors are for moist soil unless otherwise noted.)

Oe--0 to 3 inches; moderately decomposed remains of sedge and grass leaves interlaced with live fine roots; extremely acid (pH 3.8). (0 to 6 inches thick)

A--3 to 10 inches; dark grayish brown (2.5Y 4/2) silty clay loam, grayish brown (2.5Y 5/2) dry; many coarse prominent yellowish red (5YR 5/8) redox concentrations; moderate coarse angular blocky structure; hard, firm, moderately sticky and very plastic; many medium and fine roots; many fine tubular and interstitial pores; extremely acid (pH 4.0); abrupt smooth boundary. (6 to 8 inches thick)

Bg1--10 to 15 inches; dark grayish brown (2.5Y 4/2) silty clay loam, grayish brown (2.5Y 5/2) dry; common medium prominent dark reddish brown (5YR 3/4) redox concentrations; moderate coarse prismatic structure; very hard, firm, moderately sticky and very plastic; many fine and medium roots; many medium tubular and interstitial pores; few moderately thick black (5YR 2/1) organic coatings along vertical surfaces of peds; extremely acid (pH 4.0); clear smooth boundary. (3 to 8 inches thick)

Bg2--15 to 23 inches; dark grayish brown (2.5Y 4/2) silty clay, grayish brown (2.5Y 5/2) dry; common medium distinct dark reddish brown (5YR 3/4) re4dox concentrations; moderate coarse prismatic structure; very hard, very firm, moderately sticky and very plastic; few fine roots; common medium tubular and interstitial pores; few moderately thick black (5YR 2/1) organic coatings on faces of peds; extremely acid (pH 4.0); abrupt smooth boundary. (5 to 12 inches thick)

2Oa--23 to 25 inches; black (5YR 2/1) muck, dark reddish brown (5YR2/2) dry; massive; hard, friable; few fine roots; porous; extremely acid (pH 4.4); abrupt smooth boundary. (0 to 6 inches thick)

2Cg--25 to 55 inches; very dark grayish brown (2.5Y 3/2) clay; light brownish gray (2.5Y 6/2) dry; massive; very hard, very firm, very sticky and very plastic; strong sulfur smell; very strongly acid (pH 4.5).

TYPE LOCATION: Grays Harbor County, Washington; 1 mile west of South Aberdeen on State Highway 105; 100 feet south of road into field; opposite locked gate to private road; NW1/4 NW1/4 NE1/4 section 20, T.17N., R.9W., WM.

RANGE IN CHARACTERISTICS: These soils are saturated most of the year unless artificially drained. The solum is 14 to 26 inches thick. Rooting depth is normally limited to less than 20 inches because of continuous high-water tables. The mean annual soil temperature is 48 to 52 degrees F. The solum is very strongly acid or extremely acid. The control section is dominantly clay or silty clay, averages 45 to 60 percent clay and contains less than 15 percent rock fragments.

The A horizon has hue of 10YR through 5Y, value of 4 or 5 moist, 5 or 6 dry, chroma of 1 or 2 moist or dry, and is mottled. It is silty clay loam or silty clay. This horizon has moderate or strong angular or subangular blocky structure.

The Bg horizon has hue of 2.5Y or 5Y, value of 5 or 6 dry, and is mottled. It is dominantly silty clay or clay but includes silty clay loam. It has a moderate or strong prismatic structure.

The 2Cg horizon has hue of 2.5Y or 5Y and value of 3 or 4 moist, 4 through 6 dry. It is stratified from clay to silt loam. The Oa horizon may occur at any depth within the upper 60 inches. Total combined thickness of the Oa horizons is less than 12 inches.

COMPETING SERIES: There are no competing series.

GEOGRAPHIC SETTING: The Ocosta soils are in flat or depressed areas and are subject to tidal overflow during storms and high tides unless protected by dikes. The soils formed in clayey alluvium deposited in the quiet water of coastal bays. These soils occur in a coastal marine climate with relatively cool summers and mild wet winters. They have an annual precipitation of 70 to 100 inches. The average January temperature is 39 degrees F.; the average July temperature is 62 degrees F.; and the mean annual temperature is 50 degrees F. The growing season (28 degrees F.) is 180 to 250 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Orcas soils and the competing Rennie soils. Orcas soils are organic.

