Chapter 4: Estuary and Watershed Profiles

A summary of each watershed within the TEP focal area is provided in this chapter. Each profile highlights the efforts of TEP and its partners to improve water quality, restore habitat, encourage environmental literacy, and foster citizen involvement and stewardship throughout TEP's focal area.

Healthy estuaries and watersheds support the community, economy, and ecosystem. This is the balance TEP strives to achieve in furtherance of its mission of restoring and conserving all of Tillamook County's estuaries and watersheds.

Estuarine Habitat Classifications[2]

The following classifications are based on the Coastal and Marine Ecological Classification Standards (CMECS). Individual classification types are given within the profiles below.

Aquatic beds (Benthic/Attached Aquatic Vegetation Beds) include subtidal or intertidal bottoms and any other areas characterized by a dominant cover of rooted vascular plants, attached macroalgae, or mosses, which are usually submersed in the water column or floating on the surface. They may be exposed during low tides. Non-rooted floating vegetation and free floating macroalgae are included with the Planktonic Biota Biotic Setting under the Floating/Suspended Plants and Macroalgae Subclass. These are critical habitat areas that provide food and cover for fish, amphibians, and invertebrates. These habitat areas have declined greatly since 1850 due to river channelization, siltation, and in-filling.

Mudflats (Flats) are often composed of unconsolidated sediments (such as mud or sand). These forms are more commonly encountered in the intertidal or in the shallow subtidal zones. Historically, these were viewed as unimportant and were often dredged to allow for development. However, they support wildlife and are key habitats for many shorebirds, fish, crabs, and mollusks.[3]

Emergent tidal marsh are wetlands characterized by erect, rooted, herbaceous hydrophytes—excluding emergent mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.

Tidal scrub-shrub wetlands are wetland areas dominated by woody vegetation that is generally less than six (6) meters tall. Characteristic species include true shrubs, young trees, and trees or shrubs that are small or stunted due to environmental conditions. Scrub-Shrub Wetland includes the shrub-dominated portions of high salt marshes.

Forested wetlands are characterized by woody vegetation that is generally six (6) meters or taller. Coniferous swamps, lowland hardwood swamps, and floodplain forests are typical of these habitats.

[2] Federal Geographic Data Committee. Coastal and Marine Ecological Classification Standard (CMECS) version 4.0. 2012. https://www.fgdc.gov/standards/projects/FGDC-standards-projects/cmecs-folder/CMECS_Version_06-2012_FINAL.pdf

[3] "Lower Nehalem Watershed Council." Wetlands. http://lnwc.nehalem.org/?page_id=426.

Non-Estuarine Habitat Classifications[4]

The focal area includes five Level IV Coast Range ecoregions: Coastal Lowlands, Coastal Uplands, Volcanics, Willapa Hills, and Mid-Coastal Sedimentary (Figure 5).

Coastal Lowlands ecoregion covers 114 square miles (6%) of the focal area generally at elevations below 400 feet. The landscape is characterized by low gradient, meandering, tannic creeks and rivers along with beaches, dunes (stabilized by shore pine), estuaries and coastal wetlands, wet forests (spruce, cedar, hemlock, Sitka spruce), and marine terraces. The coast lowlands include agricultural land (pasture), some logging, and much of the areas residential, recreational, commercial, and port development (Garibaldi and Tillamook Bay).

Coastal Uplands ecoregion covers 206 square miles (11%) of the focal area generally at elevations between 400 and 2,500 feet. The landscape is characterized by headlands and low mountains surroundings the Coastal Lowlands with medium to high gradient tannic creeks and rivers. Forests in this ecoregion consist of spruce, cedar, hemlock, Douglas-fir canopy which has replaced much of the Sitka spruce which dominated before logging. The coastal uplands support some pastureland, logging, dairy farming, and has some recreation, rural residential, and commercial development.

Volcanics ecoregion covers 994 square miles (54%) of the focal area, mainly to the east and generally at elevations above 600 feet (but the ecoregion does extend to lower elevations near creeks and rivers). The landscape is characterized by steeply sloping mountains and capes that include higher gradient streams and rivers. The forest canopy is dominated by Douglas-fir and western hemlock. The volcanics contains much of the areas public and private timber land that supports logging, wildlife habitat, recreation, and rural residential development.

Willapa Hills ecoregion comprises 459 square miles (25%) in the northeast part of the focal area within the Nehalem watershed generally at elevations below 1,300 feet. The landscape is characterized by low, rolling hills, and gently sloping mountains with medium gradient creeks and rivers. The forest canopy is dominated by Douglas-fir and western hemlock. The ecoregion has some pastureland but is mostly forest that supports logging and contains some rural communities and residential development.

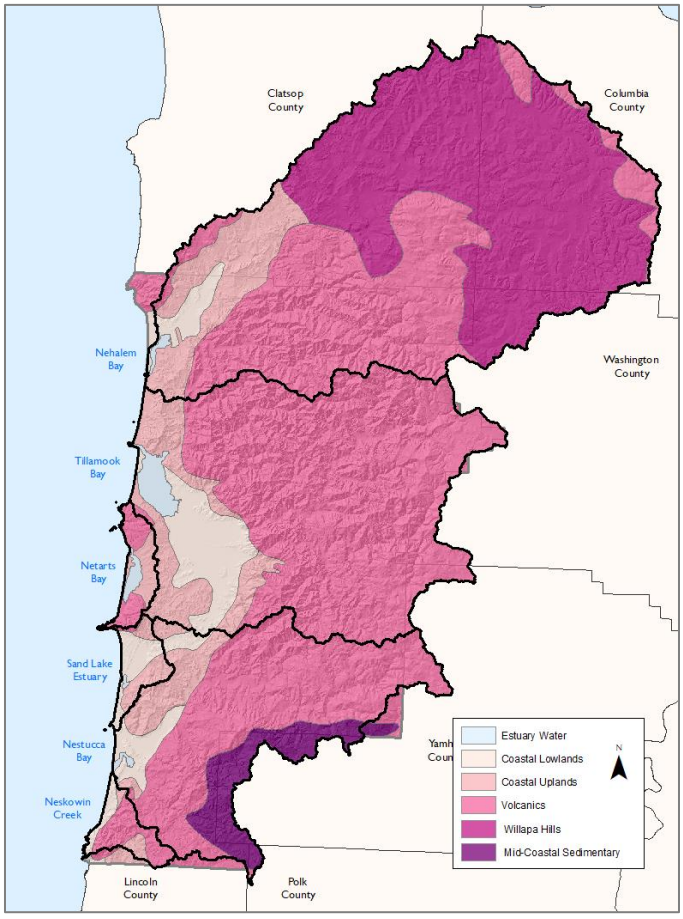

Figure 5. TEP Study Area non-estuarine habitat classifications (Level IV Ecoregions)

[4] Thorson, T.D., Bryce, S.A., Lammers, D.A., Woods, A.J., Omernik, J.M., Kagan, J., Pater, D.E., and Comstock, J.A., 2003. Ecoregions of Oregon (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000).

Mid-Coastal Sedimentary ecoregion covers 58 square miles (3%) of the southeast part of the focal area within the Nestucca watershed generally at elevations between 500 and 2,000 feet (but the ecoregion does extend to lower elevations near creeks and rivers). The landscape is characterized by moderately slopping mountains with medium to high gradient creeks and rivers. The forest canopy is dominated by Douglas-fir and western hemlock. The ecoregion has some pastureland with some rural residential development in valleys but is mostly forest that supports recreation and logging.

Fish and Wildlife

Many of Tillamook County's bays and watersheds have similar fish and wildlife present. Endangered and threatened species such as the Oregon Coast Coho salmon, marbled murrelet, and western snowy plover are known to occur within portions of the focal area. Other common animals found throughout the focal area include a variety of songbirds, shorebirds, water birds and raptors. Elk, deer, black bears, and beavers are commonly found. Tidal areas and streams provide important rearing habitat for anadromous fish including Chinook, coho, and steelhead.[5] In addition, the Oregon silverspot butterfly has historically been found at Cape Mears (Netarts watershed), Mt. Hebo (Nestucca watershed), and is being introduced to the wildlife refuge in the Nestucca Bay National Wildlife Refuge. Band-tailed pigeon mineral sites are found in Nehalem, Tillamook, and Nestucca bays.

There are commercial oyster operations in the Tillamook and Netarts watersheds. Oysters have been grown commercially in Tillamook Bay since the 1930s. Tillamook Bay has been one of the leading oyster producing bays in Oregon, with an average annual production of about 21,200 shucked gallons during the 1970s and 1980s. Beginning in 1990, the level of production dropped off sharply and has remained low due to reduced production by several Oyster Companies.[6] The Whiskey Creek shellfish hatchery in Netarts Bay is the largest shellfish hatchery in the U.S. This shellfish hatchery provides "oyster, clam, and mussel seed for commercial as well as restoration efforts. Whiskey Creek has also been at the forefront of ocean acidification research and adaptation. Beginning in 2007, the hatchery struggled with mass mortalities associated with highly corrosive upwelled water off the Oregon coast. In the last few years, thanks to research and improvements in hatchery monitoring techniques, Whiskey Creek has been able to better predict and respond to changes in ocean chemistry and the negative impacts of those changes on shellfish larvae."[7]

Watersheds within Tillamook County provide habitat for threatened species such as Oregon Coast coho salmon. The Oregon Coast Coho Conservation Plan by the Oregon Department of Fish and Wildlife (ODFW) and the Oregon Coast Coho Recovery Plan by NOAA Fisheries and ODFW. The plans address the legal requirements for conservation planning under Oregon's Native Fish Conservation Policy and provide strategic recovery actions to support coho populations through adaptive management.

[5] Lower Nehalem Community Trust. *Conservation Plan 2013*. http://www.nehalemtrust.org/wp-content/uploads/LNCT_Conservation_Plan-1.pdf.
[6] "Department of Environmental Quality." Tillamook Bay Watershed 1998. https://www.oregon.gov/deq/.
[7] Pacific Shellfish Incorporated, http://www.pacshell.org/oregon.asp

Tidal Wetland Landward Migration Zones (LMZs)[8]

Tidal Wetland Landward Migration Zones (LMZs) are the areas upslope of current tidal wetlands where wetlands may migrate in the future as sea level rises. These are based on a study by the Midcoast Watersheds Council and the Institute for Applied Ecology in 2017 which modeled different LMZ outcomes based on various sea level rise scenarios on the Oregon coast. Knowledge of these areas may assist with planning restoration and conservation opportunities.

Within each of the watershed profiles that follow, figures depict the extent and prioritization of LMZs given a 4.7-foot rise in sea level by year 2100. The 4.7-foot rise scenario is the high end of the range from the West Coast Sea Level Rise study. It is used as the basis for comparison and prioritization since it represents: (a) the earliest scenario that shows a distinct change in the distribution of tidal wetlands compared to the baseline conditions, and (b) a long range planning scenario which may provide coastal groups (such as TEP) adequate time to take action to conserve and restore tidal wetland resources. The maps are based on elevation and projected sea level rise (SLR) and do not consider rates of sediment accretion. This amount of sea level rise could occur earlier or later than the year 2100.

Current v. 4.7 ft SLR scenario

LMZ maps are provided for five of the six estuaries within Tillamook County and show LMZs at 4.7 ft SLR versus the areas that are currently within the vegetated tidal wetland (emergent, shrub, or forested) elevation ranges even if they are not currently tidal wetlands (e.g., areas behind a dike or tide gate). As such, the LMZ maps show areas that would be tidal wetlands or mudflats if they were reconnected to the tides.

Tidal Wetland LMZ Prioritization Maps

The LMZ maps show areas to prioritize, and to support decisions on where to focus efforts for the conservation and restoration of tidal wetlands. The maps show prioritization rankings (high, medium-high, medium-low, and low). Areas that are developed (impervious) are removed from the prioritization rankings.


Photo: John Bauer

Prioritizations of LMZs are based on:

- Future tidal wetland areas (in hectares) at 4.7-foot sea level rise where more future tidal wetlands are given a higher prioritization;
- Area of higher LMZs with 8.2- and 11.5-foot sea level rise;
- Current land use zoning where non-developed land is given a higher prioritization;
- Land ownership where public land is given a higher prioritization;
- Development status where undeveloped land is given a higher prioritization.

Detailed information on how developed areas and infrastructure could be impacted by sea level rise is found on the Oregon Coastal Management Program's Sea Level Rise Exposure Inventory: http://www.coastalatlas.net/index.php/tools/planners/68-slr

[8] Brophy, Laura S. and Michael J. Ewald. "Tidal wetland landward migration zones (LMZs) for 4.7 ft. sea level rise for the Nehalem River Estuary." Oregon State University Scholars Archive. Midcoast Watersheds Council. https://ir.library.oregonstate.edu/concern/technical_reports/fn107413z.

Nehalem River Watershed

The Nehalem River Watershed encompasses 855 square miles or 46% of the focal area. The estuary has the geomorphology of a drowned river mouth and is considered a major shallow draft development estuary under the Oregon Estuary Classification system. The Nehalem River stretches for 118 miles and is Oregon's largest stream contained entirely within the coast range. Along its journey, the Nehalem River flows through dense forests, then quietly meanders by green pastures, small towns and basalt canyons before entering Nehalem Bay. Around the turn of the 20th century, the margins of the bay were abuzz with a bustling community of several thousand residents centered on agricultural products, logging, and a plentiful salmon fishery. Today, the area has a quieter appeal, while still maintaining its charm of old. Tourism is an increasing focus of the local communities, as evidenced by the expansive Nehalem Bay State Park. Work to restore and conserve ecological functions throughout the watershed is buoyed by the active efforts of partners in the upper Nehalem River, lower Nehalem River, and Nehalem Bay.

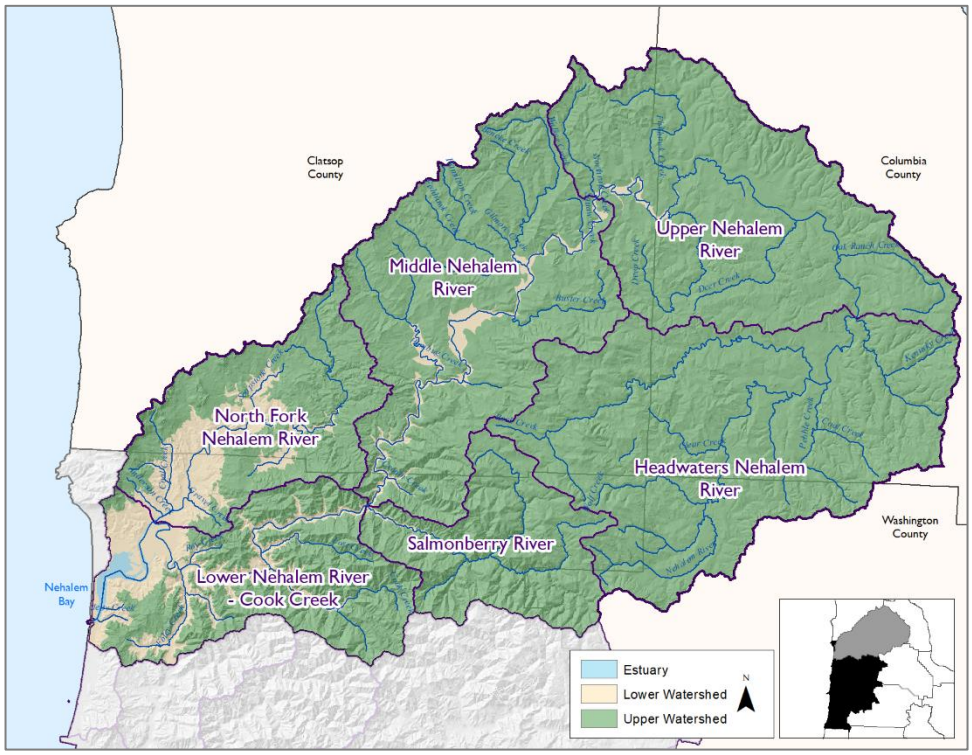

Figure 6. *Nehalem River watershed boundary showing 5th Field HUC sub-watersheds and the estuary, lower, and upper watershed regions.*

Physical Description

Nehalem River watershed is in northern Tillamook County. It lies completely within the temperate coniferous rain forest belt. The upper Nehalem is located upstream of the confluence of the Nehalem and Salmonberry rivers and is located within a geologic area called the Tillamook Highlands which is composed of sedimentary siltstone and sandstone.

