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**Subject:** EXTERNAL: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 1 of 6)
**Attachments:** Exh 1 - DOGAMI O-08-15 Report.pdf

**Importance:** High

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Hi Sarah and Allison,

Please include the attached and forthcoming DOGAMI reports (Exhibits 1-3) in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. This email transmits part 1 of 6 of this submittal. Would you please confirm your receipt of each? We will also be submitting additional items later this afternoon for inclusion in the record and the BOCC packet, so please keep an eye out for those as well. Thank you so much.

Best,
Sarah

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Applicants' July 27, 2021 Submittal
Exhibit 1 - Page 1 of 60

State of Oregon
Department of Geology and Mineral Industries
Vicki S. McConnell, State Geologist

**Open-File Report O-08-15**

# OREGON BEACH AND SHORELINE MAPPING AND ANALYSIS PROGRAM: 2007-2008 BEACH MONITORING REPORT

## TECHNICAL REPORT TO THE OREGON DEPARTMENT OF LAND CONSERVATION AND DEVELOPMENT

By

Jonathan C. Allan[1] and Roger Hart[1]

2008

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**NOTICE**

The results and conclusions of this report are necessarily based on limited geologic and geophysical data. At any given site in any map area, site-specific data could give results that differ from those shown in this report. **This report cannot replace site-specific investigations.** The hazards of an individual site should be assessed through geotechnical or engineering geology investigation by qualified practitioners.

**Cover photo:** A moderate storm on January 9, 2008, impacts oceanfront homes and condominiums in the community of Neskowin. An earlier storm (January 5) destroyed portions of the riprap wall and came close to destroying one home. Photo by Jonathan Allan.

Oregon Department of Geology and Mineral Industries Open-File Report O-08-15
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## EXECUTIVE SUMMARY

This report describes and documents the Oregon Beach and Shoreline Mapping Analysis Program (OBSMAP) maintained by the Oregon Department of Geology and Mineral Industries (DOGAMI), with funding from the Northwest Association of Networked Ocean Observing System (NANOOS contract #449958), the Oregon Department of Land Conservation and Development (DLCD contract #PS07028), and the Oregon Parks and Recreation Department (OPRD contract #07-372). The objective of this monitoring program is to document the response of Oregon's beaches to both short-term climate variability (e.g., El Niños, extreme storms) and longer-term effects associated with the changing climate of the earth (e.g., increasing wave heights, changes to storm tracks, and sea level rise), that will influence the stability or instability of Oregon's beaches over the next century. Understanding the wide range of responses characteristic of the Oregon coast is critical for effectively managing the public beach both today and into the future.

Beach monitoring undertaken as part of the OBSMAP effort is based on repeated high-accuracy surveys of selected beach profiles using a Trimble 5700/5800 Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) mounted on either a backpack or on an ATV vehicle. The OBSMAP monitoring network currently consists of 119 beach monitoring sites, which include:

- Six sites along the Clatsop Plains (Seaside to the mouth of the Columbia River);
- Twenty-five sites along the Rockaway littoral cell (Cape Meares to Neahkahnie Mountain);
- Fifteen sites in the Neskowin cell (Cascade Head to Cape Kiwanda);
- Fifteen sites in the Beverly Beach cell (Yaquina Head to Otter Rock); and,
- Fifty-eight sites in the Newport littoral cell (Yachats to Yaquina Head).

This report focuses specifically on coastal changes along the Rockaway and Neskowin littoral cells, with emphasis on measured responses following the extreme December 2-3, 2007, winter storm. Our beach monitoring efforts completed thus far have identified the following large-scale beach responses:

- The cumulative effect of the 1997-1998 and 1998-1999 winters resulted in extensive erosion along the Rockaway littoral cell; to date, some of the largest erosion responses measured on the Oregon coast. Nevertheless, the degree of change observed and the level of beach rebuilding that has taken place since then varies along the shore:
  - Erosion continues to plague much of the Rockaway subcell, which has continued to recede landward up to the present. The area presently experiencing the highest beach erosion changes is occurring north of Tillamook Bay and south of the Rockaway High School.
  - North of Rockaway High School and south of the Nehalem jetties, beaches have been slowly gaining sand and, hence, are gradually rebuilding following the extreme storms of the late 1990s.
  - Erosion continues to affect the southern half of Bayocean Spit, while the northern third of the spit has effectively been rebuilt and is now beginning to prograde (advance) seaward.
  - Similarly, erosion continues to plague the southern half of Nehalem Spit, while the northern third has gained some sand.
  - The beaches along the Rockaway littoral cell remain in a state of net deficit compared to 1997, with the loss of sand for the period 1997–2002 estimated to be about 1,439,600 $m^3$ (1,883,000 $yd^3$). Given that much of the Rockaway subcell has continued to erode and lose sand, we estimate that as of March 2008 the net sand loss from the cell is likely to be on the order of 2 million cubic meters of sand (2.6 million cubic yards). Whether the beaches recover fully and how long it takes remain important scientific and management questions, which in time will be answered by continued beach monitoring.