DRAINAGE AND PERMEABILITY: Poorly drained; slow runoff or ponded; very slow permeability.

USE AND VEGETATION: Undeveloped areas have sedge, reed, saltgrass, cattail cover with occasional spruce trees; considerable areas have been diked and drained and used for native pasture.

DISTRIBUTION AND EXTENT: Coastal areas of western Washington. This soil is of moderate extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Portland, Oregon

SERIES ESTABLISHED: Grays Harbor County (Grays Harbor County Area), Washington, 1970.

REMARKS: Diagnostic horizons and other features:
Cambic horizon from 10 to 23 inches (Bg horizons).

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ORCAS SERIES

The Orcas series consists of very deep, very poorly drained organic soils formed from sphagnum moss. Orcas soils occupy depressions on the glacial drift plains and have slopes of 0 to 2 percent. Mean annual precipitation is about 47 inches and the mean annual temperature is about 50 degrees F.

TAXONOMIC CLASS: Dysic, mesic Typic Sphagnofibrists

TYPICAL PEDON: Orcas peat, abandoned pasture. (Colors are for moist soil unless otherwise stated.)

Oi1--0 to 3 inches; dark reddish brown (5YR 2/2) (broken face) peat (fibric material), dark reddish brown (5YR 3/4) pressed and rubbed; about 90 percent fibers, 80 percent rubbed; weak thick platy structure; very friable, nonsticky, nonplastic; many very fine and fine roots; extremely acid (pH 4.4); clear smooth boundary. (3 to 10 inches thick)

Oi2--3 to 12 inches; dark brown (7.5YR 3/2) (broken face, pressed and rubbed) peat (fibric material); about 95 percent fibers, 90 percent rubbed; weak thick platy structure; nonsticky, nonplastic; few fine roots; extremely acid (pH 4.4); abrupt smooth boundary. (6 to 14 inches thick)

Oi3--12 to 60 inches; brown (7.5YR 4/4) (broken face) peat (fibric material), reddish yellow (7.5YR 7/6) pressed and rubbed; about 95 percent fibers, 90 percent rubbed; massive; nonsticky and nonplastic; extremely acid (pH 4.4).

TYPE LOCATION: Snohomish County, Washington; 2,190 feet north and 2,125 feet east of the SW corner of section 18, T.30N., R.7E.

RANGE IN CHARACTERISTICS:

Mean annual soil temperature - 47 to 50 degrees F

Oi1 horizon
Hue - 2.5 YR through 10YR
Value - 2 to 4 moist, 4 or 5 dry
Chroma - 2 to 4 moist and dry

Oi2 and Oi3 horizons
Hue - 5YR through 10YR
Value - 3 to 7 moist, 4 to 6 dry
Chroma - 3 to 8 moist and dry
Fiber content - 70 to 95 unrubbed and 50 to 90 percent rubbed
Reaction - extremely acid or very strongly acid

COMPETING SERIES: There are no competing series in this family.

GEOGRAPHIC SETTING: Orcas soils are in depressions on glacial outwash plains at elevations of 0 to 1,000 feet. Slopes are 0 to 2 percent. The soils formed in sphagnum moss with some herbaceous plants. The water table is near the surface most of the year. The soils are in humid climates that have cool, dry summers and mild, wet winters. Mean annual precipitation ranges from 18 to 90 inches, most of which falls between October and April. Some snow falls in winter. Mean January temperature is 38 degrees F;

the mean July temperature is 60 degrees F; and the mean annual temperature is about 50 degrees F. The frost free season is 160 to 240 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Alderwood, Everett, Harstine, Norma, Bellingham, Mukilteo, and Shalcar soils. Alderwood, Everett, and Harstine soils are moderately well and somewhat excessively drained mineral soils. Norma and Bellingham soils are poorly drained mineral soils. Mukilteo soils are dominantly hemic soil material. Shalcar soils have 16 to 50 inches of sapric material over mineral soil.

DRAINAGE AND SATURATED HYDRAULIC CONDUCTIVITY: Very poorly drained; very high saturated hydraulic conductivity.

USE AND VEGETATION: Orcas soils are used for wildlife habitat and when drained are used for cranberries and pasture. The native vegetation is living sphagnum moss, Labrador tea, wild cranberry, and hardhack

DISTRIBUTION AND EXTENT: Western Washington. The series is of small extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Portland, Oregon

SERIES ESTABLISHED: Mason County, Washington, 1958.

