Tillamook County
Estuarine Resilience Action Plan

Tillamook Bay during King Tides, 2014

2023

Prepared for the communities and residents of Tillamook County
with support from the Tillamook Estuaries Partnership
and the UO Institute for Policy Research and Engagement

NATIONAL FISH AND WILDLIFE FOUNDATION NFWF

OREGON
Coastal Management Program
DEPARTMENT OF LAND CONSERVATION & DEVELOPMENT

Tillamook County
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Financial assistance for this plan was provided by the National Fish and Wildlife Foundation National Coastal Resilience Fund, which aims to utilize nature-based solutions to strengthen natural hazard resilience in coastal communities.

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Cover photo: Tillamook Bay during a king tide event. January 2, 2014
Courtesy of The Wetlands Conservancy and LightHawk.

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Wild Salmon Center

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Acronyms

ADA – Americans with Disabilities Act
BRIC – (FEMA) Building Resilience Infrastructure and Communities grant
CARE – Community Action Resource Enterprises
CCMP – (TEP) Comprehensive Conservation and Management Plan
CMECS – Coastal and Marine Ecological Classification Standard
CO_2 – Carbon Dioxide
CUSP – Continually Updated Shoreline Product
CVA – Climate Vulnerability Assessment
CTGR – Confederated Tribes of Grand Ronde
DEQ – (Oregon) Department of Environmental Quality
DLCD – (Oregon) Department of Land Conservation and Development
DO – Dissolved Oxygen
DOGAMI – (Oregon) Department of Geological and Mineral Industries
DSL – (Oregon) Department of State Lands
EMP – Estuary Management Plan (DLCD)
EMS – Emergency Medical Services
ENSO – El Niño Southern Oscillation
EPA – (United States) Environmental Protection Agency
EQIP – (USDA NRCS) Environmental Quality Incentives Program
ERAP – Estuarine Resilience Action Plan (this document)
ESA – Endangered Species Act
FEMA – Federal Emergency Management Agency
IAE – Institute for Applied Ecology
ICLEI - International Council for Local Environmental Initiatives
IPRE – (University of Oregon) Institute for Policy Research and Engagement
LNCT – Lower Nehalem Community Trust
LNWC – Lower Nehalem Watershed Council
LUBA – (Oregon) Land Use Board of Appeals
LWCF – (OPRD) Land and Water Conservation Fund
LWD – Large Woody Debris
MTR – Muted Tidal Regulator
NBS – Nature Based Solutions
NCLC – North Coast Land Conservancy
NCRF – (NFWF) National Coastal Resilience Fund
NFWF – National Fish and Wildlife Foundation
NHD – National Hydrography Dataset
NHMP – Natural Hazard Mitigation Plan

NMFS – (NOAA) National Marine Fisheries Service
NNSLWC – Nestucca, Neskowin, and Sand Lake Watersheds Council
NOAA – National Ocean and Atmospheric Administration
NRCS – (USDA) Natural Resources Conservation Service
OA – Ocean Acidification
OCCEC – Oregon Central Coast Estuary Collaborative
OCMP – Oregon Coastal Management Program
OCRF – (ODFW) Oregon Conservation and Recreation Fund
OCVA – Oregon Coast Visitors Association
ODA – Oregon Department of Agriculture
ODFW – Oregon Department of Fish and Wildlife
ODOT – Oregon Department of Transportation
OEM – (Oregon) Office of Emergency Management
OPRD – Oregon Department of Parks and Recreation
OSU – Oregon State University
OWEB – Oregon Watershed Enhancement Board
PGE – Portland General Electric
PLO – Private Landowner(s)
PMEP – Pacific Marine and Estuaries Fish Habitat Partnership
RCPP – (USDA NRCS) Regional Conservation Partnership Program
RFP – Request For Proposals
RM – River Mile
SAP – Strategic Action Plan
SLR – Sea Level Rise
SSH – Salmon SuperHwy
SWCD – Soil and Water Conservation District
TBCC – Tillamook Bay Community College
TC – Tillamook County
TCCA – Tillamook County Creamery Association
TCMJ NHMP – Tillamook County Multi-Jurisdictional NHMP
TCPW – Tillamook County Public Works Department
TC SWCD – Tillamook County Soil and Water Conservation District
TEP – Tillamook Estuaries Partnership
TNC – The Nature Conservancy
TPUD – Tillamook People's Utility District
TU – Trout Unlimited
TWG – Tillamook Working Group
USACE – United States Army Corps of Engineers
USDA – United States Department of Agriculture

USDOT – United States Department of Transportation
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey
VA – Vulnerability Assessment
WSC – Wild Salmon Center

Nehalem Bay, 2012. Photo courtesy of LM Manz.

I. Introduction

Oregon's coastal population is largely situated around its estuaries. These communities are positioned to be disproportionately impacted by the threat of storms, floods, climate change, sea level rise, and other natural hazards, yet also stand to benefit the most from efforts to strengthen and restore natural systems. As the number of coastal residents and visitors continues to increase, this balance between vulnerability and buffering capacity will only be tipped by strong and deliberate efforts in coastal resilience planning and management.

Oregon has long been an innovator in estuarine planning and management, and leveraging these efforts enables coastal communities to capitalize on and expand local capacity for coastal resilience planning and implementation. Fortunately, many of these efforts have already begun in several coastal counties but vary in nature, focus, and scope. Unifying coastal resilience coordination and planning will bolster current planning efforts underway by local organizations and governments, as well as strengthen organizational and staff partnerships for future coastal planning and management. This action plan utilizes a novel process for estuarine resilience planning that attempts to identify and fill gaps in planning and capacity, leverage current efforts and existing resources, and unify goals and priorities to formalize resilience actions to build local capacity and facilitate future work.

Background and Purpose

In November 2020, the Oregon Department of Land Conservation and Development (DLCD) received funding from the National Fish and Wildlife Foundation's (NFWF) National Coastal Resilience Fund (NCRF[1]) to work with communities and local organizations to develop an Estuarine Resilience Action Plan (ERAP) for Tillamook County estuaries. This process focuses on actions to restore and strengthen natural systems to protect coastal communities from the impacts of storms, floods, and other natural hazards, improve recovery, and enhance fish and wildlife habitats by implementing nature-based solutions that focus on natural (green) infrastructure to increase resilience.

The Tillamook County ERAP (this document) attempts to assess local resilience vulnerabilities and identify and evaluate potential resilience actions. ERAP development is a bottom-up, locally driven process in partnership with stakeholders representing the county, cities, state and federal agencies, watershed councils, and other organizations with relevant interest in estuarine resilience. Coastal Tribal Nations were also invited to participate in the process. The resilience actions identified in this plan have been shaped by stakeholder engagement and feedback, representing local needs and concerns. These results aim to enable participating coastal jurisdictions to understand the scope, impacts, costs, and benefits of potential adaptation actions, prioritize them based on a variety of planning contingencies, and help resilience and natural infrastructure projects advance toward or reach completion.

[1] https://www.nfwf.org/programs/national-coastal-resilience-fund

Estuary Planning Context

Most of Oregon's estuary management plans (EMPs) have seen few updates or revisions since originally developed more than thirty years ago (DLCD 2014a). Despite the general success and durability of these plans, a number of current and anticipated developments indicate the need for modernization. In particular, current drivers for various conservation and restoration initiatives (e.g., salmonid recovery) and the potential impacts from climate change and coastal hazards are largely unanticipated by current plans. The needs and impacts on estuarine planning efforts has already been investigated (DLCD 2014b), and recent studies provide significant information related to wetland and estuary migration (Brophy & Ewald 2017), sea level rise impacts on infrastructure (DLCD 2017), and climate impacts to natural resources and ecosystem services.

A plethora of datasets and mapping tools are available to all Oregon estuary planners and managers, and provide fundamental resource inventory tools for all estuary planning efforts. Examples of these include the Oregon Coastal Management Program's (OCMP) Oregon Coastal Atlas[2] and the Estuary Planning Tool[3]. In the nearly three decades since most of Oregon's EMPs were developed, the widespread public and agency engagement that characterized the original process has waned, reducing their effectiveness as foundational decision-making tools. In some instances, the incorporation of highly detailed development decisions into plans has proven problematic. Changing markets and other forces have resulted in the need to update these highly detailed plans to a scale and frequency beyond the capacity of local governments.

The fact that Oregon incorporated estuary plans into comprehensive growth management plans in the early 1980s remains innovative at the national level today. The desire to further enhance their applicability and incorporate coastal hazards associated with climate change, will provide a holistic approach to understanding and responding to the challenges of the next century. The lessons learned from this project will apply within the state, region, and nation as all estuaries in the country will face similar challenges associated with sea level rise and flooding impacts to infrastructure and natural resources. Oregon's planning-based approach to estuary management has provided a strong foundation for estuarine resource conservation and development decisions. In particular, the management framework's emphasis on advanced decision-making based on spatial planning concepts has proven effective in providing a system-wide approach to management. Likewise, the locally focused nature of the estuary planning process has produced plans with broad-based support and increased awareness of the relationships between traditional community development planning and aquatic resource management.

Development on vulnerable low-lying shorelands is common in Oregon's estuaries. The extent of planning for hazards that threaten these developments such as sea level rise varies along the Oregon Coast, with many communities yet to initiate these efforts. In response to this data gap, an exposure inventory was developed to serve as a statewide resource for sea level rise planning in and around estuaries (DLCD 2017). As sea level rises, Oregon's estuary floodplains

[2] https://www.coastalatlas.net/
[3] https://www.coastalatlas.net/estuarymaps/

will increase in extent (Brophy & Ewald 2017). Land currently in the floodplain will be flooded more frequently, and land outside of the floodplain may become a part of the floodplain. The exposure inventory determined the assets and geographies most likely to be affected by a sea level rise-driven increase in flooding in 21 of Oregon's 22 major estuaries, and prioritized areas to focus future resources and further study.

Study Area

The geographic scope of this work centers on Tillamook County's five major estuaries (Table 1), and the areas that interact directly with the estuarine waterways, habitats, and wildlife. This includes the historic tidal floodplain and communities situated adjacent the estuaries. Of these five, Nehalem and Tillamook Bays are classified as "Shallow-draft Development" management units under Oregon Statewide Land Use Planning Goal 16, which maintains a channel depth of <22ft., and allows for construction and maintenance of jetties, dredging and channelization, and water-dependent commercial activities. Netarts and Nestucca Bays are classified as "Conservation" management units, which seek to limit major alterations of the estuary such as dredging, while still allowing for development including a variety of water-dependent uses, marinas, and aquaculture. The Sand Lake estuary is designated as a "Natural" management unit, which seeks to balance protection of significant or extensive fish and wildlife habitat while limiting development and use.

Table 1. Characteristics of the Five Major Tillamook County Estuaries

Estuary Name	CMECS[4] Classification*	EPA 2010 Classification	DLCD Estuary Management Unit	Estuary Area (acres)**	Historic vegetated tidal wetlands (acres)**	% tidal wetland loss from diking***
Nehalem Bay	Riverine	Highly river dominated drowned river mouth	Shallow-draft	5,253	2,956	54.9
Tillamook Bay	Riverine	Tide dominated drowned river mouth	Shallow-draft	14,023	5,664	71.6
Netarts Bay	Embayment	Bar-built estuary	Conservation	2,634	311	0
Sand Lake	Lagoonal	Bar-built estuary	Natural	1,177	568	11.7
Nestucca Bay	Riverine	Highly river dominated drowned river mouth	Conservation	2,766	1,632	78.3

*Heady et al. 2014
**PMEP 2020
***Brophy 2019

[4] https://iocm.noaa.gov/standards/cmecs-home.html

Figure 1. Nehalem Bay Estuary.

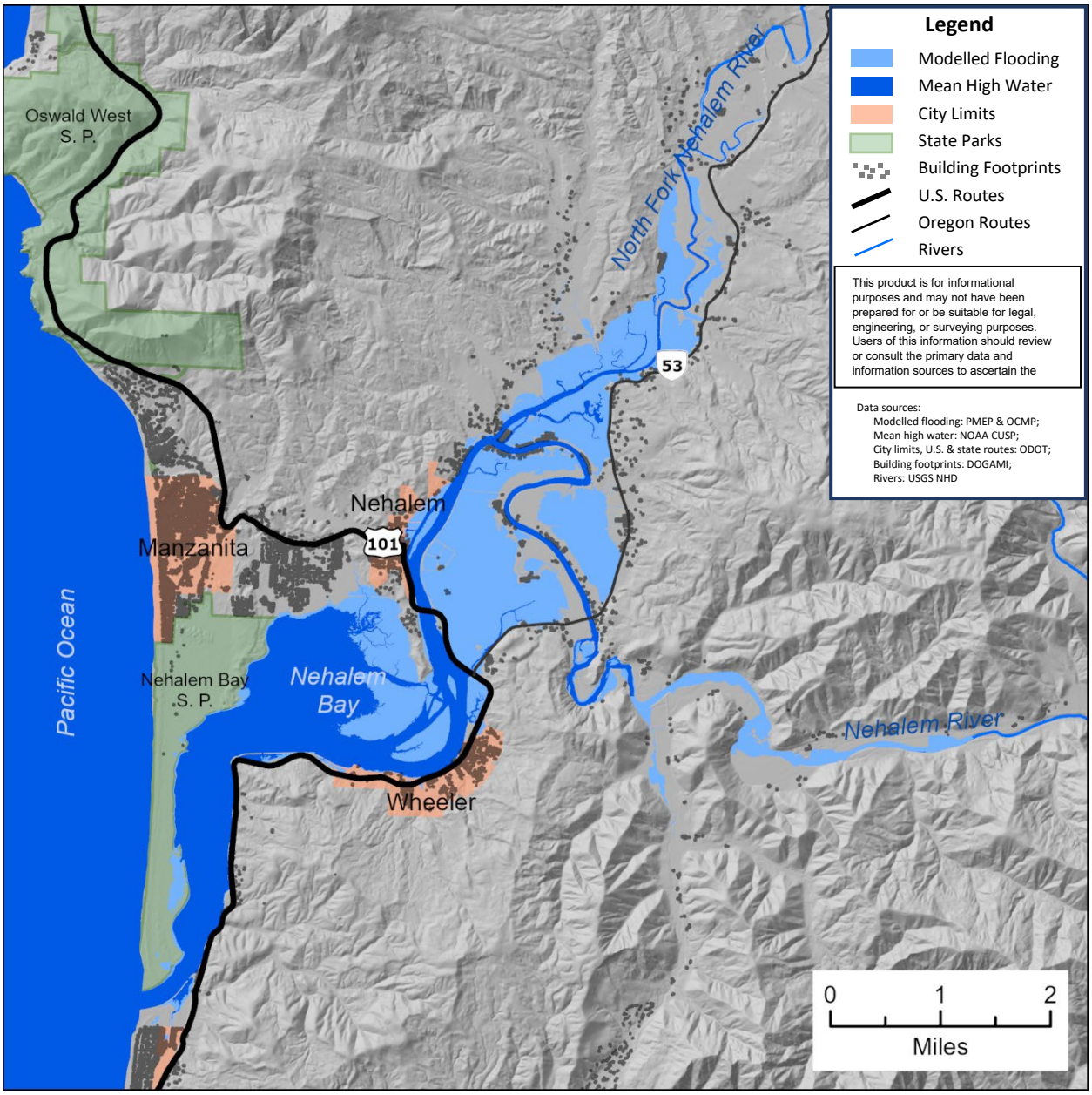


Figure 2. Tillamook Bay and Netarts Bay Estuaries.

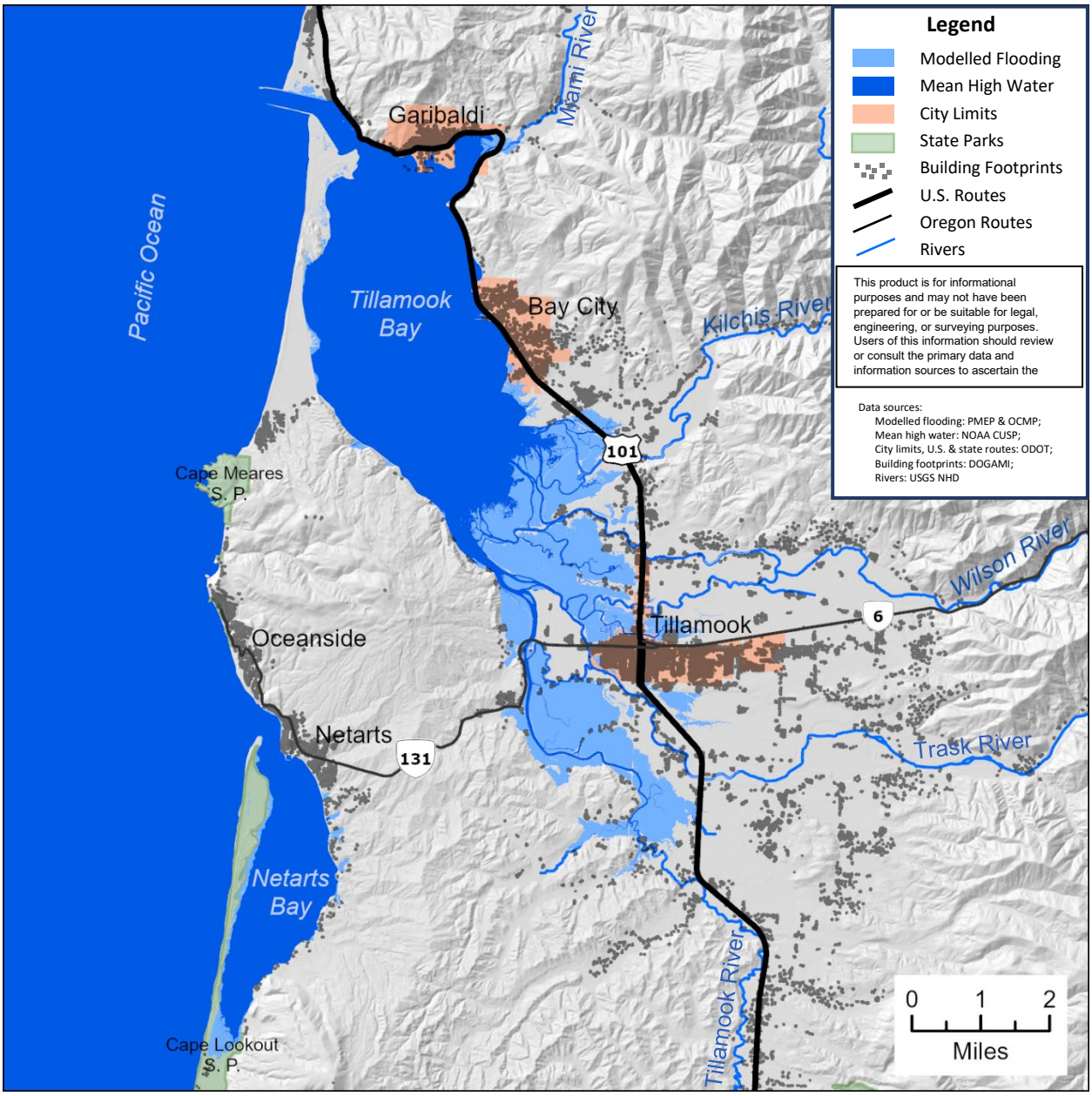


Figure 3. Sand Lake Estuary.

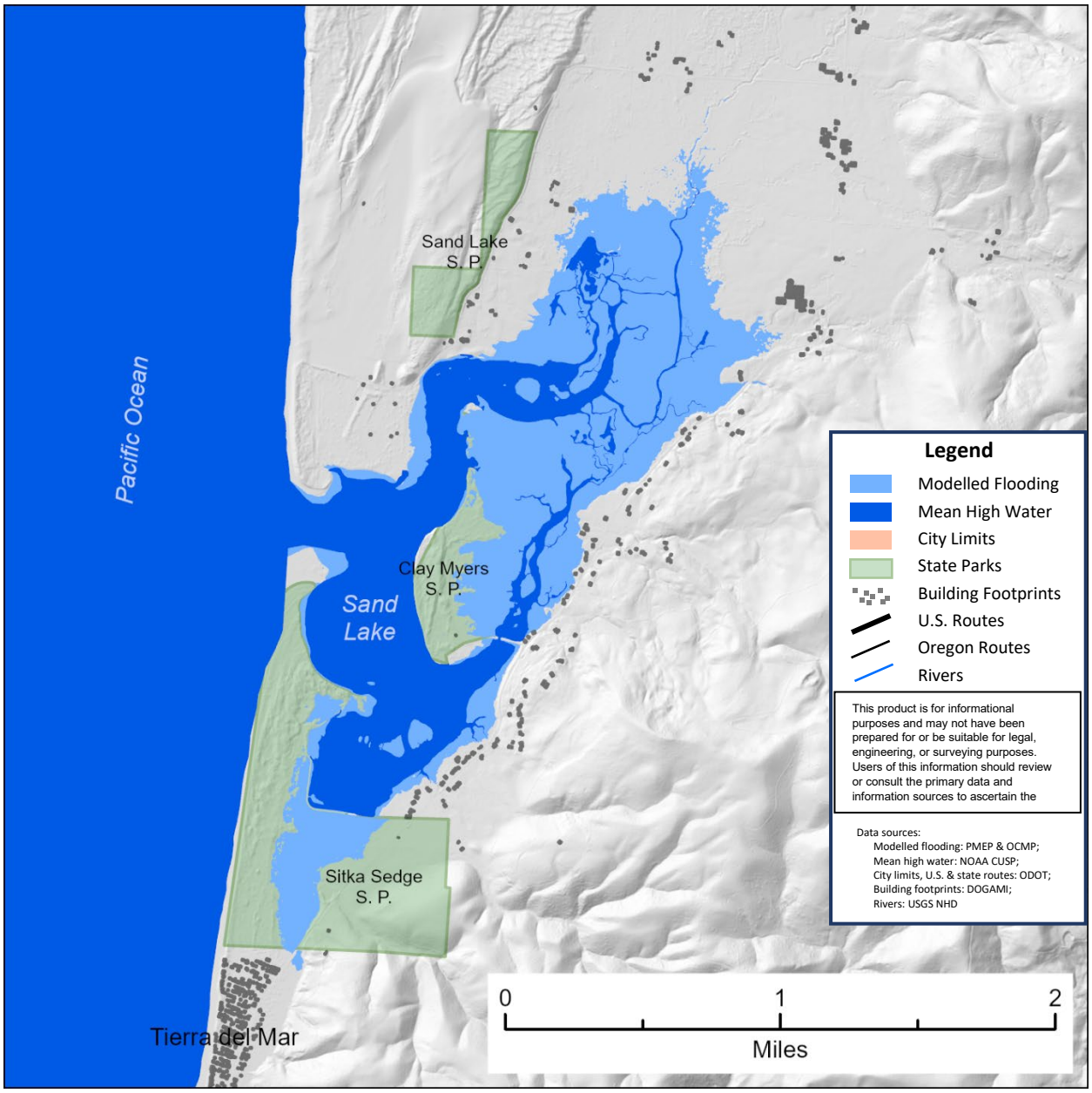
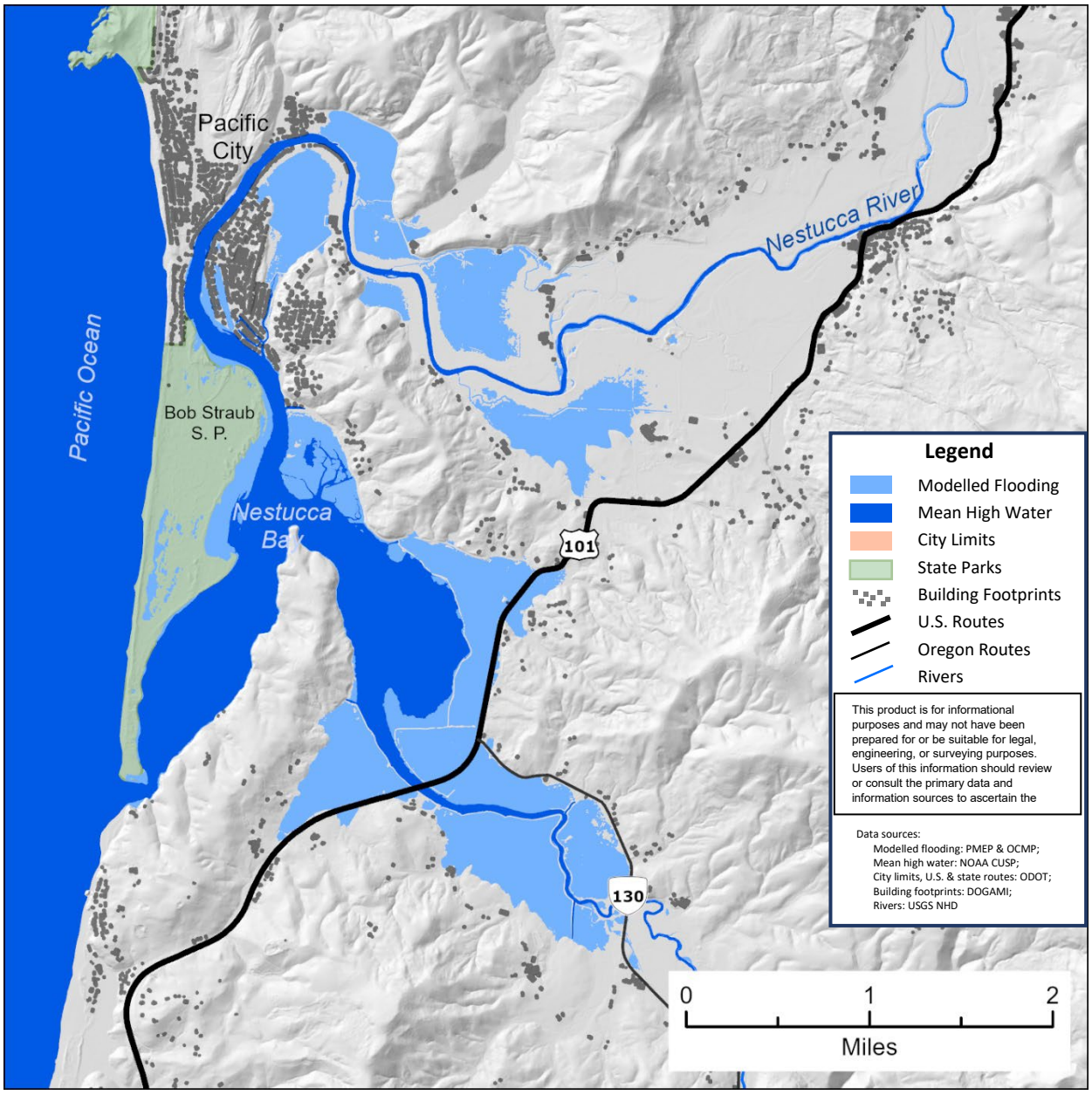


Figure 4. Nestucca Bay Estuary.