Historically, the watershed was dominated by old growth coniferous ecosystems with marshlands in the lower gradient areas and estuary. There are over 935 miles of tributaries and the watershed is divided into six 5th Field HUC sub-watersheds and the estuary: North Fork Nehalem River, Middle Nehalem River, Upper Nehalem River, Headwaters Nehalem River, Salmonberry River, and Lower Nehalem River- Cook Creek (Figure 6). With a range of elevation from sea level to over 3,600 feet, this terrain varies from dunes, salt marsh, Sitka spruce swamps, and scrub shrub wetlands in the lower watershed to a wet temperate rain forest of Sitka spruce, hemlock and Douglas fir in the upper watershed. Nehalem Bay State Park is located on the north spit and is popular for camping, hiking, biking, boating, and fishing.[9]

[9] "Portland State University." Nehalem River Watershed Assessment. http://web.pdx.edu/~maserj/project/project1/acrobat/1intro.pdf

Figure 7 shows the distribution of estuarine habitats including: aquatic beds, mudflats, emergent wetlands, scrub-shrub wetlands, and forested wetlands. In Oregon, 68% of estuarine wetlands have been lost to conversion from 1870 to 1970 – the Nehalem River estuary lost 75%, making it among the most impacted estuaries in Tillamook County.[10]

Figure 8 shows the distribution of non-estuarine habitat (ecoregions). The watershed is within the Coast Range ecoregion (Level III), specifically the Level IV ecoregions Coastal Lowlands, Coastal Uplands, Volcanics, and Willapa Hills. The lower Nehalem is primarily part of the Volcanics ecoregion while the upper Nehalem is primarily part of the Willapa Hills ecoregion.

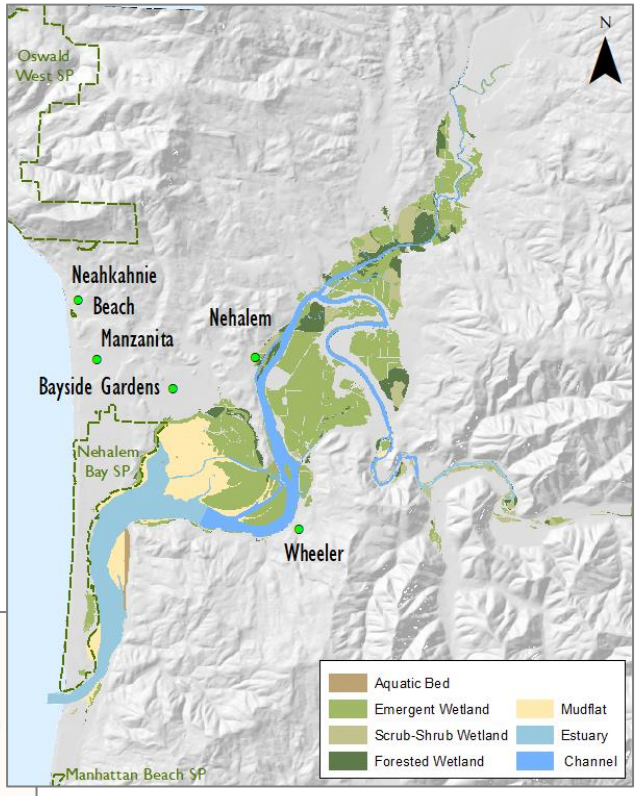

Figure 7. Nehalem watershed estuarine habitat classifications (CMECS)

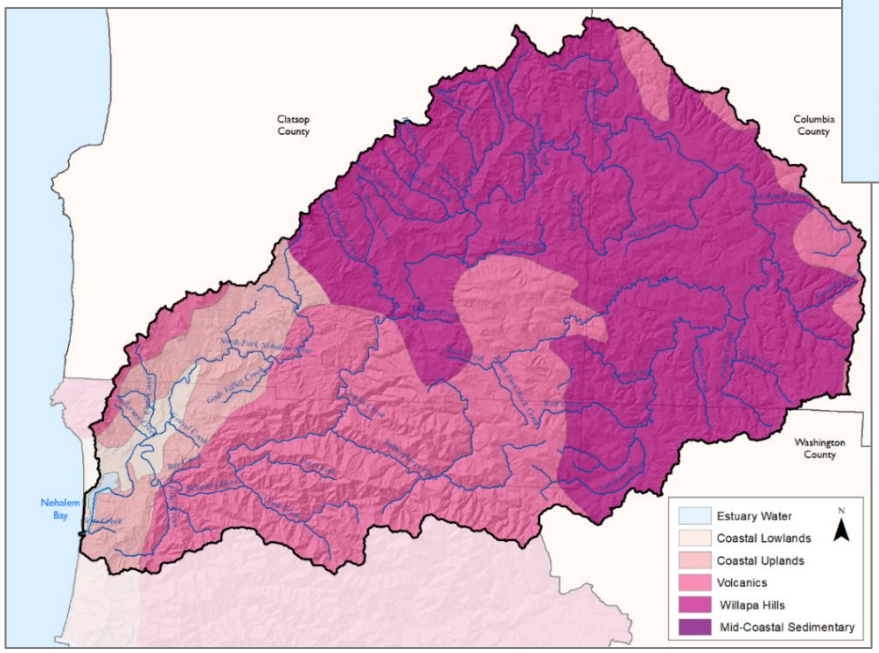

Figure 8. Nehalem watershed non-estuarine habitat classifications (Level IV Ecoregions)

Land Ownership

Much of the land in the watershed is privately or state-owned and 95% is zoned forest land. The upper watershed is primarily used for recreation and timber production, while the lower watershed is primarily used for agriculture, dairy, and residential uses. The estuary is used for commercial and sport fisheries and recreation activities. Most of the public forest lands are managed through the Oregon Department of Forestry (53%). Private timber companies also manage large tracts of land throughout the watershed (40%). Timber production is the main land use activity throughout the watershed, with agriculture representing a minor use (3%).[11] About three percent of the land is zoned for urban or rural development, including land within the cities of Nehalem (pop. 323), Vernonia (pop. 1,895), Wheeler (pop. 422), and the community of Bayside Gardens (pop. 662). In addition, the City of Manzanita (pop. 332) and the community of Neah Kah Nie Beach (pop. 54) are in the northwest portion of the County just outside the watershed.[12]

[10] Good, James W. *Summary and Current Status of Oregon's Estuarine Resources".* Oregon State of the Environment Report, Chapter III, Health of Natural Systems and Resources. Change is due to filling and diking between 1870 to 1970. Restoration of wetlands in recent years has begun to reverse the loss trends. https://www.oregon.gov/DSL/WW/Documents/soer_ch33.pdf.

[11] Ibid.

[12] U.S. Census Bureau, American Community Survey, 5-year estimates, 2012-2016.

Tidal Wetland Landward Migration Zones (LMZs)

Figure 9 shows the extent of LMZs given a 4.7 ft. rise in sea level by year 2100. Areas to the north and east of the bay are predicted to experience the greatest impacts from LMZs. The communities of Wheeler and Brighton are not predicted to see much change; however, Nehalem Bay State Park will likely be impacted.

Figure 10 shows the prioritization of LMZs. According to the Midcoast Watersheds Council and the Institute for Applied Ecology report areas to consider as priority for the conservation and restoration of tidal wetlands include Nehalem State Park and the area northeast of Wheeler that score as high or medium-high priority.

For more information visit the report on the Oregon State University Scholars Archive.

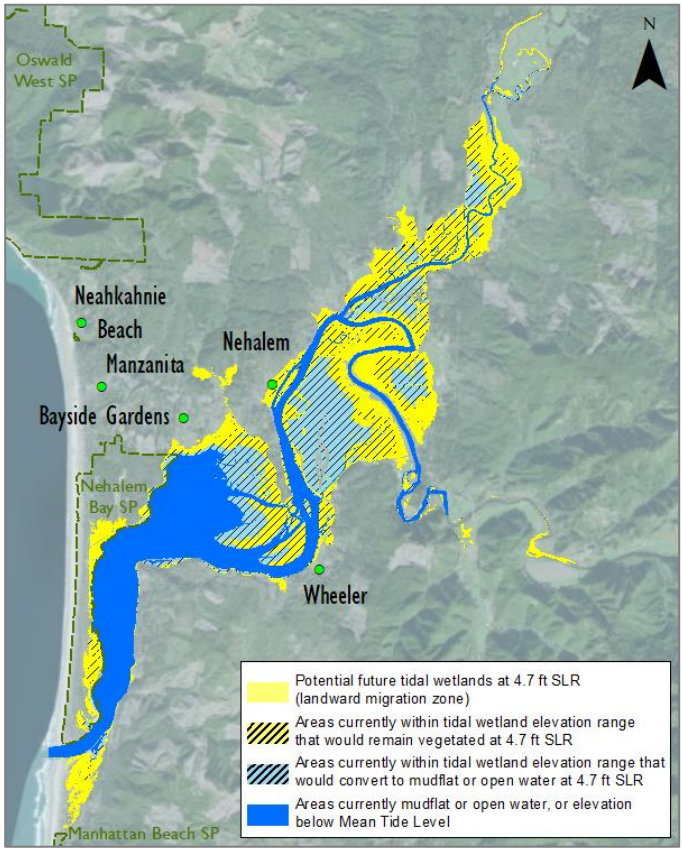

Figure 9. Nehalem Bay predicted landward migration zones (based on 4.7-foot sea level rise by year 2100).

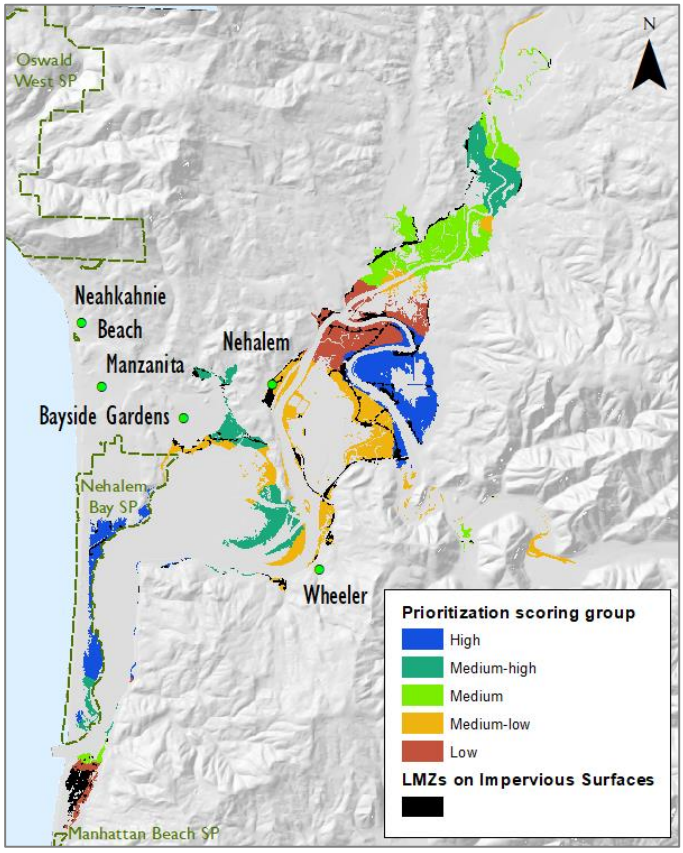

Figure 10. Nehalem Bay landward migration zone prioritization

Tillamook Bay Watershed

Nestled between rugged mountains and the Pacific Ocean with over 570 square miles of rivers and creeks and a bay totaling 13 square miles the Tillamook Bay watershed represents 31% of the focal area. The estuary has the geomorphology of a drowned river mouth and is considered a major shallow draft development estuary under the Oregon Estuary Classification system. Tillamook Bay is Oregon's second largest bay, and one of its most prized resources. The bay supports a thriving oyster industry and some of the best runs of salmon and steelhead on the West Coast. In addition, broad fertile floodplains play host to rich dairy lands which produce world-class cheese. A healthy and functioning Tillamook Bay is essential to not only honor our cultural landscape and crucial natural resources, but to the overall vitality of its surrounding communities. TEP, along with many partners, are dedicated to further understanding the mechanisms at work and finding practical solutions to ensure the long-term sustainability of this "Bay of National Significance".

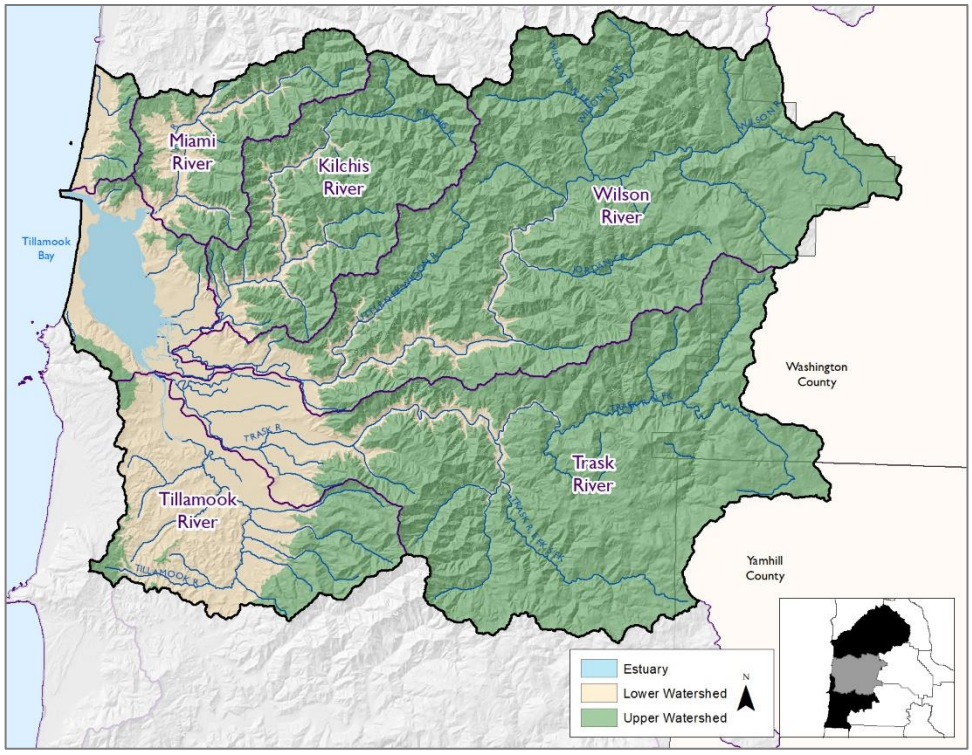

Figure 11. Tillamook Bay watershed boundary showing 5th Field HUC sub-watersheds and the estuary, lower, and upper watershed regions.

Physical Description

Tillamook Bay watershed is in central Tillamook County. The City of Tillamook (pop. 5,183) lies southeast of the estuary. Bay City and Garibaldi also sit on the bay and are directly tied to it. The vast 364,000-acre Tillamook State Forest is east of the bay and is a major area for commercial logging and recreation. Much of the land adjacent to the bay is urbanized or agricultural, private forest land abuts the bay to the south, and the spit to the west includes Bayocean Peninsula Park, a popular recreational destination. The estuary drains the watersheds of five rivers: Miami, Kilchis, Wilson, Trask, and Tillamook (Figure 11).

Figure 12 shows the distribution of estuarine habitats including: salt marshes, aquatic beds, freshwater emergent wetlands, forested wetlands, and mudflats. In Oregon, 68% of estuarine wetlands have been lost to conversion from 1870 to 1970 – the Tillamook Bay estuary lost 79%, making it among the most impacted estuaries in Tillamook County.[13]

Figure 13 shows the distribution of non-estuarine habitat (ecoregions). The watershed is within the Coast Range ecoregion (Level III), specifically the Level IV ecoregions Coastal Lowlands, Coastal Uplands, and Volcanics.