REMARKS: Diagnostic horizons and features recognized in this pedon include a surface and subsurface tier of fibric sphagnum from the surface to 60 inches averaging about 90 percent fiber rubbed.

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SEASTRAND SERIES

Landscape--coastal plains
Landform--interdunes, depressions
Slope--0 to 2 percent
Parent material--moderately decomposed organic material over tidal alluvium
Mean annual precipitation--2000 mm
Mean annual air temperature--9 degrees C
Depth class--very deep
Drainage class--very poorly drained
Soil moisture regime--aquic
Soil temperature regime--isomesic
Soil moisture subclass--typic

TAXONOMIC CLASS: Sandy or sandy-skeletal, mixed, dysic, isomesic Terric Haplohemists

TYPICAL PEDON: Seastrand mucky peat under scattered western redcedar and Sitka spruce, on a level interdune at an elevation of 3 m (Textures are apparent field textures. When described, the soil was moist throughout.)

Oe1--0 to 15 cm; mucky peat, black (10YR 2/1) broken face, rubbed and pressed, moist; weak fine granular structure; many fine and medium and common coarse roots; extremely acid (pH 3.8 in water); clear smooth boundary

Oe2--15 to 38 cm; mucky peat, very dark brown (10YR 2/2) broken face and moist, black (10YR 2/1) rubbed and pressed, moist; weak thin platy structure; common fine and medium roots, few coarse roots; extremely acid (pH 4.0 in water); gradual smooth boundary

Oe3--38 to 76 cm; mucky peat, dark reddish brown (5YR 3/2) broken face and moist, dark reddish brown (5YR 2.5/2) rubbed and pressed, moist; weak coarse subangular blocky structure; few fine, medium, and coarse roots; very strongly acid (pH 5.0 in water); abrupt smooth boundary

2Cg--76 to 150 cm; sand, gray (5Y 5/1) dry, dark grayish brown (10YR 4/2) moist; single grain; loose, nonsticky and nonplastic; few fine roots; very strongly acid (pH 5.0 in water)

TYPE LOCATION: About 225 m north and 430 m west of the southeast corner of section 6, T. 15 N., R. 11 W., Willamette Meridian; latitude 46.8110140 degrees north, longitude -124.0873760 degrees west, WGS 84 (coordinates estimated from historical location description)

RANGE IN CHARACTERISTICS:
Mean annual soil temperature--8 to 11 degrees C
Depth to terric feature--45 to 125 cm

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Reaction (pH measured in water)--3.5 to 5.0
Organic material--moderately decomposed sedges or rushes

Oe horizon
Hue--10YR, 7.5YR, 5YR
Value--2 to 3 moist
Chroma--1 to 4 moist
Fibers--35 to 70 percent unrubbed, 15 to 35 percent rubbed

2Cg horizon
Hue--10YR, 5Y
Value--4 or 5 moist or dry
Chroma--1 or 2 moist or dry
Rock fragment content--0 to 15 percent gravel

COMPETING SERIES:
Bergsvik--15 to 50 percent rubbed fiber content; hue of 7.5YR to 2.5Y in C horizon; ranges to fine sand in C horizon

GEOGRAPHIC SETTING:
Elevation--0 to 8 m
Climate--marine; cool, moist summers; cool, wet winters
Mean annual precipitation--1500 to 2500 mm
Mean annual air temperature--7 to 10 degrees C
Frost-free period--160 to 220 days

GEOGRAPHICALLY ASSOCIATED SOILS:
Netarts, Newskah, Willapa--mineral soil material; on adjacent hillslopes and terraces
Orcas--90 to 95 percent fibric material; no terric feature; in nearby depressions
Westport--mineral soil material; on adjacent coastal dunes
Yaquina--mineral soil material; in nearby interdunal depressions

DRAINAGE AND SATURATED HYDRAULIC CONDUCTIVITY:
Drainage class--very poorly drained
Saturation in normal years--saturated to the soil surface in all months unless drained
Flooding--rare
Ponding--long, frequent periods in January through December
Saturated hydraulic conductivity (Ksat)--high in Oe horizon, very high in 2Cg horizon