  - Post-storm recovery has been slow, limited to the lower beach face, and restricted to parts of Bayocean Spit, Nedonna Beach, and at the north end Nehalem Spit. The lack of significant sand accumulation high on the beach face in recent years suggests that the present climate may not be conducive for transporting sand landward from the beach face.
- In contrast to the Rockaway cell, measured beach changes on the Clatsop Plains indicate that although this section of shore was also affected by the extreme storms of the late 1990s, the degree of impact was much less; the beaches fully recovered within 1 to 2 years.
  - The exception is shoreline change taking place just south of the south jetty. Repeated beach surveys at the Eastjetty profile site has revealed that the beach has been slowly eroding landward. Given its narrow foredune width, it is likely that parts of this dune system could be breached in the near future.
  - The main foredune has steadily gained sand over the past several years. We estimate that the net sediment volume gain for the period 1997 to 2008 is about 3.4 million cubic meters (4.5 million cubic yards) of sand.
- The 2007-2008 winter caused severe erosion at selected sites in the Rockaway subcell (south end of the cell) and north of the town of Rockaway; erosion and damage to facilities at Cape Lookout State Park (including significant damage to the dynamic revetment constructed there to protect the park); damage to riprap revetments at multiple locations on the north coast but most notably at Neskowin; and exhumed cannons at Cannon Beach and a boat near Coos Bay. In most cases, the erosion was enhanced due to formation of rip embayments, allowing waves to break close to the shore with little loss in incident wave energy.
- An analysis of wave and water levels associated with the 2007-2008 winter indicates that events during this winter was not as extreme as past events. However, several major storms that occurred in winter 2007-2008 when the beaches of Oregon remained in a generally degraded state (i.e., beaches were narrower and had less sand volume), enabled the waves to cause significant damage to infrastructure along the coast.

# INTRODUCTION

Over the past century, the Oregon coast has undergone several periods of major coastal erosion in which the mean shoreline position retreated landward, encroaching on homes built atop dunes and coastal bluffs, and in several cases resulted in the destruction of homes. The most notable of these events took place in 1934, 1939, 1958, 1960, 1967 (Dicken and others, 1961; Stembridge, 1975), the winters of 1972-1973, 1982-1983 (Komar, 1997), in 1997-1998, 1999 (Allan and others, 2003), and most recently in December 2007. Of these, it is generally thought that the winter of 1938-1939, and specifically a storm in January 1939, was probably the worst on record (Dr. Paul Komar, personal communication, 2006). This storm resulted in extensive coastwide erosion (e.g., Netarts Spit was breached at several locations), along with the flooding inundation of several communities (e.g., Seaside, Cannon Beach, Rockaway, and Waldport), as ocean waves accompanied high water levels (Stembridge, 1975). Although the effects of the January 1939 storm were captured in the 1939 suite of aerial photographs flown by the U.S. Army Corps of Engineers (USACE), the fact that these photos have never been orthorectified makes it difficult to interpret the true extent of the storm's impact on the coast.

An assessment of how the beaches of Oregon respond to storms could not be fully documented until the late 1990s, when a joint venture between the U.S. Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA), used Light detection and ranging (lidar) technology to measure the topography of U.S. coastal beaches. On the Oregon coast, the results of such surveys have been published in several papers (Revell and others, 2002; Revell and Marra, 2002; Allan and others, 2003, 2004; Allan and Hart, 2005; Allan and Komar, 2005). However, while lidar provides an unprecedented amount of quantitative information that may be used to assess beach morphodynamics, on the Oregon coast such data sets have been collected infrequently (only on three occasions: 1997, 1998, and in 2002), with no additional measurements scheduled until 2009; given the present high costs, the expectation is that lidar will only be flown approximately every five years. As a result, the temporal scale of the lidar surveys is presently insufficient to adequately characterize short-term and to a lesser extent long-term trends of beaches.

The purpose of this report is to describe the Oregon Beach and Shoreline Mapping Analysis Program (OBSMAP) maintained by the Oregon Department of Geology and Mineral Industries (DOGAMI), with funding from the Northwest Association of Networked Ocean Observing System (NANOOS), the Department of Land Conservation and Development Agency (DLCD), and the Oregon Parks and Recreation Department (OPRD). The objective of the OBSMAP effort is to develop a comprehensive beach observation program, capable of providing high-quality quantitative data on the response of Oregon's beaches at a variety of time and space scales that are of most value to coastal resource managers and the public at large. OBSMAP data have been supplemented through analyses of lidar data measured along the Oregon coast in 1997, 1998, and 2002, and are now beginning to yield important new insights on how the beaches of Oregon respond to storms, El Niños, and climate change.