Much of the basin is dominated by the Oregon Coast Range, with much of the watershed classified as a temperate rainforest receiving more than 100 inches of rain annually. Much of the western extent is covered by Sitka spruce, while the eastern extent of the region has more upland varieties such as Douglas fir.[14]

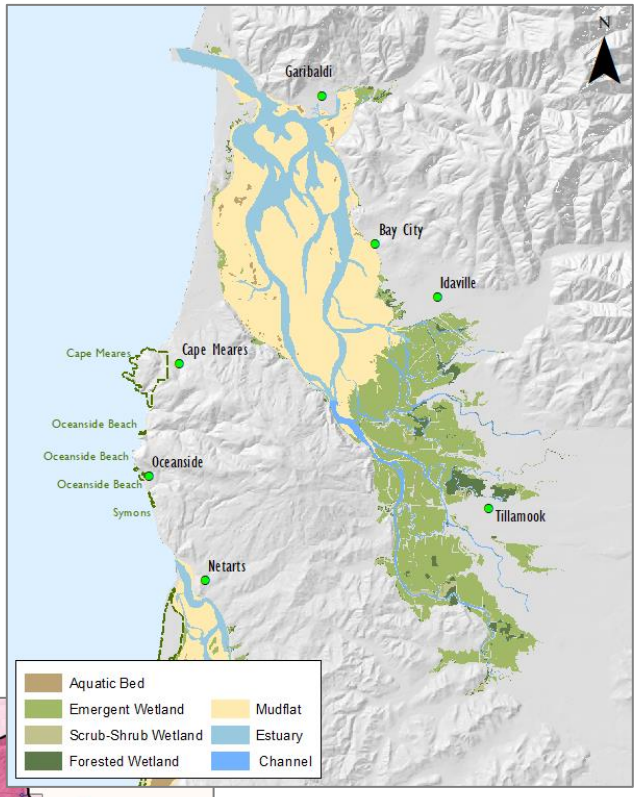

Figure 12. Tillamook Bay estuarine habitat classifications (CMECS)

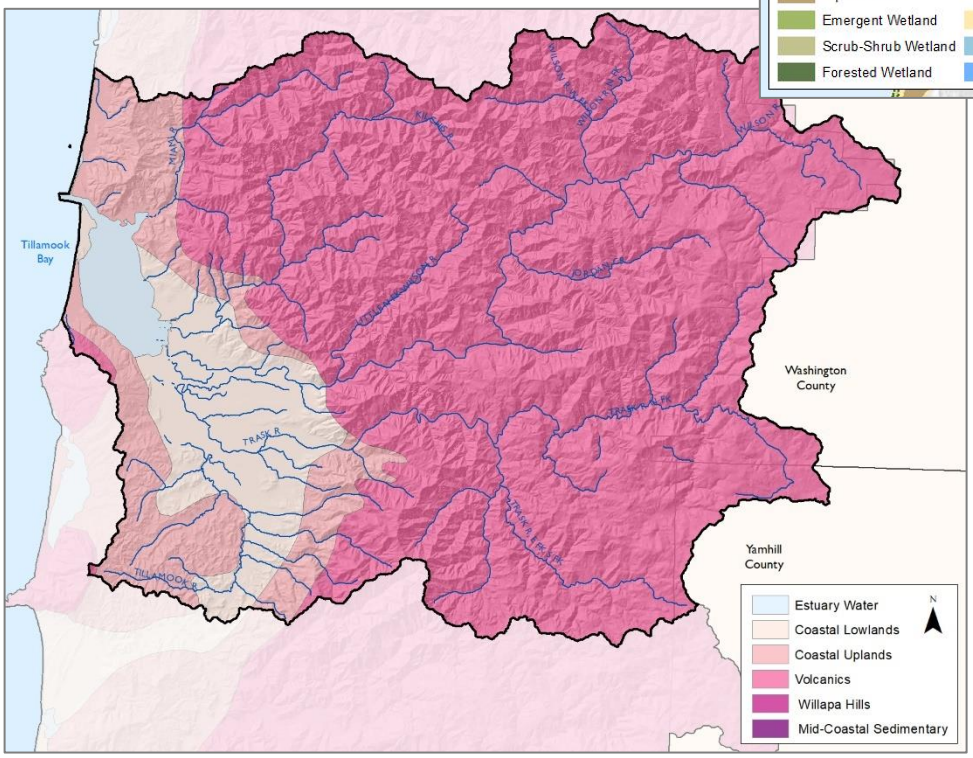

Figure 13. Tillamook Bay watershed non-estuarine habitat classifications (Level IV Ecoregions)

Much of the watershed is composed of volcanic rock types which originated from individual island terranes, although the western Tillamook and Trask sub-basins are mostly surficial glacial melt deposits and sedimentary mud and siltstones.[15] The upper watershed is part of the coastal, temperate rain forest ecosystem and nearly 89% of the total land area is covered with coniferous forests comprised of

[13] Good, James W. *Summary and Current Status of Oregon's Estuarine Resources".* Oregon State of the Environment Report, Chapter III, Health of Natural Systems and Resources. Change is due to filling and diking between 1870 to 1970. Restoration of wetlands in recent years has begun to reverse the loss trends. https://www.oregon.gov/DSL/WW/Documents/soer_ch33.pdf.

[14] "Natural Resource Conservation Service." Lower Tillamook Bay Watershed: Watershed Plan and Environmental Assessment. https://nrimp.dfw.state.or.us/web%20stores/data%20libraries/files/OWEB/OWEB_930_2_Lower%20Tillamook%20Bay%20WS%20Assessment%20pt1of3.pdf

[15] "Tillamook Estuaries Partnership." Tillamook Bay Watershed Sediment and Physical Habitat Assessment 2009.

western red cedar, Douglas fir, and Sitka spruce. Lower watershed habitats are comprised of forests, shrublands, and open grasslands which provide important habitat for a variety of wildlife. The lower watershed is used primarily for dairy and agriculture. Riparian habitat is adjacent to streams and waterways and provides a variety of benefits to fish and wildlife, as well as important services such as stream bank stabilization, large woody debris recruitment, and shade for lowering water temperature.[16]

Land Ownership

Much of the land in the watershed is privately or state-owned and 89% is zoned forest land.[17] The upper watershed is primarily used for recreation and timber production, while the lower watershed is primarily used for agriculture, dairy, and residential uses. The estuary is used for commercial and sport fisheries and recreation activities. Most of the public forest lands are managed through the Oregon Department of Forestry (59%).[18] Private timber companies also manage large tracts of land throughout the watershed (23%). Timber is the main land use activity throughout the watershed, with agriculture representing a lesser use (6%). About six percent of the land is zoned for urban and rural development, including land within the cities of Bay City (pop. 1,495), Garibaldi (pop. 821), Rockaway Beach (1,245), Tillamook (pop. 5,065), and the communities of Cape Mears (pop. 121) and Idaville (pop. 429).[19]

[16] "U.S. Environmental Protection Agency." Tillamook Bay Watershed Health Report 2010. http://19january2017snapshot.epa.gov
[17] DLCD. *"Oregon Zoning 2017"*. Oregon Spatial Data Library. April 28, 2017.
[18] BLM. "*Oregon Land Management 2015*". Oregon Spatial Data Library. January 8, 2015.
[19] U.S. Census Bureau, American Community Survey, 5-year estimates, 2012-2016.

Tidal Wetland Landward Migration Zones

Figure 14 shows the extent of LMZs given a 4.7 ft. rise in sea level by year 2100. Areas southeast of the bay, near the City of Tillamook, are predicted to experience the greatest impacts from LMZs. Areas around Garibaldi and the Bayocean Peninsula Park may also undergo LMZ movement.

Figure 15 shows the prioritization of LMZs. According to the Midcoast Watersheds Council and the Institute for Applied Ecology report areas to consider as priority for the conservation and restoration of tidal wetlands include the areas north and west of the bay, much of the City of Tillamook, and the highest priority areas that occur further east that score as high or medium-high priority.

For more information visit the report on the Oregon State University Scholars Archive.

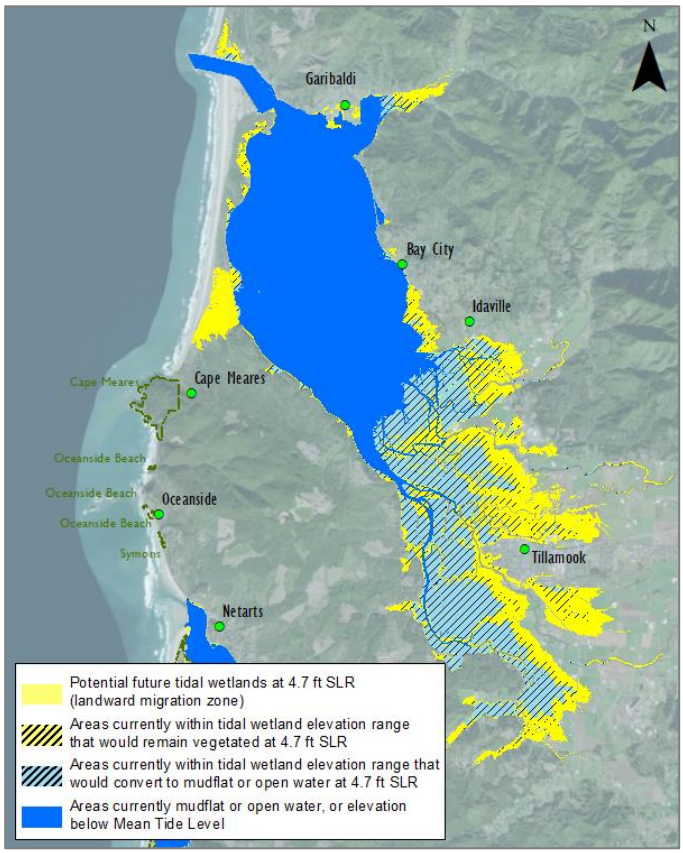

Figure 14. Tillamook Bay predicted landward migration zones (based on 4.7-foot sea level rise by year 2100).

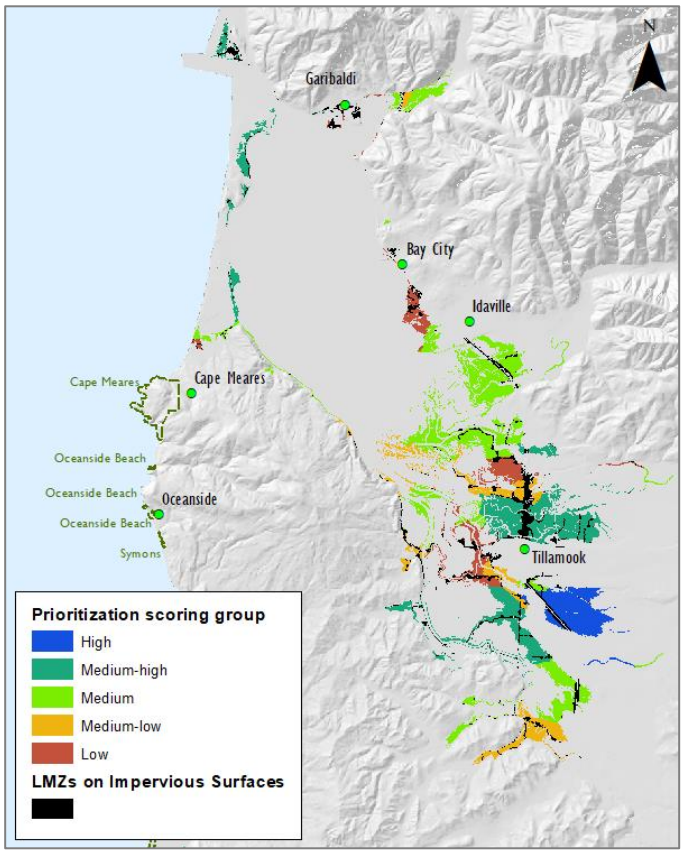

Figure 15. Tillamook Bay landward migration zone prioritization factors.

Netarts Bay Watershed

The Netarts Bay watershed encompasses 26 square miles or just over 1% of the focal area. The geomorphology of the area is that of a bar-built estuary and is considered a major conservation estuary under the Oregon Estuary Classification system. Netarts Bay (along with Sand Lake) boasts a predominately pristine estuarine environment compared to its sister bays in Tillamook County. This is due to the relatively light influence of development along its shores and throughout its watershed. Rather than being fed by larger rivers, Netarts Bay is fed by 16 smaller direct-to-bay creeks. The bay is approximately 2,325 acres, 812 acres of which are permanently submerged. Despite its size, Netarts Bay is a highly dynamic system that influences coastal erosion throughout its littoral cell. In addition to the many recreational opportunities, Netarts is home to robust commercial oyster operations and an emerging premium sea salt industry. Netarts Bay is a pilot site for a project focused on restoring the Pacific Northwest's native Olympia Oyster within its historical distribution. Because of Netarts relatively unaltered natural state, it is often used as a reference site to compare the water and habitat quality of other estuaries.

Figure 16. Netarts Bay watershed boundary (5th Field HUC sub-watershed) and the estuary, lower, and upper watershed regions.

Physical Description

Netarts Bay watershed is in central Tillamook County. To the south and west of the bay is Cape Lookout State Park which is a popular area for fishing, camping, and sightseeing.

The unincorporated community of Netarts lies northeast of the estuary. The Netarts Bay Shellfish Preserve is located on the south side of the bay. The bay is fed by several small creeks, including Fall Creek, Hodgdon Creek, O'Hara Creek, Yager Creek, Whiskey Creek, Austin Creek, and Rice Creek.[20]

The lower watershed has dune and marsh communities while the upper watershed includes dense stands of Sitka spruce, Douglas fir, and Western hemlock.[21] Much of the forested upper watershed is subject to commercial timber harvest. The Netarts Bay watershed has mixed lithology, but is predominantly composed of

[20] "Advisory Committee to the State Land Board" An Inventory of Filled Lands in Netarts Bay Estuary.
[21] McCallum, Larry D. thesis. Netarts Bay, Oregon: an assessment of human impact on an estuarine system

erodible substrate, although, much of the coast near Cape Lookout and Cape Meares is comprised of volcanic basalts.[22]

Figure 17 shows the distribution of estuarine habitats including: salt marshes, aquatic beds, freshwater emergent wetlands, forested wetlands, and mudflats. In Oregon, 68% of estuarine wetlands have been lost to conversion from 1870 to 1970 - Netarts lost 7%, making it among the least impacted estuaries in Tillamook County.[23]

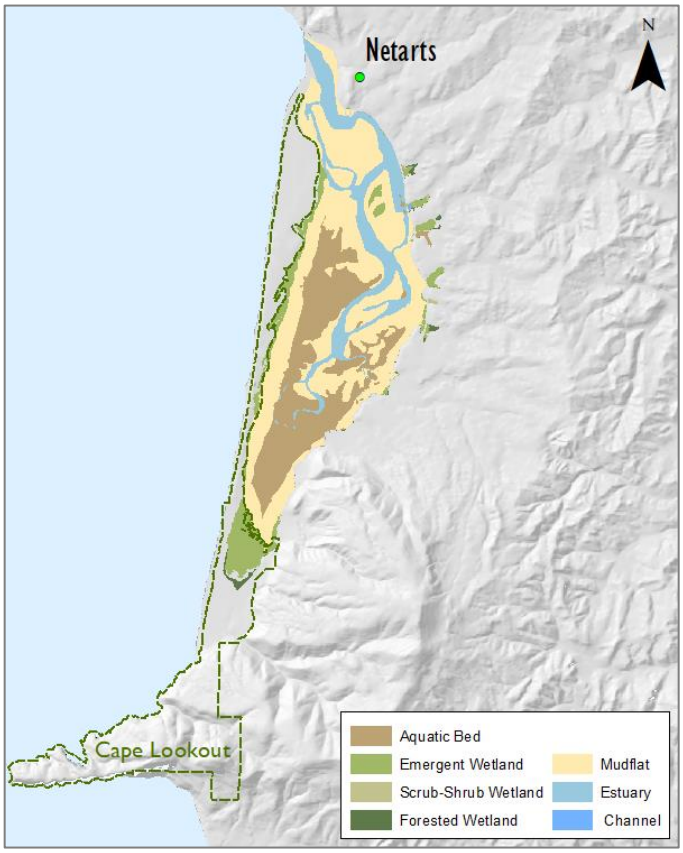

Figure 17. Netarts Bay estuarine habitat classifications (CMECS)

Figure 18 shows the distribution of non-estuarine habitat (ecoregions). The watershed is within the Coast Range ecoregion (Level III), specifically the Level IV ecoregions Coastal Uplands and Volcanics. Non-estuarine habitats include upland forests which are dominated by Sitka spruce, western red cedar, western hemlock, and Douglas fir. Low-lying riparian areas include a variety of sedges, rushes, Red alder, and Oregon maple.[24]

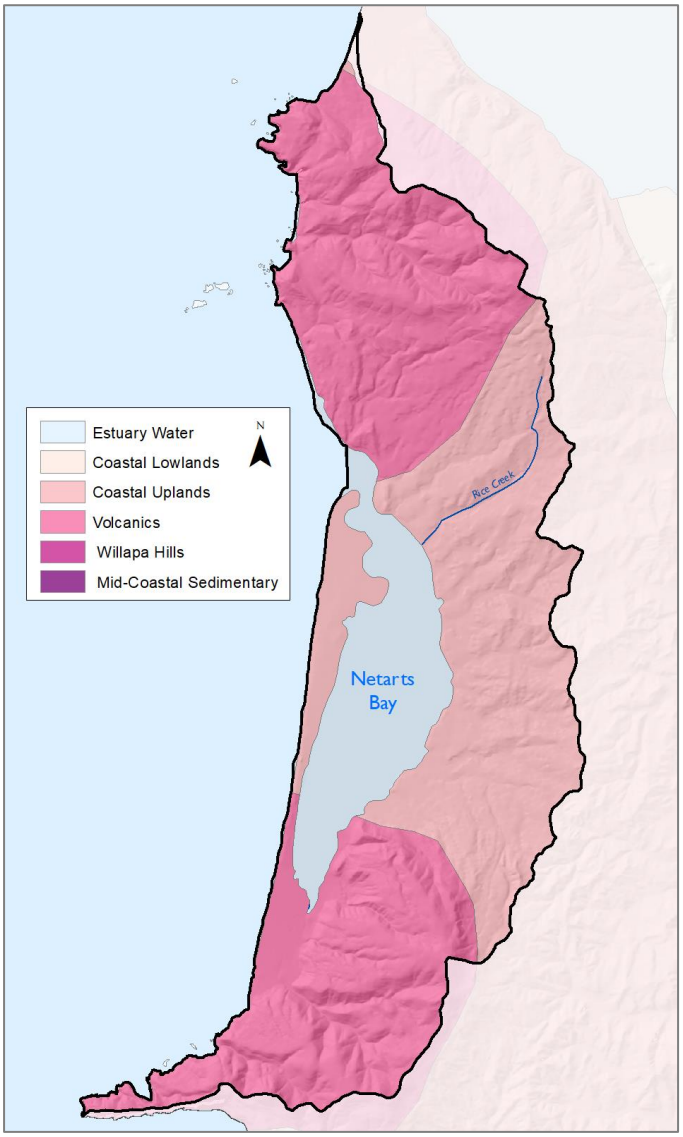

Figure 18. Netarts Bay watershed non-estuarine habitat classifications (Level IV Ecoregions)

[22] "Tillamook Estuaries Partnership." Netarts Watershed Assessment 1999.
[23] Good, James W. *Summary and Current Status of Oregon's Estuarine Resources".* Oregon State of the Environment Report, Chapter III, Health of Natural Systems and Resources. Change is due to filling and diking between 1870 t0 1970. Restoration of wetlands in recent years has begun to reverse the loss trends. https://www.oregon.gov/DSL/WW/Documents/soer_ch33.pdf.
[24] "Tillamook Estuaries Partnership." Netarts Bay Watershed Habitat Study, Restoration Plan, and Limiting Factors Analysis 2008.