II. Methods

Tillamook County Context for Resilience

Tillamook County is home to five major estuaries: Nehalem Bay, Tillamook Bay, Netarts Bay, Sand Lake, and Nestucca Bay. Tillamook Bay is the largest and most developed estuary, and includes the communities of Tillamook, Bay City, Garibaldi, and Bayocean. Tillamook County also contains the largest amount of floodplain of any jurisdiction in the state near Tillamook Bay, which is primarily agricultural land that will be flooded more frequently with sea level rise (Brophy & Ewald 2017). Extensive tidal areas have historically been diked, channelized, and drained, resulting in significant declines in local wetland habitats and species (Brophy 2019). Additionally, the number of potential contaminant sources in Tillamook Bay exceeds that of all of Oregon's other estuaries (DLCD 2017), so water quality will be an issue to monitor as flood frequency increases in the future for these areas.

The City of Tillamook experiences severe periodic flooding which has been substantially mitigated by the Southern Flow Corridor project[5] – a 20-year effort to restore over 500 acres of tidal wetland. This was a joint effort between manifold state and federal agencies, municipal governments, and non-profit organizations. Despite this work, flooding remains the primary focus of coastal resilience efforts in Tillamook County. Flooding in Nehalem Bay remains a threat to the surrounding communities of Nehalem, Wheeler, and Manzanita. Coastal and riverine sources of flooding in Nestucca Bay threaten the community of Pacific City and surrounding rural residents. Residents near Netarts Bay are less vulnerable to flooding, but habitats and species in the estuary are threatened by ocean acidification and hypoxia, as well as the impacts of storm surge. While there are few residents surrounding the Sand Lake estuary, a the small community of Tierra Del Mar resides to the south, protected by an actively-failing dike. Flooding remains a concern there for habitats and species as well, with ongoing work to identify integrated solutions for habitat restoration and water control infrastructure upgrades. US Hwy 101, the primary highway connecting Tillamook County communities, is likely to experience more frequent flooding and storm surge, increasing the need for detours in a region that is already geographically constrained. In the long-term (2100), other neighboring communities such as Rockaway Beach and Neskowin may also experience flooding.

Because of its coastal setting, the natural and cultural resources and dependent industries of these estuaries are vulnerable to both episodic and chronic natural hazards. For example, the geology underlying the area includes complex tectonic interactions between plates and oceanic ridges. This tectonically active area, known as the Cascadia Subduction Zone, has resulted in the region experiencing repeated significant (magnitude >8) earthquakes and ensuing tsunamis over the past millennia (Kelsey et al. 2002; Witter et al. 2003). These kinds of episodic hazards have been well-studied and some statewide and local planning has occurred around them (e.g., seismic design and construction requirements).

[5] https://tillamookoregonsolutions.com/

The impacts to Oregon estuaries from many hazards related to climate change are also well studied. These include sea level rise (Sweet et al. 2017), ocean acidification (OA; Gruber et al. 2012), changes to weather patterns (Fleischman 2023), and more frequent and intense marine heat waves (Frölicher 2018), among others. Systems that are vulnerable to these climate-related hazards are numerous, yet have been assessed to a much lesser degree. Those studied include tidal wetlands loss due to sea level rise (Brophy & Ewald 2017), Dungeness crab population impacts from OA (Bednaršek 2020), increased mortality of commercial oysters from marine heat waves (Green et al. 2019) and impacts to statewide transit systems from sea level rise (ODOT 2012), among others. However, many more vulnerable sites, systems, resources, and populations have not been assessed collectively and not on a local scale.

Planning and Partnership

While ERAP development is a novel process, concurrent and existing work was leveraged to the extent applicable and appropriate to avoid duplication of efforts and add value to the planning landscape. This effort was conducted alongside the University of Oregon's Institute for Policy Research and Engagement's[6] (IPRE) Coos Bay vulnerability assessment effort[7], under a FEMA Cooperating Technical Partnership grant. The methods implemented in Coos County included a vulnerability assessment and adaptation action planning workshops, and were replicated and adapted for the Tillamook County ERAP effort. Work in Tillamook County was guided by the Tillamook Working Group (TWG) composed of local stakeholders such as county and city planners, state agencies, non-profit organizations, industry and conservation interests, and other natural resource managers. The Tillamook Estuaries Partnership (TEP)[8] served as the lead local partner, helping to lead and coordinate meetings and stakeholder outreach and engagement efforts. Other participating organizations include:

- City of Bay City
- Institute for Applied Ecology
- Lower Nehalem Community Trust
- Lower Nehalem Watershed Council
- Nestucca, Neskowin & Sand Lake Watersheds Council
- North Coast Land Conservancy
- Oregon Department of Fish and Wildlife
- Oregon Parks and Recreation Department
- Port of Garibaldi
- Tillamook County Creamery Association
- Tillamook County (Community Development)
- Tillamook County Soil and Water Conservation District
- Salmon SuperHwy
- Wild Salmon Center

[6] https://ipre.uoregon.edu/
[7] https://partnershipforcoastalwatersheds.org/coastal-hazards/
[8] https://www.tbnep.org/

Other planning efforts were relied on to guide and constrain the scope and development of the ERAP process. Below is a summary of some of the extant planning conducted for Tillamook County to date used for this purpose.

Tillamook Estuaries Partnership

In 2018, TEP produced the Tillamook Estuaries and Watersheds Climate Change Vulnerability Assessment[9], which developed a risk-based assessment following the EPA's vulnerability assessment framework[10]. The assessment identified the most severe near-term climate risks, ranking highest both in likelihood and consequence to the ability of TEP to meet its goals. These include myriad impacts to salmonid success, distribution and success of aquatic species, shellfish, crab, and fish harvests, survival of riparian vegetation, and increased water demand, among others. TEP also identified four priority problem areas, which are 1) key habitats, 2) water quality, 3) erosion and sedimentation, and 4) flooding.

The companion report, TEP's Climate Change Preparedness Strategy[11], assessed risks to TEP's ability to meet their goals by reviewing climate model projections. Impacts and vulnerabilities to water, forests, fish, and wildlife were assessed and 23 strategies and actions were developed to reduce climate risks. Together, these reports paint a clear picture of the current and future threats imposed by climate change on Tillamook County estuaries.

In 2019, TEP updated their Comprehensive Conservation and Management Plan (CCMP)[12], which outlines their action agenda for the ensuing decade. The CCMP organizes actions into three broad categories: 1) Water Quality, 2) Habitat Restoration, and 3) Community Education and Engagement. Within each of these categories they identified myriad actions with associated performance measures, and even potential funding sources.

Oregon Central Coast Estuary Collaborative

In 2018, the Oregon Central Coast Estuary Collaborative (OCCEC)[13] published their Strategic Action Plan[14], which identifies goals and activities to aid conservation efforts in Oregon central coast estuaries. The plan outlines goals, strategies, objectives, and specific actions in detail. Among them, OCCEC aims to reduce the loss of historic tidal wetlands by recovering and restoring 950 acres of estuary wetland habitat by 2030, and facilitate estuary conservation, restoration, and resiliency through ongoing investments in science, collaboration, monitoring, community engagement, planning, and policy. OCCEC identifies 14 potential projects to meet their goals, laying out many details such as extent, general timelines, and costs, in a similar manner to what the NFWF process aims to achieve. Additional details are provided to evaluate progress and success toward achieving OCCEC goals.

[9] https://www.tbnep.org/reports-and-publications.php
[10] https://www.epa.gov/sites/default/files/2014-09/documents/being_prepared_workbook_508.pdf
[11] *Ibid.*
[12] https://www.tbnep.org/comprehensive-conservation-and-management-plan.php
[13] https://www.orcentralcoastestuaries.com/
[14] https://www.orcentralcoastestuaries.com/restoration-links

Other Helpful Resources

Natural Hazard Risk Report for Tillamook County, Oregon (2020)[15] by the Oregon Department of Geology and Mineral Industries (DOGAMI) provides results of a natural hazard risk assessment conducted in 2016 for Tillamook County communities. This report focused on evaluating hazard vulnerability on a building-by-building basis to estimate economic loss from flood and earthquake scenarios and susceptibility to landslides, erosion, and wildfire.

Climate Change in the Tillamook Bay Watershed (2013)[16] by the Oregon Climate Change Research Institute – evaluates historical climate trends and future projections for temperature, precipitation, sea level, and OA.

Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan (TCMJ NHMP; 2017)[17] – like other NHMPs, it includes a detailed risk assessment for major natural hazards and profiles mitigation actions for the cities and unincorporated areas in Tillamook County. The TCMJ NHMP recently completed its five-year update, and contributed to understanding of vulnerability and risk in Tillamook County.

Vulnerability Assessment

Planning for resilience requires understanding and managing the multitude of natural hazard threats on the Oregon Coast. Like every area on the Oregon Coast, Tillamook County community vulnerabilities are unique to their location. Improving resilience involves engagement and buy-in from local communities and stakeholders not only to identify their needs and concerns, but also to develop a strategy to address them. To better understand local needs and concerns with respect to natural hazard vulnerability, a vulnerability assessment was conducted in 2022. This process largely focused on understanding impacts to human communities and the built environment and is intended to complement other similar efforts. The methods and tools utilized for this process are derived from the EPA's Being Prepared for Climate Change[18] guidebook, and piloted by IPRE for the City of Eugene Climate Vulnerability Pilot Review Process[19] and the Lane County Hazard and Climate Vulnerability Assessment[20]. The EPA methodology also guided TEP's climate change vulnerability assessment work in 2018.

The TWG reached out to over 100 local stakeholders and community members who were invited to participate in a pre-survey effort and sector-based listening sessions to better understand local needs and concerns related to natural hazards vulnerability. Stakeholders self-identified their economic sectors, which were particularly focused on participants working in areas with direct influence or interaction with the estuaries. Respondents to the survey were grouped together by related sectors and invited to listening sessions. These sessions explored in greater detail the vulnerable assets, resources, and populations identified in the survey

[15] https://www.oregongeology.org/pubs/ims/IMS-58/IMS-58_report.pdf
[16] https://www.tbnep.org/reports-publications/climate-change-in-tillamook-bay-watershed-769.pdf
[17] https://www2.co.tillamook.or.us/gov/ComDev/NHMP/NHMP.html
[18] https://www.epa.gov/cre/being-prepared-climate-change-workbook-developing-risk-based-adaptation-plans
[19] https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/3/4943/files/2017/11/Eug_CVA_PilotReport-20f52o2.pdf
[20] https://www.livabilitylane.org/toolkit/community_resiliency_climate.html

responses, and the adaptive capacity and sensitivities of their sectors. Individual interviews were utilized to supplement this information and provide greater detail and context. The information in Section III summarizes the vulnerability assessment effort results to help characterize the resilience of each consolidated sector group.

Figure 5. Factors of hazard vulnerability defined.

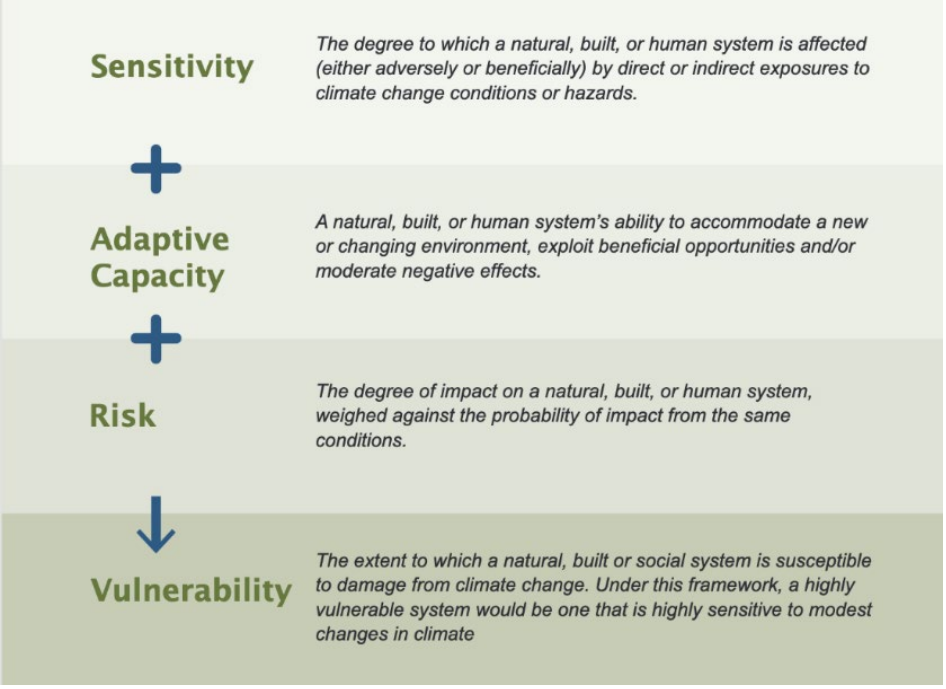


Image source: IPRE

The components of the vulnerability assessment evaluate adaptive capacity, sensitivity, and risk (Figure 5) to determine vulnerability to a particular hazard. Adaptive capacity and sensitivities were largely determined directly from stakeholder interactions. Extant planning literature, such as state and local NHMPs, the Oregon Climate Assessment (Fleishman 2023), and others listed in the previous section provided data, models, and future projections used to derive risk and additional vulnerability information. Data gathered from the survey effort and listening session were evaluated following a scoring method adapted from the IPRE, and used to determine quantitative scores and qualitative rankings for the various aspects of vulnerability within and across sectors. Vulnerability information was then used to characterize risk and identify and prioritize potential adaptation actions to increase local hazard resilience in estuarine areas.

While this effort is focused on areas that interact directly with the estuaries (either currently or historically), participants represented interests throughout Tillamook County, including those beyond the areas of estuarine influence. Consequently, some areas and concerns outside of the geographic areas of interest (areas of estuarine influence) are also discussed at times in the summaries (e.g., Neskowin, Rockaway Beach). This process largely focused on understanding impacts to human communities and the built environment and is intended to complement

other planning efforts. For a full summary of vulnerability assessment methods, see Appendix A: Vulnerability Assessment Methods.

Due to the COVID-19 pandemic, community listening sessions and other interactions were conducted remotely. Pandemic conditions severely impacted participant availability in some communities and consequently the scope of results may reflect this limitation, and additional work may be needed to fill gaps in understanding.

Whiskey Creek Fish Hatchery, Netarts Bay, 2016. Photo courtesy of Meg Reed.

III. Vulnerability Summary

Key Takeaways

Focal Hazard of Concern	Flooding*

*composite - heavy rains, river & tidal flooding, sea level rise, storm surge, tsunami

What are local stakeholders concerned about? Stakeholders expressed the greatest concern for **flood hazards**, manifested primarily as heavy rains and river flooding, but also including other causes of flooding such as storm surge and sea level rise. Seasonal flooding is a common occurrence in communities situated around Tillamook County estuaries, particularly for Tillamook and Nehalem Bays. Severe flooding is typically associated with intense El Niño Southern Oscillation events, which influence precipitation patterns in the Pacific Northwest (Ruggiero et al. 2013). The occasional combination of severe winter storm events with king tides often results in the most severe impacts to local communities. Climate change threatens to increase the severity and frequency of these events with anticipated sea level rise and increases in precipitation (Sharp et al. 2013; Fleischman et al. 2023).

Why are local stakeholders concerned about it? Flood risk is relatively high in virtually all Tillamook County estuarine communities. The expansive floodplain surrounding the central hub of Tillamook County is populated with rural properties that support a thriving local dairy industry as well as local communities. Numerous communities are struggling to recover from floods in recent years, and frequently lack the funding and staff capacity to adequately prepare for the inevitable threat of future flooding and sea level rise. The communities of Nehalem, Wheeler, Garibaldi, Bay City, Tillamook, and Pacific City are especially vulnerable, and require long-range planning contingencies to address the individual and combined flood threats. Culturally, economically, and ecologically important species and habitats (e.g., coho salmon) are also vulnerable to myriad local threats that need to be addressed with hazard planning efforts.

What do local stakeholders want to do about it? Adaptation actions to address the flood threat focus on restoration of wetland habitats and waterway connectivity to improve ecological and hydrological function, while simultaneously protecting agricultural use. Community-supported restoration work in recent decades has helped to mitigate severe flooding in some areas, such as in downtown Tillamook. However, a vast amount of historic estuarine floodplain still remains disjointed from its natural hydrologic function and converted for other land use purposes. Coordinated and well-funded efforts are needed to restore and enhance fish and wildlife habitat, waterway connectivity, fish passage, and hydrologic function in the majority of Tillamook County estuarine floodplains. This work should be planned and led by local stakeholders, leveraging existing community partnership strengths, and conducted in coordination with private landowners.

Flood Risk for Tillamook County Estuaries

Figure 6. Flood hazard areas surrounding the City of Tillamook.

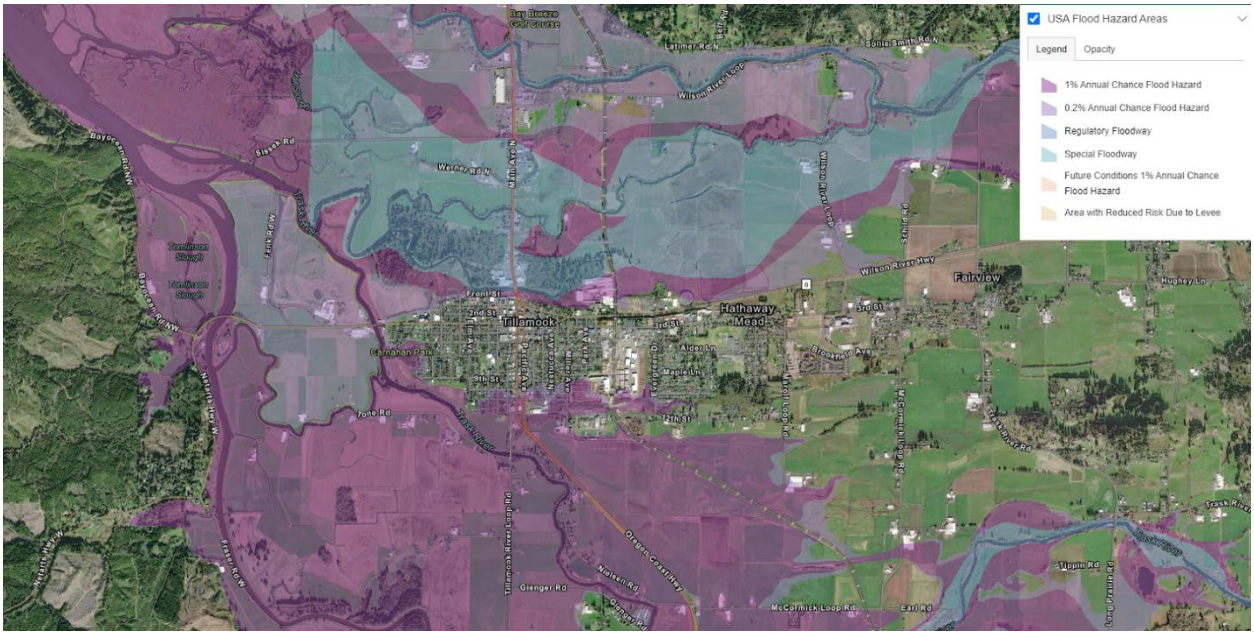


Image source: FEMA Flood Maps[21]

Tillamook County frequently experiences flooding in coastal and estuarine areas, originating from a multitude of sources such as heavy rains, high river levels, extreme tides, and storm surge. Sea level rise and tsunami also pose substantial risk to some areas and communities. Extensive historic estuarine floodplain has been converted to other uses, likely contributing to local flooding, particularly around Tillamook and Nehalem Bays (Brophy & Ewald 2017).

The City of Tillamook has experienced the greatest and most frequent flood impacts historically, often coincident with large storm events associated with the El Niño Southern Oscillation (ENSO) Cycle, particularly La Niña-driven winter storm events. Flood impacts were especially severe during the winter storms of 1978, the February and November 1996 floods, the 1997-98 El Niño, and December storms in 2007 and 2015. It is uncertain how ENSO will be impacted by future climate change, but major ENSO events will nonetheless worsen the impacts of climate change on coastal areas (Ruggiero et al. 2010a).

The most commons source of flooding in Tillamook County is riverine flooding, which is typically caused by heavy rainfall over several days (e.g., atmospheric rivers), and can be exacerbated by rapid snowmelt in the Coast Range (van Heeswijk et al. 1996). Tillamook County rivers that most frequently overtop are the Kilchis, Miami, Nehalem, Nestucca, Tillamook, Trask, Wilson, and Three Rivers, as well as Dougherty and Hoquarten Sloughs. Of these sources, all but the

[21] https://www.fema.gov/flood-maps

Nehalem, Nestucca, and Three Rivers are in the Tillamook Bay watershed, and all but the Miami River surround the City of Tillamook. Annual flooding from the Trask and Wilson Rivers has been a persistent flood nuisance for the community (Tillamook County 2017a), and often disrupts travel on US Hwy 101 just north of downtown (Collins 2019). Riverine flooding is a common occurrence in all Tillamook County estuarine communities except Oceanside-Netarts and Manzanita. Pacific City is also highly vulnerable to sources of coastal flooding.

The worst impacts are often felt when heavy rainfall events coincide with higher tides (such as king tides) and storm surge, which happens most often in winter and late spring. These storms are driven by heavy winds, particularly in the December-February timeframe. Heavier winter storms are more common during El Niño years, which can temporarily elevate sea level by up to 1.5 ft (0.5 m). ENSO parameters are changing with climate change, which may increase the frequency and intensity of winter storms (Ruggiero et al. 2010a). Wave heights in the eastern Pacific Ocean have also increased in recent decades, which may contribute to storm surge impacts in the future (Ruggiero et al. 2010b).

Sea level rise also threatens many Oregon coastal communities. Areas at the periphery of estuaries often experience the greatest impacts from sea level rise, along with effects of higher tides and storm surge. These impacts can be mitigated through efforts to reconnect and restore estuarine floodplain areas such as tidal wetlands, reducing flood height and duration (Reed et al. 2018). From 1985-2010, global average sea level increased at an average rate of 2.9 ±0.4 mm yr^{-1} (Shum & Kuo 2011). For many areas on the Oregon Coast (north of Cannon Beach and south of Coos Bay), tectonic uplift of the Cascadia Subduction Zone is currently outpacing sea level rise, but this trend is likely to reverse by 2100 (Sweet et al. 2022).

Similar to sea level rise, the threat of tsunami looms large into the future, particularly in highly vulnerable communities. The Oregon Coast is potentially vulnerable to tsunamis originating in the Pacific Ocean, such as the 2011 Japanese earthquake and tsunami which caused millions of dollars in damage to Brookings harbor. While distant tsunamis have been known to impact the Oregon Coast, the larger threat is that of a Cascadia Subduction Zone earthquake and tsunami. Priest et al. (2014) identified the south coast as the most vulnerable to this type of event, with a recurrence interval of approximately ~300-380 years for the last ~10,000 years. The recurrence interval for the north coast is ~410-500 years, with a medium size tsunami as the most likely scenario (*ibid*). The Tillamook County communities most vulnerable to tsunami (>10% of residents potentially displaced) are Neskowin (58%), Rockaway Beach (55%), Pacific City (41%), Nehalem (17%), and Manzanita (16%) (DOGAMI 2020).