## MANAGEMENT NEEDS AND MONITORING OBJECTIVES

Management of beaches and dunes in Oregon falls under the jurisdiction of the OPRD, the Coastal Management Program of DLCD, and local jurisdictions through their comprehensive plans and land-use ordinances. OPRD has jurisdiction over the active beach up to the statutory vegetation line (surveyed in 1967; Oregon Revised Statute 390.770) or the existing vegetation line, whichever is located most landward, and thereby controls the permitting of structures used to protect ocean shore property. DLCD works with the planning departments of local jurisdictions to preserve Oregon's beaches and dunes by ensuring that they apply the standards for siting development as required by specific statewide planning goals that are incorporated into their local comprehensive plans. The department provides technical assistance to local jurisdictions in the form of model ordinances, as well as support for the improved and updated mapping and inventories.

The permitting of new ocean shore development by state and local jurisdictions is based on the best available knowledge and, in some cases, site investigations of specific locations. Although the information collected through these efforts meets the standards required by agencies, at times the information is piecemeal and does not always reflect an adequate understanding of the processes affecting the property for making sound decisions (i.e., site-specific studies on dune-backed beaches tend to be too narrowly focused, effectively ignoring issues that may influence the site at larger spatial or longer time scales). Specifically, the information presented often does not fully take into account the high-magnitude episodic nature of North Pacific extratropical storms, the long-term processes that may impact the property, the manner in which the proposed alterations might affect the system, or the effect those alterations could have on adjacent properties. State and local agencies are therefore relegated to making decisions about ocean shore development with only a partial understanding of their potential impacts. Those decisions will affect not only the relative level of risk posed to that development but also the long-term integrity of ocean shore resources and a variety of public recreational assets. Improved baseline data and analysis of beach morphodynamics will enable state agencies and local governments, and the geotechnical community, to better predict future shoreline positions and will provide the quantitative basis for establishing scientifically defensible coastal-hazard setback lines.

New baseline data repeated at appropriate time intervals (e.g., seasonal to annual surveys) and space scales (hundreds to thousands of meters) in conjunction with periodic detailed topographic information derived from lidar and ground surveys will help coastal managers resolve short- and long-term specific planning issues by providing an improved understanding of the following:

- The spatial and temporal responses of beaches to major winter storms in the Pacific Northwest (PNW) and to climate events such as El Niños and La Niñas.
- The time scales required for beach recovery following major winter storms, El Niños, or from persistent El Niño conditions that characterize the warm phase of the Pacific Decadal Oscillation. Under the present climatic regime and given uncertainties over future climate conditions, an important question is how long does it take for beaches to fully recover following a major storm(s)?
- The long-term implications of climate change to Oregon's beaches that result from increased storminess, larger storm wave heights (and hence greater wave energy), and changes to the predominant tracks of the storms and sea level rise.

Several important questions that may also be addressed from repeated ongoing monitoring of Oregon beaches include:

- What are the cumulative effects of increased storm wave heights, increased armoring of shorelines, and possible accelerated sea level rise on erosion rate predictions for bluffs and dunes? Is past practice of using historical data (e.g., aerial photos, ground surveys) to predict future shoreline or bluff toe/top locations defensible? If not, what quantitative approach should take its place? Can a numerically based model be developed that adequately handles all of the forcing that affects coastal change in the PNW?
- How can we improve existing process/response models so they adequately account for the erosion of PNW beaches? Present models were developed mainly for United States East Coast wave and

sediment transport conditions rather than for the significantly different conditions in the PNW. The wave climate in the PNW is far more severe, and, unlike the unidirectional longshore movement of beach sediment typical of the U.S. East and Gulf coasts, Oregon's beach sand oscillates from south to north, winter to summer, within its headland-bounded littoral cells.

- What are the spatial and temporal morphological characteristics of rip embayments on PNW beaches? What are the "hotspot" erosion impacts of rip embayments on dunes and beaches? How often do rip embayments occur at a particular site on the coast and what is the long-term effect on bluff erosion rates?
- How has the morphology of Oregon's beaches changed since the 1960s (i.e., when the coastline was last surveyed)?
- The loss of large volumes of sediment from several littoral cells on the northern Oregon coast in recent years (e.g., Netarts and Rockaway) raises the obvious questions: why are they eroding, where has the sand gone, and will it return?