USE AND VEGETATION:
Use--wildlife habitat, commercial cranberry production, pasture
Potential natural vegetation--Sitka spruce, western redcedar, slough sedge, tule, common spikerush,

narrowleaf bur-reed, panicled bulrush

DISTRIBUTION AND EXTENT: Olympic Peninsula coast, Washington; MLRA 4; small extent

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Portland, Oregon

SERIES ESTABLISHED: Pacific County, Washington; 1978

REMARKS:
Diagnostic horizons and other features in this pedon
*Terric feature--zone from 76 to 150 cm
*Hemic material--zone from the surface to a depth of 76 cm
*Particle-size control section--zone from 76 to 106 cm
*Histosols control section--zone from the surface to a depth of 130 cm

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YAQUINA SERIES

The Yaquina series consists of very deep, somewhat poorly drained soils that formed in mixed alluvium. These soils are on terraces and have slopes of 0 to 5 percent. The average annual precipitation is about 70 inches, and the average annual temperature is about 51 degrees F.

TAXONOMIC CLASS: Sandy, isotic, isomesic Typic Endoaquods

TYPICAL PEDON: Yaquina loamy fine sand, grassland. (Colors are for moist soil unless otherwise noted.)

Oi--0 to 1 inch; partially decomposed grass, leaves, and moss.

E--1 to 7 inches; gray (10YR 5/1) loamy fine sand, light gray (10YR 7/1) dry; single grain; loose; many very fine, fine and medium roots; many very fine irregular pores; very strongly acid (pH 4.8); clear wavy boundary. (4 to 8 inches thick)

Bs1--7 to 15 inches; dark grayish brown (2.5Y 4/2) fine sand, light brownish gray (2.5Y 6/2) dry; many olive brown and light olive brown sand grains; single grain; loose; common very fine, fine and medium roots; many very fine irregular pores; common firm yellowish red (iron-cemented) nodules; very strongly acid (pH 5.0); gradual wavy boundary. (6 to 12 inches thick)

Bs2--15 to 31 inches; grayish brown (2.5Y 5/2) fine sand, light brownish gray (2.5Y 6/2) dry; few olive brown (2.5Y 4/4) sand grains; single grain; loose; few fine roots; many very fine irregular pores; common coarse faint and few medium distinct pale brown (10YR 6/3) and yellowish brown (10YR 5/6) masses of iron accumulation; common medium and fine soft yellowish red (iron-cemented) nodules; strongly acid (pH 5.4); gradual wavy boundary. (12 to 20 inches thick)

C--31 to 61 inches; variegated light olive brown (2.5Y 5/4), pale brown (10YR 6/3), dark reddish gray (5YR 4/2), and pinkish gray (5YR 6/2) fine sand; single grain; loose; strongly acid (pH 5.2).

TYPE LOCATION: Tillamook County, Oregon; about 1 mile southwest of town of Nehalem, 2,220 feet south of U.S. Highway 101 and 300 feet east of north-south road 1/2 mile west of Nehalem; SW1/4 SE1/4 of section 28, T. 3 N., R. 10 W. (Latitude 45 degrees, 42 minutes, 41 seconds N. and Longitude 123 degrees, 54 minutes, 43 seconds W.)

RANGE IN CHARACTERISTICS: Unless artificially drained, the soil is continually saturated with water most of the year. The soil is over 60 inches thick, but rooting depth is limited by a water during the winter months below a depth of 24 inches and is saturated to the surface for brief periods during storm periods. The soil is over 60 inches deep to bedrock, but rooting depth is limited by the water table. The mean annual soil temperature is 47 to 54 degrees F. The difference between the mean summer and mean winter soil temperature varies from 5 to 9 degrees F. The solum commonly is underlain by many feet of variegated sand, but in some places it is underlain by buried soils formed in finer textured marine sediments or organic or mineral soil material at a depth greater than 40 inches.

The E horizon has value of up through 6 moist, and chroma of 1 or 2. It is loamy fine sand or fine sand. The thickness varies considerably within a horizontal distance of only a few yards.

The Bs horizon has hue of 5Y to 5YR, value of 4 or 5 moist, 5 or 6 dry, and chroma of 2 or 3 moist and dry. Redox features are faint or distinct with hue of 2.5Y and 10YR, value of 4 to 6, and chroma of 2 to 6 moist. Firm or very firm reddish colored weakly cemented nodules and thin very firm lenses are common throughout.