Land Ownership

Much of the land in the watershed is privately owned and 75% is zoned forest land.[25] The upper watershed is primarily used for timber production, while the lower watershed is primarily used for residential uses. The estuary is used for sport and shellfish fisheries, and recreation activities. Private timber companies manage most of land throughout the watershed (72% with other areas including state parks (Netarts Spit Park) and federal lands (13%).[26] Timber is the main land use activity throughout the watershed. About 11% of the land is zoned for urban and rural development, including land within the communities of Netarts (pop. 878) and Oceanside (pop. 317).[27]

Netarts Bay | Don Best

[25] DLCD. *"Oregon Zoning 2017"*. Oregon Spatial Data Library. April 28, 2017.
[26] BLM. "*Oregon Land Management 2015*". Oregon Spatial Data Library. January 8, 2015.
[27] U.S. Census Bureau, American Community Survey, 5-year estimates, 2012-2016.

Tidal Wetland Landward Migration Zones

Figure 19 shows the extent of LMZs given a 4.7 ft. rise in sea level by year 2100. Areas southwest and west of the bay are predicted to experience the greatest impacts from LMZs.

Figure 20 shows the prioritization of LMZs. According to the Midcoast Watersheds Council and the Institute for Applied Ecology report areas to consider as priority for the conservation and restoration of tidal wetlands include the areas along the spit to the west and east of the bay that score as high or medium-high priority.

For more information visit the report on Oregon State University Scholars Archive.

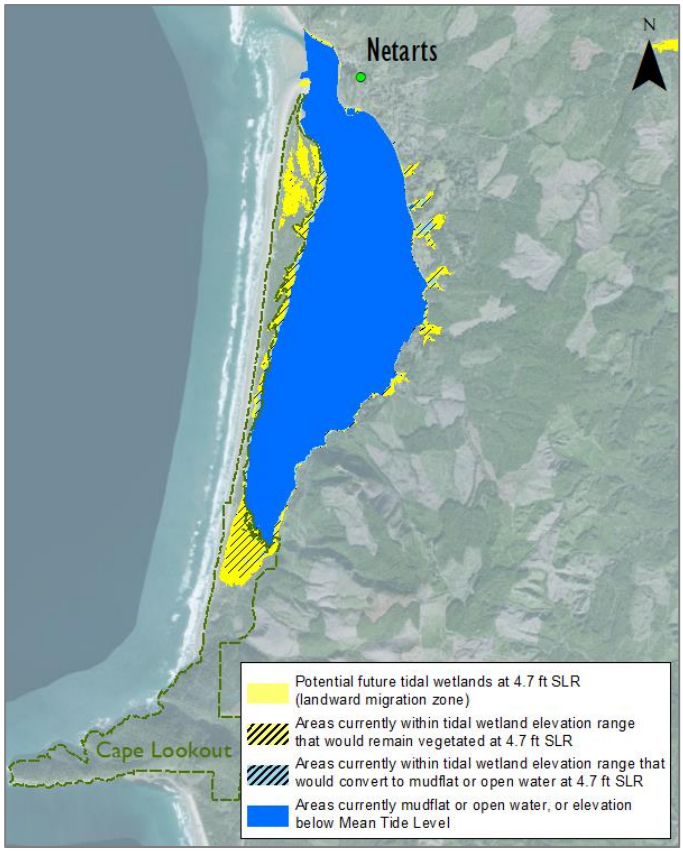

Figure 19. Netarts Bay predicted landward migration zones (based on 4.7-foot sea level rise by year 2100).

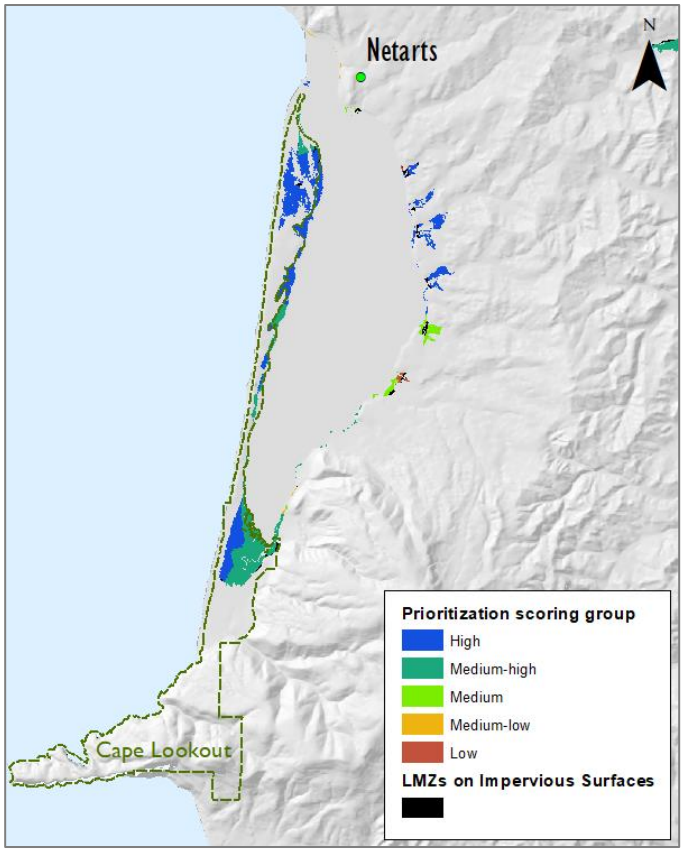

Figure 20. Netarts Bay landward migration zone prioritization factors.

Sand Lake Watershed

The Sand Lake watershed is the smallest in Tillamook County encompassing 25 square miles or just over 1% of the focal area. The geomorphology of the area is that of a bar-built estuary and it is considered a major natural estuary under the Oregon Estuary Classification system. The Sand Lake Estuary is a beautiful, relatively untouched estuarine ecosystem. It is only one of five estuaries on the Oregon Coast designated as a "natural estuary". There is minimal freshwater influence within the estuary from the watershed, as such it is dominated by tidal influence. Much of the land encompassed by the estuary is estuarine marsh which is exposed by tides daily. Because of this, Sand Lake is home to many unique tidal wetland plant species. Thousands of visitors each year enjoy the adjacent Sand Lake Recreation area, the Clay Myers State Natural Area, and one of Oregon State Parks newest acquisition's, the Sitka Sedge State Natural Area on Sand Lake spit.

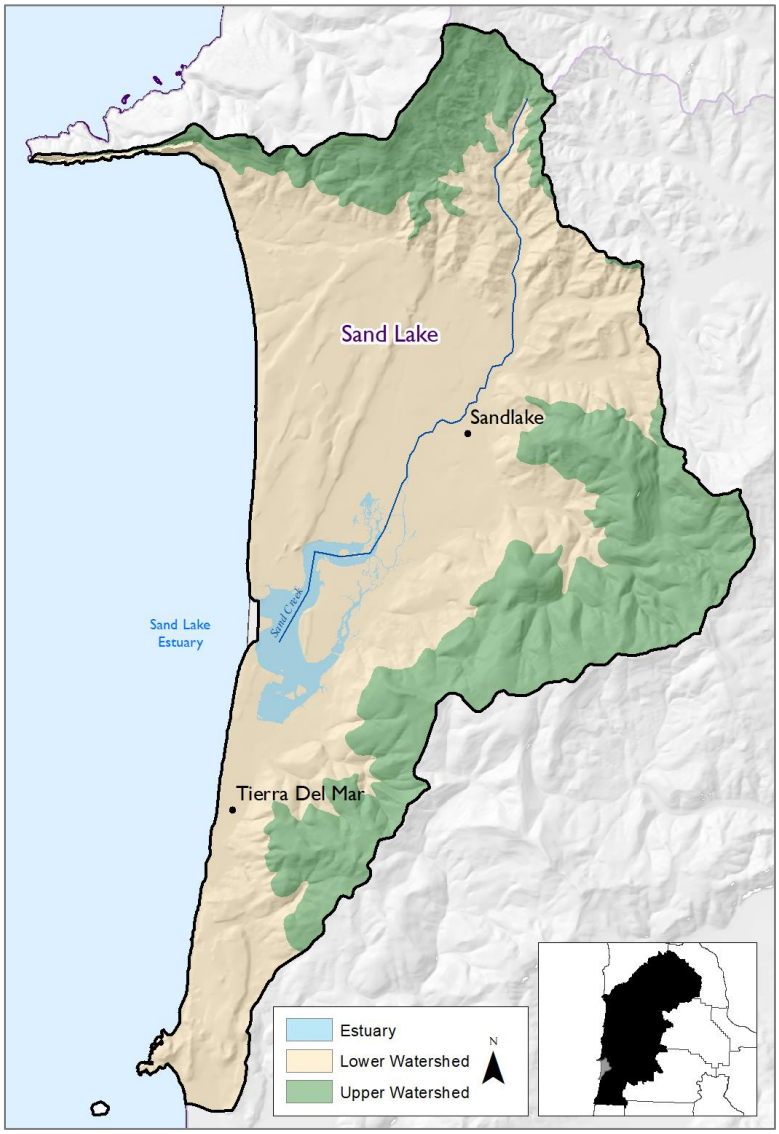

Figure 21. Sand Lake Estuary watershed boundary (5th Field HUC sub-watershed) and the estuary, lower, and upper watershed regions.

Physical Description

The Sand Lake estuary is in south Tillamook County between Pacific City and Cape Lookout. The surface area of Sand Lake is roughly 897 acres making it Tillamook County's second smallest major estuary; the entire watershed totals only 17 square miles. Four small creeks feed into the Sand Lake estuary: Jewell Creek, Sand Creek (most of the freshwater input), Gurtis Creek, and Reneke Creek.

The estuary consists of upper watershed areas to the east, and a small isolated island, Whalen Island, positioned to the south. Whalen Island is composed of a stabilized dune and tidal marsh. The state park located on the island is a popular site for hikers, kayakers, and nature enthusiast alike. To the north, and within the Reneke sub-watershed, Beltz Creek has a dike that retains water and results in a primarily freshwater wetland with some tidal influence through a failing tide gate. The estuarine habitat is largely intact along the western portion of Sand Lake with some agricultural land use activities taking place in the eastern portion of the estuary. The fertile valleys and extensive dunes of the Sand Lake basin offer pristine land for dairy farmers as well as other agriculture and recreation land users. The Sand Lake recreation area located further north from the estuary is a popular attraction within the basin offering year-round campgrounds, day use facilities, and off highway vehicle riding (OHV) through many miles of sand dunes.

Sand lake is one of four bar built or restricted mouth estuaries in Oregon and it consists of intertidal salt marsh, tidal streams, barrier islands, and diked tidal flats.

Figure 22 shows the distribution of estuarine habitats including: saltmarshes, freshwater marshes, tidal mudflats, scrub-shrub wetlands, aquatic and submerged plant communities, low vegetation sandy beaches, upland shrub lands, native dunal grasslands, stabilized and semi-stabilized dunes, forest habitat, and pasture land. In Oregon, 68% of estuarine wetlands have been lost to conversion from 1870 to 1970 - Sand Lake lost 2%, making it the least impacted estuaries in Tillamook County.[28]

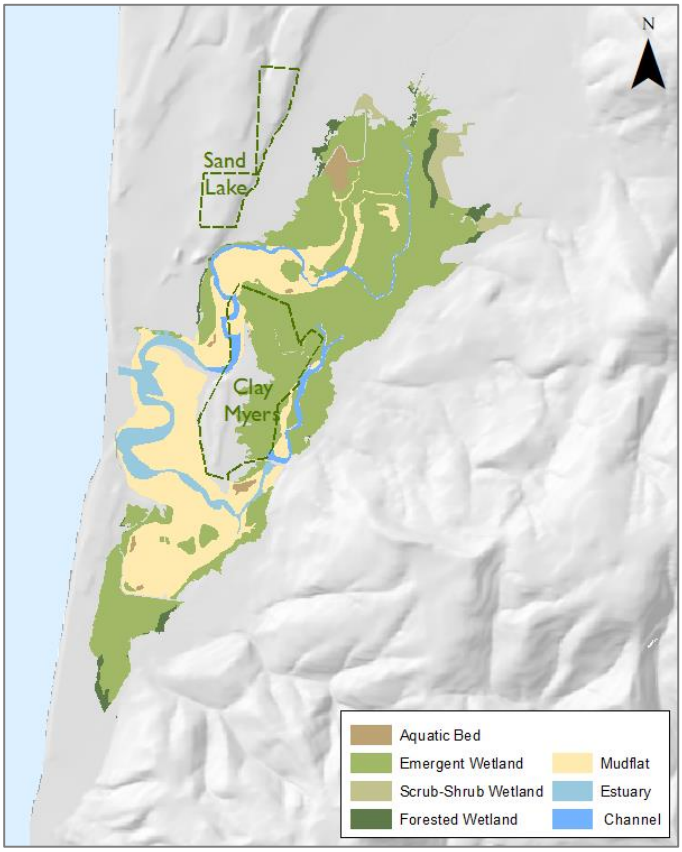

Figure 22. Sand Lake estuarine habitat classifications (CMECS)

Figure 23 shows the distribution of non-estuarine habitat (ecoregions). The watershed is within the Coast Range ecoregion (Level III), specifically the Level IV ecoregions Coastal Lowlands, Coastal Uplands, and Volcanics.

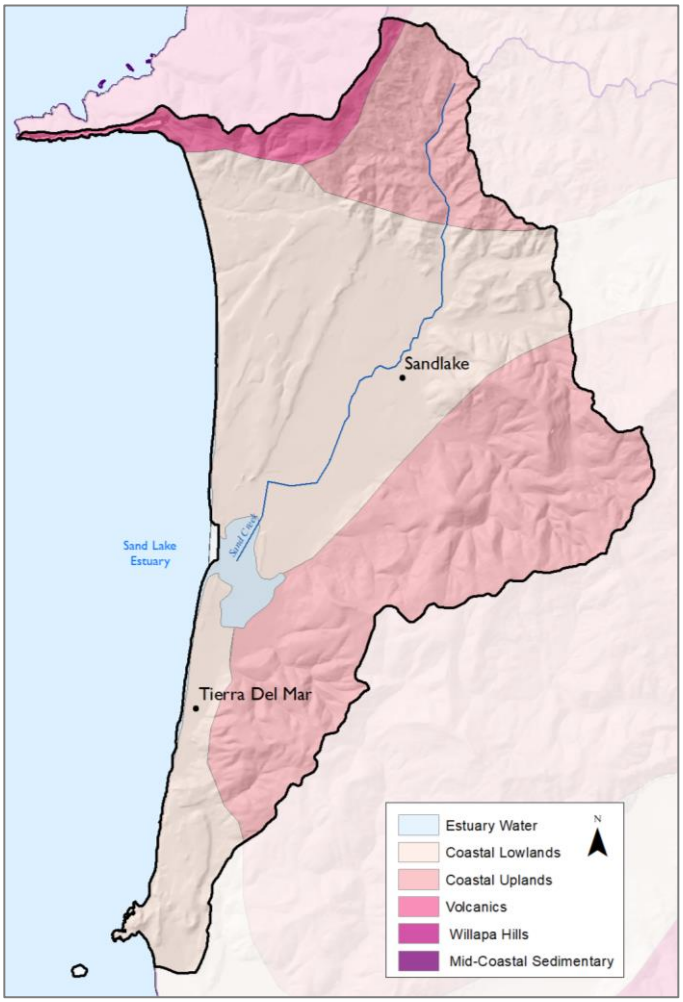

Figure 23. Sand Lake Estuary watershed non-estuarine habitat classifications (Level IV Ecoregions)

Sand Lake is the single remaining estuary of its size on the Oregon Coast that is dominated by such a diverse set of native plant communities due to very little agricultural or commercial development. Tufted Hair Grass and Henderson's Sidalcea are a few examples of common plants found within the high marsh of the estuary. Further up, in the tidally influenced freshwater wetlands, less common plants such as seacoast bulrush and Three-square Bulrush can also be found. The estuary also supports a rare tidally influenced lower watershed

[28] Good, James W. *Summary and Current Status of Oregon's Estuarine Resources".* Oregon State of the Environment Report, Chapter III, Health of Natural Systems and Resources. Change is due to filling and diking between 1870 to 1970. Restoration of wetlands in recent years has begun to reverse the loss trends. https://www.oregon.gov/DSL/WW/Documents/soer_ch33.pdf.

non-linear forested wetland composed of Sitka Spruce and Creek dogwood. According to The North Coast Land Conservancy, the Sand Lake estuary also supports Oregon's largest known remnant stand of old-growth western red cedar swamp.