Integral to answering many of these questions and for making informed decisions based on technically sound and legally defensible information is an understanding of the scales of morphodynamic variability within the coastal zone. Comprehensive beach monitoring programs have enhanced decision-making in the coastal zones of populous states such as Florida (OBCS, 2001), South Carolina (Gayes and others, 2001), Texas (Morton, 1997), Washington state (Ruggiero and Voigt, 2000), and in the United Kingdom, where the UK government recently endorsed the expansion of a pilot beach and bluff monitoring to extend around the bulk of the English coastline (Bradbury, 2007). These programs typically include the collection of topographic and bathymetric surveys, remote sensing of shoreline positions (aerial photography or lidar), and measurements of environmental processes such as currents, waves, and sediment transport. Over time such data sets prove critical in calibrating predictive models of shoreline change, in the design of shore-protection measures, and in determining regional sediment budgets (Gayes and others, 2001).

The general purpose of this study is to continue to document the response of Oregon's beaches using real-time kinematic differential global positioning system (RTK-DGPS) technology. Although the OBSMAP program now spans several littoral cells, this report will focus primarily on the measured responses in the Rockaway and Neskowin littoral cells, particularly as a result of the December 2-3, 2007, extreme storm and the problems that have arisen as a result of that event. The specific tasks associated with completing this ongoing study include the following:

1. Undertake quarterly (spring, summer, fall, and winter) surveys of the Neskowin (15 sites), Rockaway (25 sites) and Clatsop Plains (6 sites) beach monitoring network, Figure 1, in order to provide ongoing documentation of the response of Oregon's beaches to North Pacific winter storms, El Niños, and climate change.
    - Surveys were undertaken during the following months (approximately): March 2007; May/June 2007; September/October 2007; December 2007; March/April 2008.
2. Maintain and update the existing OBSMAP website (http://www.oregongeology.org/sub/nanoos1/index.htm). Continue to develop new data products that may be of value to coastal resource managers, and to improve the readability and usability of the website;
3. Disseminate beach state/change data and products among coastal managers and regulatory authorities in appropriate formats. Specific products produced as part of this monitoring effort include the measured beach profile responses, and the response of the beach at specific contour intervals. For the purposes of this study, we use the 6.0-m (20 ft) and 5.0-m (16 ft) contour changes to account for changes that may be occurring adjacent to the dune toe (i.e., caused predominantly by storms, El Niños, and long-term shoreline responses), while the 3.0-m (10 ft) contour reflects those changes near the Mean Higher High Water (MHHW) line (i.e., seasonal to interannual to longer-term changes); and,
4. Develop a report that summarizes the latest findings for each of the littoral cells.