The BC horizon, when present, has color similar to the Bs horizon.

COMPETING SERIES: There are no competing series. The Blacklock and Netarts soils are similar. Blacklock soils are poorly drained, contain higher organic matter and have ortstein in the B horizon. Netarts soils are well drained and lack redox features.

GEOGRAPHIC SETTING: Yaquina soils are on terraces and low interdune positions along the Oregon and Washington coastline at elevations ranging from 0 to 130 feet. Slopes are 0 to 5 percent. The soil formed in beach and dune sands that have been nearly leveled by wind and water action. The climate is characterized by cool, wet winters and cool, moist summers with fog. The average annual precipitation is 60 to 120 inches. The average January temperature is 41 degrees F., the average July temperature is 61 degrees F., and the average annual temperature is 45 to 53 degrees F. The frost-free period is 160 to 300 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Depoe, Gearhart, Heceta, Nelscott, Netarts, Waldport, Warrenton and Westport soils. Depoe soils are fine-loamy and have ortstein. Netarts, Gearhart, Waldport and Westport soils are well or excessively drained on stabilized dunes. Heceta and Warrenton soils are poorly drained and lack E and Bs horizons. Nelscott soils are moderately well drained, are fine-loamy over sandy or sandy-skeletal, and have a Bsm horizon.

DRAINAGE AND PERMEABILITY: Somewhat poorly drained; moderately rapid permeability. An apparent water table is at its uppermost limit during periods from November through April.

USE AND VEGETATION: Cleared areas are used for pasture and homesites. Native vegetation is mostly shore pine, Pacific rhododendron, azalea, spiraea, salal, evergreen huckleberry, and scattered Sitka spruce.

DISTRIBUTION AND EXTENT: Coastal areas of Oregon and Washington; MLRA 4A. The series is of small extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Portland, Oregon

SERIES ESTABLISHED: Tillamook County, Oregon, 1961.

REMARKS: This draft reflects a change in classification from sandy, isotic, isomesic Aquentic Haplorthods to sandy, isotic, isomesic Typic Endoaquods based on Soil Taxonomy 8th edition.

Diagnostic horizons and features in this pedon include:
Albic horizon - from 1 to 7 inches (E horizon).
Spodic Horizon - from 7 to 31 inches (Bs1 and Bs2 horizons).
Redox concentrations - from 15 to 31 inches (Bs2 horizon).

ADDITIONAL DATA: Characterization data for 2 pedons (S74 Oreg. 11-17 and S74 Oreg. 11-21) sampled in Coos County Oregon, SCS, Riverside Soil Survey Lab in computer printout form. Characterization data for one pedon (S73 Oreg. 20-3) by Oregon State University - unpublished.

National Cooperative Soil Survey
U.S.A.

SALZER SERIES

Landscape--river valleys
Landform--oxbows, backswamps, depressions
Slope--0 to 3 percent
Parent material--alluvium
Mean annual precipitation--about 1500 mm
Mean annual air temperature--about 11 degrees C
Depth class--very deep
Drainage class--very poorly drained
Soil moisture regime--aquic
Soil temperature regime--mesic
Soil moisture subclass--typic

TAXONOMIC CLASS: Fine, smectitic, acid, mesic Vertic Endoaquepts

TYPICAL PEDON: Salzer silty clay loam (When described on October 21, 2015, the soil was moist to a depth of 15 cm and wet below that depth.)

A--0 to 15 cm; silty clay loam, very dark grayish brown (10YR 3/2) moist, dark grayish brown (10YR 4/2) dry; moderate fine granular structure; slightly hard, friable, slightly sticky and moderately plastic; many very fine and few medium and coarse roots; many very fine to few medium irregular pores; 25 percent fine prominent yellowish red (5YR 4/6) masses of oxidized iron lining pores; very strongly acid (pH 4.6); abrupt smooth boundary

Bg1--15 to 32 cm; clay, very dark gray (N 3/0) moist, gray (5Y 5/1) dry; moderate fine subangular blocky structure; moderately hard, friable, moderately sticky and moderately plastic; common very fine to many coarse roots; common very fine tubular pores; 25 percent medium prominent yellowish red (5YR 4/6) masses of oxidized iron lining pores; very strongly acid (pH 4.6); clear wavy boundary