Future conditions for Tillamook County are likely to reflect regional changes in climate, with wetter winters and drier summers anticipated for much of Oregon. This is likely to affect local hydrology with higher mean flows expected in the fall season by 2065 (Steele et al. 2012), but reductions in summer flows due to higher summer temperatures and decreased precipitation (Sharp 2013, Steele et al. 2012). Climate modeling also indicates more intense winter storms, and more frequent extreme summer heat, drought, and wildfire. The Tillamook Bay watershed is expected to experience a 5% increase in annual mean precipitation by the year 2100 (Sharp et al. 2013). Sea level rise will also continue, with projections for the Oregon Coast ranging from 1-5 ft (0.3 - 1.5 m) by 2100 (Sweet et al. 2022).

Figure 7. Tsunami inundation map of Pacific City, Oregon.

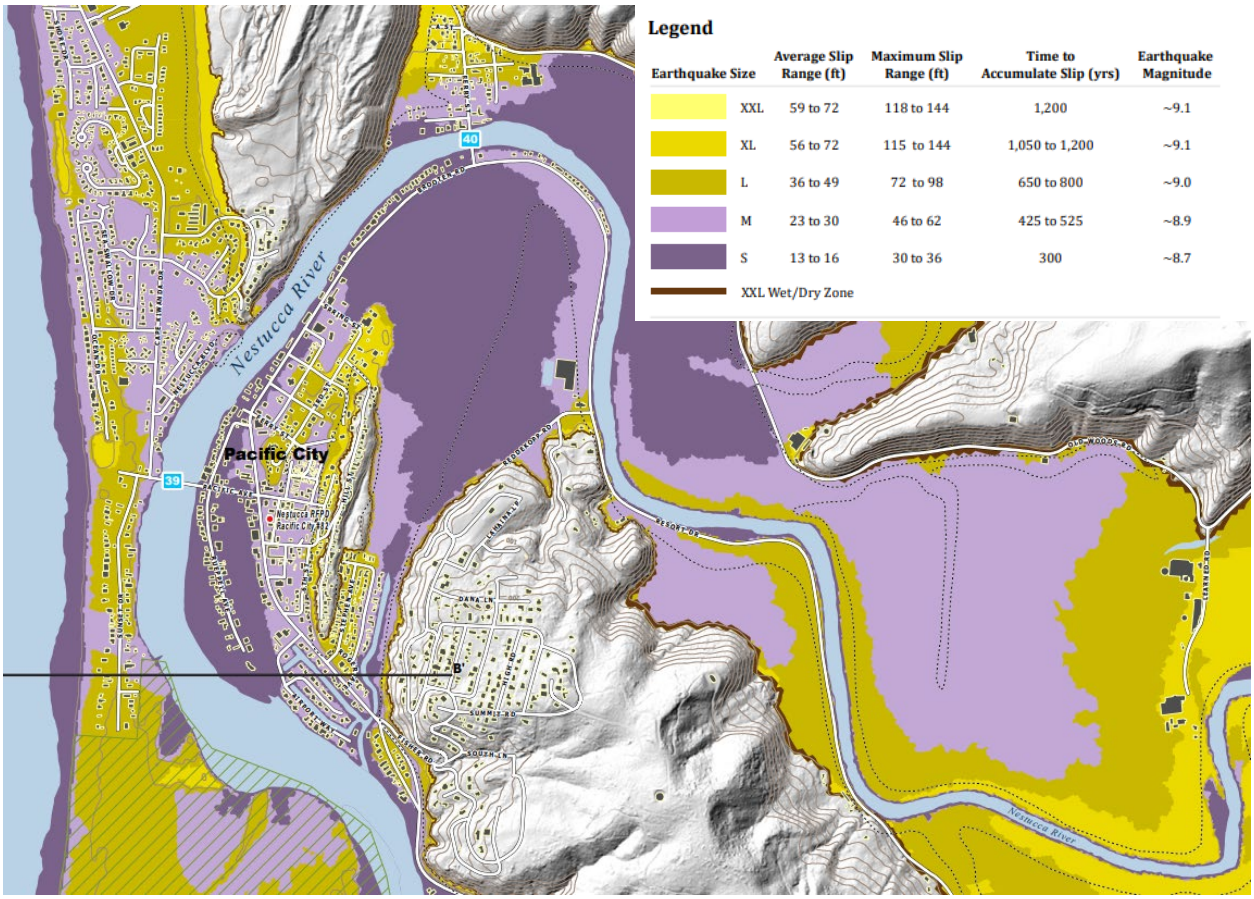


Image source: DOGAMI[22]

[22] https://www.oregongeology.org/pubs/tim/p-TIM-overview.htm

Vulnerability Assessment Sector Analysis

Table 2. Qualitative Adaptive Capacity and Vulnerability Rankings by Sector

Sector	Adaptive Capacity	Sensitivity	Impact	Hazard Vulnerability
Community	LOW	MEDIUM	MEDIUM	HIGH
Natural Resources	VERY LOW	MEDIUM	LOW	HIGH
Industry & Infrastructure	LOW	MEDIUM	MEDIUM	HIGH
Tillamook County Overall	LOW	MEDIUM	MEDIUM	HIGH

The colored table above summarizes the major findings from the stakeholder outreach and engagement effort. The qualitative vulnerability rankings shown were assessed relative to the composite flood hazard. Adaptive capacity, however, is evaluated separately from hazard-specific risk, and assesses the system's ability to adapt to changing conditions. The more a system is able to adapt to a given hazard, the higher that system's resilience.

Overall, the hazard vulnerability ranking relative to flood hazard for Tillamook County is **HIGH**. Sensitivity and impact are generally **MEDIUM**, owing in part to stakeholder familiarity and preparedness for the regular (annual) occurrence of local flooding. Second and third-order constraints largely imposed by geography (e.g., isolation, small communities, limited transportation routes, personnel capacity) result in generally **LOW** adaptive capacity throughout the region.

Across all sectors evaluated for this effort, consistent themes arose for a few key local vulnerable assets, resources, and populations. These primary vulnerabilities identified are:

- Important transportation routes (US Hwy 101, OR 6, Miami-Foley Rd., Burton-Fraser Rd.)
- Major and key water crossings (bridges, culverts)
- Water and sewer infrastructure (wastewater treatment facilities, aging pipes)
- Key facilities (hospital, ports, emergency evacuation sites)
- Sensitive aquatic species and habitats (salmon and steelhead, shellfish, eelgrass)
- Vulnerable populations in low-lying areas (homeless, RV/mobile home parks, elderly/homebound)

While these are the primary cross-sector vulnerabilities identified by the participants in this effort, it is relative to the composite flood hazard only, and represents a Tillamook Bay-centric focus. This information is not comprehensive of all potential hazard vulnerabilities across Tillamook County estuaries and communities. Vulnerability assessment results should be interpreted in the broader context of similar efforts such as TEP's Vulnerability Assessment, the TCMJ NHMP, and others.

Community Sector

Sector Description

This section details the vulnerabilities of those participants grouped and evaluated under the "Community" sector. The sectors consolidated as Community include municipalities (county and city planning departments), schools and school districts, emergency and healthcare services, religious organizations, community organizations, Tribal Nations, and other organizations serving local needs. These stakeholders generally focus on broader community-level concerns, provide goods and services to meet peoples' basic needs, and may be more likely to interface with vulnerable populations.

Participating Stakeholder Organizations

- Adventist Health Tillamook
- City of Bay City (Planning Dept.)
- City of Garibaldi (Public Works Dept.)
- City of Tillamook (Planning Dept.)
- Neah-Kah-Nie School District
- Neskowin Citizen Advisory Committee
- Nestucca, Neskowin, and Sand Lake Watersheds Council
- Oregon Department of Parks and Recreation
- Tillamook County (Planning, Parks, & Health Depts.)
- Tillamook County Soil & Water Conservation District
- Tillamook Bay Community College
- Tillamook County Community Health Center
- Tillamook County Creamery Association
- The Nature Conservancy

Vulnerability

Community sector participants indicated their hazards of greatest concern to be tsunami/earthquake, heavy rains & river flooding, and wildfire. However, heavy rains & river flooding was identified as the top priority when asked to rate the hazard of greatest risk, followed closely by decreased summer precipitation/heavier winter storms. Vulnerabilities were assessed primarily based on the composite flood hazard in mind, and many indicated heavier winter storms were of greater concern than decreased summer precipitation. However, concern was also expressed at times for the threat of decreased summer precipitation and drought, in conjunction with increased risk of wildfire. Table 3 provides a summary of the vulnerability assessment findings for the Community Sector.

Table 3. Community Sector Vulnerabilities Summary

Critical Interdependencies	Critical Vulnerabilities
The systems, resources, assets, infrastructure, and populations that this community depends on to properly function include: • Transportation infrastructure (highways, water crossings) • Communications infrastructure • Water infrastructure, sewer systems • Electrical power infrastructure	**The resources, assets, and populations identified as particularly vulnerable to the assessed hazard include:** • Water infrastructure, storage • Dairy producers, distribution networks • Adventist Health Tillamook • Vulnerable populations (homeless, mobile home parks, homebound)
Hazards of Greatest Risk	**Hazards of Greatest Concern**
Subjective ranking of the perceived risk imposed by current or projected natural hazards based on probability and consequence of occurrence: • Heavy rains & river flooding • Decreased summer precipitation; heavier winter storms • Tsunami	**The most critical natural hazards of concern that may be chronic or episodic in nature:** • Tsunami/earthquake • Heavy rains & river flooding • Wildfire

Vulnerability Rankings

Adaptive Capacity†	VERY LOW	**LOW**	MEDIUM	HIGH	VERY HIGH

Primary Hazard Assessed: Flooding (composite: heavy rains, river & tidal flooding, sea level rise, storm surge, tsunami)

Sensitivity	Impact	Hazard Vulnerability
MEDIUM	MEDIUM	HIGH

†*Note:* Adaptive capacity is ranked in the *opposite* direction of the other factors (i.e., low adaptive capacity is bad, whereas low vulnerability is good), and is evaluated independent of a given hazard.

Some of the notable assets or resources (e.g., specific infrastructure, natural resources, critical habitat, vulnerable populations, cultural resources, equipment/tools, structures, etc.) identified as most vulnerable to the hazard of concern are as follows:

- US Highway 101, OR 6
- Water distribution and wastewater collections systems (Cities of Bay City, Garibaldi, Nehalem, and Tillamook in particular)
- Kilchis Point area (neighborhood residences and Bay City Wastewater Treatment)
- Burton-Fraser Road

- Wells located along Miami-Foley Road
- Port of Garibaldi facilities
- County recreational boat launches (*n.* 21), especially highest use facilities
- Major grocery stores in City of Tillamook
- North County Food Bank (Wheeler)
- Adventist Health Tillamook
- Adventist Health ambulance service in Garibaldi
- Pacific City and Nehalem Bay State Airports
- North County Health Center, employees, patients (Rockaway Beach)
- Tillamook City Hall, Fire District, and Library
- Tillamook County Pioneer Museum (object collections of greatest concern)
- Neskowin - village along Hawk St., Salem St. bridge, core area
- Members of Tribal Nations
- Community Action Resource Enterprises (CARE) Tillamook social service populations (unhoused/underhoused, Hispanic/ESL, elderly/homebound)
- Residents dependent on medical devices and home oxygen
- Vulnerable populations in low-lying flood/tsunami hazard areas

Sensitivity for the Community Sectors was ranked **MEDIUM**, while adaptive capacity was ranked **LOW**, resulting in a vulnerability ranking of **HIGH** for the flood hazard. While some adaptation to frequent "nuisance" flooding has reduced sensitivity in recent years, adaptive capacity at present is limited by lack of redundancies and geographic restrictions.

Adaptive Capacity

Adaptive Capacity is a natural, built, or human system's ability to accommodate a new or changing environment, exploit beneficial opportunities and/or moderate negative effects.

Adaptive Capacity	LOW

Current Condition

Overall, the adaptive capacity of the community-related sectors was rated **LOW**. Adaptive capacity is particularly challenged by the difficulty posed with replacing, repairing, restoring, and/or mitigating loss of function of the key facilities, infrastructure, and sites for this sector. This is driven largely by limited redundancies for many resources and services, as well as strict limitations imposed by local geography.

The City of Tillamook serves as the central hub for the majority of goods and services in the county. Transportation access in and out of Tillamook Valley is limited to a few key routes, which are highly vulnerable to flood disruption. Residents in satellite communities must travel 60-90 minutes over the Coast Range to access a broader complement of services in the larger cities of the Willamette Valley. Seasonal conditions in a typical year can occasionally preclude

this possibility, leaving residents wholly reliant on the often-limited services available in nearby coastal communities. These limitations emphasize the importance of maintaining access and availability of these services for local residents with respect to hazard disruptions. Some of the most important yet vulnerable services identified include health and medical care, grocery and food, essential government services, drinking and wastewater, and port facilities.

Virtually all the estuarine communities in Tillamook County are vulnerable to some degree of flooding and sea level rise. These threats may be amplified for residents located in low-lying areas or that coincide with other social vulnerabilities. Many residents are located directly in the regulatory floodways or the 100-year floodplains for the North Fork Nehalem, mainstem Nehalem, Miami, Kilchis, Trask, Tillamook, mainstem Nestucca, and Little Nestucca Rivers. Other vulnerable populations in the county such as the elderly, homebound, unhoused, and others, can be difficult to locate and provide services to, as they are often not geographically consolidated within communities. Members of Tribal Nations may also be more vulnerable and spread throughout the county.

Redundancies

Demand on water sources and infrastructure is generally expected to exceed capacity within 5-20 years. The lifespan of many water distribution and collection infrastructure components currently in place is 21-50 years. Increased water storage, particularly in the upper watershed, is needed now but will take several years of planning and implementation to expand. Sewer systems in some areas will need replacing in less than 5 years. Replacing/upgrading this infrastructure is challenged by funding constraints and availability of equipment. There are few if any redundancies in the system, particularly for wells and other water sources. Wells along Miami-Foley Rd. are threatened by flooding from the Miami River, which can increase demand on reservoir supply to service local residents. Drinking water is often supplied by special districts with varying levels of staff capacity, preparedness, and adaptive capacity.

Healthcare facilities currently fully utilize their spaces, but facilities are aging and will need to be overhauled or replaced within the next 5-20 years. The main hospital (Adventist Tillamook) is highly vulnerable to flooding and tsunami. There are two main clinic locations (Nehalem and Pacific City), plus a mobile clinic, so there is some capacity to adapt to natural hazard disturbances, but some departments are better able to adapt than others.

Primary transportation routes such as US Hwy 101 and OR 6, and communications networks (cell and radio service) were recognized as critical interdependencies, particularly in the event of evacuations. A lot of local capacity in the county is built on emergency volunteers, citizen advisory committees, the Peoples' Utility District, and other community groups, which need coordination and access to aid affected communities. Flooding has disrupted road access to Neskowin for extended periods (5-8 days) in previous years, and some residents had to be evacuated by US Coast Guard helicopter. Healthcare providers rely on constant delivery of supplies and also serve the needs of home-bound patients. Many community-based organizations rely on the hospital infrastructure and local clinics to serve their populations. The dairy industry (producers, haulers, processors) also depends on local routes to move milk twice

daily. A major disruption to delivery of supplies would be devastating to these industries, potentially taking years to recover.

Management Actions

Some organizations have engaged in hazard planning, however, the focus is often limited to tsunami or other episodic hazards rather than more chronic hazards. The TCMJ NHMP is a primary source of planning preparedness. A high degree of coordination across sectors occurs for local hazard planning and emergency preparedness efforts. Community coordination and volunteerism (such as the Emergency Volunteer Corps of Nehalem Bay) are regarded as a local strength.

Sensitivity

Community-related sectors in Tillamook County are particularly vulnerable to the threat of flood-related hazards. Community sector stakeholders' hazard of greatest concern is tsunami, followed closely by flooding. However, flooding ranked highest with respect to risk, followed by drought and tsunami.

The vulnerable assets, resources, and populations identified by Community sectors stakeholders are broadly categorized as "Key Facilities & Systems" and "Vulnerable Populations".

Key Facilities & Systems: Infrastructure and systems relied upon to meet basic needs and services, and used by community to coordinate and respond to emergencies.

Vulnerable Populations: Communities with fewer resources, located in low-lying or hazard-prone areas, communities of color, people with disabilities, elderly, children, non-native English speakers, lack transportation, manufactured housing/RVs, etc.

Key Facilities & Systems

Critical Facilities

A number of critical facilities are located in areas subject to annual ("nuisance") flooding, as well as less frequent but more severe flood events, or are relied upon in the event of a hazard disruption. In the City of Tillamook, more than a mile of US Hwy 101 north of downtown lies within a defined FEMA Flood Hazard Area. Regular, "nuisance" flooding often inundates this important community lifeline, which can cut off access to critical downtown facilities such as Tillamook City Hall, Tillamook Fire District, Tillamook County Courthouse, Tillamook County

Emergency Communications District, the post office, and the Tillamook County Library, which is used as a safe collection area.

The Adventist Health Tillamook hospital and medical plaza lie on the west end of Tillamook between Stillwell Slough and the Trask River. During flood events, the adjacent agricultural fields to the north fill with water and spill onto the helipad and parking lot. Water levels have reached the back of the building in the past, with staff needing to mobilize resources to prevent water from entering the building. Adventist also operates clinics in Manzanita and Pacific City, with ambulance services at the Manzanita facility and the Port of Garibaldi. The state airports in Nehalem and Pacific City are relied on for Life Flight helicopter services to transport critical care patients. Disruptions to accessing or utilizing airport facilities is a top concern, particularly for the Pacific City State Airport, which has a runway that frequently floods.

Other critical facilities (or access to them) may be threatened by a combination of future flooding and sea level rise, especially if projections meet or exceed current expectations for 2050.

Critical Systems

Many critical systems (such as drinking and wastewater) are already in need of replacing or major upgrades and demand will exceed current capacity in <5 years. Some redundancies exist for short-term disruptions but are insufficient for major events. Wastewater treatment and storage facilities in Nehalem, Bay City, and Tillamook lack redundancies and are highly vulnerable to major disruption. All lie partially or completely below the Base Flood Elevation, with large impoundments in Nehalem and Bay City protected by aging levees. The components of these wastewater treatment systems are expensive to maintain and difficult to replace, and some are already periodically overwhelmed by incoming floodwaters. Sea level rise and saltwater intrusion currently threaten wastewater treatment facilities in Garibaldi, as well as the Adventist Health ambulance service and other neighboring facilities. The water supply lines for Garibaldi come from the Miami River canyon and a strong earthquake could sever them. Further, decreasing groundwater supply threatens several drinking water wells along Miami-Foley Road relied upon by the Garibaldi community. Water storage in the upper watershed also needs to be increased to ensure long-term water supply in the region.

Key Networks

Transportation and communications networks are relied on to coordinate back-up and emergency volunteer staff and access facilities and vulnerable residents to maintain critical services. Adaptive capacity and level of emergency response are dependent on major routes (US Hwy 101, OR 6) remaining open. US Hwy 101 runs north to south, while OR State Route 6 cuts west to east across the Oregon Coast Range. Short-term disruptions to local routes already routinely isolate residents and, at times, entire communities. Longer-term disruptions, such as at major water crossings, may have catastrophic impacts for isolated residents and communities. Flooding of major routes routinely isolates residents in Nehalem, Tillamook, and

Neskowin, among others, and can impact bridge access to Whalen Island in Sand Lake, depending on water levels.

Vulnerable Populations

Geography & Capacity

Tillamook County is sparsely populated, with less than 28,000 people among seven cities and numerous small unincorporated communities. With approximately 5,200 people, the City of Tillamook is the largest community by far, and serves as the central hub for the county. Bounded by rugged, mountainous terrain on three sides, the communities are relatively isolated, relying on a handful of small highways and local routes for access in and out of the area. Many residents fill multiple roles within and across communities, compounding the effects of major disruptions to key networks and local ability to maintain operations for vital services. Major flood events are also often accompanied by other hazards and impacts such as storm surge, landslides, erosion, power outages, etc., that can contribute to isolation and affect communication, transportation, infrastructure, and vulnerable populations.

Food Producers and Services

Food services such as farmers, growers, grocery services, and dairy processors are all highly vulnerable to flood impacts. Significant portions of the agricultural lands surrounding Nehalem, Tillamook, and Nestucca Bays are below the Base Flood Elevation or directly within the Regulatory Floodway. Flooding can impact oyster farmers' access to oyster grounds in Netarts Bay, depending on water levels.

Access to local routes is vital to dairy producers, milk haulers, and dairy processors, who must move milk twice daily and transport dairy products on OR 6. Extended disruptions could be potentially fatal to the local industry as well as livestock. There is a large dairy operation near downtown Tillamook that lies below the Base Flood Elevation and is partially within the Regulatory Floodway. Numerous other dairies dot the major estuarine floodplains of Nehalem, Tillamook, and Nestucca Bays. Flooding and erosion also pose a threat to losing fertile topsoil and could lead to reduced crop yields in the future.

There are few large grocery stores in Tillamook County, with much of the region relying on a small handful of large grocery retailers in the City of Tillamook. Two of the three major grocery stores (Fred Meyer and Grocery Outlet on US Hwy 101) lie within, or are surrounded by, some of the largest flood hazard areas in the state. The Safeway in downtown Tillamook was moved to its present location several years ago due in part to similar flooding concerns. Access to these services is disrupted on a nearly annual basis due to nuisance flooding.

Access to county boat launches (*n.* 21) can also be affected by flooding, presenting challenges to recreational and commercial fishing. Use levels vary, with primary concerns focused mainly on the highest use facilities, which include the boat launches at Netarts, Memaloose, Nehalem Bay, Mills Bridge and Sollie Smith along the Wilson River, and two in Pacific City on the Little

Nestucca River. The Nehalem south dock and Garibaldi Marina are also threatened by sea level rise and flooding concerns.

Other Vulnerable Populations

Other vulnerable populations include in-home care patients, ventilator/O_2-dependent residents, the homeless population, low-income Hispanic communities, members of Tribal Nations, residents in low-lying flood zones, and other social service populations that rely on key services such as CARE Inc. and the North County Food Bank.

In the event of an emergency, residents in need of medical care would need to be evacuated from the hospital. With limited staff capacity and an aging building, a major flood event could prevent hospital staff from accessing the facilities and evacuating patients, and would be particularly challenging for non-ambulatory patients. Access to the homebound, in-home care patients, and those dependent on medical devices may be disrupted by flooding.

Vulnerable residences located in hazard areas or other low-lying flood zones are another vulnerability focus. Numerous rural properties and residences lie below the Base Flood Elevation in the Nehalem, Tillamook, and Nestucca floodplains, with a handful in the Regulatory Floodway. Many residences in the Miami River canyon are highly vulnerable to flooding, with geographical constraints severely threatening safe access and egress. There are several residences in the Kilchis Point area in southwest Bay City that are threatened by flooding and future sea level rise. A long-term plan to relocate these residences by 2050 needs to be developed. Other vulnerable residential locations include the Trask River Mobile Home Park, Pacific City Trailer Park, waterfront homes in Netarts (e.g., Pearl St. W, Happy Camp Rd.), Rockaway Beach, those east of 9th St. in Nehalem, and significant portions of Pacific City. The community of Neskowin, while not located adjacent to a major estuary, is uniquely vulnerable to the threat of tsunami as well as transportation disruptions from winter storms, which in the past have isolated the entire community for several days.

Risk

The assets, resources, and populations described above are vulnerable to several hazards, with the greatest concern expressed for earthquake/tsunami, flooding (all-cause), and wildfire. While major episodic events (e.g., tsunami) are top of mind, adapting to chronic hazards (e.g., flooding) is the more critical need. Tsunami risk is high in places such as the southwest part of Bay City, which may eventually need to relocate several residences and government offices. Around the estuaries, Nehalem and Pacific City are especially at high tsunami risk, among other communities such as Neskowin. Other hazards of concern mentioned include drought (with respect to wildfires), saltwater intrusion, severe weather/storm surge, and climate change (with respect to most other consequent hazards).

Time frames to address hazard-associated risks are immediate. Episodic events such as earthquakes and tsunamis require preemptive planning and preparation, while adaptation to chronic hazard events must occur within the decade, if not already. Tsunami threat in Neskowin could result in the loss of up to 1,000 lives and simultaneously eliminate access to the

community. Neah-Kah-Nie Junior and High Schools in Rockaway Beach are vulnerable to tsunamis as well. An earthquake + tsunami combination event could result in loss of drinking water and wastewater treatment capacity in Tillamook, Garibaldi, and Bay City, among others. Additionally, increasing intensity and severity of summer drought is increasing wildfire hazard potential. With a 6-month (Nov.-Apr.) annual flood season, flood-related damage potential is high in all communities. While locals are accustomed to annual "nuisance" flooding to an extent, impacts are anticipated to worsen in the near term.