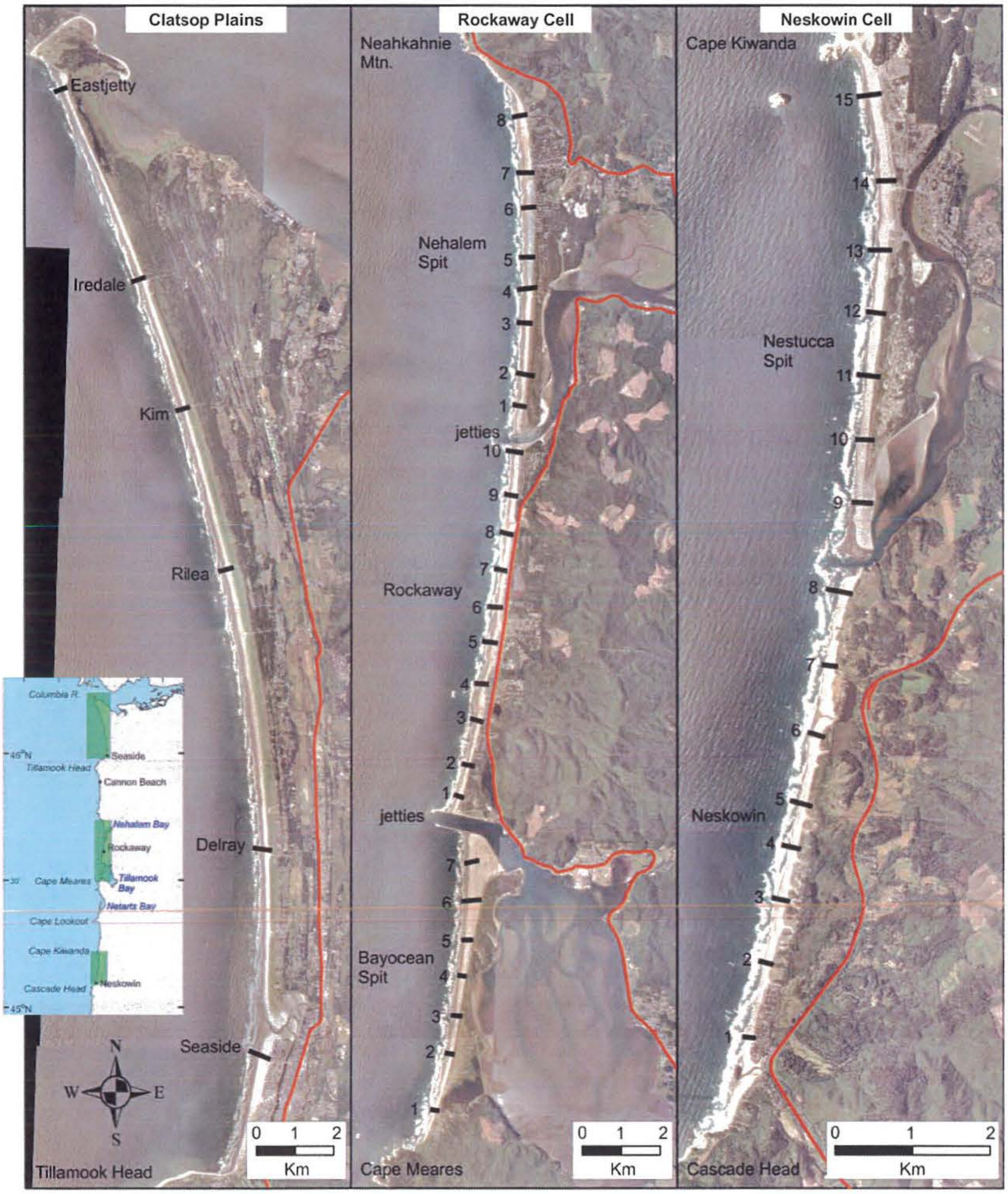

**Figure 1.** Location maps of Oregon Beach and Shoreline Mapping and Analysis Program (OBSMAP) beach monitoring stations (locations shown by black bars) established on the northern Oregon coast and overlaid on 2005 ortho-imagery (OGIC; http://gis.oregon.gov/DAS/EISPD/GEO/data/doq.shtml). Red line is U.S. Highway 101.

# BACKGROUND

Beaches composed of loose sediments are among the most dynamic and changeable of all landforms, responding to a myriad of complex variables that reflect the interaction of processes that drive coastal change (waves, currents, and tides), and the underlying geological and geomorphological characteristics of the beaches (sediment grain size, shoreline orientation, beach width, sand supply, losses, etc.). These factors have a threefold role in contributing to the morphology and position of the beach:

1. Promoting the supply of sediments to the coast for beach construction;
2. Transferring sediments through the system; and ultimately,
3. Removing sediments through the process of erosion.

Because beaches are composed of loose material, they are able to respond and to adjust their morphology rapidly in intervals of time ranging from seconds to days to years (Figure 2) in response to individual storm events, and enhanced periods of storm activity and increased water levels (e.g., the 1982-1983 and 1997-1998 El Niños).

Beginning with the 1997-1998 El Niño, the Oregon coast experienced a series of 20 unusually severe storms in which the deep-water significant wave heights exceeded 6 m (20 ft) for 9 hours or longer. Prior to the 1997-1998 winter the largest number of major storms experienced in a single season was 10 to 12, which occurred in the early 1980s (1982–1986). Furthermore, on the basis of wave data up through 1996, researchers (Ruggiero and others, 1996) had calculated the 100-year storm waves to be around 10 m (33 ft) for the Oregon coast. However, an event on November 19-20, 1997, exceeded that projection, and wave conditions were far worse the following winter, 1998-1999, when 22 major storms occurred, four of which generated deep-water significant wave heights over 10 m, the largest having generated wave heights of 14.1 m (47 ft). When wave energy of this magnitude (approximately proportional to the square of the wave height) is expended on the low sloping beaches characteristic of the Oregon coast, especially at times of elevated ocean water levels, these storms have the potential for creating extreme hazards to developments in foredunes and atop sea cliffs backing the beaches. For example, the cumulative impact of these recent extreme storms along the Neskowin and Netarts littoral cells in Tillamook County resulted in the foredune retreating landward by, on average, 11.5 m (38 ft) to 15.6 m (49 ft) respectively, and as much as 55 m (180 ft) in some locations, damaging properties fronting the eroding shore (Allan and others, 2004). In response to the erosion, property owners have resorted to the placement of riprap to safeguard their properties. Following erosion there is usually a period lasting several years to a few decades during which the dunes rebuild, until later they are eroded by another storm (Allan and others, 2003). How long this process takes is not known for the Oregon coast.