Bg2--32 to 75 cm; clay, dark gray (N 4/0) moist, gray (5Y 6/1) dry; weak fine subangular blocky structure; moderately hard, firm, very sticky and very plastic; few very fine to coarse roots; common very fine tubular pores; very strongly acid (pH 4.6); abrupt wavy boundary

Cg1--75 to 100 cm; clay, dark gray (N 4/0) moist, gray (5Y 6/1) dry; massive; moderately hard, firm, very sticky and very plastic; few very fine roots; common very fine tubular pores; 15 percent wood fragments; very strongly acid (pH 4.8); clear wavy boundary

Cg2--100 to 150 cm; clay, very dark gray (N 3/0) moist, gray (5Y 5/1) dry; massive; moderately hard, firm, very sticky and very plastic; few very fine roots; common very fine tubular pores; very strongly acid (pH 4.8)

TYPE LOCATION: Grays Harbor County, Washington, about 4.5 km southwest of Rochester and about 260 m south of Independence Road SW; about 710 m west and 795 m north of the southeast corner of section 11, T.15 N., R.4 W., Willamette Meridian; Oakville, Washington, U.S. Geological Survey quadrangle; latitude 46.8003990 degrees north, longitude 123.1489810 degrees west, WGS 84 (coordinates determined with a GPS)

RANGE IN CHARACTERISTICS:
Mean annual soil temperature--10 to 12 degrees C
Depth to aquic conditions--0 to 30 cm
Depth to cracks 1 cm wide or more upon drying--0 to 60 cm
Particle-size control section--40 to 60 percent clay (weighted average)

O horizon (where present)
Thickness--5 to 20 cm

A horizon
Hue--10YR to 2.5Y, neutral
Value--2 to 4 moist, 4 to 7 dry
Chroma--neutral, 1 or 2 moist or dry
Fine-earth texture--silty clay loam, silt loam, silty clay
Clay content--25 to 50 percent
Reaction (pH)--3.5 to 5.0
Combined thickness--10 to 20 cm

Bg horizon
Hue--2.5Y, 5Y, neutral
Value--3 to 6 moist, 6 or 7 dry
Chroma--neutral, 1 or 2 moist or dry
Fine-earth texture--clay, silty clay
Clay content--40 to 60 percent
Reaction (pH)--3.5 to 5.0
Combined thickness--50 to 130 cm

Cg horizon
Hue--2.5Y, 5Y, neutral
Value--3 to 6 moist, 5 to 7 dry
Chroma--neutral, 1 or 2 moist or dry
Fine-earth texture--clay, silty clay, sandy clay loam, clay loam, silty clay loam
Clay content--30 to 50 percent
Reaction (pH)--4.5 to 6.0

COMPETING SERIES:

CAPE--mean annual soil temperature of 11 to 15 degrees C; pH of 3.5 to 5.5; no redoximorphic features or aquic conditions within 15 cm of the soil surface

GEOGRAPHIC SETTING:
Elevation--5 to 150 m
Mean annual precipitation--1000 to 1800 mm
Mean annual air temperature--10 to 11 degrees C
Frost-free period--150 to 200 days

GEOGRAPHICALLY ASSOCIATED SOILS:
RENNIE--18 to 35 percent clay (weighted average) in particle-size control section; pH of 5.0 or more in control section; on similar landforms
CHEHALIS, **ELD**--no aquic conditions; on flood plains
MAYTOWN--no aquic conditions within 50 cm of the soil surface; in concave to linear positions of flood plains

DRAINAGE AND SATURATED HYDRAULIC CONDUCTIVITY:
Drainage class--very poorly drained
Depth to apparent seasonal water table--at the surface to a depth of 30 cm at times in October through May, at the surface to a depth of more than 100 cm in June through September
Flooding--frequent, brief to long periods in November through April
Ponding--frequent, long or very long periods in October through June
Saturated hydraulic conductivity (Ksat)--low to moderately high in A horizon, very low to moderately low in Bg and Cg horizons

Ponding and the seasonal high water table in some pedons may be altered by artificial drainage. Flooding in some pedons may be altered by flood protection structures.