The native plant association also supports a diverse community of fish and wildlife. Sand Creek offers important rearing habitat for coho, Chinook, and steelhead. Historically chum salmon have also been recorded in the system. The creek connects to three other tributaries (Jewel, Andy, and Davis Creeks). This totals 4.7 miles of spawning reaches. In addition, there are four miles of spawning reaches throughout the rest of the estuary system on adjacent tributaries. The estuary supports a substantial web of other marine organisms such as starry flounder, three spine stickleback, Pacific Herring, Dungeness crab, and many more.

Land Ownership

Much of the land in the watershed is privately or federally-owned and 67% is zoned forest land.[29] The upper watershed is primarily used for recreation and timber production, while the lower watershed is primarily used for agriculture and residential uses. The estuary is used for sport fisheries and recreation activities. Most of the public forest lands are managed through the U.S. Forest Service (42%).[30] Private timber companies also manage large tracts of land throughout the watershed (21%). Timber is the main land use activity throughout the watershed, with agriculture representing a lesser use (10%). About seven percent of the land is zoned for rural development, including land within the community of Sand Lake.

The Sand Lake estuary is composed of a network of privately conserved and publicly owned lands. The North Coast Land Conservancy (NCLC), U.S. Forest Service, and Oregon Parks and Recreation Department all manage land within the estuary and its surrounding area. Oregon State Parks has recently acquired a 357-acre parcel of land on the south end of the estuary once known as Beltz Farm; in partnership with NCLC they have also acquired 167 acres of estuarine habitat that crosses Sand Creek to the North of the estuary. Other parcels of conserved land include hundreds of reclaimed acres of estuarine pasture associated with Clay Myers State Park Natural Area on Whalen Island; and public land managed by the Siuslaw National Forest.

[29] DLCD. *"Oregon Zoning 2017"*. Oregon Spatial Data Library. April 28, 2017.
[30] BLM. "*Oregon Land Management 2015*". Oregon Spatial Data Library. January 8, 2015.

Tidal Wetland Landward Migration Zones

Figure 24 shows the extent of LMZs given a 4.7 ft. rise in sea level by year 2100. Areas central to the estuary and moving northeast are predicted to experience the greatest impacts from LMZs.

Figure 25 shows the prioritization of LMZs. According to the Midcoast Watersheds Council and the Institute for Applied Ecology report areas to consider as priority for the conservation and restoration of tidal wetlands include the areas surrounding Sand Lake that score as high or medium-high priority.

For more information visit the report on Oregon State University Scholars Archive.

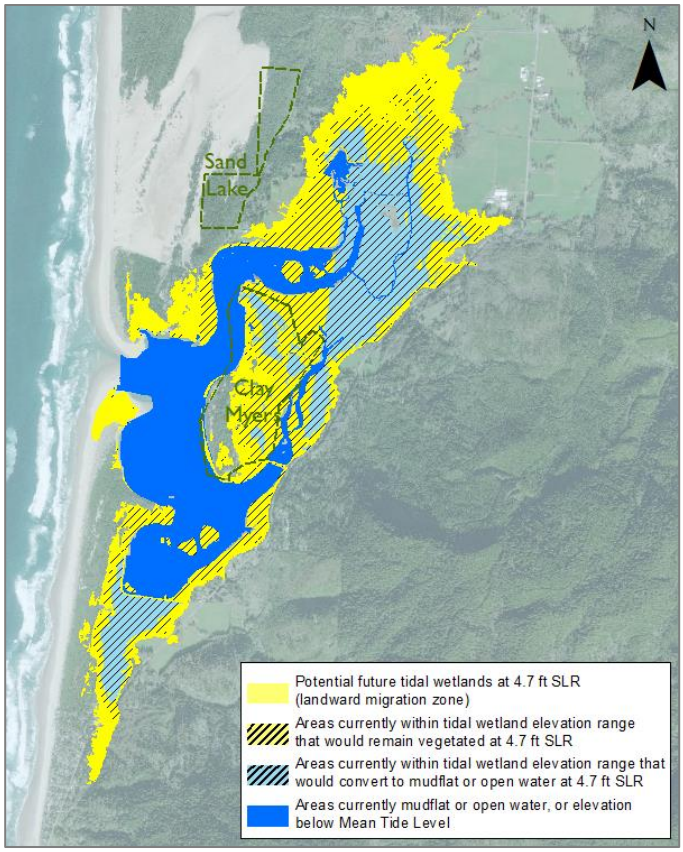

Figure 24. Sand Lake estuary predicted landward migration zones (based on 4.7-foot sea level rise by year 2100).

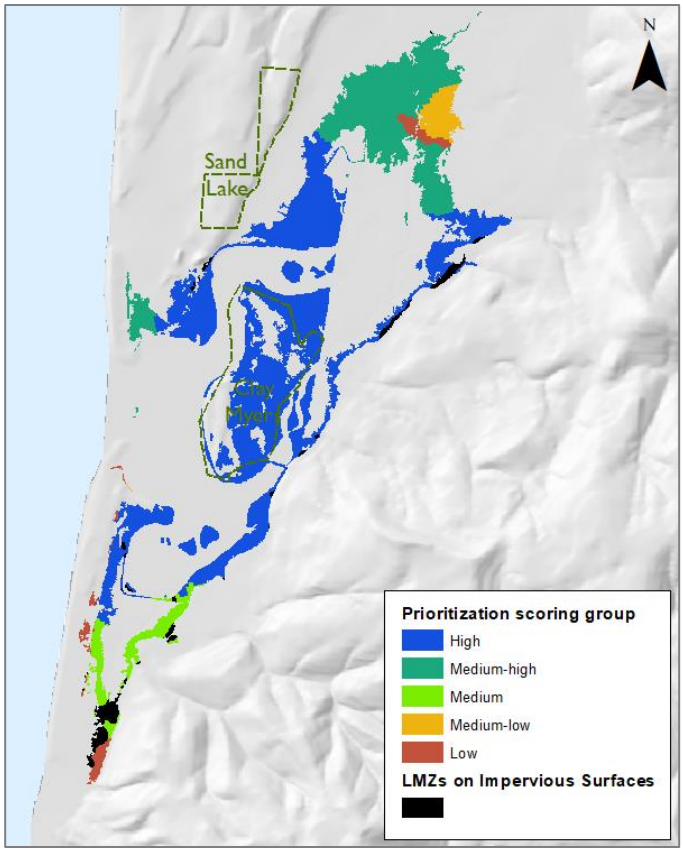

Figure 25. Sand Lake estuary landward migration zone prioritization factors.

Nestucca Bay Watershed

The Nestucca Bay watershed encompasses 319 square miles or 17% of the focal area. The estuary has the geomorphology of a drowned river mouth and is considered a major conservation estuary under the Oregon Estuary Classification system Seasonally, a variably-sized sand bar (spit) forms from the interaction of currents from the ocean and freshwater rivers and separates the bay and the ocean. Part of the bay is contained within the Nestucca Bay National Wildlife Refuge. Like many of the estuaries in Tillamook County, Nestucca Bay is a valuable natural resource supporting an economy dependent on fishing, forestry, tourism, and agriculture. The fishing culture of the Nestucca is highlighted by the century-old beach-launched dory fishery at Cape Kiwanda. Partners in the watershed are working diligently to improve water quality, fish passage, and salmonid habitat in the watershed and bay.

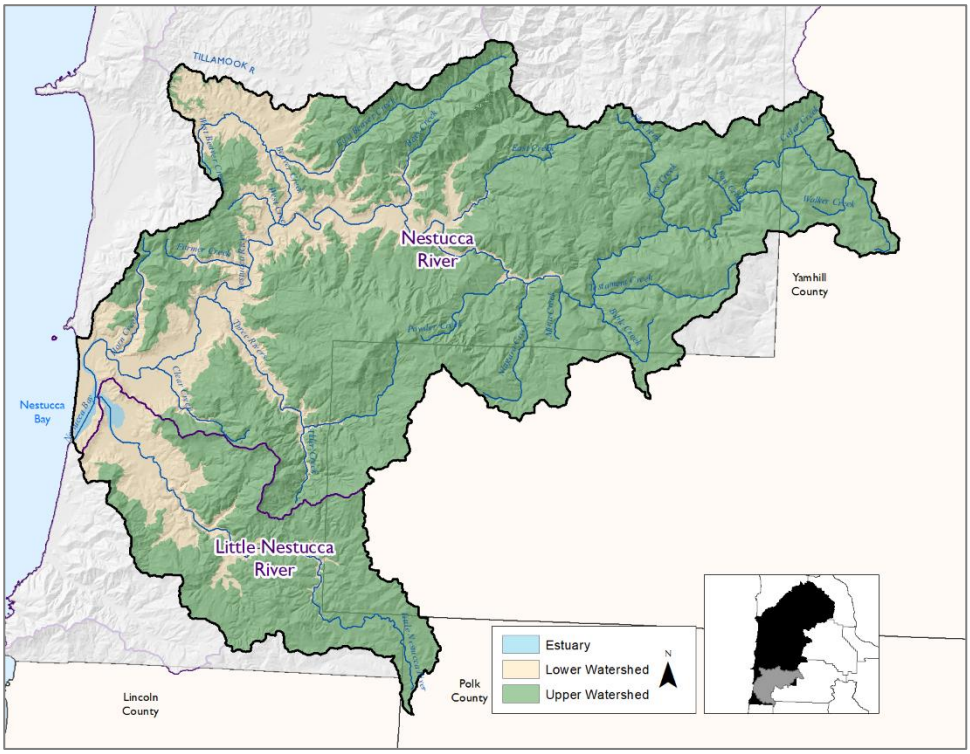

Figure 26. Nestucca Bay watershed boundary showing 5th Field HUC sub-watersheds and the estuary, lower, and upper watershed regions.

Physical Description

Of the 22 major estuaries in the state of Oregon, the Nestucca Bay estuary is one of six estuaries that lacks maintained jetties or channels yet lies adjacent to urban areas which have altered shorelines. The 1,176-acre estuary is located at the confluence of the Pacific Ocean, and the Nestucca, and Little Nestucca rivers in south Tillamook County between Pacific City and Neskowin. The Nestucca River is the larger of the two tributaries and flows 53 miles east-northeast with a watershed that extends over 258 square miles. The smaller Little Nestucca flows approximately 18 miles Southeast of the estuary mouth and has a basin of approximately 64 square miles. The mainstem Nestucca River extends upstream to Pacific City, then through farmland up to the community of Cloverdale. Nestucca Bay spit was formed by ocean currents and constitutes the western boundary of the estuary. The estuary also extends east along the little Nestucca River at the Nestucca Wildlife Refuge, into a broad floodplain dominated almost exclusively by wetland pastures, and tidal marsh. The topography of the area ranges from winding rivers and extensive floodplains to steep hills and mountains.

Figure 27 shows the distribution of non-estuarine habitat (ecoregions). The watershed is within the Coast Range ecoregion (Level III), specifically the Level IV ecoregions Coastal Lowlands, Coastal Uplands, Mid-coastal Sedimentary, and Volcanics.

Figure 28 shows the distribution of estuarine habitats including: intertidal salt marsh, tidal streams, mudflats, tidal flats, and estuarine forestland. In Oregon, 68% of estuarine wetlands have been lost to conversion from 1870 to 1970 – Nestucca Bay lost 91%, making it the most impacted estuary in Tillamook County.[31]

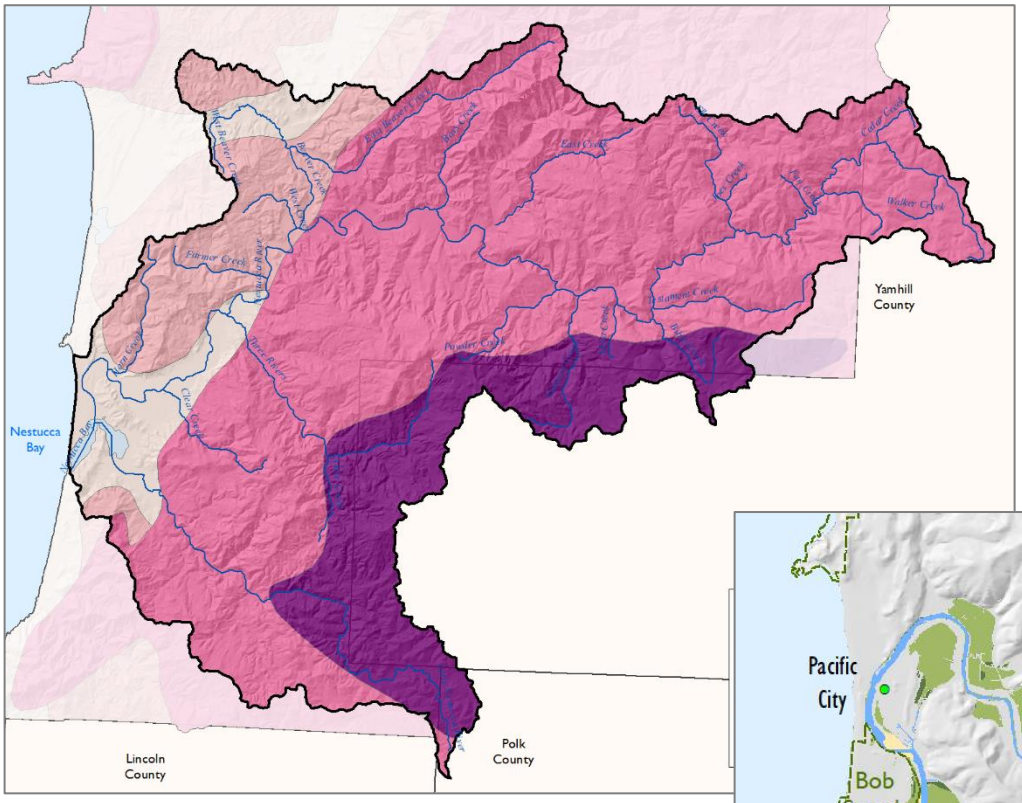

Figure 27. Nestucca Bay watershed non-estuarine habitat classifications (Level IV Ecoregions)

Over 40% of the National Wildlife Refuge is low land pasture that falls behind either dikes or tide gates. Following European settlement, diking and draining estuarine and wetland habitat became the standard practice along the Nestucca and Little Nestucca rivers to create usable land for agricultural activities.

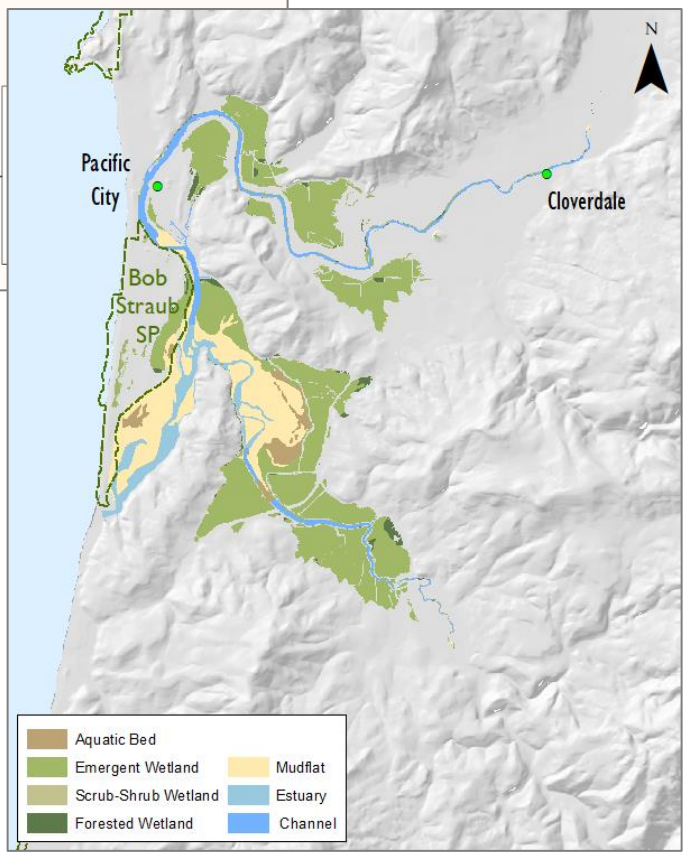

Figure 28. Nestucca Bay watershed estuarine habitat classifications (CMECS)

Additional vegetation surrounding the estuary include freshwater marshes, scrub-shrub wetlands, aquatic and submerged plant communities, low vegetation sandy beaches, upland shrub lands, forested wetlands, grassland, and pasture land. Red alder and big leaf maple dominate along the banks of the watershed while the estuary itself holds several acres of Sitka spruce tidal swamps. Saltmarsh plants are situated at varying levels of salinity throughout the estuary. Plants such as pickleweed and salt grass are important buffers as their densely matted roots stabilize shorelines and absorb pollutants.