Longer-term adjustments of the beaches may also result from changes in sediment supply or mean sea level. However, attempts to quantify these processes suggest that erosion due to rising sea level is considerably lower compared with the effects of individual storms or from storms in series.

The monitoring of two-dimensional beach profiles over time provides an important means of understanding the morphodynamics of beaches and the processes that influence the net volumetric gains or losses of sediment (Morton and others, 1993; Ruggiero and Voigt, 2000). Beach monitoring is capable of revealing a variety of information concerning short-term trends in beach stability, such as the seasonal response of a beach to the prevailing wave energy, responses due to individual storms, or hotspot erosion associated with rip embayments. Over sufficiently long periods, beach monitoring can reveal important insights about the long-term response of a particular coast, such as its progradation (seaward advance of the mean shoreline) or recession (landward retreat), attributed to variations in sediment supply, storminess, human impacts, and ultimately as a result of a progressive increase in mean sea level.

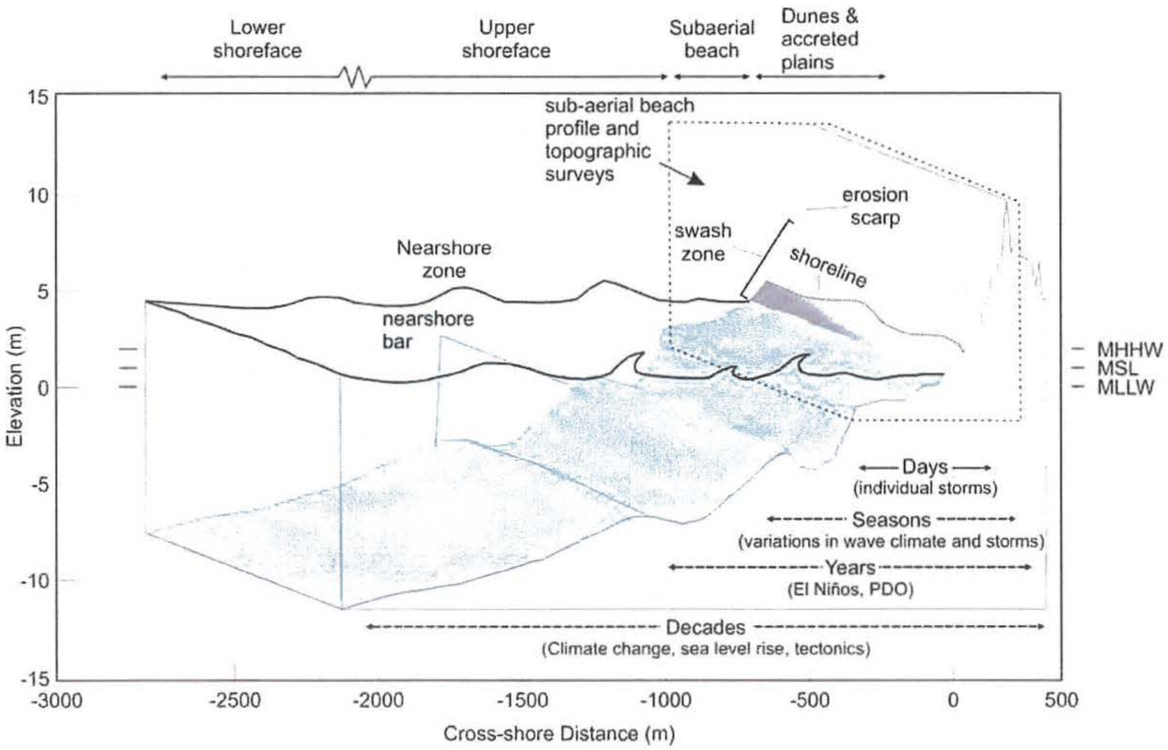

**Figure 2.** Conceptual model of beach and shoreline changes that occur over various time and space scales (after Ruggiero and Voigt, 2000). Dashed box indicates the portion of beach measured as part of OBSMAP. MHHW is mean higher high water; MSL is mean sea level; MLLW is mean lower low water; PDO is Pacific Decadal Oscillation.

## METHODOLOGY

Beach profiles that are nominally orientated perpendicular to the shoreline (Figure 1) can be surveyed using a variety of approaches, including a simple graduated rod and chain, surveying level and staff, Total Station theodolite and reflective prism, lidar, and RTK-DGPS technology.