Efforts to adapt to the threat of hazards are occurring to various degrees, most of which require coordination across sectors. Several stakeholders report having tsunami evacuation plans in place while others are developing them or other emergency preparedness plans. Tillamook County is currently implementing elements of the Tsunami Hazard Overlay Zone[23].

Funding constraints to address needed upgrades, mitigation, adaptation, and other preparatory actions is an external stressor moderately impacting sensitivity to flood-related hazards. The assets, resources, and populations of concern were unanimously rated as 'extremely sensitive' to this hazard. In the event of a large flood, it is likely to take months to years for the affected assets to fully recover. Some are still recovering from the floods in 2019.

While only moderate flood impacts were anticipated for most assets, some may easily incur catastrophic impacts with a sufficiently severe flood event. Some communities and residents are seen as more vulnerable to flood impacts than others, but those in southwest Bay City, downtown/west Tillamook, and Neskowin, were seen as extremely vulnerable.

Runway at the Pacific City State Airport, Nestucca Bay, 2022. Photo courtesy of Scott Lane and Wendy Ackley.

[23] https://www.oregon.gov/lcd/ocmp/pages/tsunami-planning.aspx

Natural Resources Sector

Sector Description

This section details the vulnerabilities of those participants grouped and evaluated under the "Natural Resources" sector. The sectors consolidated as Natural Resources include those stakeholders who primarily manage natural resources such as state and federal natural resource agencies, watershed councils, local water districts, municipal parks departments, and conservation organizations. These stakeholders generally focus on monitoring and managing fish and wildlife populations and their habitats. A major concern in this sector is sensitive aquatic species that are experiencing multiple environmental and anthropogenic stressors, and do not respond well to large perturbations.

Participating Stakeholder Organizations

- Lower Nehalem Community Trust
- Lower Nehalem Watershed Council
- Neahkahnie Water District
- Nestucca, Neskowin, and Sand Lake Watersheds Council
- Oregon Dept. of Fish & Wildlife
- Salmon SuperHwy
- Tillamook County (Parks Dept.)
- Tillamook County Creamery Association
- Tillamook Estuaries Partnership
- Tillamook County Soil and Water Conservation District
- Trout Unlimited
- USDA Natural Resources Conservation Service
- Wild Salmon Center

Vulnerability

Natural Resources sector participants indicated their hazards of greatest concern to be heavy rains & river flooding, water table/quality issues, and king tides/tidal flooding. The highest rated hazard of greatest risk was king tides/tidal flooding, followed by heavy rains & river flooding and erosion, accretion, or deposition of beaches, dunes, or soils (long-term). Vulnerabilities were assessed primarily with the composite flood hazard in mind, which is reflected by this sector's focus on different sources of flooding, as well as their focus on erosion, which is often attendant with winter storms and flooding. Table 4 provides a summary of the vulnerability assessment findings.

Table 4. Community Sector Vulnerabilities Summary

Critical Interdependencies	Critical Vulnerabilities
The systems, resources, assets, infrastructure, and populations that this community depends on to properly function include: • Natural water infrastructure • Habitats (wetlands, connectivity) • Transportation & water connectivity infrastructure (roads, bridges, culverts) • Ports and other water access infrastructure (boat launches, docks)	**The resources, assets, and populations identified as particularly vulnerable to the assessed hazard include:** • Sensitive aquatic species • Highways, other local routes • Burton-Fraser Rd. (Tillamook) • Nehalem River flooding • Bridge at Neskowin Creek • Low-income populations in low-lying areas
Hazards of Greatest Risk	**Hazards of Greatest Concern**
Subjective ranking of the perceived risk imposed by current or projected natural hazards based on probability and consequence of occurrence: • Tidal flooding, king tides • Heavy rains & river flooding • Erosion, accretion, or deposition of beaches, dunes, or soils (long-term)	**The most critical natural hazards of concern that may be chronic or episodic in nature:** • Heavy rains & river flooding • Water table/quality issues • King tides/tidal flooding

Vulnerability Rankings

Adaptive Capacity†	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Primary Hazard Assessed: Flooding (composite: heavy rains, river & tidal flooding, sea level rise, storm surge, tsunami)

Sensitivity	Impact	Hazard Vulnerability
MEDIUM	LOW	HIGH

†*Note:* Adaptive capacity is ranked in the *opposite* direction of the other factors (i.e., low adaptive capacity is bad, whereas low vulnerability is good), and is evaluated independent of a given hazard.

Some of the notable assets or resources (e.g., specific infrastructure, natural resources, critical habitat, vulnerable populations, cultural resources, equipment/tools, structures, etc.) identified as most vulnerable to the hazard(s) of concern are as follows:

- Coldwater fishes, including ESA-listed coho
- Spawning and rearing fish habitats, high-flow and cold water refugia
- Cold, clean water, and hydrologic connectivity
- In-stream fish passage barriers, culverts, tide gates
- Freshwater and estuarine ecosystem health
- Anadromous and resident fishes

- Critical habitat for ESA-listed fishes
- Fisheries accessed by community stakeholders (recreational & commercial)
- Agricultural and forestry producers
- Springwater sources
- Water quality and quantity
- Levees, dikes, tide gates, jetties, and other water control structures
- Roadways, bridges, and other waterway crossings that frequently flood
- Water treatment facilities
- Burton-Fraser Road
- Intertidal flats & species (e.g., eelgrass, shellfish)
- Water storage for irrigation and farm use
- Low-income populations in low-lying areas (e.g., trailer parks)
- Low-elevation pasture protected by dikes, levees, tide gates, etc.
- Farmland, top-soils, farm structures

While sensitivity for the Natural Resources Sectors was ranked **MEDIUM**, adaptive capacity was ranked **VERY LOW**, resulting in a vulnerability ranking of **HIGH** for the composite flood hazard. While some adaptation to frequent "nuisance" flooding has reduced sensitivity in recent years, adaptive capacity at present is limited by lack of redundancies and geographic restrictions.

Adaptive Capacity

Adaptive Capacity is a natural, built, or human system's ability to accommodate a new or changing environment, exploit beneficial opportunities and/or moderate negative effects.

Adaptive Capacity	VERY LOW

Current Condition

Overall, the adaptive capacity of the natural resources-related sectors was rated **VERY LOW**. This is largely due to species declines and habitat degradation associated with land use changes and other environmental stressors, including climate change and ocean acidification. Primary concerns in this sector focused on habitat interconnectivity throughout the watershed (particularly with respect to upland connectivity to the estuary) and maintaining and restoring ecosystem function.

While Tillamook County estuaries support a diverse array of species, with extensive stretches of intertidal mud flats, tidal wetlands, and other important aquatic habitats, sea level rise and increases in temperature and precipitation, among other climate change impacts, threaten to alter the extent and distribution of these habitats, affecting many species, particularly salmonids. (Flitcroft et al. 2013). Coho salmon populations are especially sensitive to ocean acidification exposure and increases in stream temperature (Crozier et al. 2019). Estuarine

wetlands are also likely to experience changes in distribution and salinity, altering distribution of attendant aquatic species such as *Zostera* eelgrass (Tillman & Sieman 2011).

Redundancies

Species and habitats managed by this sector are fully or nearly fully utilizing habitat availability and capacity. Sensitive estuarine species such as eelgrass and shellfish are currently present at the fullest extent of habitat potential. Tidal wetlands may have additional capacity for fish species, but estuaries in their current state may be a limiting factor for some. Local agricultural land capacity is also utilized to its fullest extent, but productivity may be challenged in the next few decades as human populations increase without strong farmland protection measures.

Restoration of sites, species, and habitats is difficult, with needs and challenges varying on a site-by-site basis. Restoration success is often challenged by funding constraints, and increased funding for projects would likely improve outcomes. Successful habitat restoration efforts may rely on cooperation from private landowners, which at times can be challenging. The need for restoration and mitigation is immediate and will be ongoing with anticipated changes to climate and other human impacts on the environment. Habitat redundancy is little to none as there is already a "shortage" of available aquatic habitats. Shellfish species (broadly) may be slightly more resilient with multiple species inhabiting different zones. Conversely, *Zostera* eelgrass, which provides habitat structure for many other species, is more sensitive and limited in its habitat profile.

Infrastructure that provides waterway connectivity is a critical interdependency, particularly that associated with transportation (roads, bridges, culverts). Other important built infrastructure includes power, communications, sewer, and port facilities (boat launches, docks). Waterways, wetlands, and healthy forests and watersheds at the top end of the watershed system are also important for natural function. Springwater sourced from Neahkahnie Mountain is of particular concern (Complete Water Management 2018), which can be impacted during flood events. The capacity of local natural systems to recover from major impacts is present but can often be slow, depending greatly on the quality of ocean-estuary-river connections. Fish species will have greater difficulty recovering from disturbance, likely taking decades given the rapid rate of environmental changes occurring. Impacts of past events (such as the 1964 flood event) are still visible, but contemporary adaptation efforts are focused on different stressors than in the past. One of the biggest challenges moving forward is trying to understand how to manage for future conditions.

Management Actions

A lot of planning for managing natural resources has been conducted in Tillamook County. In 2019, TEP published their Comprehensive Conservation and Management Plan, an adaptive management strategy developed with many stakeholders. This 10-year action plan includes a crosswalk between action items and vulnerability strategies. The Nestucca, Neskowin, and Sand Lake Watersheds Council developed their action plan in 2018 and is currently updating it. The Oregon Department of Environmental Quality has an Oil Spill Response plan for critical estuary habitat. Tillamook County recently completed an update to their Natural Hazard Mitigation Plan in 2023. Efforts by TEP, Salmon SuperHwy, the Wild Salmon Center, and other partners are also

currently underway to develop salmon recovery plans for threatened coho salmon in the Tillamook Bay watershed, with plans to initiate work for the Nestucca Bay watershed in the near future.

Sensitivity

The managed natural resources in Tillamook County estuaries are extremely vulnerable to the threat of flood-related hazards. Stakeholders in the Natural Resources sectors identified "heavy rains & river flooding" as their hazard of greatest concern, followed closely by "water table/quality issues" and "king tides/tidal flooding". This was consistent with their rankings of perceived hazard risk. Aquatic species and their habitats are experiencing impacts from a number of climate change-related and other anthropogenic stressors such as changes to water quality and quantity, sea level rise, drought, and saltwater intrusion. Increasing frequency and severity of flood-related hazards will degrade habitats and disrupt ecological communities. These impacts will likely be exacerbated by compound effects from anticipated changes to climate and ocean conditions in the coming decades.

The vulnerable assets, resources, and populations identified by Natural Resources sectors stakeholders are broadly categorized as "Ecosystem Health & Connectivity" and "Vulnerable Species & Habitats".

Ecosystem Health & Connectivity: The influences and interactions of human presence on the landscape with the quality, availability, and connectivity of water throughout the river-estuarine system.

Vulnerable Species & Habitats: Those species seen as most vulnerable to impacts of natural hazards and effects of climate change, and their relationships to habitat quality and availability.

Ecosystem Health & Connectivity

Water Quality

Water quality can be impacted by changes in flow, turbidity, temperature, nutrient availability, dissolved oxygen (DO) concentration, acidification, and other measures. Natural resources are presently moderately impacted by increasing temperatures, low DO, and low flow, particularly as they relate to climate change impacts. Flooding and land use changes exacerbate issues of increased sedimentation, low water flow, increasing temperatures, and low DO. Increased

sedimentation negatively impacts intertidal eelgrasses (*Zostera* spp.) by reducing light penetration and DO. Increases in large storm events associated with climate change can also increase erosion of eelgrass beds, further reducing water quality and available habitat. Commercial and recreational fish and shellfish harvests are expected to be negatively impacted as well, with increased shellfish mortality associated with estuarine freshening and climate change impacts. Changes in temperature and precipitation have already impacted some restoration efforts. Groundwater and spring water sources may also be increasingly threatened by changes in precipitation patterns as well as saltwater intrusion. Improved watershed management is needed with a focus on water table protection by improving upland water storage for lean times.

Waterway Control and Access Infrastructure (Connectivity)

Many water control structures (e.g., culverts, levees, dikes, tide gates, jetties, et al.) throughout the county are failing and in need of upgrades, repairs, or replacement. These structures can maintain or inhibit waterway and habitat connectivity for many species, as well as transportation connectivity for human communities. Natural resources concerns for these structures mainly focused on structures associated with road crossings (e.g., bridges, culverts), which are seen as particularly vulnerable to flood-related impacts. Culverts and other water crossings already frequently flood, and can be subject to washouts and other forms of degradation, disrupting habitat connectivity and fish passage. The Salmon SuperHwy group and partners including watershed councils, TEP, and Tillamook County Public Works among others, are coordinating many local efforts to address fish passage needs. Other ongoing efforts are focused on maintenance of aging levees such as at the south end of Sand Lake, and surrounding the bayside lagoons at the Nehalem Wastewater Agency, which are frequently overtopped by floodwaters.

Transportation infrastructure concerns were two-fold: 1) impacts to accessibility and connectivity of local stakeholders, and 2) the status of culverts and other water crossings. US Hwy 101 and OR 6 were identified as key vulnerabilities, as they are the primary access routes for these communities. However, participants noted that the duration of annual flooding on US Hwy 101 in the City of Tillamook has improved in recent years following implementation of the Southern Flow Corridor project. There is a high density of small, private roads in the county with stream crossings that are generally able to cope with moderate flows but are overwhelmed by larger flood events. Wilson River Loop is a backup route north of town, but is also subject to regular flooding. Burton-Fraser Road along the Tillamook River experiences frequent flooding and is degrading rapidly. If it fails, it could impact access to numerous residents in three communities.

Flooding in the Nehalem River estuary continues to impact US Hwy 101, which could isolate the communities of Nehalem, Wheeler, and Manzanita. Large rain and flood events are often accompanied by landslides as well, and recent landslides have impacted US Hwy 101 access near Wheeler. Miami-Foley Road is an alternate route but is quite vulnerable to landslides, floods, and culvert washouts.

Excess water is also likely to exacerbate runoff and other pollution issues and overtax wastewater treatment facilities. Impacts to water access infrastructure such as boat launches and docks managed by the Ports threaten the ability of natural resource managers to access habitats and species for assessment, monitoring, and restoration efforts.

Working Lands

Agricultural and working lands are often at a nexus between sea level rise and increasing inundation and severity of winter storms, which can accelerate erosion on streambanks. These conditions also threaten fish access to refugia from impending culvert failures but can be improved by removing unnecessary instream barriers and replacing aging structures. This would also improve the condition and resilience of local transportation infrastructure. Restoration of other natural stream processes will improve habitat function and connectivity and benefit fish and other aquatic species. Runoff from agricultural activity (e.g., pesticides, manure waste, sediment, petroleum products) are also a key concern for local water quality and ecosystem health. Farmlands increasingly experience loss and inundation, including stream bank failure on farmland streams, and a large flood could spoil a whole year of production for smaller producers especially.

Vulnerable Species & Habitats

Key Species

All fish species that utilize the estuaries were seen as vulnerable to hazard impacts, but in particular more sensitive species such as salmon, steelhead, trout, lamprey, etc. Juvenile coho in particular rely on sufficient connectivity and can be negatively impacted by disruptions to habitat connectivity and water quality. Eelgrass and shellfish are both impacted by flooding everywhere in the estuaries, but largely in Tillamook and Netarts Bays relative to the other estuaries. Recreational and commercial harvests of fish and shellfish accessed by local stakeholders and members of Tribal Nations are likely to experience impacts as well. Invasive species issues will likely be exacerbated by climate change related impacts as well.

Habitats

Climate change-resilient habitats and habitat connectivity for salmonids and other fish and aquatic species were identified as key assets of concern. Many coldwater fishes rely on a diversity of habitats for spawning and rearing and are very vulnerable to climate impacts, including endangered coho salmon. Sensitive habitats such as *Zostera marina* eelgrass beds, intertidal mudflats, and tidal wetlands, are restricted by temperature, climate, elevation, and geography. Eelgrass currently occupies all the available suitable estuarine habitat, limiting capacity for expansion other than through potential changes in distribution induced by future climate change and sea level rise.

Negative impacts to habitats and species can be addressed through avenues to maintain ocean-estuary-river connections. Tidal wetland restoration and reconnection through removal, replacement, or upgrading of connectivity barriers can help restore lost connections and absorb

or redirect flood waters. Other efforts to protect or restore habitats and biological diversity will also improve natural resource outcomes.

Other

Other community impact concerns included floodwaters overtaxing wastewater treatment facilities, which take time to come back online, requiring regulatory testing. Flood inundation in and around Neskowin has made roads and bridges impassable at times (most recently at the height of the November 2021 flood event), inundating and isolating neighborhoods including Proposal Rock Loop, the adjacent RV park, and other portions of the Neskowin community. Low-income, temporary workforce housing, and RV parks on the Wilson and Nestucca Rivers are especially vulnerable to flood impacts. Other concerns included impacts to communications networks, disruptions to OR Hwy 6 (floods, landslides), and wildfire.

Risk

Tillamook County has a natural resources-dependent economy, with many vulnerable assets, resources, and populations in flood hazard areas. The assets, resources, and populations described above are vulnerable to several hazards, with the greatest concern expressed for river flooding, water table/quality issues, and tidal flooding. Concern for these hazards was frequently framed in the context of climate change-related impacts to aquatic species and habitats (e.g., warming, ocean acidification & hypoxia) as well as working lands (e.g., sea level rise, saltwater inundation). Additive impacts of climate change factors (e.g., water temperatures, drought, flooding, precipitation, ocean cycles) are anticipated across terrestrial and aquatic systems. Increasing frequency, intensity, and severity of flooding will impact working lands and subsequently increase community impacts. Decreasing water storage in the upper reaches of the watershed is also impacting natural resources and challenges agricultural productivity. Addressing impacts and stressors on natural resources was frequently viewed in a regional or global context, such as tackling greenhouse gas emissions, or in combination with efforts to mitigate impacts of multiple natural hazards.

A large flood event will have considerable direct and indirect impacts to human and natural communities. Negative impacts to fish and shellfish and their habitats may indirectly affect tourism and the local economy. Costs associated with industry interruptions, repairing or rebuilding infrastructure, and adaptation measures, will degrade economic resilience and impact way-of-life. Changes to city planning often battle economic pressure for simpler or short-term solutions, which may not be compatible with natural resource protection and management.

Overall, sensitivity of natural resources to flood-related impacts was seen as unclear, but high for human communities and built infrastructure. This was related to variable resilience among habitats, species, and sites, and potential positive outcomes such as an increase in in-stream large woody debris. Consequently, potential recovery could take anywhere from days to decades, depending on severity of the event. A significant flood event could result in permanent changes to the system, which are not always beneficial. However, efforts have improved resilience in some places to the standard of the 1996 flood event.

Stakeholders in the Natural Resources Sectors reported the highest average level of urgency to reduce hazard risks (VERY URGENT) when compared to the other sectors evaluated. Time frames to address these risks are generally seen as immediate, with time horizons of the next decade or two to take significant mitigation action. Negative impacts are already occurring on local natural resources and are expected to increase dramatically in the next several decades. Actions to address these impacts need to account for long-term change and anticipated future conditions. There are some specific concerns expressed about the impacts of increasing CO_2/low pH conditions already occurring on the Oregon Coast. Future changes in climate are expected to amplify these issues, as well as contribute to second and third order effects in ecological communities.

Efforts to adapt to the threat of hazards are occurring to various degrees, and often focus on habitat connectivity and restoration efforts. The Salmon SuperHwy group oversees numerous projects to improve infrastructure and restore habitat access for fish. The Oregon Agricultural Trust is coordinating with local landowners to identify farmlands for voluntary conservation easements. Trout Unlimited and the USDA are working on multiple projects through a Regional Conservation Partnership Program (RCPP) grant to replace undersized culverts and other infrastructure improvements to reduce flooding and restore riparian habitat, with significant financial support from the Tillamook County Creamery Association. The Nestucca, Neskowin, and Sand Lake Watersheds Council along with TEP, Lower Nehalem Watershed Council, ODFW, and others, are improving riparian habitats to encourage beaver presence and reconnect floodplains. Several stakeholders participated in the Southern Flow Corridor project led by Tillamook County and TEP, which also maintains a Comprehensive Conservation and Management Plan, and conducted the climate preparedness vulnerability assessment and adaptive management strategy in 2018.

Burton-Fraser Road, Tillamook Bay, 2020. Photo courtesy of Tamara Enz.

Industry & Infrastructure

Sector Description

This section details the vulnerabilities of those participants grouped and evaluated under the "Industry & Infrastructure" sector. Stakeholders consolidated as the Industry & Infrastructure sector include those whose primary functions are managing economic and built infrastructure including utilities, state and federal agencies, municipal governments, and many local businesses. These stakeholders generally focus on construction and maintenance of hard infrastructure (e.g., roads, bridges, buildings, utilities) and generating driving local economies through local goods, services, and other revenue sources. Major concerns for this sector are maintaining transportation connectivity, and replacing, upgrading, and overhauling aging water infrastructure. Participants also expressed concerns regarding ecological health related to estuarine habitats and species.

Participating Stakeholder Organizations

- Kayak Tillamook County
- Neahkahnie Water District
- Nehalem Bay Wastewater Agency
- Oregon Department of Transportation
- Port of Garibaldi
- Port of Tillamook Bay
- Stimson Lumber Company
- Tillamook Coast Visitors Association
- Tillamook County (Community Development)

Vulnerability

Industry & Infrastructure sector participants indicated their hazards of greatest concern to be heavy rains & river flooding, tsunami/earthquake, and water table/quality issues. The highest rated hazard of greatest risk remained heavy rains & river flooding, while tidal flooding/king tides and climate change were also most highly rated. Vulnerabilities were assessed primarily with the composite flood hazard in mind, composed from the varying concern with the different flood sources. Table 5 provides a summary of the vulnerability assessment findings.

Table 5. Industry & Infrastructure Sector Vulnerabilities Summary

Critical Interdependencies	Critical Vulnerabilities
The systems, resources, assets, infrastructure, and populations that this community depends on to properly function include: • Transportation infrastructure (roads, bridges, connectivity) • Water and sewer infrastructure • County fairgrounds, airport • Community connectivity	**The resources, assets, and populations identified as particularly vulnerable to the assessed hazard include:** • US Hwy 101, OR 6 • Water infrastructure • Nehalem wastewater plant • Tillamook railway (fiber optic cables, escape route)
Hazards of Greatest Risk	**Hazards of Greatest Concern**
Subjective ranking of the perceived risk imposed by current or projected natural hazards based on probability and consequence of occurrence: • Heavy rains & river flooding • Tidal flooding, king tides • Climate change	**The most critical natural hazards of concern that may be chronic or episodic in nature:** • Heavy rains & river flooding • Tsunami/earthquake • Water table/quality issues

Vulnerability Rankings

Adaptive Capacity†	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

Primary Hazard Assessed: Flooding (composite: heavy rains, river & tidal flooding, sea level rise, storm surge, tsunami)

Sensitivity	Impact	Hazard Vulnerability
MEDIUM	MEDIUM	HIGH

†*Note:* Adaptive capacity is ranked in the *opposite* direction of the other factors (i.e., low adaptive capacity is bad, whereas low vulnerability is good), and is evaluated independent of a given hazard.

Some of the notable assets or resources (e.g., specific infrastructure, natural resources, critical habitat, vulnerable populations, cultural resources, equipment/tools, structures, etc.) identified as most vulnerable to the hazard(s) of concern are as follows:

- Transportation networks connecting with rest of state (US Hwy 101, OR 6, OR 53)
- Bridges and other water crossings
- Tillamook Port railway, buildings, and utilities
- Tillamook Municipal Airport, historic blimp hangar
- In-ground sewer lines
- Backup generators, pump stations, trailer-mounted pumps, vacuum sewer cleaner, and other emergency equipment for water infrastructure and utilities
- Vulnerable electrical grid components
- ~⅓ of county culverts in need of maintenance or upgrades

- Vulnerable housing, vacation rentals, workforce housing
- Safety for tourists
- Neskowin Beach Golf Course
- Fish and shellfish cultivation
- Estuarine & stream system habitat for key species (e.g., salmon, Dungeness crab, other shellfish)
- Water quality (streams, ocean, Netarts Bay, sea salt)
- Springwater sources on Neahkahnie Mtn.
- Salmon passage
- Beaches and sand dunes

Figure 8. Highway and road impacts across Tillamook Bay.