Land Ownership

The Nestucca Bay Estuary is composed of a diverse network of public and private land owners due to its

[31] Good, James W. *Summary and Current Status of Oregon's Estuarine Resources".* Oregon State of the Environment Report, Chapter III, Health of Natural Systems and Resources. Change is due to filling and diking between 1870 t0 1970. Restoration of wetlands in recent years has begun to reverse the loss trends. https://www.oregon.gov/DSL/WW/Documents/soer_ch33.pdf.

proximity to Pacific City. Residential and commercial land owners occupy land within the estuary that fall within the city limits of Pacific City. However, most of the critical estuarine habitat is located south of Pacific City where the two rivers converge and falls under the governance of the USFWS Oregon Coast National Wildlife Refuge Complex.

Much of the land in the watershed is privately or federally-owned and 89% is zoned forest land.[32] The upper watershed is primarily used for recreation and timber production, while the lower watershed is primarily used for agriculture and residential uses. The estuary is used for sport fisheries and recreation activities. Most of the public forest lands are managed through the U.S. Forest Service (43%) and the Bureau of Land Management (18%).[33] Private timber companies also manage large tracts of land throughout the watershed (20%). Timber is the main land use activity throughout the watershed, with agriculture representing a lessor use (7%). About two percent of the land is zoned for urban and rural development, including land within the communities of Beaver (pop. 170), Cloverdale (pop. 297), Hebo (pop. 238), and Pacific City (pop. 972).[34]

The Nestucca Refuge was established in 1991 to protect and enhance habitat for Dusky Canada Geese with the acquisition of a 384-acre dairy farm, and over the years has expanded to 893 acres. The Nestucca Bay National Wildlife Refuge Actively engages in pasture management with local dairy farmers to offer prime habitat for geese during the winter. Since its founding, there have been several additions to the National Wildlife Refuge that impact the Nestucca Bay Estuary. In 2007, an 83-acre tidal marsh restoration project was completed on the Little Nestucca River Unit of the refuge. The restoration project established a 30% increase in tidal marsh habitat in the estuary. In 2009, the refuge also acquired the 76-acre Martella Tract, located along the Little Nestucca River where the entire subpopulation of Semidi Islands Aleutian Cackling Geese reside during the winter. There is an additional 2,500+ acres still in private ownership that falls within the approved refuge boundary.

Nestucca | Don Best

[32] DLCD. *"Oregon Zoning 2017"*. Oregon Spatial Data Library. April 28, 2017.
[33] BLM. "*Oregon Land Management 2015*". Oregon Spatial Data Library. January 8, 2015.
[34] U.S. Census Bureau, American Community Survey, 5-year estimate, 2012-2016.

Tidal Wetland Landward Migration Zones

Figure 29 shows the extent of LMZs given a 4.7 ft. rise in sea level by year 2100. Areas within Bob Straub State Park, Pacific City, and along the Nestucca Bay and River are predicted to experience the greatest impacts from LMZs.

Figure 30 shows the prioritization of LMZs. According to the Midcoast Watersheds Council and the Institute for Applied Ecology report areas to consider as priority for the conservation and restoration of tidal wetlands include the areas west and north of the bay that score as high or medium-high priority.

For more information visit the report on Oregon State University Scholars Archive.

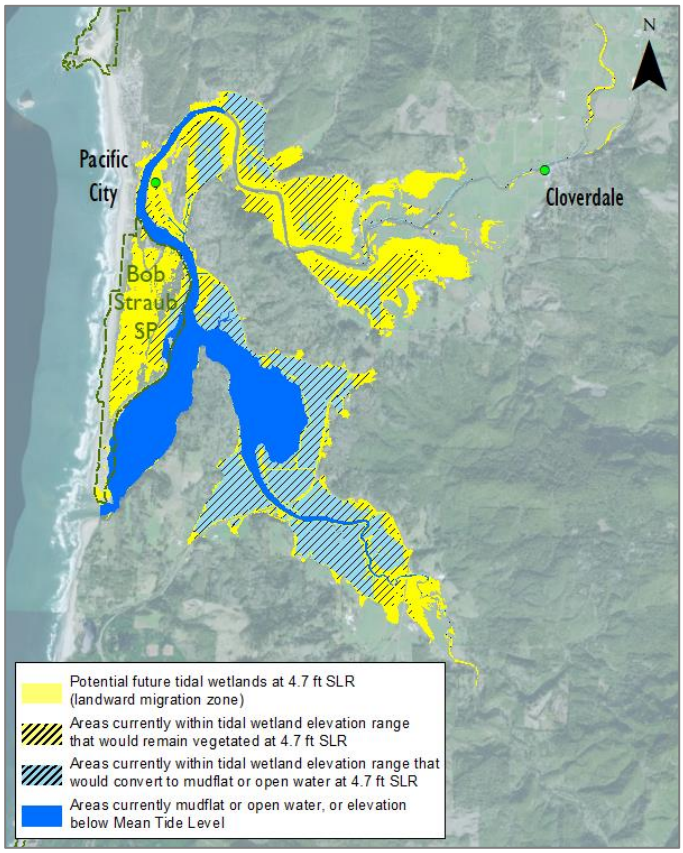

Figure 29. Nestucca Bay predicted landward migration zones (based on 4.7-foot sea level rise by year 2100).

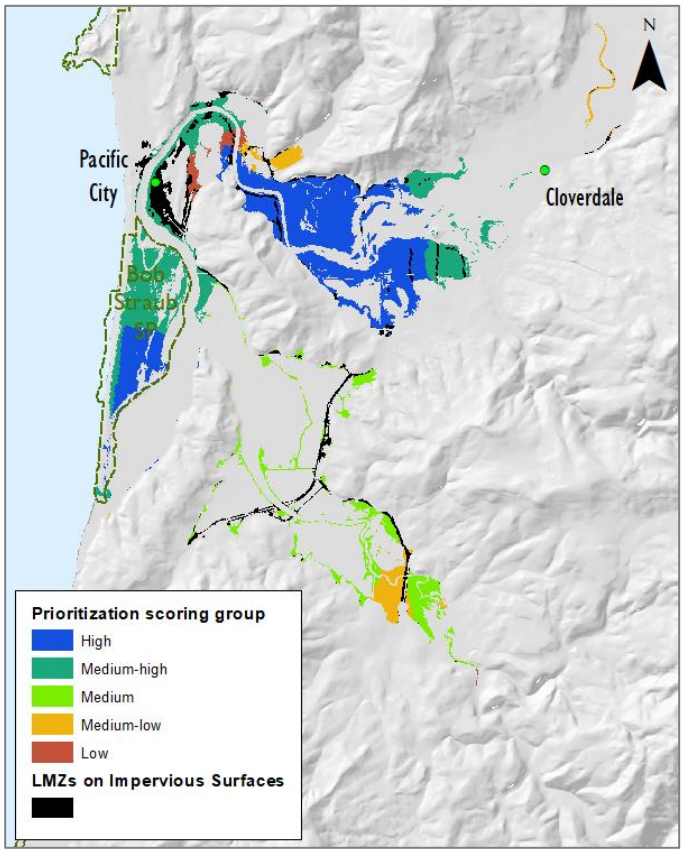

Figure 30. Nestucca Bay landward migration zone prioritization factors.

Neskowin Creek Watershed

The Neskowin Creek watershed encompasses 26 square miles or just over 1% of the focal area. Neskowin Creek estuary is Tillamook County's smallest estuary. Located at the confluence of Neskowin and Hawk Creeks in the heart of Neskowin, the 30-acre estuary offers a brief transition between fresh and saltwater ecosystems. Twice a day saltwater encroaches up the creeks on incoming tides providing saltmarsh, mudflat, and estuarine forest habitats. The estuary is fed by the Kiwanda and Neskowin Creeks which occupy a watershed basin of approximately 12 square miles. The creeks and their accompanying tributaries wind through national forest land, commercial logging property, and various other private entities.

The Neskowin Creek estuary is classified as a minor conservation estuary under the Oregon Estuary Classification system. The mouth of the estuary has no maintained jetties or channels and provides no passage for boats. Most of the estuary lies adjacent to urban areas with developed shorelines. The estuary is also influenced by a tide gate on Butte Creek, approximately two (2) miles above the junction with Hawk Creek.

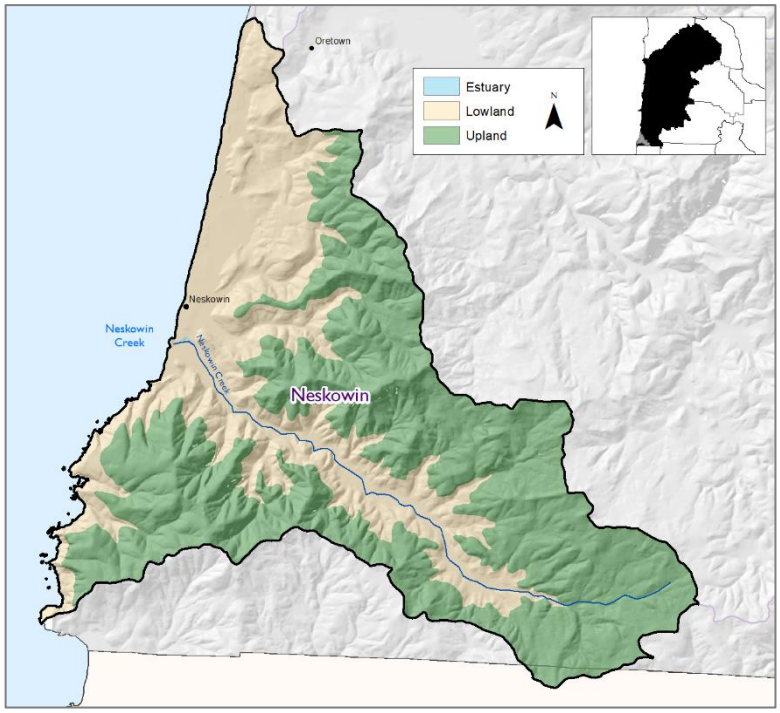

Figure 31. Neskowin Creek watershed boundary (5th Field HUC sub-watershed) and the estuary, lower, and upper watershed regions.

Physical Description

The estuary is composed of a network of public and private land owners due to its location within the Neskowin community. Many private homes, hotels, and businesses are positioned along the estuary banks where the two creeks converge. Further west towards the ocean, the estuary habitat transitions into a sandy beach. This transition lies on public land within the jurisdiction of Oregon Parks and Recreation Department (OPRD) in accordance with the Beach Bill enacted in 1967. To the east, the estuary extends further up the Neskowin Creek and provides important saltmarsh and estuarine forest habitat along its banks. Private land owners are situated adjacent to the creeks north side while highway 101 runs parallel to the creeks south bank.

Further up the Kiwanda Creek, beyond the northern reach of the estuary, the USFWS manages the Neskowin Marsh National Wildlife Refuge. The refuge protects a unique coastal sphagnum bog that houses over 100

native wetland plant species in 23 vegetation associations.[35] Rare species present at Neskowin Marsh include russet cottongrass, native cranberry, and pohlia moss, all of which occur only in sphagnum mires.[36]

Much of the Neskowin watershed is dominated by Sitka spruce and western hemlock. Further inland, Douglas fir and Noble fir communities are firmly established.

Figure 32 shows the distribution of non-estuarine habitat (ecoregions). The watershed is within the Coast Range ecoregion (Level III), specifically the Level IV ecoregions Coastal Lowlands, Coastal Uplands, and Volcanics. Much of the watershed consist of volcanic rocks and marine sediments. The south-central area of the watershed is represented by the Siletz River Volcanics which is composed of claystone, siltstone, and sandstone.[37]

Land Ownership

Much of the land in the watershed is privately or federally-owned and 77% is zoned forest land.[38] The upper watershed is primarily used for recreation and timber production, while the lower watershed is primarily used for agriculture and residential uses. Neskowin Creek estuary is primarily used for recreation activities. Most of the public forest lands are managed through the U.S. Forest Service (52%).[39] Private timber companies also manage large tracts of land throughout the watershed (25%). Timber is the main land use activity throughout the watershed, with agriculture representing a lesser use (2%). About 12% of the land is zoned for urban and rural development, including land within the community of Neskowin (pop. 177).[40]

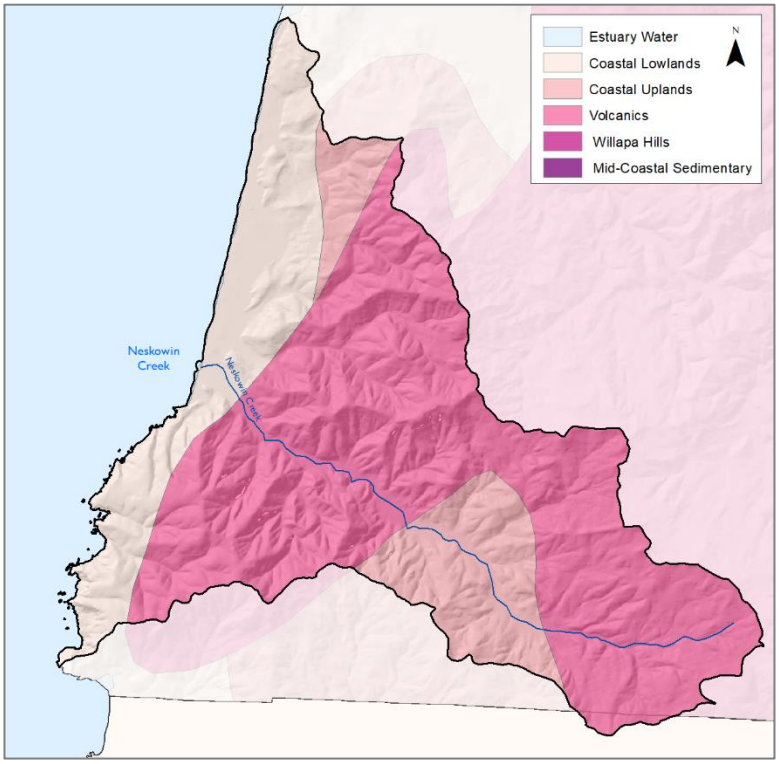

Figure 32. Neskowin Creek watershed non-estuarine habitat classifications (Level IV Ecoregions)

Tidal Wetland Landward Migration Zones

The Mid-Coast Watersheds Council study did not include Neskowin within their study, so there is currently no LMZ data available for the Neskowin Creek estuary.

[35] Christy, J.C. and L.S. Brophy. 2002. Vegetation of Neskowin Marsh Unit, Nestucca Bay National Wildlife Refuge, Tillamook County, Oregon. Prepared for the U.S. Fish and Wildlife Service, Oregon Coast National Wildlife Refuge Complex. 30 pp
[36] Ibid.
[37] "USDA." Salmon-Neskowin Watershed Analysis 1999.
[38] DLCD. *"Oregon Zoning 2017"*. Oregon Spatial Data Library. April 28, 2017.
[39] BLM. "*Oregon Land Management 2015*". Oregon Spatial Data Library. January 8, 2015.
[40] U.S. Census Bureau, American Community Survey, 5-year estimate, 2012-2016.

Natural Hazard and Climate Impacts

This section summarizes potential chronic and catastrophic natural hazard risks and impacts in the focal area. The focal area ecosystems have evolved over time in response to such changes. Therefore, it is important to understand the range of potential impacts as well as the capacity for the focal area ecosystems to deal with those impacts.

The estuaries and lower and upper watersheds that compose TEP's focal area exist within a dynamic and changing landscape. Subject to a range of geologic and climatic forces, the area is constantly subject to both slow and abrupt environmental changes. Flooding, erosion, and storms, among other events, regularly shift the subtle dynamics between the focal area's ecological systems. On rare occasions, large wildfires and massive earthquake and tsunami events result in rapid reorganization of the entire area.

Additional information on natural hazard risks posed to Tillamook County is available within the Oregon Department of Geology and Mineral Industries (DOGAMI) Interpretive Map Series-58 (IMS-58).

Chronic Threats, Impact, and Vulnerability Assessment

The Tillamook County Multi-Jurisdictional Natural Hazards Mitigation Plan (NHMP) provides extensive descriptions and data related to chronic hazards in Tillamook County (Section II: Risk Assessment, Subsection C: Natural Hazards is incorporated herein by reference).[41] The following information presents a summary for relevant hazards. For additional hazard specific information, refer to the Tillamook County NHMP.

Flood

Annual flood events shape the estuary and lower, and upper watershed ecosystems in Tillamook County. Winter storms and prolonged rainfall generate significant amounts of riverine runoff. In addition, coastal flooding from high tides and wind-driven waves occurs on a regular basis. Individually or in combination, these events inundate lowland areas, erode and migrate upper watershed riverine channels, and move significant amounts of sediment throughout the TEP focal area.