USE AND VEGETATION:
Use--wildlife habitat, livestock grazing, hay and crop production in cleared and/or artificially drained or protected areas
Native vegetation--Douglas spirea, redosier dogwood, willow, skunk cabbage, slough sedge, and bulrush; some areas have an overstory of red alder and Oregon ash

DISTRIBUTION AND EXTENT: Southwestern Washington; MLRA 2; moderate extent

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Portland, Oregon

SERIES ESTABLISHED: Grays Harbor County (Grays Harbor County Area), Washington; 1970

REMARKS:
Diagnostic horizons and other features in this pedon

*Particle-size control section--zone from 25 to 100 cm
*Ochric epipedon
*Cambic horizon--zone from the surface to a depth of 75 cm
*Aquic conditions--zone from the surface to a depth of 150 cm
*Endosaturation--zone from the surface to a depth of 150 cm
*Reduced matrix--zone from 15 to 150 cm

04/1994--Previously classified as fine, montmorillonitic, acid, mesic Vertic Haplaquepts; classification change based on amendments to Soil Taxonomy.

11/2016--Based on update field investigations, the type location was moved and the series concept was limited to MLRA 2 soils with endosaturation. The official series description was edited according to SSR01 Technical Note--Content and Format of Official Series Descriptions (revised 12/2015). Further field investigation to recorrelate Salzer soils mapped in the flood plains of MLRAs 1 and 4a is recommended.

FLUVAQUENTS, TIDAL

Map Unit Setting

- *National map unit symbol:* 2gm8
- *Elevation:* 0 to 100 feet
- *Mean annual precipitation:* 30 to 100 inches
- *Mean annual air temperature:* 50 degrees F
- *Frost-free period:* 200 to 240 days
- *Farmland classification:* Not prime farmland

Map Unit Composition

- *Fluvaquents and similar soils:* 100 percent
- *Estimates are based on observations, descriptions, and transects of the mapunit.*

Description of Fluvaquents

Setting

- *Landform:* Tidal flats, deltas, flood plains
- *Parent material:* Alluvium

Typical profile

- *H1 - 0 to 6 inches:* very fine sand
- *H2 - 6 to 60 inches:* stratified sand to silty clay

Properties and qualities

- *Slope:* 0 to 1 percent
- *Depth to restrictive feature:* More than 80 inches
- *Drainage class:* Very poorly drained
- *Capacity of the most limiting layer to transmit water (Ksat):* Moderately low to moderately high (0.06 to 0.20 in/hr)
- *Depth to water table:* About 0 inches
- *Frequency of flooding:* Very frequent
- *Frequency of ponding:* None
- *Maximum salinity:* Moderately saline to strongly saline (8.0 to 16.0 mmhos/cm)
- *Available water supply, 0 to 60 inches:* Low (about 3.8 inches)

Interpretive groups

- *Land capability classification (irrigated):* None specified.
- *Land capability classification (nonirrigated):* 6w
- *Hydrologic Soil Group:* C/D
- *Hydric soil rating:* Yes

BEACHES

Map Unit Setting

National map unit symbol: 2gnq
Mean annual precipitation: 42 to 48 inches
Mean annual air temperature: 52 to 57 degrees F
Frost-free period: 190 to 210 days
Farmland classification: Not prime farmland

Map Unit Composition

Beaches: 100 percent

Description of Beaches

Setting

Landform: Beaches
Parent material: Beach sand and gravelly sand

Typical profile**--***H1 - 0 to 60 inches:* Error

Properties and qualities

Slope: 1 to 5 percent
Depth to water table: About 0 inches
Frequency of flooding: Very frequent

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydric soil rating: No

SEASTRAND VARIANT MUCK

Map Unit Setting

National map unit symbol: 2gk7
Elevation: 0 to 660 feet
Mean annual precipitation: 60 to 90 inches
Mean annual air temperature: 48 to 52 degrees F
Frost-free period: 160 to 180 days
Farmland classification: Not prime farmland

Map Unit Composition

Seastrand variant, drained, and similar soils: 70 percent
Seastrand, undrained, and similar soils: 15 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Seastrand Variant, Drained

<u>Setting</u>

Landform: Depressions
Parent material: Herbaceous organic material

<u>Typical profile</u>

Oa - 0 to 18 inches: muck
Oe - 18 to 60 inches: mucky peat

<u>Properties and qualities</u>

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Available water supply, 0 to 60 inches: Very high (about 26.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B/D
Ecological site: R004AA005WA - Bog or Fen
Forage suitability group: Wet Soils (G004AC102WA)
Other vegetative classification: Wet Soils (G004AC102WA)
Hydric soil rating: Yes