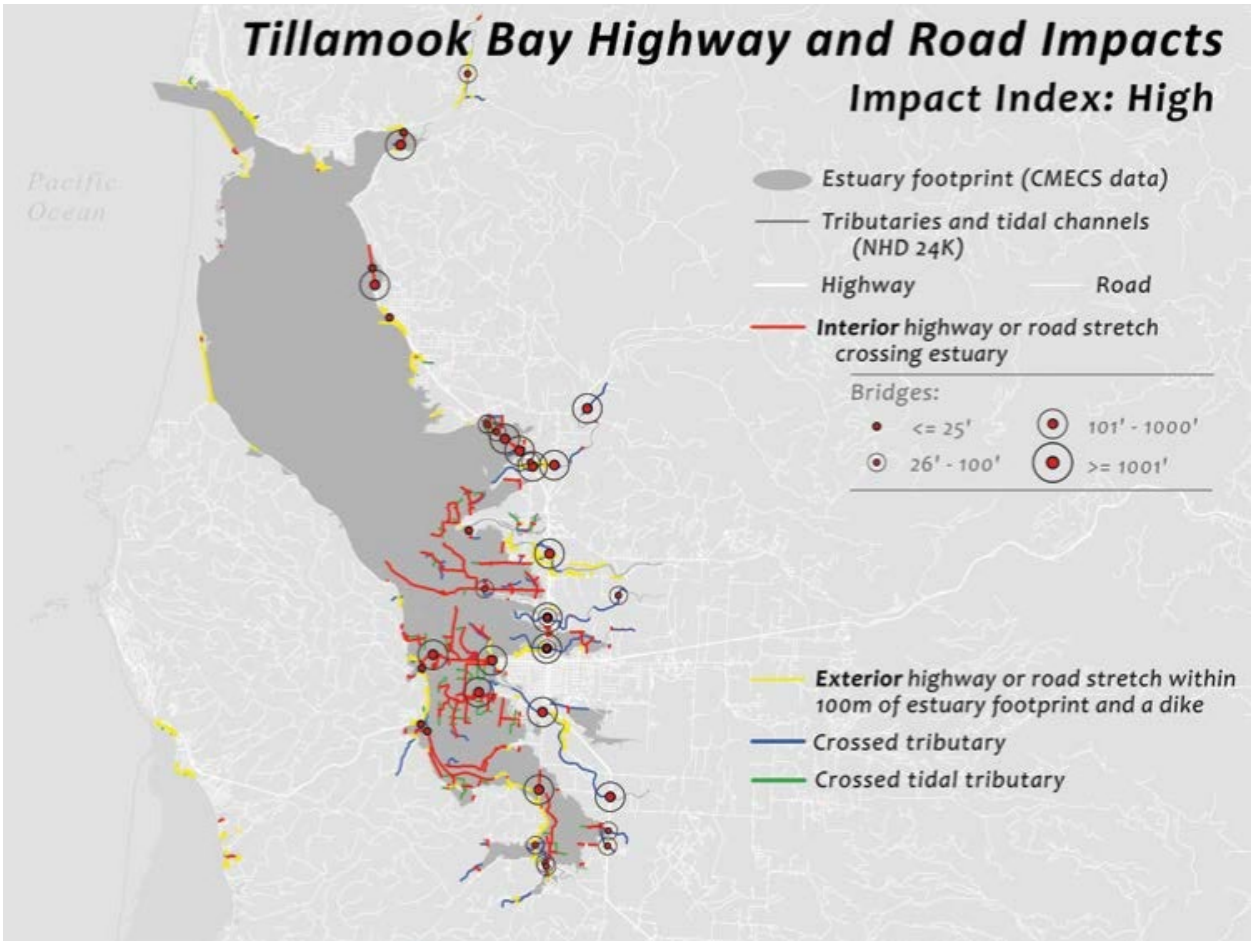


Image source: Pickering et al. 2018

Adaptive Capacity

Adaptive Capacity is a natural, built, or human system's ability to accommodate a new or changing environment, exploit beneficial opportunities and/or moderate negative effects.

Adaptive Capacity	LOW

Current Condition

Overall, the short-term adaptive capacity of the Industry & Infrastructure sector was determined to be **LOW**. Limitations on supplies to replace, repair, or maintain infrastructure, and the ability to transport people and resources, were identified as challenges to natural hazard readiness and response for these sectors.

The primary routes in Tillamook County are US Hwy 101, and Oregon Routes 6, 22, and 53. Portions of all these routes are susceptible to earthquakes, landslides, and flooding, with annual disruptions a common occurrence along US Hwy 101 and many other local routes (TCMJ NHMP 2017). The majority of the county's primary and secondary roads have bridges, with 36% of them identified as distressed or structurally deficient (*ibid*). Air travel and Life Flight services in the region are served primarily by the Tillamook Municipal Airport and two state airports in Nehalem and Pacific City. The Ports of Tillamook Bay and Garibaldi are also important transportation nodes.

Water utilities in the region rely on groundwater supply and upland reservoirs, the Port of Tillamook Bay an important water rights distributor. The primary wastewater treatment plants adjacent to the estuaries are located in Nehalem, Bay City, and Tillamook, with all three vulnerable to sea level rise and other flood-related hazards. Electric power in the region is provided by the Tillamook People's Utility District with substations throughout the county and an easement at the Port of Tillamook Bay grounds.

Redundancies

Demand on infrastructure systems is relatively high, with expectations to exceed capacity dependent on the system in question. For most infrastructure systems (in particular transportation), expectations are for a 5-20 year time frame, whereas water infrastructure is more urgently needed within the next 1-5 years. Groundwater and wastewater systems are most vulnerable due to aging components and infiltration. Tillamook People's Utility District (TPUD) is conducting a groundwater study to develop their own water sources. During construction of the Tillamook Municipal Airport, a creek was moved, and water lines were placed under the runway. Those pipes are corroding and currently being moved and replaced. Other infrastructure concerns include storm damage to roads, culvert capacity and fish passage issues, and capacity for tourism demands. Replacing, repairing, or upgrading infrastructure in this sector likely needs to occur within less than five years, but is regarded as logistically and financially difficult. For some (ports, transportation, water, wastewater), upgrades and

maintenance are a perennial need and full readiness as a goal will always be out of reach. Few, if any, systemic redundancies exist.

Transportation routes are recognized as a critical interdependency. While most communities rely on the primary transportation routes (US Hwy 101, OR 6), when they are disrupted then other key county, city, and forest roads become essential for many, including Oregon Dept. of Transportation (ODOT). Similarly, water crossings are also a high concern as alternatives are often limited or non-existent.

Critical water infrastructure components have limited availability and are unable to be stockpiled, limiting adaptability of those systems. While emergency septic systems could temporarily provide wastewater capacity, getting systems working again requires local staff capacity to be maintained near current levels.

Other critical interdependencies include the Tillamook County Fairgrounds and local airports (Tillamook, Nehalem, Pacific City) as emergency staging areas, and the Tillamook Railway and its associated right-of-way for utilities. Tax revenue generated through tourism activity is also critical as it's partially used to build and maintain infrastructure.

Management Actions

Finally, capacity for many services, including essential and emergency services, is frequently constrained. Funding is perennially lacking, while staffing is often part-time or on a voluntary basis. Responsibilities for a number of services are disproportionately maintained by a relatively small pool of local residents. When services are urgently needed, disruptions to the ability of even a small handful of people to access facilities, resources, equipment, or service populations, can temporarily eliminate multiple services.

Sensitivity

Industry and infrastructure-related sectors in Tillamook County are moderately vulnerable to the threat of flood-related hazards, with some assets and resources being especially vulnerable. Stakeholders in the Industry & Infrastructure sectors identified "heavy rains & river flooding" as their hazard of greatest concern, followed closely by "tsunami/earthquake" and "water table/quality issues". Similarly, "heavy rains & river flooding" was ranked highest for perceived hazard risk, but followed by "tidal flooding, king tides" and "climate change". Critical infrastructure such as transportation and water infrastructure are most threatened and have limited redundancies resulting in low adaptive capacity. Many facilities, sites, and infrastructure are in need of being replaced, upgraded, or overhauled within <5 years, but few are slated for such maintenance. Sensitivity was perceived to be very high, with restoration to normal operations likely to take weeks or months in the event of a severe flood impacting most of the surrounding communities.

The vulnerable assets, resources, and populations identified by Industry & Infrastructure sectors stakeholders are broadly categorized as "Built Infrastructure" and "Economic Dependencies".

Built Infrastructure: Buildings, homes, ports, roads, highways, bridges, railways, utilities, water and wastewater systems, electrical grids, and other community lifelines.

Economic Dependencies: Natural resources and the industries and economies that rely on their quality and availability, including the majority of coastal tourism. Local community connections and interdependent nature.

Built Infrastructure

Maintenance & Supplies

Regular maintenance schedules are needed for most built infrastructure, which are compounded by natural hazard impacts such as erosion and corrosion from flooding. Demand on infrastructure systems is relatively high, with expectations to exceed capacity for key systems such as water infrastructure in the next couple of decades. Approximately one third of the 3,000 culverts in Tillamook County are in poor condition and undersized for significant rain events, which have washed the surrounding soil out of many, weakening support and threatening integrity of road crossings. Already a regular occurrence, emergency culvert replacements are increasing rapidly.

Groundwater and wastewater systems were viewed as most vulnerable, due to aging components and infiltration. Many pipes are corroding and in need of replacement. The Nehalem Bay Wastewater Agency facility is located in a flood zone and while backup generators are available, roads need to remain open to deliver fuel and other regular supplies. Drinking water pipes are corroding in some places and need to be moved and replaced (e.g., under the Tillamook State Airport runway). The City of Rockaway Beach is threatened by flooding from two groundwater wells that serve as the community's drinking water source, and further research may be needed to assess the vulnerability of that groundwater to saltwater intrusion.

Replacing, repairing, or upgrading infrastructure in this sector likely needs to occur within less than five years, but is regarded as difficult logistically as well as financially. For some (ports, transportation, water, wastewater), upgrades and maintenance are a perennial need and full readiness as a goal is viewed as always out of reach. Few if any redundancies for these systems exist.

Critical Facilities

A number of facilities were identified which are either uniquely vulnerable to hazard impacts or are relied upon in the event of an emergency, and are thus deemed 'critical' facilities. The

Tillamook County Fairgrounds is used as a Red Cross station and emergency evacuation site, particularly for evacuating RV parks. The Port of Tillamook Bay railway runs from the south end of the City of Tillamook along the coast through Bay City, Garibaldi, Rockaway Beach, and up to Wheeler before it cuts east through the Coast Range and is an important right-of-way for utilities (e.g., transoceanic fiber optic cables) connecting to the Willamette Valley and beyond. Disruptions to those lines could impact utilities for a significant portion of the western U.S. The Salmonberry Trail also follows the railroad and may be used as an evacuation route in the future.

The Port of Tillamook Bay facilities and railroad are located adjacent to Tillamook Municipal Airport, which is also used for emergency evacuations. Water lines run under both runways and work is currently underway to relocate them. Infrastructure at the main Port of Tillamook campus (buildings, utilities, airport, historic blimp hangar) are vulnerable to natural hazard impacts, although generally not subject to flooding making it a potentially useful staging area for emergency response.

Vulnerable housing was identified as also critical. This includes housing located in flood hazard areas throughout the county, areas with a high density of vacation or rental homes, and workforce housing.

Critical Systems

These infrastructure systems connect communities to one another and can be important community lifelines, yet are uniquely vulnerable to hazard impacts and relied upon in the event of an emergency. Keeping primary transportation routes open emerged as a primary concern for responding to natural hazard impacts especially in the event of a major flood. US Hwy 101 and OR 6 are top priorities for maintaining access during any hazard event. Disruptions to transportation systems will impact many businesses and industries, including agriculture and tourism. The highways have no reliable detours available, so keeping the main routes functioning is vital when police, fire, EMS, and other first responders need to access communities and impact sites, or citizens need to get to work or access vital services such as healthcare facilities. Flooding is the primary threat to roads, not only with inundation at water crossings (bridges and culverts), but also through erosion and corrosion of built infrastructure. Major water crossings can't be repaired quickly if they are washed out, potentially isolating some communities for extended periods of time. State, county, and private forest roads are all needed in the event of an emergency. Forest roads are relied upon by timber companies to get logs out of woods and to the mill, but can also serve as backup routes when access is otherwise blocked on primary routes.

Adaptive capacity of the water infrastructure systems is currently very low. Many pipes are corroding and in need of replacement. The Nehalem Bay Wastewater Agency facility is located in a flood hazard area and is threatened by inundation during severe storm events. Levees surround the lagoons, but stormwater has been known to overtop them, and during the storm of 1996 a foot of water infiltrated the plant facility. While backup generators are available, with sewer lines, pump stations, and electrical infrastructure all vulnerable to flooding, roads would

need to remain open to deliver fuel and other supplies to maintain operations. COVID-19 pandemic-related impacts to global supply chains currently challenge the logistics of acquiring water pipes and consequently there is no stockpile of pipes available even for routine maintenance.

Economic Dependencies

Ecosystem Health

Healthy natural systems and resources support local economies, especially on the Oregon Coast, and these important linkages are vital to numerous industries and businesses. There is concern that industry-related activities may be negatively impacting species and ecosystems, which may in-turn harm local economies.

Healthy habitats, especially estuarine and stream habitats that support key species such as salmon, Dungeness crab, shellfish, and other consumptive harvest species, including areas utilized for fish and shellfish cultivation. Maintaining and improving fish passage is also an important component to protecting ecosystem health.

Natural landscapes and coastal wildlife attract tourism dollars that are relied upon by many communities and businesses. Maintaining healthy beach and dune ecosystems is an important aspect to supporting the local tourism industry. Natural hazards also now draw considerable tourist attention for king tide and winter storm events, but this increases hazard risk. Tourism activities are increasing coastwide and it is unclear how industry and infrastructure can keep pace with capacity demands while also maintaining safety.

Water Quality & Availability

The TPUD is wholly dependent on the City of Tillamook for water distribution, but is conducting a groundwater study to develop their own water sources. There are three spring water sources on Neahkahnie Mountain that are all at high risk of residential septic discharge threatening their water quality. Mitigation will likely require improving local drainage, expanding septic capacity, and reducing impact of expanding residential development (CWM 2018). Runoff and habitat degradation threaten water quality in the watershed, which accumulate and compound in the estuaries.

Community

Finally, local capacity for services in Tillamook County is often built through personal relationships and people “wearing many hats” (e.g., many individuals are cross-trained for emergency response). This community connectivity was recognized as a key strength in hazard response and recovery. However, given the geographic and transportation constraints of the region, this connectivity is highly vulnerable to disruption by impacts to transportation routes or other critical infrastructure. The ability of a handful of individuals to access essential sites could make or break hazard response and recovery. With a relatively small population, capacity across the county can be limited with many people filling multiple vital roles. This results in a

tight knit community with a high degree of interdependency on contractors, volunteers, and other helping hands in times of need. The ability to communicate, coordinate, and supply these efforts is critical to Tillamook County resilience. While normally this community interconnectivity is regarded as a strength, a moderate disruption can quickly turn it into a vulnerability during an emergency.

Risk

The assets, resources, and populations described above are vulnerable to several hazards, with the greatest concern expressed for heavy rains & river flooding, tsunami/earthquake, and water table/quality issues. While major episodic flood events are top of mind, chronic issues with flooding and climate change-related hazards compound the ability to adapt quickly enough.

The effect of additional stressors is moderate. Funding to maintain and upgrade infrastructure is needed but often not enough is available. With many small roads throughout the county in need of repair from erosion or inundation, deterioration may outpace the ability to respond. Sections of US Hwy 101 are built on ancient landslides and are at greater risk of catastrophic failure. Impacts to water distribution and the water table are also of concern.

Natural hazard impact sensitivity is extreme for this sector given the threat of a major flood event equal to or greater than those seen in 1996 or 2007. Recovery would be slow, with potential for devastating impacts. Stakeholders feel reasonably prepared for response and recovery from more frequent storm events that are of moderate severity, with return to normal operations taking at least several weeks, depending on the facilities impacted. Anticipated impacts may still be considerable however, affecting most local communities, which already experiences indirect effects. Downstream impacts to industry are felt via disruption to movement of goods (e.g., logs and lumber to and from mills), and access to employers and services. Miami-Foley Road is often used as a detour route by ODOT vehicles which compensates the county for its use and is impacted by associated fuel costs. Infrastructure needs are often served by special districts with limited capacity, which changes as priorities shift and can impact progress on other work. There needs to be a clear way to prioritize responses and funding efforts, and greater clarity and cooperation from and within state agencies to move forward with necessary work.

Critical infrastructure vulnerabilities are largely associated with utilities and transportation, including Port facilities. The condition of the blimp hanger is deteriorating and is highly vulnerable to storm damage and fire. Further, the blimp hangar houses several local businesses and extensive high-dollar-value personal property (e.g., airplanes, RVs), but has been deemed uninsurable. Other critical utility assets include the Nehalem Bay Wastewater Agency's sewer lines and pump stations, and the electrical grid, and are vulnerable to major disruption.

Urgency to address these issues is elevated, with many stakeholders seeing immediate need for action to reduce severity of damage from a Cascadia subduction zone earthquake and tsunami. Others report the need to prepare within five years for other hazards. While planning and partnership efforts to adapt are actively occurring, progress is slow, and capacity and funding

are limited. Several stakeholders report efforts to increase stockpiles of supplies and equipment for emergencies, as well as utilizing new methods and strategies for adaptation such as designing structures to meet or exceed 100-year flood events standards, updating infrastructure inventories, planting dune/beach grasses for erosion control, and engaging in planning and management efforts.

Downtown Nehalem and Nehalem Bay Wastewater Agency, Nehalem Bay, 2021. Photo courtesy of Tyler Sloan.

IV. Adaptation Strategies and Actions

The following section outlines potential actions identified by local stakeholders to address natural hazard resilience in Tillamook County estuaries. The majority of these actions fall under the broad umbrella of "nature-based solutions", which typically rely on natural ("green") infrastructure and processes to mitigate the impacts of natural hazards and other environmental stressors. These stressors can be greatly exacerbated by human land use activities in the estuarine basins, but can often be mitigated through relatively simple actions such as habitat restoration and reconnection of waterways.

Adaptation Strategies

Vulnerability information gathered from the stakeholder outreach and engagement work was compiled and evaluated for initial vulnerability determinations, and used to help identify and develop lists of potential adaptation actions that local stakeholders and partners would be willing to support. This information was presented to stakeholders for validation in a series of adaptation action planning workshops and individual interviews held in spring and fall 2022, which focused on reviewing vulnerability assessment results and refining adaptation action details. Similar local vulnerability assessment efforts in the past focused on a wide range of potential actions that include a variety of structural and non-structural solutions that may or may not be site-specific. The potential actions identified for the ERAP effort are intended to be narrower in scope, focusing mostly on site-specific nature-based solutions and green infrastructure options wherever possible.

Tillamook Bay near US Hwy 101, 2021. Photo courtesy of Bill Hassell.

Nature-Based Solutions

Figure 9. Examples of nature-based solutions utilizing green infrastructure.

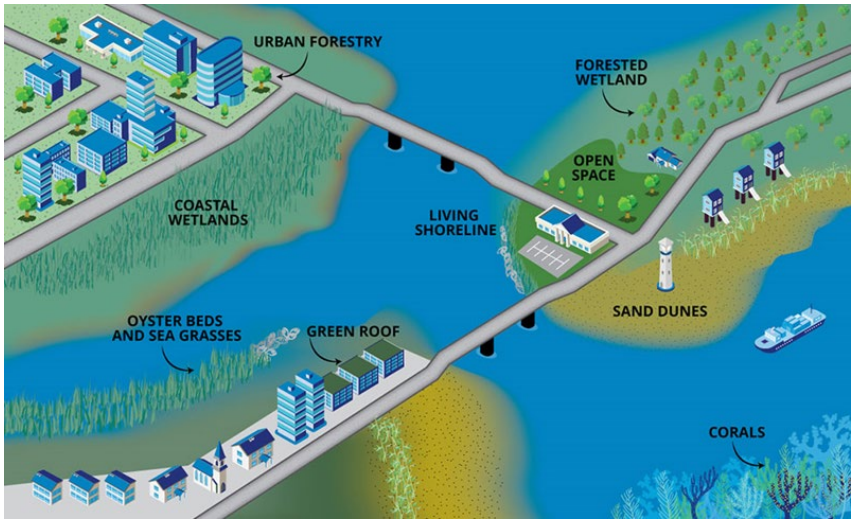


Image source: NOAA

The goal of the ERAP process is to identify and describe potential nature-based solutions for local estuarine resilience needs, and help prepare projects for future funding by NFWF and other funding organizations. The umbrella of nature-based solutions covers many kinds of actions, but stands in contrast to traditional "hard" (gray) infrastructure options. Gray infrastructure relies on steel and concrete structures such as seawalls, dams, tide gates, stormwater pumps, etc., to control flooding and erosion. While effective, engineering these structures is often a more costly solution and time-intensive process than nature-based solutions. They require more frequent maintenance, increase runoff, minimize natural hydrological function, reduce ecosystem service benefits, and are less aesthetically pleasing. These factors may manifest themselves as impacts on the local economy over time by increasing municipal costs and decreasing revenue generated by tourism and recreation.

When it comes to vulnerable coastal areas, natural infrastructure is a proven and cost-efficient approach to mitigate coastal hazards. The components vary but the basic premise is often the same: slowing and absorbing floodwaters by redirecting water, reducing wave height, and attenuating wave energy. They also provide many other benefits to fish and wildlife by creating coastal habitats, protecting sensitive species, improving water quality, reducing erosion, improving local conditions and economies, and many other co-benefits. The components may include coastal wetlands/marshes, oyster and coral reefs, beaches and sand dunes, coastal vegetation (e.g., seagrasses), permeable pavements and bioswales, green roofs and rain barrels, and incorporation of natural areas into city designs and other planning efforts. Natural infrastructure can help mitigate non-flood-related hazards as well, such as threats to water or air quality, or excessive wind, heat, or drought, but flooding is often the focus.

Highlighting Nature-Based Solutions: Southern Flow Corridor Project

This collaborative multi-phase project highlights the positive impact of leveraging local stakeholder partnerships to implement nature-based solutions and increase estuarine resilience. Located on a delta near the City of Tillamook, the Southern Flow Corridor area was diked and drained for agricultural use. Nearly 20 years of planning and cooperation between local communities, state agencies, conservation organizations, and private landowners, produced a hybrid solution that provides benefits to important aquatic species (e.g., coho salmon) by restoring habitat, and to local communities through flood mitigation.

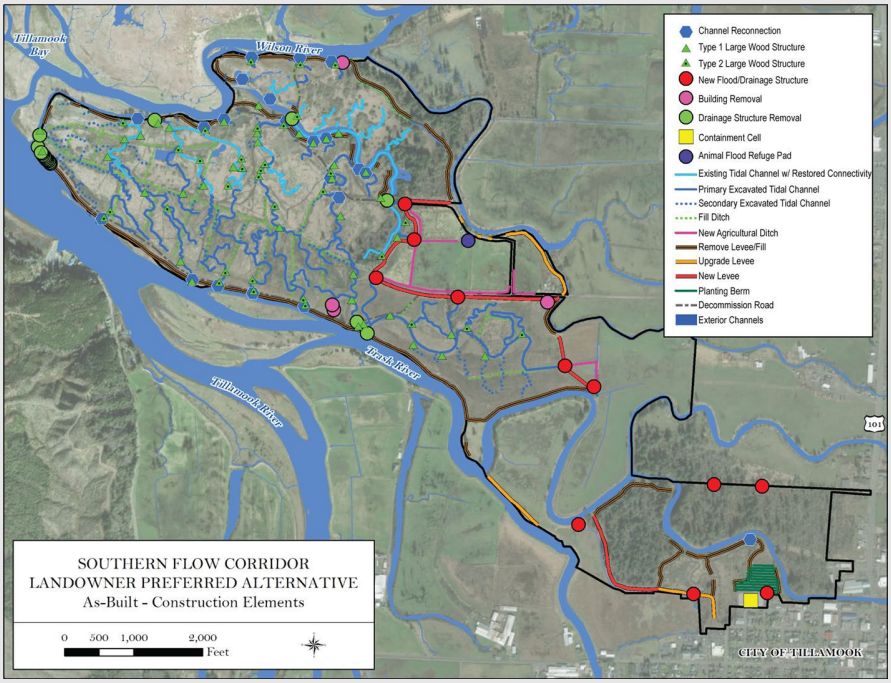


Image Source: Allan et al. 2018

Project Accomplishments

- Restored >500 acres of habitat for species such as coho salmon
- Reconnected >13 miles of tidal channels
- Reduced flooding to 4,800 acres of the community
- Stored 27,000 tons of coastal blue carbon valued at >$0.5m
- Supported 108 jobs and $14.6m in economic value
- Increased value of nearby homes by 10%
- Improved estuarine water quality (temp., DO, turb.)
- Increased tidal wetland habitat complexity and availability
- Enhanced ecological function for many species

A Hybrid Approach Restoration work at the Southern Flow Corridor site relied on numerous green infrastructure tools and methods to reconnect waterways and enhance fish and wildlife habitats. This included removal of over 7.5 miles of levees and 15 tide gates, and filled 4.5 miles of agricultural ditches. Hydrologic function was then restored with construction of 9,000 feet of new setback levees, eight new fish-friendly tide gates, and six flood gates. In addition, restoration included construction of 70 large woody debris structures with a complement of native plantings focused on enhancing tidal wetland habitat for fish and wildlife (TEP 2021).