Traditional techniques such as leveling instruments and Total Stations are capable of providing accurate representations of the morphology of a beach but are demanding in terms of time and effort. For example, typical surveys undertaken with a Total Station theodolite may take anywhere from 30 to 60 minutes to complete, which reduces the capacity of the surveyor to develop a spatially dense profile network. At the other end of the spectrum, high-resolution topographic surveys of the beach derived from lidar are ideal for capturing the three-dimensional state of the beach over an extended length of coast within a day; other forms of lidar technology are now being used to measure nearshore bathymetry but are dependent on water clarity. However, the technology remains expensive and is impractical along small segments of shore. More importantly, the high cost of lidar effectively limits the temporal resolution of the surveys and hence the ability of the end-user to understand short-term changes in the beach morphology (Bernstein and others, 2003). Within this range of technologies, the application of RTK-DGPS for surveying the morphology of both the subaerial and subaqueous portions of the beach has effectively become the accepted standard (Morton and others, 1993; Ruggiero and Voigt, 2000; Bernstein and others, 2003; Ruggiero and others, 2005).

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations, originally developed by the U.S. Department of Defense. In its simplest form, GPS can be thought of as triangulation with the GPS satellites acting as reference points, enabling users to calculate their position to within several meters (e.g., by using off-the-shelf hand-held units [note that the vertical error is typically about twice the horizontal error]), while survey-grade GPS units are capable of providing positional and elevation measurements that are accurate to a centimeter.

At least four satellites are needed to determine mathematically exact position, although more satellites are generally available. The process is complicated because all GPS receivers are subject to error, which can significantly degrade the accuracy of the derived position. These errors include the GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere and multipath effects (where the signals bounce off features and create a noisy signal). For example, hand-held autonomous receivers have positional accuracies that are typically less than about 10 m (<~30 ft), but can be improved to less than 5 m (<~15 ft) using the Wide Area Augmentation System (WAAS). This latter system is essentially a form of differential correction that accounts for the above errors, which is then broadcast through one of two geostationary satellites to WAAS-enabled GPS receivers.

Greater survey accuracies are achieved with differential GPS (DGPS) using two or more GPS receivers to simultaneously track the same satellites, thus enabling comparisons to be made between two sets of observations (Figure 3). One receiver is typically located over a known reference point and the position of an unknown point is determined relative to the reference point. With the more sophisticated 24-channel dual-frequency RTK-DGPS receivers, positional accuracies can be improved to the subcentimeter level when operating in static mode and to within a few centimeters when in RTK mode (i.e., as the rover GPS is moved about).

### Survey benchmarks

Allan and Hart (2007) fully describe the procedures used to establish survey benchmarks and the beach profiles established in the Neskowin cell, while Ruggiero and Voigt (2000) describe procedures used to establish the beach monitoring network on the Clatsop Plains. Here we briefly describe our earlier efforts to establish a dense GPS beach monitoring network in the Rockaway cell, located in Tillamook County. It is important to note that this effort was originally undertaken in the summer/fall of 2004 and was funded in part by DLCD and through the initial NANOOS pilot project.

Twenty-five beach profile sites and survey benchmark locations were initially identified in a Geographical Information System (GIS). These sites were then

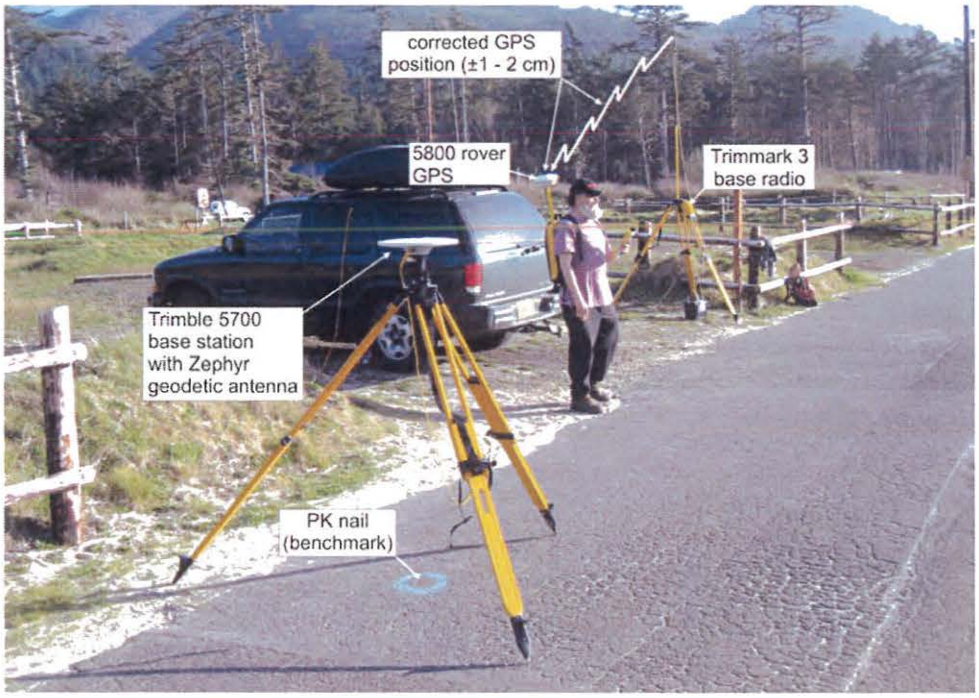

**Figure 3.** The Trimble 5700 base station antenna located over a known reference point at Cape Lookout State Park, Oregon. Corrected GPS position and elevation information is then transmitted by a Trimark III base radio to the 5800 GPS rover unit.