There have been 12 "significant" flood events in Tillamook County in the past 30-years. In addition, numerous localized flooding events occur on an annual basis. Importantly, flooding is part of the natural cycle that contributes to the overall health of TEP ecosystems. However, the interplay between human and natural systems changes those natural dynamics. Increased human development within Tillamook County can negatively affect water quality. This occurs through

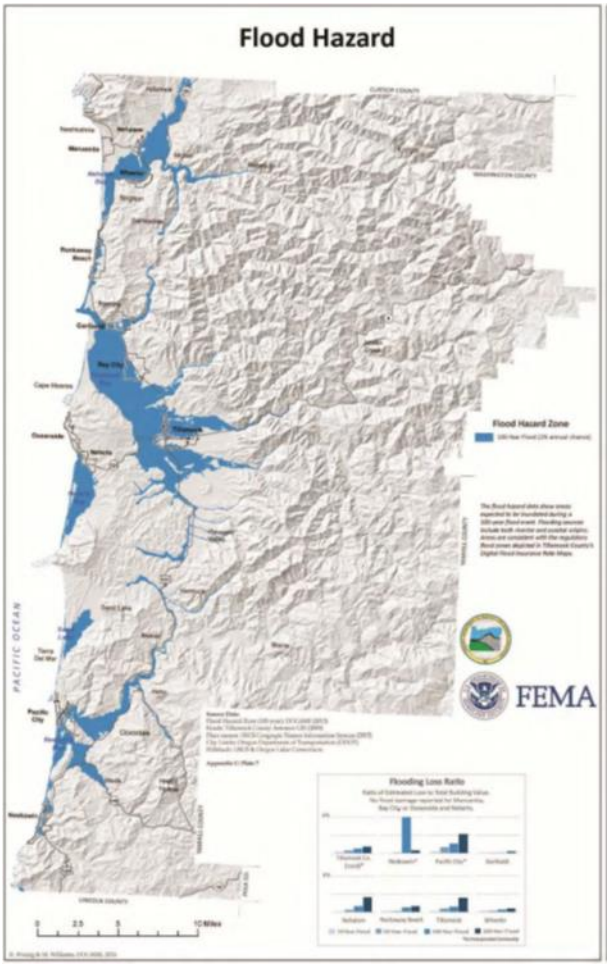

Figure 33. *Flood Hazard in Tillamook County (Tillamook NHMP, DOGAMI, 2016)*

[41] Tillamook County. (2017) Tillamook County Multi-Jurisdictional Natural Hazard Mitigation Plan.

increased sedimentation and the introduction of industrial, agricultural, and human derived pollutants into natural systems.[42] Additionally, higher seasonal flood waters could heighten terrestrially-derived bacteria and nitrogen inputs, which, combined with expected decrease of spring/summer flushing, may create conditions for the development of hypoxic (low dissolved oxygen) zones in estuarine waterways.[43]

Landslide

Characteristics of landslides include a range of slowly- to rapidly-moving rock falls, debris flows, and earth slides. Landslides occur throughout the Coast Range, primarily in areas of steep slopes. While landslides primarily impact upper watershed portions of TEP's focal area, it is important to note that they often occur in conjunction with significant winter storm or rainfall events. Notably, Tillamook County has "one of the highest landslide counts of all the Oregon Counties."[44]

In the past 30-years, there have been eight federally declared disaster declarations in Tillamook County that include landslides or mudslides. Each of these declarations correspond with significant rain events and include lowland/estuarine flooding. Minor landslides occur on an annual basis. The Tillamook NHMP notes that the Port of Tillamook Bay is vulnerable to landslides originating on Anderson Hill.

Landslides contribute to the degradation of the estuary waters through increasing turbidity levels and may also increase remobilization of heavy metals and contaminants from sediments to the water column.[45] Landslide conditions may increase where vegetation and slope stability is impacted by wildfires, logging, and other land clearing activities.

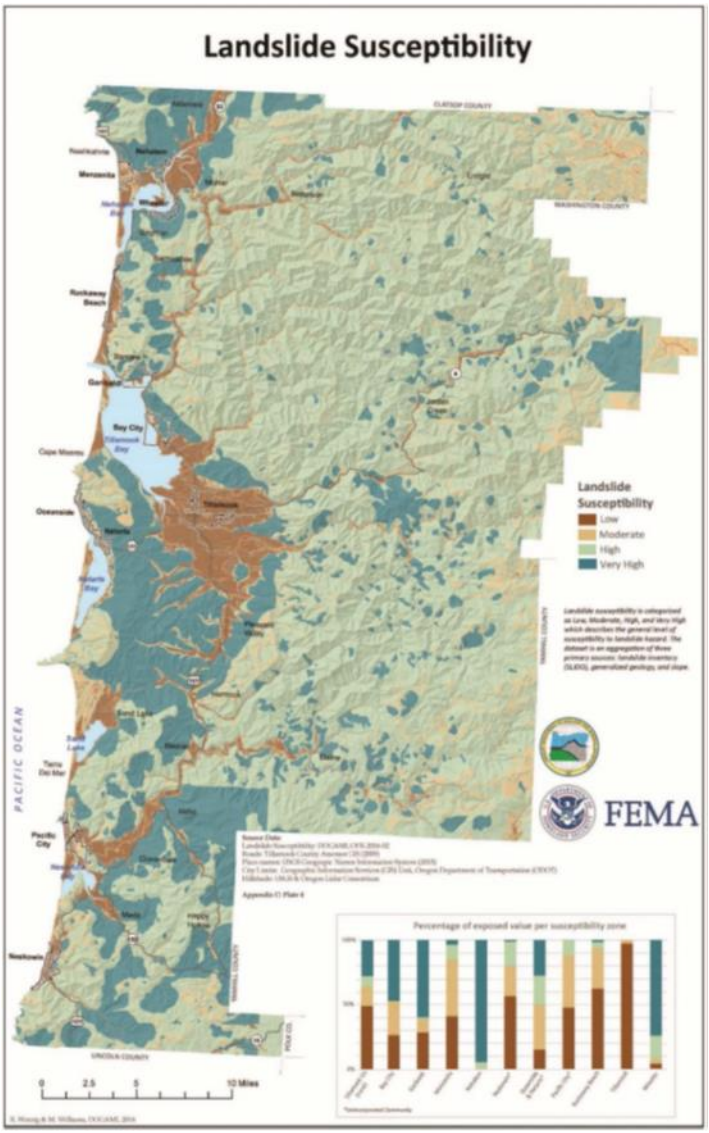

Figure 34. Landslide Susceptibility in Tillamook County (Tillamook NHMP, DOGAMI, 2016)

Drought

The drought hazard occurs primarily during periods of diminished water availability. This can result from reduced snow pack or diminished precipitation. Impacts to TEP systems include reduced stream flows, soil moisture deficits, diminished surface and subsurface water

[42] Koopman, M. E., Geos Institute. (2018) Tillamook Estuaries Partnership Climate Change Vulnerability Assessment.
[43] Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, et al. 2002. Climate Change Impacts on U.S. Coastal and Marine Ecosystems. Estuaries. 25 (2): 149-164.
[44] Tillamook County. (2017) Tillamook County Multi-Jurisdictional Natural Hazard Mitigation Plan.
[45] Whitehead, P. G., R. L. Wilby, R. W. Battarbee, M. Kernan, and A. J. Wade. 2009. A review of the Potential Impacts of Climate Change on Surface Water Quality". Hydrological Sciences Journal. 54 (1): 101-123.

availability, and an increase in upper watershed forest vulnerabilities ranging from pest infestations to wildfire.

While droughts are not as common along Oregon's coast, they do occur. Significant statewide droughts have affected Tillamook County several times in the past century. Droughts may lead to lower summer flows which, in turn, could lead to decreased oxygen levels and increased temperatures, particularly in the upper estuary reaches. Decreased summer flows, along with increased winter flows, may also affect the estuarine salinity regime and may also heighten terrestrially-derived bacteria and nitrogen inputs, which may create hypoxic zones (low dissolved oxygen) in estuaries.[46] Additionally, dry season salinity can be expected to increase over time, which will change estuarine plant and animal communities, and possibly create openings for the establishment of new or spread of existing invasive species.[47]

Wildfire

Wildfires include any uncontrolled outdoor fire. Like the other hazards discussed in this section, wildfire is a natural part of the local ecology. Even so, wildfires can result in significant impacts to forest, water, and habitat resources. Additionally, wildfires pose a significant risk to life-safety and property. Over the past decade, communities throughout the west are reporting an increased incidence of extreme wildfire behavior.

Figure 35. Tillamook Burn (1933), (Dave Knows)

Tillamook County has a history of wildfire, including several fires larger than 100,000 acres. The "Tillamook Burn" area consists of roughly 350,000 acres burned by multiple large wildfires over two-decades between 1933 and 1951. The largest of these events, fueled by high temperatures and strong east winds grew by approximately 200,000 acres in a 24-hour period. Importantly, the fire boundary includes most of the upper watershed within TEP's focal area. A modern stand replacement fire in this area could significantly alter the ecology of systems throughout Tillamook County.

Wildfires pose a significant risk to infrastructure, natural resources, and the quality of the environment. Potential climate changes may lead to more invasive weeds (e.g., gorse, scotch broom) that are highly flammable. Increased incidence of wildfires may also increase landslide risk in areas where soil conditions are destabilized. As such, water flows will also increase during winter storm events and summer flows may decrease further where water cannot be stored in previously vegetated areas, thereby exacerbating drought conditions.

[46] Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, et al. 2002. Climate Change Impacts on U.S. Coastal and Marine Ecosystems. Estuaries. 25 (2): 149-164.

[47] Oregon Climate Change Research Institute (OCCRI). 2010. "Chapter 6. Impacts of Climate Change on Oregon's Coasts and Estuaries", in Oregon Climate Assessment Report. K.D. Dello and P.W. Mote (eds). College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR.

Catastrophic Threats, Impact, and Vulnerability Assessment

The Tillamook County Natural Hazard Mitigation Plan (NHMP) provides extensive descriptions and data related to catastrophic hazards in Tillamook County. The following information presents a summary for relevant hazards. For additional hazard specific information, refer to the Tillamook County NHMP.

Earthquake

Earthquakes involve movement in the earth's crust. In Tillamook, the primary risk is from a megathrust earthquake along the Cascadia subduction zone. Megathrust earthquakes are extremely powerful with magnitudes ranging from 8.0 to 9.0+ on the Richter scale. Characterized by 4-5 minutes of ground shaking, subduction zone earthquakes can result in coastal subsidence, landslides, soil liquefaction, and deformation of land surfaces. Of principle concern to TEP's focal area is the likelihood of coastal subsidence and related impacts to tide flat, low and high marsh, and forest edge ecosystems.[48] [49]

Megathrust earthquakes occur infrequently along the Oregon coast. The last recorded earthquake was in January of 1700. With a recurrence interval ranging between 240 years (magnitude 8.0-8.5) and 530 years (magnitude 9.0+), the probability of any subduction zone earthquake occurring in the next 50-years ranges from a low of 7% to a high of 43% depending on earthquake size and extent.

Tsunami

Tsunami hazard includes both locally generated and distant events. Tsunamis can result in significant lowland coastal flooding, scouring, sedimentation, sand relocation, saltwater intrusion, vegetation impacts, and habitat contamination from debris. A 2013 USGS study of tsunami impacts on marine ecosystems in California found that, "All low-lying coastal habitats, such as beaches and marshes, will be inundated. Strong currents, massive water flows, and tsunami debris are likely to cause severe ecological harm in many places."[50]

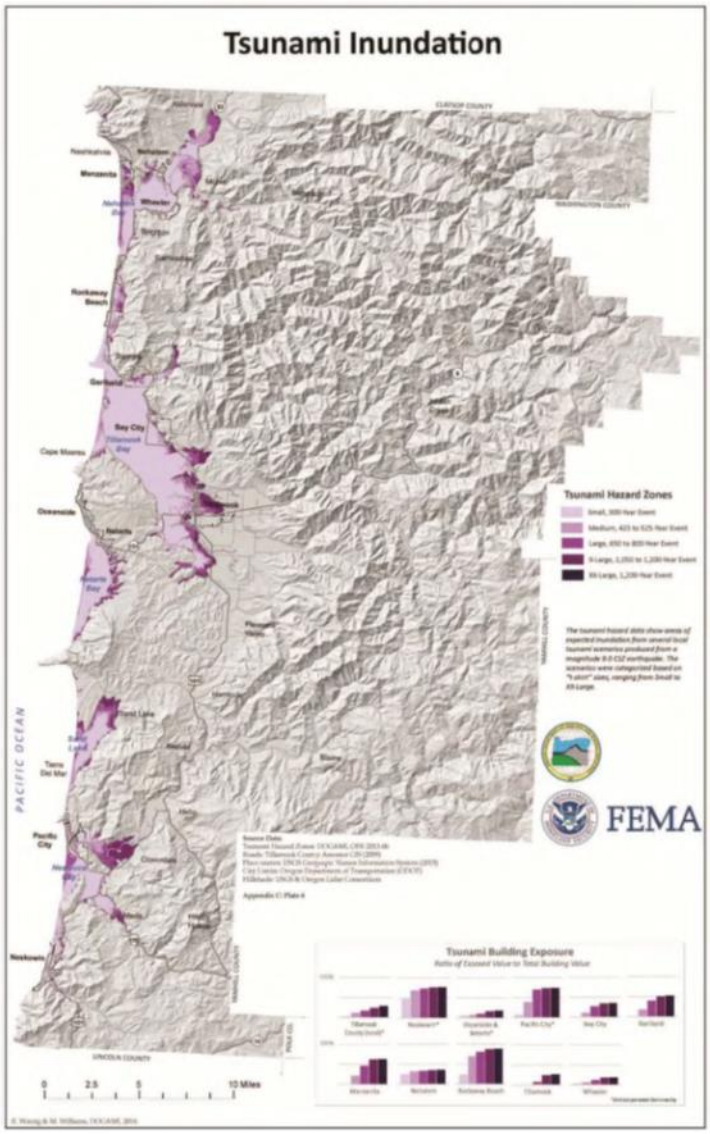

Figure 36. Tsunami Hazard in Tillamook County (Tillamook NHMP, DOGAMI, 2016)

[48] Department of Geology and Mineral Industries. (1997). Open-File Report O-97-05, Estimates of Coastal Subsidence from Great Earthquakes in the Cascadia Subduction Zone, Vancouver Island, B.C., Washington, Oregon, and Northernmost California. (http://oregongeology.org/pubs/ofr/O-97-05.pdf)

[49] Hawkes, A.D., et. al. (2011). Coastal Subsidence in Oregon, USA, During the Giant Cascadia Earthquake of AD 1700. Quaternary Science Reviews. (http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.908.7810&rep=rep1&type=pdf)

[50] United States Geological Survey. (2013) SAFER Tsunami Scenario – Impacts on California Ecosystems, Species, Marine Natural Resources, and Fisheries. (https://pubs.usgs.gov/of/2013/1170/g/pdf/ofr2013-1170g.pdf)

In the case of Oregon, a locally generated tsunami will likely result in impacts to marine and estuarine resources that far exceed those modeled in the California study.

Several distant tsunamis have affected the Oregon coast over the past century. However, impacts in Tillamook County were minimal. The probability of a locally generated tsunami event corresponds with the probability of Cascadia subduction zone earthquake (described above).

El Niño Southern Oscillation

El Niño Southern Oscillation (ENSO) weather patterns can increase the frequency and severity of drought. During El Niño periods, alterations in atmospheric pressure in equatorial regions yield an increase in the surface temperature off the west coast of North America. This gradual warming sets off a chain reaction affecting major air and water currents throughout the Pacific Ocean. In the North Pacific, the Jet Stream is pushed north, carrying moisture laden air up and away from its normal landfall along the Pacific Northwest coast. In Oregon, this shift results in reduced precipitation and warmer temperatures, normally experienced several months after the initial onset of the El Niño. These periods tend to last nine to twelve months, after which surface temperatures begin to trend back towards the long-term average. El Niño periods tend to develop between March and June, and peak from December to April. ENSO generally follows a two to seven-year cycle, with El Niño or La Niña periods occurring every three to five years. However, the cycle is highly irregular, and no set pattern exists. According to the National Weather Service, Climate Prediction Center, 21 El Niño episodes have occurred since 1950, with the two most recent strong El Niño episodes occurring in 1997-98 and 2015-16.[51]

Climate Change Vulnerability Assessment and Preparedness Strategy

In 2018, the GEOS Institute completed the *Tillamook Estuaries and Watersheds Climate Change Vulnerability Assessment* and *Climate Change Preparedness Strategy for Tillamook Estuaries Partnership* covering Tillamook County.

The assessment found that ecosystems within TEP's focal area will experience overall warming of between four- and seven-degrees Fahrenheit over the next 50-years. This will result generally in warmer (wetter) winters and drier summers. Accompanying this temperature increase will be increased climate extremes overall, including higher incidents of extreme heat, precipitation, flooding, and drought.

The reports uncovered that vital resources and habitats within Tillamook County estuaries are impacted by stressors (e.g., pollution, sedimentation, land conversion) that will be exacerbated by climate change impacts (climate stressors).

Considering the predicted climate stressors, TEP, Stakeholders, and other local experts identified and assessed 74 risks to TEP's 1999 CCMP goals. The risks were predominately associated with water quality and key habitat goals, "specifically those to assess, protect, and enhance specific types of habitat (riparian, in-stream, wetland, and estuary and tidal), as well as promoting the beneficial uses of bays and rivers".[52] Risks are ranked as High, Medium, or Low. The risk matrix was used during the development of adaptation strategies and actions.

[51] National Weather Service, "Climate Prediction Center", http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

[52] Koopman, M.E. 2018. Tillamook Estuaries and Watersheds Climate Change Vulnerability Assessment. GEOS Institute and Tillamook Estuaries Partnership.