Successful green infrastructure practices often rely on natural areas and open spaces and incorporate multi-functionality (e.g., recreation, stormwater storage, filtration, etc.) They connect people to open areas and help provide a sense of place. Potential projects should be placed in the context of the greater community. Typically, green infrastructure projects serve to preserve and enhance natural features by mimicking or enhancing existing hydrology or other natural functions. They can also provide ecosystem benefits by utilizing urban streetscapes (e.g., minimizing impervious cover, enhancing bioretention and filtration), and should offer a return on the investment through ecosystem services.

Adaptation Actions

The adaptation actions identified below arose from the stakeholder outreach and engagement efforts conducted in 2022. Some actions were already in development while others represent ideas that have been deprioritized due to unmet needs such as lack of funding or design plans. Details for each action are outlined including lead organization and potential partners, green infrastructure components, project status and readiness, and prioritization rankings. **'Proposed Lead' and 'Potential Partners' columns do not represent formal commitments, but rather recommendations from steering committees and other stakeholders.** 'Status' and 'Project Readiness' columns represent general estimates of where the project currently stands with respect to development and initiation. Prioritization rankings – highlighted in green – were negotiated by project partners and stakeholders, using the following criteria developed by IPRE:

Ease

- Low = Difficult to accomplish with existing resources/capabilities
- Medium = Moderately easy to accomplish with existing resources/capabilities
- High = Relatively easy to accomplish with existing resources/capabilities

Impact

- Low = Will have little impact on decreasing vulnerability/increasing resilience
- Medium = Will have moderate impact on decreasing vulnerability/increasing resilience
- High = Will have large impact on decreasing vulnerability/increasing resilience

Cost

- $ = $100K or less
- $$ = $100k to $1 million
- $$$ = $1 million or more

A priority ranking was then assigned to each action based on the factors above, and determined in consideration with stakeholder input:

Priority

- Low = generally ease (lower), impact (lower), cost is a factor
- Medium = generally ease (low, medium), impact (low, medium), cost is a factor
- High = generally ease (high, medium), impact (high, medium), cost is a factor

Implementation

Development of the Tillamook County ERAP was overseen by the Tillamook Working Group, representing numerous stakeholder organizations. While the County, cities, state and federal agencies, non-profit organizations, tribes, and others are responsible for implementing the identified resilience actions, the structure of this effort can be leveraged for continued resilience planning. While the goal is to move all the identified resilience actions toward advanced stages of completion, ongoing coordination can help sustain proper maintenance and identify future opportunities.

The TEP can help recommend future resilience actions for development and funding, and along with the OCMP, periodically coordinate and facilitate meetings to evaluate progress. Organizations identified as potential project leads and partners should be engaged throughout development to support project planning and acquisition of funding. Other local planning efforts, such as Natural Hazard Mitigation Planning by county and city governments, can support and integrate these actions in their resilience strategies.

The Tillamook Working Group and OCMP recommend that partner organizations involved in the ERAP process convene at least once annually to review resilience actions, evaluate progress and funding opportunities, discuss coordination needs, share new data and information, and identify future resilience actions. Additional recommendations have been identified by OCMP to help clear the way for local communities and organizations to implement resilience work, including:

- Create a central digital exchange for funding opportunities, permitting assistance, and implementation support for community members and organizations developing and implementing resilience actions.
- Streamline regulatory processes for implementation, especially regarding state and federal coordination. The current regulatory process is too costly and often does not reflect the urgency of issues. A single permitting policy process that expedites and reduces costs to implement projects needs to be agreed upon by both state and federal agencies. Additional streamlining of regulations can be achieved by providing continued input at local, state, and federal levels.
- Encourage FEMA and NMFS coordination on floodplain regulation as concerns riparian planting projects in floodways.
- Develop shared outreach materials that target multiple stakeholder groups with real life examples for promoting green infrastructure solutions.
- Review and update zoning code regarding riparian setback exceptions in developed areas.

Tillamook County Actions

Stakeholder engagement efforts resulted in identification of the following nature-based actions. These actions are organized by estuary from north to south, generally going in order upriver, with a few geographically broader actions listed at the end.

Table 6. Resilience Actions Identified for Tillamook County Estuarine Areas

Action #	Estuary / Location	Action Description	Proposed Lead	Potential Partners	Status	Project Readiness	Ease (L, M, H)	Impact (L, M, H)	Cost ($, $$, $$$)	Priority (L, M, H)
1	Nehalem / Manzanita	**Neptune Way** - Property acquisition, restoration to clear blocked culvert, remove invasive parrotfeather, and reestablish sitka dominated habitat.	LNCT	LNWC, WSC	Design Phase: Seeking designs	<5 yrs	medium	high	$$	medium
2	Nehalem / Manzanita	**Sitka Wetlands** - Property restoration west and south of Tohl Ave in Nehalem to replace low open shrub habitat with sitka dominated habitat.	LNCT	LNWC, WSC	Design Phase: Seeking designs	<5 yrs	high	medium	$	medium
3	Nehalem / Manzanita	**Alder Creek** - Property improvements to continue prior restoration work and enhance hydrologic function and fish passage. Channelize stream banks and improve riparian area, reestablish large pool of tidal flow toward west end of property.	LNCT	LNWC, WSC, NRCS, OWEB, Ducks Unlimited	Design Phase: Seeking designs	5 yrs	low	high	$$$	medium
4	Nehalem / Wheeler	**Wheeler Waterfront Park** - Redesign to incorporate bioswales (to catch more runoff), native plants, trails, ADA compliance.	Wheeler	OPRD, ODFW, Port of Nehalem	Idea Phase	n/a	medium	high	$$$	high
5	Nehalem / Wheeler	**Hemlock St.** - Restore and improve drainage in marshy areas off Hemlock St. Restore/mitigate springwater flow.	Wheeler		Idea Phase	n/a	low	low	$$	low
6	Nehalem / Wheeler	**Zimmerman Marsh** - Restoration/reconnection (separated from Bott's Marsh by US Hwy 101 and Scenic RR roadbeds).	LNWC	LNCT, ODOT, OR Coast Scenic Railroad	Planning Phase	10 years	medium	medium	$$$	low
7	Nehalem / Wheeler	**McCoy Marsh** - Reduce flood/erosion risk at major transportation corridor junction (US Hwy 101, OR 53) in Nehalem Bay. Breach dikes to reduce saturation of soils, reestablish tidal flow, reconnect habitats, and restore 6 acres of wetland and fish rearing habitats.	LNCT	LNWC, ODOT	Engineering Phase: Conducting study to determine dike breaches	ongoing	high	high	$$	high
8	Nehalem	**Gallagher Slough** - Riparian vegetation restoration. Install MTRs at main gate, install riparian corridors for fish rearing habitat and water level maintenance near US Hwy 101, OR 53 junction.	LNWC	TCCA, PLOs	Design Phase: Seeking designs	ongoing	low	high	$$$	medium

9	Nehalem	**Bob's Creek Wetland** (downstream confluence of N. Fork and mainstem) - Replace two undersized culverts under N. Fork Rd. for fish passage and to reopen tidal inundation to wetland behind. Includes rerouting of creek to connect to drainage ditches, and restoration work on channels above road on Bob's Creek and small tributary.	LNWC	TCPW, LNCT	Planning Phase: Limbo	15 years	low	high	$$$	low
10	Nehalem	**Kebbe Creek** - Fish-friendly tide gate upgrades and replacements at Kebbe Creek confluence and upstream unnamed tributary.	TCCA		Planning Phase: Seeking funding opportunities	Sites identified	medium	high	$$	medium
11	Nehalem	**Foley Creek** (Miami-Foley Rd.) - Install bank setback with log crib wall and LWD for protection to provide coldwater refugia for juvenile salmonids.	LNWC	PLO	Idea Phase	2025	medium	high	$$	low
12	Nehalem / N. Fork	**Culvert 470 Wetland** (N. Fork Rd.) - Working with PLO for plan to remove nonfunctional tidegate, fill from tidal channel, reinforce ditch on south side, realign/reinforce levees, restore spruce marsh habitat (multiple options possible). Maintain grazing area.	LNWC	PLO	Idea Phase	n/a	medium	high	$$$	medium
13	Nehalem / N. Fork	**Coal Creek** - Riparian enhancement project. Restoration planting, bank setback, potential tide gate removal. Keep property in production so PLO can increase cattle.	LNWC	PLO, NCLC, WSC	Design Phase	ongoing	high	medium	$$	medium
14	Nehalem / N. Fork	**Bandy Slough** - Restoration and waterway reconnection, remove tide gate, restore fish passage, and reconnect to Adjacent Slough.	LNWC	PLO	Design Phase	ongoing	medium	medium	$$	medium
15	Tillamook / Bay City	**Kilchis Point** - Protect vulnerable neighborhood and vital infrastructure by mitigating anticipated future inundation of Kilchis Point area.	Bay City	PLOs	Idea Phase	n/a	low	high	$$$	medium
16	Tillamook	**Porter Property** - Restoration of ~60 acres on lower Kilchis River to enhance tidal and spruce swamp habitat.	TNC		Planning Phase: SB1517 Hearings	1-2 years	low	medium	$$	high
17	Tillamook	**Dougherty Slough** - Reduce total number of tide gates, remove old/failing tide gates, install newer higher quality tide gates to improve drainage and ability to redirect flood water from residents and city.	City of Tillamook PW	PLOs	Planning Phase: Limbo		medium	high	$$$	high
18	Tillamook	**Holden Creek** - Restoration/wetland reconnection. Remove tide gates to allow more flooding on adjacent (private) fields. Remove debris from ditch surrounding stream. Repair/replace culverts and gray infrastructure.	Tillamook County	City of Tillamook, PLOs	Planning Phase		medium	high	$$	high
19	Tillamook	**Tillamook Bioswales** - Improve bioswales/bioretention ponds along Main St. Replant, improve function/flow-thru.	City of Tillamook	ODOT	Design Phase: Limbo		high	low	$	medium
20	Tillamook	**TBCC** - Relocation of stormwater retention area in lot adjacent to Tillamook Bay Community College.	TBCC	PW, ODOT	Planning Phase: Limbo		medium	medium	$$$	low
21	Tillamook	**Tillamook River Wetlands** - Road relocation and habitat restoration project on about 70 acres off of Burton-Fraser Road.	TEP	NCLC, TCPW, PLO	Planning Phase: Outreach and funding		low	high	$$$	high

22	Sand Lake	**Sitka Sedge Natural Area** - Protect vulnerable community of Tierra Del Mar by addressing actively failing dike and restore tidal wetland and estuarine function on 87 acres in Sand Lake Estuary including tide gate removals, stream realignments, and culvert replacements.	TEP	OPRD, TCPW, NNSLWC, SSH, OWEB, DSL, USFWS, TEP, Tierra Del Mar	Design Phase: At 30% design, need geotech. study to assess options	ongoing	low	high	$$$	high
23	Sand Lake	**Sand Lake Large Wood Placement** - Placement of 80 large wood pieces and structures in Sand, Andy, and Jewel Creeks affecting 2.7 miles of stream channel.	NNSLWC	OWEB	Implementation Phase	Implement Aug 2023	high	medium	$	medium
24	Sand Lake & Nestucca	**Nestucca & Sand Lake Watersheds** - Restore hydrologic connectivity and function and reduce local flood risk via stream channel reconstruction, realignment, enhancements, and culvert replacements on Reneke ($1.5m), Beltz ($1m), Sand ($800k), Davis ($1m), Gurtis ($800k), No Name ($700k), Limestone ($700k), & Bower ($800k) Creeks.	TCPW	TCPW, USFS, SSH, NNSLWC	Design Phase: Varying levels of design completed	2026	medium	high	$$$	high
25	Nestucca	**Nestucca Watershed** - Large wood habitat enhancements on Horn, Louie, and Baxter Creeks.	NNSLWC	NNSLWC, PLOs, ODFW, USFWS	Design Phase	2025	medium	medium	$$	high
26	Nestucca	**Nestucca Coho SAP** - Develop coastal Coho Strategic Action Plan for Nestucca basin (including Neskowin and Sand Lake) which will prioritize future restoration actions to support coho populations.	NNSLWC	ODFW, WSC, NOAA	Planning Phase: Seeking funding opportunities	2024	high	high	$	high
27	Neskowin Watershed	**Butte Creek** - Stream channel enhancement and culvert replacement project (US Hwy 101).	ODOT	ODOT, ODFW, NNSLWC	Design Phase	2025	high	high	$$$	high
28	Neskowin Watershed	**Sutton Creek** - Stream channel enhancement and culvert replacement project on upper and lower reaches.	NNSLWC	NNSLWC, USFS, USFWS, TEP, SSH/TU, ODFW, PLOs	Design Phase: Grants submitted	2024	medium	high	$$$	high
29	Tillamook & Nestucca & Sand Lake & Neskowin Watersheds	**Tillamook Bay & Sand Lake Watersheds** - Restore hydrologic connectivity and function through stream channel enhancements, culvert and tide gate replacements, and restoration work on Flowerpot Creek tide gate ($1.5m), MP1 Creek Slab Creek Road ($700k), Mill Creek Trib B ($650k), and Mary's Creek ($100k).	SSH	NNSLWC, USFS, USFWS, TCPW, TEP, TCCA, TU, ODFW	Design Phase: Varying levels of design completed (30-90%)	1-5 years	medium	medium	$$$	high
30	Tillamook & Nestucca Watersheds	**Tillamook & Nestucca Watersheds** - Bank stabilizations on Trask River (RM3), Nestucca River near Cloverdale, Wilson River near Dougherty Slough offtake, and Kilchis River, using bio-engineered solutions (encapsulated soil lifts).	TCCA	PLOs	Design Phase: Grant submitted	ongoing	low	high	$$	medium
31	Tillamook County Watersheds	**Riparian Planting Program** - Continued funding needed to support program for Tillamook County landowners.	TEP	NRCS, TCSWCD, NNSLWC, TCCA	Implementation Phase: Seeking additional funding	ongoing	high	medium	$	medium

Adaptation Action Descriptions

The following adaptation action descriptions provide additional details and context for the identified adaptation actions listed in Table 6*. High level milestones and timelines are outlined and, where possible, expected dates are assigned to major milestones. Anticipated target funding grants and programs are also listed. The identified green infrastructure components and anticipated resilience benefits of each project are highlighted using icons to represent common elements of each. Refer to the symbol keys below for those sections. **See Acronyms*Acronyms *for additional context.*

Green Infrastructure Component(s) Key

 = restoration

 = invasive species control

 = riparian/stream channel enhancements

 = native plants

 = wetlands/marsh

 = levee/dike

 = water drainage/retention features

 = large woody debris/log cribs

 = natural area

 = myriad nature-based solution options

Anticipated Resilience Benefits Key

 = improved waterway connectivity and hydrologic function

 = flooding/storm surge reduction

 = improved fish passage

 = habitat enhancements

 = improved community resilience

 = erosion mitigation

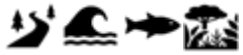
 = improved safety and access

1. **Neptune Way**
   Restoration of adjacent property to clear blocked culvert, remove invasive parrot-feather (*Myriophyllum aquaticum*), and reestablish sitka spruce-dominated habitat on 8-10 acres. Challenged by unclear ownership over culvert under private road.

   Milestones/Timeline
   - project planning
   - apply for funding

   Target Funding Source(s)
   OWEB, NFWF

   Green Infrastructure Component(s)
   

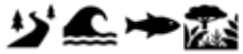
   Anticipated Resilience Benefits
   

2. **Sitka Wetlands**
   Restoration of property west and south of Tohl Ave in Nehalem to replace low, open shrub habitat with more sitka spruce-dominated habitat.

   Milestones/Timeline
   - project planning
   - apply for funding

   Target Funding Source(s)
   OWEB, NFWF

   Green Infrastructure Component(s)
   

   Anticipated Resilience Benefits
   

3. Alder Creek

Improve property to continue prior restoration work and enhance hydrologic function and fish passage. Channelize stream banks and enhance riparian area, reestablish a large pool of tidal flow toward the west end of the property.

Milestones/Timeline

- develop funding and implementation strategy
- assess options
- apply for funding

Target Funding Source(s)

OWEB, NRCS (possibly)

Green Infrastructure Component(s)

Anticipated Resilience Benefits

4. Wheeler Waterfront Park

Redesign and update waterfront park as a multi-use space that incorporates bioswales (to catch more runoff), native plants, nature trails, and improve ADA compliance. Project would also include addressing undersized culvert on Gervais Creek to improve fish passage and local drainage.

Milestones/Timeline

- community outreach and engagement
- develop vision and planning
- identify funding source(s)

Target Funding Source(s)

OPRD, ODFW OCRF, LWCF
Recreational Trails Program
ODOT Community Paths Grant

Green Infrastructure Component(s)

Anticipated Resilience Benefits

5. Hemlock Street

Restore and improve drainage in marshy areas off Hemlock St. in Wheeler to improve local safety, restore springwater flow, and mitigate and improve drainage problems. Will likely include installation of gambion boxes to prevent further erosion.

Milestones/Timeline

- project planning
- apply for funding

Target Funding Source(s)

OWEB, ODA, DEQ

Green Infrastructure Component(s)

Anticipated Resilience Benefits

6. Zimmerman Marsh

Habitat restoration of property and reconnection of waterways including culvert replacement.

Milestones/Timeline

- project planning
- apply for funding
- design work
- permitting
- earthwork

Target Funding Source(s)

OWEB Technical Assistance Grant

Green Infrastructure Component(s)

Anticipated Resilience Benefits

7. McCoy Marsh

Reduce flood/erosion risk at major transportation corridor junction (US Hwy 101, OR 53) in Nehalem Bay. Breach dikes to reduce saturation of soils, reestablish tidal flow, reconnect habitats, and restore 6 acres of wetland and fish rearing habitats.

Milestones/Timeline

2023: study
2024: engineering/permitting
2025: earthwork

Target Funding Source(s)

OWEB Technical Assistance Grant awarded in 2023 ($75k), but will have other costs

Green Infrastructure Component(s)

Anticipated Resilience Benefits

8. Gallagher Slough

Restoration of riparian vegetation and fish habitat. Replace broken tide gates with MTRs at the main gate. Install riparian corridors for fish rearing habitat and water level maintenance.

Milestones/Timeline

2023: planning and funding application, PLO outreach
2024: design work/alternatives analysis
2025: permitting
2026: earthwork

Target Funding Source(s)

OWEB, TNC, NRCS EQIP, RCPP, ODFW
NOAA Restoring Fish Passage Through Barrier Removal Grant

Green Infrastructure Component(s)

Anticipated Resilience Benefits

9. Bob's Creek Wetland

Replace two undersized culverts under N. Fork Rd. for fish passage and reopen tidal inundation to the large (36-40 acre) wetland behind. Includes rerouting of Bob's Creek to connect to drainage ditches, and restoration work on channels above road on Bob's Creek and small tributary. Restoration would create 20 acres of tidal spruce swamp wetland, 20 acres of riparian/floodplain habitat, and facilitate spawning for coho, steelhead, chum, and cutthroat, as well as rearing habitat for other salmonid species.

Milestones/Timeline

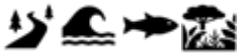
- design work
- permitting
- earthwork

Target Funding Source(s)

OWEB, NFWF, USFWS, NOAA, NRCS EQIP, RCPP

Green Infrastructure Component(s)

Anticipated Resilience Benefits



10. Kebbe Creek

Enhance stream channel and upgrade or replace tide gate with fish-friendly tide gate at Kebbe Creek confluence with unnamed tributary immediately upstream of Kebbe Creek.

Milestones/Timeline

- planning
- PLO outreach and engagement
- design work
- permitting
- earthwork

Target Funding Source(s)

OWEB, USFWS, NOAA, NFWF

Green Infrastructure Component(s)

Anticipated Resilience Benefits

11. Foley Creek

Install bank setback with log crib wall and large woody debris for protection to provide coldwater refugia for juvenile salmonids. Located near Miami-Foley Rd.

Milestones/Timeline

2023: PLO outreach and engagement
2025: apply for funding
- design work
- permitting
- earthwork

Target Funding Source(s)

OWEB

Green Infrastructure Component(s)

Anticipated Resilience Benefits

12. Culvert 470 Wetland

Working with landowner for plan to remove nonfunctional tide gate, fill from tidal channel, reinforce ditch on south side, realign/reinforce levees, restore spruce marsh habitat, with aim to maintain grazing area for active dairy farm. Healthy remnant spruce swamp that may be expanded. Weed control needed for invasive Japanese knotweed, Himalayan blackberry, and garden loosestrife. Project may include additional downstream work on N. Fork Rd.

Milestones/Timeline

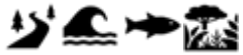
- PLO outreach and engagement
- design work/alternatives
- permitting

Target Funding Source(s)

OWEB

Green Infrastructure Component(s)

Anticipated Resilience Benefits



13. Coal Creek

Riparian enhancement including restoration planting, bank setback, and potential tide gate removal near Coal Creek Road. Aim is to keep private property in agricultural production for cattle grazing while restoring riparian area.

Milestones/Timeline

2023: design funding, issue RFP
2024: final designs, water monitoring data
2025: seek construction funding, permitting
2026: earthwork and completion

Target Funding Source(s)

OWEB, NOAA, NFWF

Green Infrastructure Component(s)

Anticipated Resilience Benefits

14. Bandy Slough

Habitat restoration and channel reconnection with Adjacent Slough on North Fork Nehalem River. Remove tide gate at mouth of Bandy Slough to restore fish passage. Power line easement on property will need to be maintained.

Milestones/Timeline

2023: secure funding for design, assess design alternatives
2024: water monitoring data, final designs, permitting, contracting
2025: earthwork and completion

Target Funding Source(s)

OWEB

Green Infrastructure Component(s)

Anticipated Resilience Benefits

15. Kilchis Point

Mitigation of anticipated future sea level rise-induced inundation of Kilchis Point area in Bay City. This includes a residential neighborhood and Bay City Wastewater Treatment plant. Future impacts and potential options are not yet well understood and will need to be studied, along with long-term needs.

Milestones/Timeline

- assess extent of threat and anticipated impacts
- develop strategy

Target Funding Source(s)

[none yet identified]

Green Infrastructure Component(s)

Anticipated Resilience Benefits

16. Porter Property

Habitat restoration on ~60-acre property on the lower Kilchis River to enhance tidal and spruce swamp wetland habitats. Some dikes will be lowered 1 ft., several ditches filled, tidal channels installed, and low (~1 ft.) vegetated mounds to be built for topographic relief for planting spruce. Several failing water control structures (tide gates, culverts, berms, etc.) will be removed, repaired, or replaced, including removal of a large cement culvert that will open the tidal channel.

Milestones/Timeline

- LUBA process (if applicable)
- permitting
- earthwork

Target Funding Source(s)

OWEB, private funding

Green Infrastructure Component(s)

Anticipated Resilience Benefits

17. Dougherty Slough

Drainage project to reduce total number of tide gates and improve the ability of Dougherty Slough to redirect flood waters away from residential homes and city buildings in Tillamook. Will include replacement of old and failing tide gates with newer, higher quality tide gates.

Milestones/Timeline

- hire new city engineer
- PLO outreach and engagement
- planning

Target Funding Source(s)

OWEB, NFWF, USFWS, NOAA, NRCS EQIP, RCPP

Green Infrastructure Component(s)

Anticipated Resilience Benefits

18. Holden Creek

Wetland restoration and reconnection including removal of tide gates to allow more flooding on adjacent (private) fields, and removal of debris from ditch surrounding the stream. Includes repair and/or replacement of culverts under US Hwy 101.

Milestones/Timeline

- planning
- PLO outreach and engagement

Target Funding Source(s)

OWEB, NFWF, USFWS, NOAA, NRCS EQIP, RCPP

Green Infrastructure Component(s)

Anticipated Resilience Benefits

19. Tillamook Bioswales

Replant and improve bioretention ponds along Main St. in downtown Tillamook to improve function and flow-through.

Milestones/Timeline

- negotiate shared responsibilities
- community outreach and engagement
- develop workable solution

Target Funding Source(s)

OWEB, ODA, DEQ

Green Infrastructure Component(s)

Anticipated Resilience Benefits

20. Tillamook Bay Community College

Relocate stormwater retention area in adjacent lot.

Milestones/Timeline

- engage with TBCC, TCPW, others
- develop strategy
- planning

Target Funding Source(s)

FEMA BRIC, LWCF
Travel OR Competitive Grants Program

Green Infrastructure Component(s)

Anticipated Resilience Benefits

21. Tillamook River Wetlands

Habitat restoration and potential road relocation on ~70 acres off of Burton-Fraser Road to mitigate local erosion and recurrent flooding.

Milestones/Timeline

- develop strategy
- PLO outreach and engagement
- project scoping
- planning
- engineering design

Target Funding Source(s)

[none yet identified]

Green Infrastructure Component(s)

Anticipated Resilience Benefits

22. Sitka Sedge Natural Area

Protect vulnerable community of Tierra Del Mar by addressing actively failing dike and restore tidal wetland and estuarine function on 87 acres in Sand Lake Estuary including tide gate removals, stream realignments, and culvert replacements.