Description of Seastrand, Undrained

Setting

Landform: Depressions
Parent material: Herbaceous organic material over beach sand

Typical profile

H1 - 0 to 30 inches: mucky peat
H2 - 30 to 60 inches: sand

Properties and qualities

Slope: 0 to 1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Available water supply, 0 to 60 inches: Very high (about 15.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B/D
Forage suitability group: Wet Soils (G004AC102WA)
Other vegetative classification: Wet Soils (G004AC102WA)
Hydric soil rating: Yes

Minor Components

Yaquina

Percent of map unit: 10 percent
Landform: Depressions
Other vegetative classification: Wet Soils (G004AC102WA)
Hydric soil rating: Yes

Orcas, undrained

Percent of map unit: 5 percent
Landform: Depressions
Other vegetative classification: Wet Soils (G004AC102WA)
Hydric soil rating: Yes

APPENDIX E: Beaufort Wind Wave Scale

Estimating Wind Speed and Sea State with Visual Clues				
Beaufort number	Wind Description	Wind Speed	Wave Height	Visual Clues
0	Calm	0 knots	0 feet	Sea is like a mirror. Smoke rises vertically.
1	Light Air	1-3 kts	< 1/2	Ripples with the appearance of scales are formed, but without foam crests. Smoke drifts from funnel.
2	Light breeze	4-6 kts	1/2 ft (max 1)	Small wavelets, still short but more pronounced, crests have glassy appearance and do not break. Wind felt on face. Smoke rises at about 80 degrees.
3	Gentle Breeze	7-10 kts	2 ft (max 3)	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses (white caps). Wind extends light flag and pennants. Smoke rises at about 70 deg.
4	Moderate Breeze	11-16 kts	3 ft (max 5)	Small waves, becoming longer. Fairly frequent white horses (white caps). Wind raises dust and loose paper on deck. Smoke rises at about 50 deg. No noticeable sound in the rigging. Slack halyards curve and sway. Heavy flag flaps limply.
5	Fresh Breeze	17-21kts	6 ft (max 8)	Moderate waves, taking more pronounced long form. Many white horses (white caps) are formed (chance of some spray). Wind felt strongly on face. Smoke rises at about 30 deg. Slack halyards whip while bending continuously to leeward. Taut halyards maintain slightly bent position. Low whistle in the rigging. Heavy flag doesn't extended but flaps over entire length.
6	Strong Breeze	22-27 kts	9 ft (max 12)	Large waves begin to form. White foam crests are more extensive everywhere (probably some spray). Wind stings face in temperatures below 35 deg F (2C). Slight effort in maintaining balance against wind. Smoke rises at about 15 deg. Both slack and taut halyards whip slightly in bent position. Low moaning, rather than whistle, in the rigging. Heavy flag extends and flaps more vigorous.
7	Near Gale	28-33 kts	13 ft (max 19)	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of wind. Necessary to lean slightly into the wind to maintain balance. Smoke rises at about 5 to 10 deg. Higher pitched moaning and whistling heard from rigging. Halyards still whip slightly. Heavy flag extends fully and flaps only at the end. Oilskins and loose clothing inflate and pull against the body.
8	Gale	34-40 kts	18 ft (max 25)	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind. Head pushed back by the force of the wind if allowed to relax. Oilskins and loose clothing inflate and pull strongly. Halyards rigidly bent. Loud whistle from rigging. Heavy flag straight out and whipping.
9	Strong Gale	41-47 kts	23 ft (max 32)	High waves. Dense streaks of foam along direction of wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	Storm	48-55 kts	29 ft (max 41)	Very high waves with long overhanging crests. The resulting foam, in great patches is blown in dense streaks along the direction of the wind. On the whole, the sea takes on a whitish appearance. Tumbling of the sea becomes heavy and shock-like. Visibility affected.
11	Violent Storm	56-63 kts	37 ft (max 52)	Exceptionally high waves (small and medium-sized ships might be for time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are blown into froth. Visibility greatly affected.
12	Hurricane	64+ kts	45+ ft	The air is filled with foam and spray. The sea is completely white with driving spray. Visibility is seriously affected.

Source: [NOAA. https://www.weather.gov/pqr/beaufort](https://www.weather.gov/pqr/beaufort)

FACET