Adaptation Strategies and Actions

Following the EPA's *Being Prepared for Climate Change* framework[53], risks to TEP's goals were addressed using four different approaches. These included:

1. **Mitigate** - developing adaptation strategies to reduce the risk
2. **Transfer** - identifying another group or agency responsible for adaptation
3. **Avoid** - changing the original goal to avoid the risk or failure to meet the goal
4. **Accept** - continue as usual, allowing the climate impacts to occur

Local experts and stakeholders identified 23 general strategies and 78 specific actions (35 *high priority* actions) to address the vulnerabilities (Table 5). For each adaptation action, the following variables were addressed:

- **Co-benefits** – Any additional benefits that the action provides, beyond those directly related to the risk being addressed
- **Potential barriers or conflicts** – Major issues that would need to be resolved or that could prevent the action from being successfully implemented or supported
- **Partners** – The local, state, and federal agencies or organizations that could assist in implementing the action
- **Effectiveness** – How effective the action is expected to be in reducing the specific climate risk (ranked as Low, Medium, or High)
- **TEP influence** – The ability of TEP to implement the action and affect the target resource or population (ranked as Low, Medium, or High)
- **Relative cost** – Compared to other actions that TEP implements, the overall cost of the specific actions being considered (ranked as Low, Medium, or High)

These variables allowed potential adaptation strategies and actions to be compared and prioritized. Priority actions were grouped into the 23 adaptation strategies. Table 5 shows how the Strategies and Actions identified within the *Climate Change Preparedness Strategy for Tillamook Estuaries Partnership* relate to the actions identified in this CCMP. As shown in the table, many of the CCMP actions directly address climate change.

[53] EPA. 2014. Being prepared for climate change: A workbook for developing risk-based adaptation plans. https://www.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf

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Table 5. Climate Change Preparedness Strategies and Actions linked to associated CCMP actions. (Climate Change Preparedness Strategy, Geos Inst., 2018)

Priority	Potential Actions	WAQ-01	WAQ-02	WAQ-03	WAQ-04	WAQ-05	HAB-01	HAB-02	HAB-03	HAB-04	HAB-05	HAB-06	HAB-07	HAB-08	HAB-09	HAB-10	HAB-11	HAB-12	HAB-13	HAB-14	HAB-15	CEE-01	CEE-02	CEE-03	CEE-04	CEE-05
1	Strategy: Limit nutrient inputs																									
High	Point source identification	X																								
High	Storm water management		X							X		X	X	X					X							
High	Bacterial DNA identification to identify source																									
High	Domestic sewage - septic system improvements or upgrades		X																							
High	Farm water quality plans	X																								
High	Water quality monitoring and assessment (for quicker response)	X																								
Medium	Municipal sewage – wastewater treatment plant upgrades		X																							
Low	County level ordinance or rulemaking																				X					
2	Strategy: Agricultural management																									
High	Animal exclusion fencing			X						X		X	X	X					X		X					
High	Off channel watering									X		X	X	X					X		X					
High	Education and outreach on manure management	X																								
High	Manure management	X																	X		X					
Medium	Promote (construct) livestock crossings at bridge/hardened fords																		X		X					
Medium	Improve drainage function of lower tidal wetlands through restoration, thereby improving productivity of upland agricultural areas						X					X							X		X					
Medium	Rainwater collection off barn/ storage roofs for watering		X																X		X					
3	Strategy: Improvements to infrastructure																									
High	Improvements to septic systems		X																							
High	Identify culverts and roads most at risk of failure from high flows (esp. those culverts with insufficient capacity)		X		X		X	X	X	X	X								X							
High	Replace or remove culverts and roads most at risk				X							X	X	X	X				X							

Priority	Potential Actions	WAQ-01	WAQ-02	WAQ-03	WAQ-04	WAQ-05	HAB-01	HAB-02	HAB-03	HAB-04	HAB-05	HAB-06	HAB-07	HAB-08	HAB-09	HAB-10	HAB-11	HAB-12	HAB-13	HAB-14	HAB-15	CEE-01	CEE-02	CEE-03	CEE-04	CEE-05
Medium	Improvements to stormwater infrastructure (including stormwater retention)		X		X							X	X	X	X				X							
Medium	Move/improve (lagoon -> cistern) wastewater treatment lagoons (a few in Nehalem, Bay City, Cloverdale) to reduce risk from overflowing		X																							
Medium	Reduce miles of unmaintained forest roads by fully decom-missioning (remove culverts, pull back unstable slopes, reduce landslide risk)				X						X	X	X	X	X											
4	Strategy: Identify and prioritize areas for restoration																									
High	Identify sites where gravel deposits and downed wood might enhance fish habitat								X	X	X				X						X					
High	Identify areas and prioritize by estuarine and freshwater type. Freshwater wetlands expected to be more vulnerable under drought scenarios.						X	X							X						X					
5	Strategy: Protect existing habitat																									
High	Protect existing healthy riparian vegetation, which provides shade			X								X	X	X											X	
6	Strategy: Improve land management practices in high risk areas																									
Medium	Change policy on ground cover retention on steep slopes to increase cover and re-plant																			X						
7	Strategy: Restore wetlands and floodplains																									
High	Restore floodplain connectivity for freshwater and tidally influenced wetlands and examine underlying influences on hydrology						X	X		X	X	X	X		X											
High	Riparian restoration in stream related wetlands			X						X			X	X											X	
Medium	Planting and restoration of wetlands with species that are better adapted to climate variability						X	X		X		X	X	X		X									X	

Priority	Potential Actions	WAQ-01	WAQ-02	WAQ-03	WAQ-04	WAQ-05	HAB-01	HAB-02	HAB-03	HAB-04	HAB-05	HAB-06	HAB-07	HAB-08	HAB-09	HAB-10	HAB-11	HAB-12	HAB-13	HAB-14	HAB-15	CEE-01	CEE-02	CEE-03	CEE-04	CEE-05
8	Strategy: Habitat improvement																									
High	Large woody debris (LWD) to collect gravels for more subsurface flow and assist catching landslide material			X	X				X	X			X	X												
High	Riparian plantings			X			X			X		X	X	X		X			X		X					
High	Floodplain habitat restoration			X	X		X	X		X		X	X						X		X					
High	Reconnect springs, wetlands, floodplains that can serve as cold water refugia			X	X		X	X		X		X	X	X	X											
Medium	Increase diversity of habitat to create more salmonid life history options			X	X		X	X	X	X		X	X	X	X		X									
Medium	Increase off-channel habitat						X	X	X			X	X	X												
Medium	Stream channel restoration to create more channel complexity				X				X	X			X	X												
Medium	Expand conservation and restoration activities to ensure maintenance of specific types of wildlife habitat						X	X	X	X	X	X	X	X	X		X				X					
Medium	Large scale, holistic floodplain management to maintain and enhance complexity and function			X	X							X	X		X					X	X					
Medium	Address warming caused by inline impoundments																		X							
Medium	Forest management strategy to balance water absorption		X	X	X									X	X				X	X						
Low	Set back dikes to increase channel width and improve floodplain function											X	X		X						X					
9	Strategy: Increase natural upland water storage																									
Medium	Promote beaver habitat in the uplands			X							X			X						X						

Priority	Potential Actions	WAQ-01	WAQ-02	WAQ-03	WAQ-04	WAQ-05	HAB-01	HAB-02	HAB-03	HAB-04	HAB-05	HAB-06	HAB-07	HAB-08	HAB-09	HAB-10	HAB-11	HAB-12	HAB-13	HAB-14	HAB-15	CEE-01	CEE-02	CEE-03	CEE-04	CEE-05
10	Strategy: Reduce impacts of new and existing development on estuaries																									
High	Replace/remove/remediate existing infrastructure and development vital to estuary conservation and ecological functioning over long time frames	X	X			X	X					X			X											
Medium	Make recommendations to County and Planning Department for policies, related to new development, that sup- port estuary conservation and habitat migration						X													X	X					
11	Strategy: Assess and manage for projected change																									
High	Using sea level rise study/ report, assess culverts, dikes, other infrastructure, and natural areas at risk		X				X	X	X	X	X						X	X	X							
High	Protect/restore/conserve areas that will become new habitat with sea level rise						X					X	X							X	X					
Medium	Develop/use models to view stream and estuary conditions 50-100 years out (for planning current and near future actions)						X								X					X	X					
Medium	Education and outreach to promote appropriate standards to all groups (landowners, agencies, Counties, etc.)																		X	X	X					X
Medium	Identify at risk habitats, birds, and species						X	X	X	X	X						X	X								
Medium	Assess precipitation standards for culverts and roads (e.g. 100-year storms) based on climate projections and review current standards						X	X	X	X	X				X											
Medium	Prioritize, replace, remove, and remediate based on the results of the study						X	X	X	X	X				X											
Medium	Re-map estuarine sediments and habitats						X																			
Low	Revise management units to protect estuarine fringe						X	X												X						
Low	Accept loss of current boundaries																									

Priority	Potential Actions	WAQ-01	WAQ-02	WAQ-03	WAQ-04	WAQ-05	HAB-01	HAB-02	HAB-03	HAB-04	HAB-05	HAB-06	HAB-07	HAB-08	HAB-09	HAB-10	HAB-11	HAB-12	HAB-13	HAB-14	HAB-15	CEE-01	CEE-02	CEE-03	CEE-04	CEE-05
12	Strategy: Expand organizational capacity																									
High	Write grant proposals																				X					X
Medium	Extend partnerships																								X	X
Medium	Expand capacity																								X	X
13	Strategy: Manage streamflow																									
Medium	Sustainable water storage and release		X					X		X	X	X	X	X	X				X							
14	Strategy: Reduce water demand																									
High	Education and outreach on water conservation																			X	X	X		X		
15	Strategy: Protect groundwater sources																									
Medium	TBD - protect groundwater sources		X																							
16	Strategy: Increase strategy for invasive management																									
Medium	Aggressive PRISM approach																	X	X					X		
Low	Herbicide use for control	X																						X		
17	Strategy: Improve riparian planting survival																									
High	Plant diverse species in riparian areas						X			X		X	X	X		X			X		X					
High	Replant riparian areas as needed			X								X	X	X		X	X		X							
High	Monitor riparian planting survival			X						X		X	X	X		X	X		X							
18	Strategy: Increase forest diversity and resilience																									
High	Replant with multiple tree species to preserve and enhance diversity									X		X	X	X		X										
Medium	Assess establishment and survivial of tree species post- disturbance and over longer time periods to determine the most suitable species for planting						X	X	X	X	X					X										
19	Strategy: Reduce greenhouse gas emissions																									
Medium	TBD - reduce GHG emissions across the County						X	X		X	X	X	X	X												
20	Strategy: Develop appropriate vegetation management actions if changes are detected																									
Medium	Change in the type of vegetation used in riparian restoration activities															X			X							

Priority	Potential Actions	WAQ-01	WAQ-02	WAQ-03	WAQ-04	WAQ-05	HAB-01	HAB-02	HAB-03	HAB-04	HAB-05	HAB-06	HAB-07	HAB-08	HAB-09	HAB-10	HAB-11	HAB-12	HAB-13	HAB-14	HAB-15	CEE-01	CEE-02	CEE-03	CEE-04	CEE-05
21	Strategy: Continue with current management strategies and monitor for changes																									
High	Continue water quality monitoring					X																	X	X		
Medium	Monitor for changes in vegetation					X	X	X	X	X	X					X	X	X					X	X		
Medium	Maintain Riparian Management Areas (RMAs) strategies			X																X						
22	Strategy: Improve understanding of risks related to wildfire, forest management and climate change																									
Medium	Assess fuels across landscape (wetter coast to drier inland) and manage appropriately						X	X	X	X	X							X	X	X						
Medium	Review riparian practices for areas affected by wildfire						X	X	X	X	X							X	X							
Medium	Based on the results of the assessment, manage fuels for reduced wildfire severity while maintaining ecological values and function.											X	X	X			X	X	X							
Low	Review salvage logging practices for better understanding of how this risk affects the region								X								X	X	X							
23	Strategy: Reduce visitor impacts to bays and rivers																									
High	Education and outreach to share water quality info with stakeholders and users	X	X																					X		
High	Education and outreach on visitor impacts																							X	X	
High	Education and outreach to keep users away from stressed areas																							X	X	

National Disaster Recovery Framework

The Department of the Interior and the Environmental Protection Agency (among others) provide post-disaster recovery assistance for natural and cultural resources following major disasters. Informed by Presidential Policy Directive 8: National Preparedness, the federal government established a National Disaster Recovery Framework (2nd edition, 2016).

The NDRF framework outlines the Natural and Cultural Resources Recovery Support Function (NCR-RSF) as follows:

> *"The NCR RSF facilitates the integration of capabilities of the Federal Government to support the protection of natural and cultural resources and historic properties through appropriate response and recovery actions to preserve, conserve, rehabilitate, and restore them consistent with post-disaster community priorities and in compliance with applicable environmental and historical preservation laws and Executive orders."*[54]

In addition, the NDRF defines eight recovery core capabilities (critical functions to enable preparedness and recovery):

- Planning;
- Public Information and Warning;
- Operational Coordination;
- Economic Recovery;
- Health and Social Services;
- Housing;
- Infrastructure Systems; and
- Natural and Cultural Resources.

At the local level, TEP will be a primary contact for natural resources-based post-disaster recovery activities. Under the framework, local partners should be ready to address post-disaster natural and cultural resource recovery needs. Current planning activities should anticipate the following post-disaster recovery activities:

- TEP focal area post-disaster natural systems recovery needs identification.
- TEP focal area post-disaster preservation, conservation, rehabilitation, and restoration prioritization.
- Development and implementation of sustainable recovery strategies within the TEP focal area.
- Participation in post-disaster planning and networking activities.
- Identification of multi-objective, multi-discipline strategies that consider long-term environmental effects to sensitive natural resources, open spaces, and community well-being.
- Writing a plan for pre-disaster and post-disaster strategic, operational, and tactical actions for natural and cultural resources that is consistent with the NDRF (2nd Ed.) template.

[54] Federal Emergency Management Agency, Natural and Cultural Resources Recovery Support Function. National Disaster Recovery Framework (2nd Ed., 2016). Retrieved from https://www.fema.gov/media-library-data/1466014998123-4bec8550930f774269e0c5968b120ba2/National_Disaster_Recovery_Framework2nd.pdf

Local Economy

Healthy estuaries and watersheds provide many ecological benefits including clean water and habitat for fish and wildlife. But healthy and functioning watersheds and estuaries also have direct social and economic benefits: resiliency against storm damage and flooding, robust sports and commercial fisheries (including oysters and crabs), a vast array of recreational opportunities, and jobs. The "restoration economy" – the labor, materials, and private-sector contracts resulting from financial investment in restoration projects – has gained attention in the economic development community in recent years for its potential to help struggling rural economies. Communities that have relied upon natural resource extraction are increasingly finding ways to use natural resources in new ways that emphasize environmental stewardship and ecological restoration.[55] In a recent study of Oregon's watershed councils, University of Oregon researchers calculated that $1 million of OWEB funds invested in ecological restoration results on average in 16.3 jobs created and $2.3 million in economic output.[56] Restoration projects directly contribute to making Tillamook County's economy more diverse and resilient.

As the health of Tillamook County's watersheds increase, the potential for recreation-related economic activity also expands. In Oregon, the combined expenditures from fish and wildlife recreation related to travel, local recreation, and equipment purchases amounted to $2.5 billion in 2008 (the most recent year with available data).[57] In Tillamook County, travel-generated expenditures for fish and wildlife recreation amounted to $63.4 million in 2008, with an additional $5.2 million from locally-generated recreation.[58] As restoration enhances wildlife and their habitats, visitors and local residents may find more and more reasons to spend their time and money in Tillamook County.

Projects taken on by TEP and its partners will make it possible for local estuaries and watersheds to be healthy and fully functional. Healthy watersheds, in turn, will support a healthy economy for communities in Tillamook County. As Tillamook County and Oregon adjust to the realities of a new, more mechanized natural resource sector, the county and state have a tremendous opportunity to pivot with the times while remaining true to a natural resource heritage. The "new" natural resource economy, supported by the activities of TEP and its partners, will enhance the precious resources of land and water while simultaneously building good local jobs and generating recreation spending.[59]

[55] Hibbard, M. and S. Lurie. 2013. The New Natural Resource Economy: Environment and Economy in Transitional Rural Communities. Society and Natural Resources 26(7): 827-844.
[56] Nielsen-Pincus, M. and C. Moseley. 2013. The Economic and Employment Impacts of Forest and Watershed Restoration. Restoration Ecology 21:2, 207–14.
[57] Dean Runyan Associates. "Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon, 2008." Prepared for the Oregon Department of Fish and Wildlife and Travel Oregon. 2009. https://www.dfw.state.or.us/agency/docs/Report_5_6_09--Final%20(2).pdf
[58] Ibid. Table 13 and 14.
[59] Hibbard, M. and S. Lurie. 2013. The New Natural Resource Economy: Environment and Economy in Transitional Rural Communities. Society and Natural Resources 26(7): 827-844.