Milestones/Timeline

2024: complete design work
2025: initiate construction
2027: complete construction

Target Funding Source(s)

NOAA, OWEB, USFS, USDOT, NFWF

Green Infrastructure Component(s)

Anticipated Resilience Benefits

23. Sand Lake Large Wood Placement

Placement of up to 80 large wood pieces and structures in Sand, Andy, and Jewel Creeks affecting 2.7 miles of stream channel.

Milestones/Timeline

Aug 2023: Initiate construction
Sep 2023: complete construction

Target Funding Source(s)

OWEB (secured), TEP

Green Infrastructure Component(s)

Anticipated Resilience Benefits

23. Nestucca & Sand Lake Watersheds

Restore hydrologic connectivity and function and reduce local flood risk via stream channel reconstruction, realignment, enhancements, and culvert replacements on Reneke, Beltz, Sand, Davis, Gurtis, No Name, Limestone, & Bower Creeks.

Milestones/Timeline

2023 and 2024: design work

Target Funding Source(s)

USFS, ODOT, USDOT, TCPW

Green Infrastructure Component(s)

Anticipated Resilience Benefits

25. Nestucca Watershed

Placement of up to 65 large wood pieces and structures in Horn, Louie, and Baxter Creeks affecting 2.2 miles of stream channel.

Milestones/Timeline

2023: design and identify funding sources
2025: initiate and complete project

Target Funding Source(s)

NOAA, USFS

Green Infrastructure Component(s)

Anticipated Resilience Benefits

26. Nestucca Coho SAP

Develop coastal coho SAP for Nestucca basin (including Neskowin and Sand Lake), which will prioritize future restoration actions to support coho populations with a focus on broadscale actions and benefits.

Milestones/Timeline

2023: funding application
2025: begin work
2026: draft plan
2027: complete work

Target Funding Source(s)

NOAA, OWEB, NFWF

Green Infrastructure Component(s)

Anticipated Resilience Benefits

27. Butte Creek (Neskowin Watershed)

Stream channel enhancement and failing culvert replacement under US Hwy 101 to preserve access and egress to the community of Neskowin.

Milestones/Timeline

2023-24: design work, PLO outreach and engagement

Target Funding Source(s)

ODOT, USDOT

Green Infrastructure Component(s)

Anticipated Resilience Benefits

28. Sutton Creek (Neskowin Watershed)

Stream channel enhancement and culvert replacement project on upper and lower reaches of Sutton Creek to improve access and egress in a residential area that is subject to flooding and at risk of tsunami inundation. Involves replacement of four failing culverts. Aim is to provide tsunami evacuation routes, reduce flooding, and improve fish passage.

Milestones/Timeline

2023: design work, identify funding source(s)
2024: initiate and complete construction

Target Funding Source(s)

OWEB, USFS, PGE, NOAA, ODFW, PLOs

Green Infrastructure Component(s)

Anticipated Resilience Benefits

29. Tillamook Bay and Sand Lake Watersheds

Restore hydrologic connectivity and function through stream channel enhancements, culvert and tide gate replacements, and restoration work on Flowerpot Creek tide gate, MP1 Creek Slab Creek Road, Mill Creek Trib B, and Mary's Creek.

Milestones/Timeline

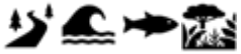
2023: funding application
2024: implementation

Target Funding Source(s)

USFS Collaborative Aquatic Landscape Implementation Fund

Green Infrastructure Component(s)

Anticipated Resilience Benefits



30. Tillamook & Nestucca Watersheds

Restoration, large wood placements, encapsulated soil lifts, and other bio-engineered solutions on the Trask River (RM3), Nestucca River (near Cloverdale), Wilson River (near Dougherty Slough offtake), and Kilchis River.

Milestones/Timeline

- identify funding source(s) and apply
- design work
- permitting

Target Funding Source(s)

NFWF

Green Infrastructure Component(s)

Anticipated Resilience Benefits

31. Riparian Planting Program

Continued funding for collaborative Tillamook County effort that works with landowners to facilitate riparian restoration work.

Milestones/Timeline

- identify funding source(s) and apply

Target Funding Source(s)

USFS, DEQ, OWEB
Tillamook County SWCD (for match)

Green Infrastructure Component(s)

Anticipated Resilience Benefits

V. References

Allen, C., Hagerty, R., Levesque, P., Palter, A., Foster, K., & Wyntergreen, P. (2018). Southern flow corridor landowner preferred alternative management plan. Southern Flow Corridor Project Management Team.

Bednaršek, N., Feely, R. A., Beck, M. W., Alin, S. R., Siedlecki, S. A., Calosi, P., Norton, E.L., Saenger, C., Štrus, J., Greeley, D., Nezlin, N.P., Roethler, M., & Spicer, J. I. (2020). Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients. *Science of The Total Environment, 716*, 136610.

Brophy, L. S., & Ewald, M. J. (2017). Modeling sea level rise impacts to Oregon's tidal wetlands: Maps and prioritization tools to help plan for habitat conservation into the future.

Brophy, L. S. (2019). Comparing historical losses of forested, scrub-shrub, and emergent tidal wetlands on the Oregon coast, USA: A paradigm shift for estuary restoration and conservation.

Collins, V. (2019). (rep.). As-Built Project Validation of Peak Water Level Reduction During the October 2017 Flood. Tillamook Oregon Solutions.

Complete Water Management. (2018). Neahkahnie Water District Drinking Water Quality Protection Feasibility Study.

Crozier, L. G., Zabel, R. W., Hockersmith, E. E., & Achord, S. (2010). Interacting effects of density and temperature on body size in multiple populations of Chinook salmon. *Journal of Animal Ecology, 79*(2), 342-349.

Feely, R. A., Sabine, C. L., Byrne, R. H., Millero, F. J., Dickson, A. G., Wanninkhof, R., Murata, A., Miller, L. A., & Greeley, D. (2012). Decadal changes in the aragonite and calcite saturation state of the Pacific Ocean. *Global Biogeochemical Cycles, 26*(3).

Fleishman, E., editor. (2023). Sixth Oregon climate assessment. Oregon Climate Change Research Institute, Oregon State University. Corvallis, Oregon.

Flitcroft, R., Burnett, K., & Christiansen, K. (2013). A simple model that identifies potential effects of sea-level rise on estuarine and estuary-ecotone habitat locations for salmonids in Oregon, USA. *Environmental Management, 52*, 196-208.

Frölicher, T. L., Fischer, E. M., & Gruber, N. (2018). Marine heatwaves under global warming. *Nature, 560*(7718), 360-364.

Green, T. J., Siboni, N., King, W. L., Labbate, M., Seymour, J. R., & Raftos, D. (2019). Simulated marine heat wave alters abundance and structure of Vibrio populations associated with the Pacific Oyster resulting in a mass mortality event. *Microbial Ecology, 77*, 736-747.

Gruber, N., Hauri, C., Lachkar, Z., Loher, D., Frölicher, T. L., & Plattner, G. K. (2012). Rapid progression of ocean acidification in the California Current System. *Science, 337*(6091), 220-223.

Kelsey, H. M., Witter, R. C., & Hemphill-Haley, E. (2002). Plate-boundary earthquakes and tsunamis of the past 5500 yr, Sixes River estuary, southern Oregon. *GSA Bulletin, 114*(3), 298-314.

National Oceanic and Atmospheric Administration. (1998). National Estuarine Eutrophication Survey. Office of Ocean Resources Conservation and Assessment.

Oregon Department of Land Conservation and Development. (2014a). Assessment of Oregon's Regulatory Framework for Managing Estuaries.

Oregon Department of Land Conservation and Development. (2014b). Assessment of Trends Affecting Planning for Oregon's Estuaries and Shorelands.

Oregon Department of Land Conservation and Development. (2017). Sea Level Rise Exposure Inventory for Oregon's Estuaries.

Oregon Department of Transportation. (2012). Climate Change Adaptation Strategy Report.

Pickering, D., Jones, A., Aldous, A., & Schindel, M. (2018). Where Road Projects Could Improve Oregon's Estuaries and Benefit Local Communities. The Nature Conservancy. Portland, Oregon.

Reed, D., van Wesenbeeck, B., Herman, P. M. J., & Meselhe, E. (2018). Tidal flat-wetland systems as flood defenses: Understanding biogeomorphic controls. Estuarine, Coastal and Shelf Science, 213, 269–282.

Richter, A., & Kolmes, S. A. (2005). Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. *Reviews in Fisheries science, 13*(1), 23-49.

Ruggiero, P., C.A. Brown, P.D. Komar, J.C. Allan, D.A. Reusser & H. Lee, II. (2010a). Impacts of climate change on Oregon's coasts and estuaries. In: Oregon Climate Change Research Institute (2010), Oregon Climate Assessment Report, K.D. Dello and P.W. Mote (eds). College of Oceanic and Atmospheric Sciences, Oregon State University. Corvallis, OR.

Ruggiero, P., Komar, P. D., & Allan, J. C. (2010b). Increasing wave heights and extreme value projections: The wave climate of the US Pacific Northwest. *Coastal Engineering, 57*(5), 539-552.

Ruggiero, P., Kratzmann, M. G., Himmelstoss, E. A., Reid, D., Allan, J., & Kaminsky, G. (2013). National assessment of shoreline change: historical shoreline change along the Pacific Northwest coast. US Geological Survey.

Sharp, D., Dello, K., Rupp, D., Mote, P., & Calmer, R. (2013). Climate Change in the Tillamook Bay Watershed. Oregon Climate Change Research Institute. Corvallis, Oregon.

Shum, C. K., & Kuo, C. Y. (2011). Observation and geophysical causes of present-day sea-level rise. Climate change and food security in South Asia, 85-104.

Steele, M. O., Chang, H., Reusser, D. A., Brown, C. A., & Jung, I. W. (2012). Potential Climate-Induced Runoff Changes and Associated Uncertainty in Four Pacific Northwest Estuaries (p. 63). US Department of the Interior, US Geological Survey.

Sweet, W. V., Kopp, R. E., Weaver, C. P., Obeysekera, J., Horton, R. M., Thieler, E. R., & Zervas, C. (2017). Global and regional sea level rise scenarios for the United States (No. CO-OPS 083).

Sweet, W. V., Hamlington, B. D., Kopp, R. E., Weaver, C. P., Barnard, P. L., Bekaert, D., Brooks, W., Craghan, M., Dusek, G., Frederikse, T., & Zuzak, C. (2022). Global and regional sea level rise scenarios for the United States: updated mean projections and extreme water level probabilities along US coastlines. National Oceanic and Atmospheric Administration.

Tillamook County. (2017a). (rep.). Performance Progress report. NOAA Fisheries.

Tillamook County, Oregon. (2017b). Tillamook County Multi-Jurisdictional Natural Hazard Mitigation Plan.

Tillamook Estuaries Partnership. (2021). Socio-economic Impacts of the Southern Flow Corridor Restoration Project.

Tillman, P., & Siemann, D. (2011). Climate change effects and adaptation approaches in freshwater aquatic and riparian ecosystems in the North Pacific landscape conservation cooperative region. National Wildlife Federation.

van Heeswijk, M., Kimball, J. S., & Marks, D. (1996). Simulation of water available for runoff in clearcut forest openings during rain-on-snow events in the western Cascade Range of Oregon and Washington (Vol. 95, No. 4219). US Department of the Interior, Geological Survey.

Williams, M. C., Appleby, C. A., Bauer, J. M., & Roberts, J. T. (2020). Natural Hazard Risk Report for Tillamook County, Oregon. Oregon Department of Geology and Mineral Industries.

Witter, R. C., Kelsey, H. M., & Hemphill-Haley, E. (2003). Great Cascadia earthquakes and tsunamis of the past 6700 years, Coquille River estuary, southern coastal Oregon. *Geological Society of America Bulletin, 115*(10), 1289-1306.

Netarts Bay, 2017. Photo courtesy of Michael Moses.

Appendix A: Vulnerability Assessment Methods

To plan for potential resilience activities, an understanding of local needs, perspectives, and priorities on community vulnerability and adaptation planning for natural hazards must be assessed. Our team reviewed a variety of methods, approaches, examples, guidebooks, and other resources in the planning and resilience literature to guide a natural hazards vulnerability assessment (VA) for Tillamook County. These methods were developed by the University of Oregon's Institute for Policy Research and Engagement (IPRE) and piloted for the Coos Bay estuary VA, led by the Partnership for Coastal Watersheds. With feedback from the Tillamook Working Group (TWG), the methods described below were adapted to suit the needs and priorities of Tillamook County estuaries by evaluating several components of vulnerability. Stakeholder engagement was leveraged as the key to determining local understanding of natural hazard threats, and identifying priority sites, assets, resources, and populations.

The TWG reached out to over 100 local stakeholder organizations and individuals, who were invited to participate in a pre-survey effort and virtual community listening sessions to better understand local needs and concerns related to natural hazards vulnerability. Stakeholders were identified based on those with active interest areas with direct influence or interaction with Tillamook County estuaries. Responses to the pre-survey were evaluated to help provide context to understanding in the community listening sessions, and categorize responses by economic sector. The listening sessions explored in greater detail the vulnerable assets, resources, and populations identified in the survey responses, as well as their adaptive capacity and sensitivities. The information following summarizes the vulnerability assessment effort to help characterize the resilience of each consolidated sector group.

Tillamook Working Group Perspectives

The tables below provide summary results from two Google Jamboard exercises conducted with the TWG in fall 2021. This information reflects the TWG's initial perspectives on Tillamook County estuarine resilience and establishes the context and framework for the vulnerability assessment work that followed in 2022.

Best Outcomes/Greatest Fears

The purpose of this exercise was to capture early in the planning process some of the TWG's hopes for best outcomes for the process, and identify some of their greatest fears. Sticky notes were placed on Jamboard slides and aligned roughly with four aspects of planning – *process*, *tools*, *impacts*, and *deliverables*. Similar responses have been consolidated for brevity.

Table A-1. Tillamook Working Group Perspectives on the ERAP Process

Best Outcomes	Greatest Fears
Process	
• Broad participation, understanding, support, and acceptance by local community • Human and natural environment improved • Strategic sourcing of funds to minimize impacts on local budgets	• Duplication of efforts • Local needs remain unmet • Lack of balance between people/resource needs • Insufficient public support/buy-in • Insufficient feedback/representation from stakeholders (e.g., south Tillamook County interests, major economic players such as agriculture, lumber, shellfish, tourism, etc.) • Feedback from local participants or local agencies overridden by State or Federal participants • Social conflicts with proposed solutions • Insufficient strategy for implementation or funding
Tools	
• Identify mutually beneficial projects to address multiple needs • Materials and money for landowners to encourage tidal wetland restoration • Good and clear development standards • Estuary and shoreland code updates • Coordinate with other agencies/organizations conducting projects (e.g., USACE)	• Insufficient funding available • Current policies, political climate, administrative, rules or permitting limitations challenge achievable solutions
Deliverables	
• Actionable steps to achieve goals • Healthy and productive estuaries • Community education on issues and solutions • Coordination with the Tillamook County NHMP • Improved farmland protection (e.g., through voluntary easements) • Mix of potential infrastructure solutions (e.g., “green”, tide gates, etc.)	• Lack of engagement from, or outreach to, potential partners/stakeholders • Stakeholder relationships degraded • Health, productivity of estuaries not improved • Planning deficiencies impact vulnerable populations • Soil erosion or other impacts reduce productivity of agricultural soils
Impacts	
• On the ground projects benefit local resources, people, and are cost-effective • Increased capacity of local agencies and organizations to implement planned actions. • Improved flood mitigation, hydrologic connectivity • Broad understanding of vulnerabilities and community support for potential solutions	• Lack of agency support for proposed projects • Bad economic outcomes tied to estuaries • Planning deficiencies impact vulnerable populations • Infrastructure failures isolate communities • Projects are only on public lands - private landowners ignored (lack of funding or recognition)

Dimensions of Resilience

A variety of methods, approaches, examples, guidebooks, and other resources exist in the planning and resilience literature. In 2012, the National Research Council produced the report Disaster Resilience: A National Imperative[24], which assessed challenges to national disaster resilience. Four dimensions critical to evaluating resilience were identified:

1. **Vulnerable Populations**—factors that capture special needs of individuals and groups, related to components such as minority status, health issues, mobility, and socioeconomic status
2. **Critical and Environmental Infrastructure**—the ability of critical and environmental infrastructure to recover from events—components may include water and sewage, transportation, power, communications, and natural infrastructure
3. **Social Factors**—factors that enhance or limit a community's ability to recover, including components such as social capital, education, language, governance, financial structures, culture, and workforce
4. **Built Infrastructure**—the ability of built infrastructure to withstand impacts of disasters, including components such as hospitals, local government, emergency response facilities, schools, homes and businesses, bridges, and roads

The following table summarizes results from a Google Jamboard exercise in which the TWG identified the relevant hazards, places, stakeholders, and opportunities for action, along the four dimensions of resilience. This exercise helped initially characterize resilience needs and to guide and focus the assessment effort.

Table A-2. Dimensions of Resilience for Tillamook County Estuaries

Vulnerable Populations	
Hazards	**Places**
• Flooding impacts, saltwater intrusion/inundation (e.g., agricultural lands, livestock, geographic isolation) • Sea level rise • Climate change impacts • Earthquake • Tsunami • Mud slides • Ocean acidification	• Mobile home parks • Cape Meares, Oceanside (isolation issues) • Neskowin RV park
Stakeholders	**Opportunities for Action**
• Farmers • Private landowners, businesses within floodplain • Tillamook County Creamery Association • Habitat for Humanity • Low-income seniors, CARE	• Isolated communities • Homeless community • Language barriers • Evacuation limitations • Anglers (impacts to fish, access, opportunity)

[24] https://abag.ca.gov/sites/default/files/disaster_resilience_a_national_imperative.pdf

• Tourism industry, hotels • Emergency responders • Fishing industry (commercial & recreational) • Seaweed growers industry, shellfish hatcheries • Tillamook County Wellness, Adventist Health • Tillamook Bay Comm. College, OSU Extension	• Shellfish growers (Netarts)

Critical & Environmental Infrastructure

Hazards	Places
• Flooding • King tides • Storm surge • Wind • Soil erosion • Wildfire	• Ports, county parks, marinas, boat launches, and other related facilities • Port of Tillamook Bay compost facility • Forested watersheds that supply drinking water • Wastewater treatment plants • US Hwy 101 in Nehalem (flooding) • Farmlands, flood basins, etc. • Fish habitat, cool water refugia
Stakeholders	**Opportunities for Action**
• Tillamook Cty Soil & Water Conservation District • Utilities (e.g., Tillamook People's Utility District) • Diking, flood control districts • Cities • Ports • Fishing industry • Agriculture, silviculture industries • Transportation industry, ODOT	• Jetties, dikes, tide gates, stormwater, drainage districts • Water quality • Farmland ecosystem services, dairy digesters • Upland connectivity • Dredging issues (e.g., sediment) • Shoreline, riparian habitat restoration

Social Factors

Hazards	Places
• Erosion (e.g., impacts to recreation) • Transportation stressors • Rising water table • Solid waste issues • Fisheries (population impacts)	• TBCC Rural Innovation Center • OSU Extension • Community centers • Bay City Art Center • Oceanside Community Club • Cape Meares community
Stakeholders	**Opportunities for Action**
• Emergency management • Fishing industry • Business community (e.g., Chamber of Commerce, Small Business Development Center) • Tillamook County Parks • Tourism industry (e.g., Visit Tillamook Coast, hotels) • City councils • Tillamook County Creamery Associations • Ports (Garibaldi, Tillamook Bay) • Agriculture industry	• Workforce access to critical operations • Affordable housing (e.g., outside flood zones) • Partnership coordination, competing interests • Water stress issues • Homeless facilities • Language barriers • Recreation (e.g. health/healthcare, economic benefits) • Food production • Tourism (e.g., facilities, awareness)

Built Infrastructure

Hazards	Places

• Flooding (e.g., US Hwy 101 north of Tillamook, stormwater overflow) • Earthquake • Tsunami • Increase in impervious surfaces	• Burton-Fraser Road • Undersized, failing culverts
Stakeholders	**Opportunities for Action**
• Agricultural industry • Drainage districts (tide gates) • Salmon SuperHwy • Tillamook County Public Works • Transportation (e.g., ODOT, Fed. Hwy. Admin.) • Tillamook People's Utility District • Oregon Parks & Recreation Dept. • Water districts	• Planting, restoration efforts • Boat ramps, docks, parks, etc. • Water storage (e.g., upland) • Local renewable energy (e.g., wind, solar) • Evacuation routes • Private landowners with culverts • Agricultural industry (e.g., dairy digesters)

Vulnerability Assessment Model

The baseline VA model identified for this process was adapted from the International Council for Local Environmental Initiatives (ICLEI)[25] assessment model. The model takes a community-scale view of resilience and aims to improve it by connecting goals and services to infrastructure systems and community lifelines, identifying social and economic interdependencies, and focusing on practical planning for recovery. The IPRE adapted and piloted these methods in 2013 for the City of Eugene Climate Vulnerability Assessment (CVA) and later adapted a more simplified version for the 2020-22 Coos Bay VA. While the Eugene CVA focused on climate change-related impacts, it also incorporated considerations for natural hazards vulnerability, borrowing from established Oregon Office of Emergency Management (OEM) risk assessment methodology and IPRE's relative risk assessment. The EPA's Being Prepared for Climate Change guidebook outlines similar methods for assessing vulnerability and risk-based adaptation action plans and was used by the Tillamook Estuaries Partnership and the Oregon Central Coast Estuary Collaborative to create their VAs and action plans. The Tillamook VA described here is an adaptation of IPRE's methods used in Coos Bay and, with priorities identified by our local stakeholders, aims to fill any potential gaps in understanding of local vulnerability, with an eye toward natural infrastructure solutions.

Evaluation Components

Feedback collected from the stakeholder engagement effort was evaluated to determine local vulnerability to the assessed hazard(s) of concern. The primary components of vulnerability determined by the evaluation are 1) adaptive capacity, 2) sensitivity, and 3) risk (Figure A-1).

[25] https://icleiusa.org/

Figure A-1. Factors of hazard vulnerability defined.

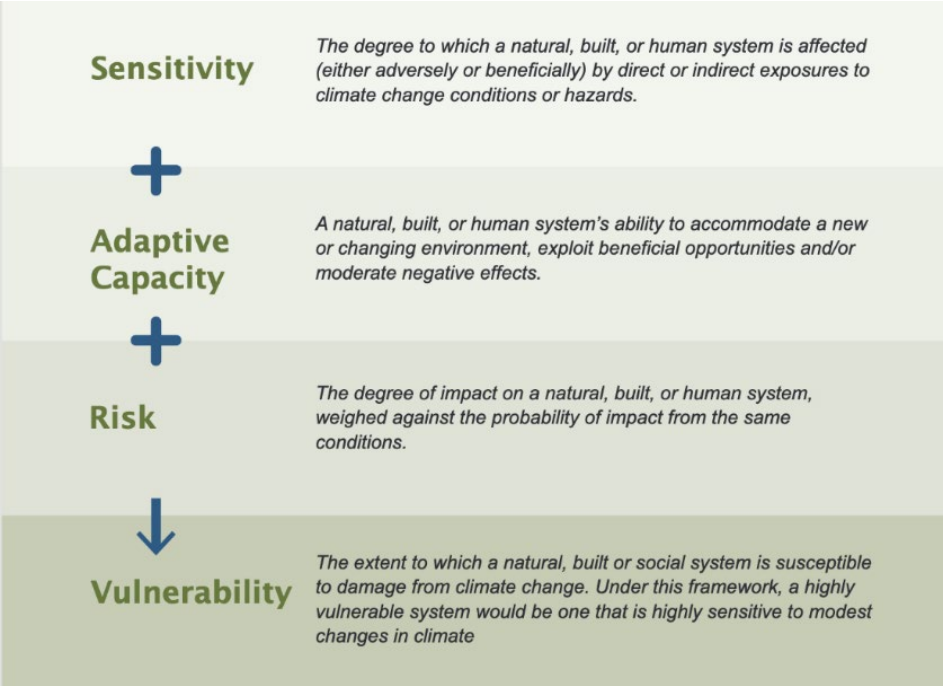


Image source: IPRE

To assess these components, the model adapted from ICLEI utilizes a variety of assessment tools to deliver narrative questions to stakeholder representatives. The assessment tools of the Tillamook VA model are:

- An online survey effort
- Sector-specific stakeholder listening sessions
- Individual interviews

The online questionnaire is used to establish contact with stakeholders, inform them of the process, and gather preliminary information to help shape the listening sessions. Respondents to the survey are then organized into broadly related sectors and invited to sector-specific listening sessions. Given sufficient level or response, participants may be grouped by economic sector and evaluated separately. For this effort, three sector-based listening sessions were conducted, including Community, Natural Resources, and Industry & Infrastructure. Guided discussion is used to structure the listening sessions and walk participants through a series of questions focused on assessing adaptive capacity and sensitivity of their sector with respect to a chosen hazard of concern. Individual interviews are substituted for stakeholders unable to participate in the listening sessions, following the same structure.

Stakeholder feedback gathered using these tools is evaluated and subjectively scored to characterize vulnerability in the study area, which can then be used to help prioritize actions. Several questions provide a quantitative score utilizing Likert-type scales (1 to 5) or ranked responses and can be used to derive the vulnerability score. Narrative or discussion-based questions are also used to gather specifics on vulnerable assets, resources, and populations,

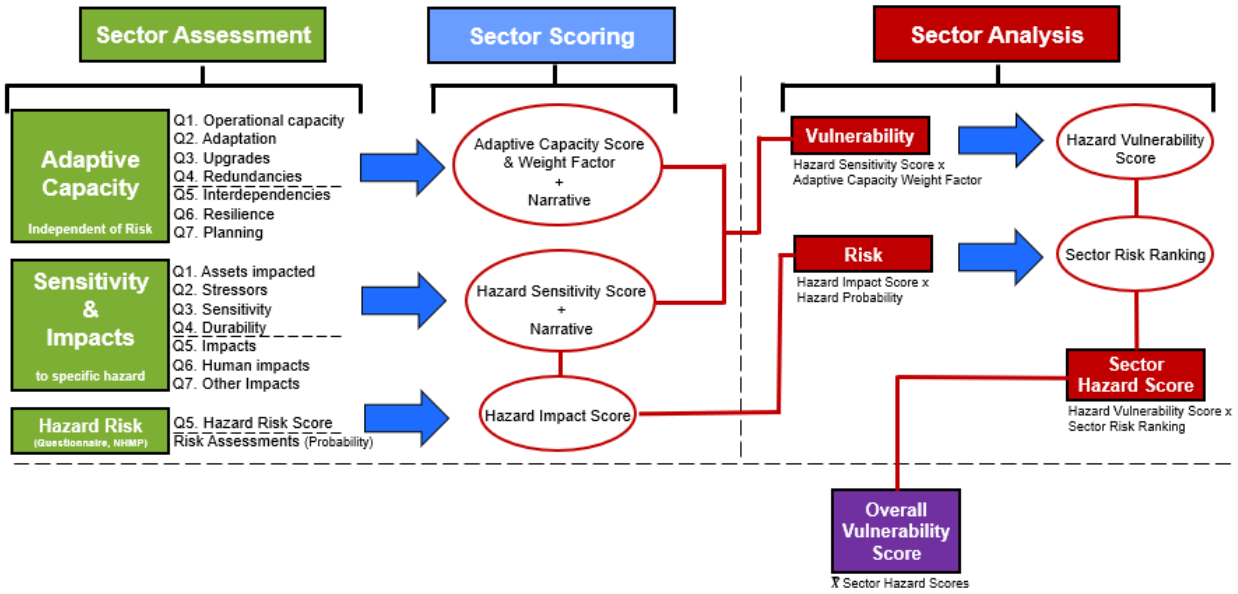
provide additional context and nuanced explanations, and are qualitatively evaluated to adjust scoring as needed.

Hazard Assessment

The tools and components of the vulnerability assessment model yield both quantitatively scored and qualitatively evaluated responses. This data is used to determine local adaptive capacity and hazard vulnerability. Given sufficient participation, these components can be evaluated and compared across stakeholder sectors.

A scoring system to determine vulnerability was adapted from the Eugene and Coos Bay VAs (Figure A-2). Participants agree on evaluating their greatest hazard of concern for each assessment effort, typically limiting evaluation of one hazard per listening session. This scoring system yields sector and hazard-specific scores for hazard vulnerability, hazard impact, risk, and an overall sector hazard score. Relativistic comparisons are then made across sectors for the same hazard. Sector hazard scores can be added together to reflect an overall vulnerability score for a given hazard across all sectors evaluated and compared to other vulnerability scores for the same hazard in other jurisdictions.

Figure A-2. Vulnerability Assessment Sector Scoring Diagram.



Adapted from IPRE

Sector Analysis

Scores for adaptive capacity, sensitivity, and impact are assigned to Likert-type scales between 1 and 5, with low scores indicating low adaptive capacity, sensitivity, or impact, and high scores indicating high adaptive capacity, sensitivity, or impact. Sector assessment scores were derived by calculating a mean for each set of relevant questions, for example:

$$\frac{(Q1\ score + Q2\ score + Q3\ score + \ldots)}{Total\ Number\ of\ Questions}$$

The adaptive capacity scores were assigned to a weight factor, following previous adaptations of IPRE's methods, and guidance from the OEM Hazard Analysis Methodology[26], in order to calculate the hazard vulnerability score (Table A-3). Scores for risk and sensitivity (impacts Qs) are added together to form an impact score. Narrative responses are evaluated to qualitatively adjust the adaptive capacity score if necessary, and compared against an adaptive capacity check question, before assigning a weight factor. Sensitivity is determined similarly to adaptive capacity, averaging the scores of the sensitivity-specific questions from listening session/individual interview questions.

Table A-3. Adaptive Capacity Value Scale

Adaptive Capacity Score	Adaptive Capacity Ranking	Assigned AC Weight Factor
1 – 1.99	Very Low	1.50
2 – 2.99	Low	1.25
3 – 3.99	Medium	1
4 – 4.99	High	0.50
5	Very High	0.25

Scores collected from the pre-survey and listening session efforts are evaluated to produce scores for four variables. The following is adapted directly from IPRE's Lane County VA.

I. Vulnerability Score

Sector Vulnerability to Hazard = Hazard Sensitivity Score x Adaptive Capacity Weight Factor

Each hazard assessed yields a hazard sensitivity score. That score is multiplied by the weight factor (only) to get an adjusted score for that sector's vulnerability to that particular

[26] https://www.oregon.gov/lcd/NH/Documents/Apx_9.1.19_OEM_Hazard_Analysis_Methodology_OPT.pdf

hazard. This is repeated for each hazard assessed (if more than one). The lower vulnerability scores the better.

II. Risk Score

Sector Risk to Hazard = Hazard Impact Score x Hazard Probability

Each hazard assessed has a local probability of occurrence. This probability factor is multiplied by the sector's impact score for that particular hazard. This is repeated for each hazard assessed (if more than one). The lower risk scores the better. Risk probability scores were derived from the Oregon NHMP[27].

III. Sector Hazard Score

Sector Hazard Score = Hazard Vulnerability Score x Risk Score

Each hazard has an overall score that reflects the sector's overall susceptibility to the hazard assessed. This score can be used across sectors to analyze what sectors are at greatest or least risk of disruption due to this hazard. **Effectively, this is the actual hazard vulnerability score for a given sector.**

IV. Overall Vulnerability Score

Overall Vulnerability Score = Average Score of all Sector Hazard Scores

Each sector may assess a different number or types of hazards according to their perceived threats. In order to compare overall scores across sectors, the Overall Vulnerability Score is the average for all Hazard Scores for a given sector. This provides a comparable number to analyze overall sector health against other sectors. The lower the Overall score the better.

Note: For this effort, only one hazard (flooding) was assessed per sector, so the Sector Hazard Score represents the Overall Vulnerability Score for each sector.

[27] https://www.oregon.gov/lcd/NH/Pages/Mitigation-Planning.aspx

Appendix B: Pre-Survey Questionnaire

Tillamook ERAP Vulnerability Assessment Survey

Introduction Page

Greetings!

Thank you for agreeing to fill out this questionnaire. The State of Oregon is conducting a planning process aimed at improving resilience to natural hazards in select coastal jurisdictions. This work will focus on impacts to Oregon's estuaries, with a focus on natural ("green") infrastructure solutions. This may include projects such as floodplain and habitat restoration, construction of levees, dunes, or other natural barriers, use of bioswales, raingardens, or permeable pavements, rezoning or other land use changes, and many more.

To better understand local hazard vulnerabilities and resilience needs, stakeholder feedback will be collected through a survey effort (this questionnaire), followed by stakeholder listening sessions to provide additional context and information. The project team seeks to identify what resilience needs are of greatest concern, and what critical infrastructure, areas, and/or natural resources should be assessed in greater detail for vulnerabilities. Your responses will also help identify where different organizations' priorities may overlap.

Information collected through this survey and the proposed listening sessions will inform a menu of potential adaptation actions to be explored over the next 12-18 months, and will culminate in the creation of an Estuarine Resilience Adaptation Plan (ERAP) for Tillamook County estuaries.

This survey should take about 15 minutes to complete.

We aim to schedule listening sessions for late February through March. Once your responses have been reviewed, you will be emailed a link to a scheduling poll to provide your availability. Listening sessions will be approximately two hours and conducted via Zoom.

Please complete the survey by [timeframe].

Please contact Michael Moses (michael.moses@dlcd.oregon.gov) with any questions.

Definitions Page

Some helpful terms and definitions:

Estuary: Estuaries are bodies of water, and their surrounding coastal habitats, typically found where rivers meet the sea. Estuaries harbor unique plant and animal communities because their waters are brackish — a mixture of fresh water draining from the land and salty seawater. This includes areas influenced (presently or historically) by river flow, tides, and localized weather.

Natural (or "green") Infrastructure: Natural infrastructure, also referred to as "green" infrastructure, uses existing natural areas or engineered solutions that mimic natural processes such as flooding, erosion, and runoff, to minimize, redirect, or redistribute their impacts. Additional benefits can include increased recreational opportunities, improvements to wildlife habitat, water quality improvements, and many more.

Hazard: is any situation that has the potential of causing damage to people, property, or the environment. For the purposes of this questionnaire, we are focusing on hazards induced by the forces of nature ("natural hazards").

Resilience: Resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events (such as natural hazards).

Stakeholder: Individuals, organizations, or communities who have an interest in or are affected by decisions, planning, or policies.

Vulnerability: The extent to which a natural, built, or social system is susceptible to damage from natural hazards. Under this framework, a highly vulnerable system would be one that is highly sensitive to modest impacts from natural hazards.

1. Please provide the following information:

Name

Organization

Preferred Email Address

2. Please select the local estuary(ies) that may be of interest or relevance to you/your organization:

- [ ] Nehalem Bay
- [ ] Tillamook Bay
- [ ] Netarts Bay
- [ ] Sand Lake
- [ ] Nestucca Bay
- [ ] Salmon River

3. Please select the sector that is most closely related to your job duties or organization for the purposes of hazard planning, or use the space below under 'other' to enter a different sector.

- [ ] Transportation (eg Roads, Ports, Shipping, Etc...)
- [ ] Agriculture
- [ ] Forestry & Wood Products
- [ ] Fishing and Shellfish Cultivation
- [ ] Emergency Services
- [ ] Health Services
- [ ] Social Services (eg Low-Income Services, Job Placement, Childcare, Etc...)
- [ ] Utilities
- [ ] Housing
- [ ] Parks/Open Space
- [ ] Education
- [ ] Community and Cultural Centers
- [ ] Business (eg Tourism, Hospitality, Retail, Services, Etc...)
- [ ] Other Natural Resources
- [ ] Industry (eg Manufacturing, Materials, Construction, Etc...)

☐ Land Use Planning

☐ Other (Please Specify)

For the purposes of responding to this questionnaire, please consider the context of the landward areas of estuarine influence highlighted in blue on the following maps, or adjacent areas that may directly interact with them.

4. What planning efforts, if any, has your organization undertaken to investigate, prepare for, adapt to, or otherwise mitigate risk associated with any of the potential hazards listed below? Please list any organizations you have partnered or collaborated with on hazard planning. If a hazard is not listed below, please include it in your response.

If you have documentation that would help us gather information about Tillamook County hazard vulnerability, please include a weblink (URL) with your response.

Please consider the following list of potential hazards in your response.

Chronic Hazards (those that carry the potential for cumulative, long-term impact):

- Air quality (increased pollutants: ozone, smoke, pollen, etc.)
- Average air temperature rise (long-term)
- Changes to water temperature, quality, or chemistry (e.g., ocean acidification)
- Changes to climate regime (climate change)
- Increased invasive species and pests, or other impacts to fish and wildlife
- Sea level rise and saltwater intrusion
- Decreased summer precipitation; heavier winter storms
- Changing ocean cycles (Pacific Decadal Oscillation, El Niño/La Niña, spring transition timing)
- Erosion, accretion, or deposition of beaches, dunes, or soils (long-term)
- Subsidence

Episodic Hazards (discrete events with immediate impact):

- Heavy rains and river flooding
- Tidal flooding, king tides
- Tsunamis
- Landslides
- Erosion, accretion, or deposition of beaches, dunes, or soils (short-term)
- Heat waves (short-term)
- Cold snaps (short-term)
- Severe weather events (high winds, storm surge)
- Drought
- Wildfire
- Earthquakes
- Water table issues

5. What level of risk do you perceive the following current or projected hazards pose? Consider your organization, its mission, the resources and assets it manages, the communities and populations it serves, and your area(s) of concern.

Risk is a combination of (a) the probability that an event will occur, and (b) the consequence of its occurrence.

Select the level of risk.

	Does not apply	Do not know	No risk	Very low	Low	Medium	High	Very high
Air quality (increased pollutants: ozone, smoke, pollen, etc.)	○	○	○	○	○	○	○	○
Average air temperature rise (long-term)	○	○	○	○	○	○	○	○
Changes to water temperature, quality, or chemistry (e.g. ocean acidification)	○	○	○	○	○	○	○	○
Changes to climate regime (climate change)	○	○	○	○	○	○	○	○
Increased invasive species and pests, or other impacts to fish and wildlife	○	○	○	○	○	○	○	○

Sea level rise and saltwater intrusion	○	○	○	○	○	○	○	○
Decreased summer precipitation; heavier winter storms	○	○	○	○	○	○	○	○
Changing ocean cycles (Pacific Decadal Oscillation, El Niño/La Niña, spring transition timing)	○	○	○	○	○	○	○	○
Erosion, accretion, or deposition of beaches, dunes, or soils (long-term)	○	○	○	○	○	○	○	○
Subsidence	○	○	○	○	○	○	○	○
Heavy rains and river flooding	○	○	○	○	○	○	○	○
Tidal flooding, king tides	○	○	○	○	○	○	○	○

Tsunamis	◯	◯	◯	◯	◯	◯	◯	◯
Landslides	◯	◯	◯	◯	◯	◯	◯	◯
Erosion, accretion, or deposition of beaches, dunes, or soils (short-term)	◯	◯	◯	◯	◯	◯	◯	◯
Heat waves (short-term)	◯	◯	◯	◯	◯	◯	◯	◯
Cold snaps (short-term)	◯	◯	◯	◯	◯	◯	◯	◯
Severe weather (high winds, storm surge)	◯	◯	◯	◯	◯	◯	◯	◯
Drought	◯	◯	◯	◯	◯	◯	◯	◯
Wildfire	◯	◯	◯	◯	◯	◯	◯	◯
Earthquakes	◯	◯	◯	◯	◯	◯	◯	◯
Water table issues	◯	◯	◯	◯	◯	◯	◯	◯

Other (please specify)

6. What asset(s) or resource(s) (e.g., specific natural resources, critical habitat, vulnerable populations, cultural resources, equipment/tools, infrastructure, structures, etc.) are most vulnerable to the hazard(s) you chose in Q3? Feel free to limit your answer to one asset or resource, or expand on several that are most vulnerable.

In your response consider specifying:

1. Which assets/resources
2. Locations of assets/resources
3. How often they are impacted (current/projected)
4. In what ways they are impacted

7. What is the most critical hazard you chose in Question 3? What can be done by your organization or others to reduce the risks posed by this hazard? Please indicate at least one (1) most critical hazard, but feel free to list others.

List of hazards from Question 3:

- Air quality (increased pollutants: ozone, smoke, pollen, etc.)
- Average air temperature rise (long-term)
- Changes to water temperature, quality, or chemistry (e.g., ocean acidification)
- Changes to climate regime (climate change)
- Increased invasive species and pests, or other impacts to fish and wildlife
- Sea level rise and saltwater intrusion
- Decreased summer precipitation; heavier winter storms
- Changing ocean cycles (Pacific Decadal Oscillation, El Niño/La Niña, spring transition timing)
- Erosion, accretion, or deposition of beaches, dunes, or soils (long-term)
- Subsidence
- Heavy rains and river flooding
- Tidal flooding, king tides
- Tsunamis
- Coastal erosion, landslides
- Erosion, accretion, or deposition of beaches, dunes, or soils (short-term)
- Heat waves (short-term)
- Cold snaps (short-term)
- Severe weather events (high winds, storm surge)
- Drought
- Wildfire
- Earthquakes
- Water table issues

8. On a scale from 1 to 5, how urgent (time sensitive) is the need to reduce the risk(s) of the most critical hazard you identified in Question 5? In your response, consider impacts to your most vulnerable assets and resources.

- 1. Not urgent
- 2. Slightly urgent
- 3. Somewhat urgent
- 4. Very urgent
- 5. Extremely urgent

9. Are there specific time frame indicators for the risk(s) you chose in Question 6? Please explain why you chose your answer. Time frame indicators could be within a certain time window (e.g., immediately, months, years, decades), when a specific event has occurred (e.g., earthquake, tsunami), or when a particular threshold has been crossed (e.g., sea level rise, average temperature, seawater pH, etc.)

10. What other information regarding hazards can you tell us about (e.g., concerns, partnerships, planning efforts, adaptation actions)?

Thank you for participating in our survey!

You will have an opportunity to provide additional feedback during an online listening session to be held via Zoom in late February or March.

We will send you an email poll with instructions for providing your availability to attend the meeting. We look forward to working with you to create a vulnerability assessment and adaptation plan for Tillamook County estuaries!

For questions or comments please contact Michael Moses
- michael.moses@dlcd.oregon.gov (971) 332-0946.

Appendix C: Listening Session Questions

Listening Session Questions: Sensitivity and Adaptive Capacity

Questions may be adapted based on the context of the specific asset and interviewee.

Refer to pages 4-5 for a list of hazards and definitions, as well as the survey results summary (separate document). The following questions will be asked with respect to that context.

Sector: _____

Most critical hazard: _____

Adaptive Capacity: *A natural, built, or social system's ability to adjust to new or changing conditions, make use of beneficial opportunities, and/or reduce negative effects. Adaptive capacity is assessed independently of hazard or climate change considerations.*

1. Do the specific facilities/sites/infrastructure in your sector currently operate at capacity? If not, when do you foresee demand exceeding capacity?
    - **1 = Now**
    - **2 = 1-4 years**
    - **3 = 5-20 years**
    - **4 = 21-50 years**
    - **5 = Never**

2. How easy is it to replace and/or repair the facilities/sites/infrastructure in your sector?
    - **1 = Impossible**
    - **2 = Difficult**
    - **3 = Moderate**
    - **4 = Easy**
    - **5 = Very easy**

3. When will the facilities/sites/infrastructure in your sector need to be overhauled or replaced?
    - **1 = Now**
    - **2 = 1-4 years**
    - **3 = 5-20 years**
    - **4 = 21-50 years**
    - **5 = Never**

4. What level of redundancies or backups exist for these facilities/sites/infrastructure? If so, what, where, etc?
    - **1 = None**
    - **2 = A little**

- **3 = Some**
- **4 = A lot**
- **5 = Complete**

5. Which other resources (e.g., transportation networks, communication infrastructure) do your resources/assets/populations fundamentally rely on? Please include specifics.
    - Similarly, which other resources/assets/populations rely on them?

6. In what ways might your sector's resources/assets/populations be able to adapt or bounce back? (Consider: strengths and weaknesses of your sector, diversity of resources/assets/populations, etc.)

7. What, if any, are the hazard adaptation, mitigation, or emergency response plans related to these resources/assets/populations?

Sensitivity & Impacts: *The degree to which a natural, built, or social system is affected (adversely or beneficially) by direct or indirect exposure to natural hazards.*

1. Which resources/assets/populations do you see as most vulnerable to [hazard]? Please list specific names, locations, etc.

2. Are these resources/assets/populations currently impacted by any stressors? If yes, what are the stressors and how impacted is the resource? (Example stressors may be things such as climate change, land use change, funding, adaptability of resources/assets/populations, etc.)
    - **1 = Not really at all**
    - **2 = A little**
    - **3 = Moderately**
    - **4 = A lot**
    - **5 = Entirely**

3. How sensitive would you rate these assets/resources/populations to [hazard]?
    - **1 = Extremely insensitive:** the resource will not be affected by a large hazard or chronic events, or the effects will be negligible.
    - **2 = Mostly insensitive:** some effects may be noticed, but the resource will be largely unaffected by a large hazard or chronic events.
    - **3 = Unknown sensitivity:** it is unclear whether the resource will be affected by a large hazard event or chronic events.
    - **4 = Somewhat sensitive:** a large hazard event will have moderate effects on the resource, or chronic events will have moderate effects in the short-term.
    - **5 = Extremely sensitive:** a large hazard event will have devastating effects on the resource, or chronic events will have devastating effects in the short-term.

4. How long will it take to return to normal levels if the facilities/sites/resources are affected by [hazard]?

- **1 = Days or weeks**
- **2 = Months**
- **3 = 1-5 years**
- **4 = 5-10 years**
- **5 = Decades**

5. To the best of your knowledge, what is the degree and extent of impact to those resources/assets/populations expected by [hazard]?
   - **1 = Not affected or negligible effects**
   - **2 = Minor:** damage/impact is minimal, recoverable; extent is localized
   - **3 = Moderate:** damage/impact is considerable, resulting in long-term effects
   - **4 = Major:** damage/impact is substantial and/or irreversible
   - **5 = Catastrophic:** damage/impact causes total devastation

6. Using your best judgment, how much of the surrounding human community would be adversely affected if the resources/assets/populations were impacted by [hazard]?
   - **1 = None**
   - **2 = A little**
   - **3 = Some**
   - **4 = Most**
   - **5 = All**

7. What are expected long-term or indirect impacts caused by [hazard] of the assets/resources/populations?

*****

8. Based on today's discussion, how would you rank your sector overall with respect to adaptive capacity?
   - **1 = Very low**
   - **2 = Low**
   - **3 = Medium**
   - **4 = High**
   - **5 = Very high**

Context of Potential Natural Hazards in Tillamook County

The purpose of the listening sessions is to gain a deeper understanding of the needs and vulnerabilities of Oregon coastal communities to natural hazards. As we work through the session, please keep the following context in mind for our discussion:

Some helpful terms and definitions:

Estuary: Estuaries are bodies of water, and their surrounding coastal habitats, typically found where rivers meet the sea. Estuaries harbor unique plant and animal communities because their waters are brackish — a mixture of fresh water draining from the land and salty seawater. This includes areas influenced (presently or historically) by river flow, tides, and localized weather.

Natural (or "green") Infrastructure: Natural infrastructure, also referred to as "green" infrastructure, uses existing natural areas or engineered solutions that mimic natural processes such as flooding, erosion, and runoff, to minimize, redirect, or redistribute their impacts. Additional benefits can include increased recreational opportunities, improvements to wildlife habitat, water quality improvements, and many more.

Hazard: is any situation that has the potential of causing damage to people, property, or the environment. For the purposes of this questionnaire, we are focusing on hazards induced by the forces of nature ("natural hazards").

Hazard Exposure: The presence of people, livelihoods, species, ecosystems, services, resources, infrastructure, or other environmental, economic, social, or cultural assets in places that could be adversely affected by a hazard.

Resilience: Resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events (such as natural hazards).

Stakeholder: Individuals, organizations, or communities who have an interest in or are affected by decisions, planning, or policies.

Vulnerability: The extent to which a natural, built, or social system is susceptible to damage from natural hazards. Under this framework, a highly vulnerable system would be one that is highly sensitive to modest impacts from natural hazards.

Questions to Consider Regarding Hazard Exposure in Your Sector

- How much of your sector or your sector's components (e.g., resources, assets, populations) are projected to be exposed to the most critical hazard of interest?
- On what kind of timescales do you anticipate these components to be exposed to this hazard? [Example: weeks, months, 1-4 years, 5-10 years, decades]
- What do you believe is the certainty, likelihood, or probability of these projections?

List of Oregon Coastal Natural Hazards:

Chronic Hazards (those that carry the potential for cumulative, long-term impact):

- Air quality (increased pollutants: ozone, smoke, pollen, etc.)
- Average air temperature rise (long-term)
- Changes to water temperature, quality, or chemistry (e.g., ocean acidification)
- Changes to climate regime (climate change)
- Increased invasive species and pests, or other impacts to fish and wildlife
- Sea level rise and saltwater intrusion
- Decreased summer precipitation; heavier winter storms
- Changing ocean cycles (Pacific Decadal Oscillation, El Niño/La Niña, spring transition timing)
- Erosion, accretion, or deposition of beaches, dunes, or soils (long-term)
- Subsidence

Episodic Hazards (discrete events with immediate impact):

- Heavy rains and river flooding
- Tidal flooding, king tides
- Tsunamis
- Landslides
- Erosion, accretion, or deposition of beaches, dunes, or soils (short-term)
- Heat waves (short-term)
- Cold snaps (short-term)
- Severe weather events (high winds, storm surge)
- Drought
- Wildfire
- Earthquakes
- Water table issues