assessed in the field to refine the benchmark locations and to make sure that the sites would have an unobstructed view of the sky. The benchmarks consisted of either:

- aluminum sectional rods (Figure 4A) hammered approximately 12–24 ft into the ground and capped with a 2½" aluminum cap. The ends of the rods and caps are concreted into the ground; or,
- 2½-ft deep holes that include a 4- to 6-ft-long galvanized steel earth anchor (with a 6" helix screw) screwed into the hole to provide additional support and rigidity and then backfilled with concrete (Figure 4B). These latter benchmarks are characterized by brass survey caps.

All survey caps are stamped with an Oregon Department of Geology designation *but currently do not have an ID number on them.*

Precise coordinates and elevations were determined for the Rockaway beach and shoreline network by the Tillamook County Surveyor's Office using several GPS units. The GPS units were mounted on fixed height (2.0 m) survey rods and located over known geodetic survey monuments to establish precise survey control. Surveys of the new monuments were then undertaken and typically involved occupation times of 20 minutes or more. This approach enabled multiple baselines to be established from known survey benchmarks points to the unknown monuments, which produced excellent survey control. Coordinate information for each of the benchmarks were determined in both geographic coordinates and in the Oregon State Plane (northern zone, meters) coordinate system. All elevations are expressed in the North American Vertical Datum of 1988 (NAVD88). All benchmark information can be accessed via the web at: http://www.oregongeology.org/nanoos1/Benchmarks/benchmarks.htm

Figure 1 shows the general layout of the final Rockaway cell survey network, which consists of seven profiles sites between Cape Meares and the Tillamook estuary mouth, ten sites located between Tillamook and Nehalem bays, and eight sites between Nehalem bay and Manzanita in the north. Surveying of beach

**Figure 4.** A) Sectional aluminum rod capped by a 2½" aluminum cap serves as a benchmark at Rock8 in the Rockaway subcell. B) Where rods are not used, a 5-ft-long helix anchor screw is inserted into an 8" diameter hole (3 ft deep) and filled with concrete. The monument is then capped with a 2½" brass cap. Example shown is for the Bay2 monument located on Bayocean Spit.

profiles commenced on October 26, 2004, using a Trimble® 5700/5800 Total Station GPS (Figure 3). This system consists of a GPS base station (5700 unit), Zephyr Geodetic™ antenna, TRIMMARK™ 3 radio, and 5800 "rover." The 5700 base station was mounted on a fixed height (2.0 m) tripod and located over a known geodetic survey monument followed by a site calibration on the remaining benchmarks to precisely establish a local coordinate system (Figure 5). This step is critical to eliminate various survey errors. For example, Trimble reports that the 5700/5800 GPS system results have horizontal errors of approximately ±1-cm + 1-ppm (parts per million × the baseline length) and ±2-cm in the vertical (Trimble Navigation Limited, 2005). These errors may be compounded by other factors such as poor satellite geometry, multipath, and poor atmospheric conditions, combining to increase the total error to several centimeters. Thus, the site calibration process is critical to minimize these uncertainties (Ruggiero and others, 2005).

Once the local site calibration was completed, cross-shore beach profiles were surveyed with the 5800 GPS rover unit mounted on a backpack (Figure 6). This process was typically undertaken during periods of low tide. The approach was to walk a straight line from the landward edge of the primary dune, over the dune crest, down the beach face, and out into the ocean to approximately wading depth by navigating along a predetermined line perpendicular to the shoreline and displayed on a hand-held Trimble TSCe computer, connected to the 5800 rover. The computer shows the position of the operator relative to the survey line and indicates the deviation of the GPS operator from the line. The horizontal variability during and between subsequent surveys is generally minor, approximately 1 m (3 ft) (i.e., about ±0.5 m either side of the line), and typically results in negligible vertical uncertainties due to the wide gently sloping beaches characteristic of much of the Oregon coast (Ruggiero and others, 2005). The surveys were repeated on approximately a quarterly basis and/or after major storms. According to previous research, this method can reliably detect elevation changes on the order of 4-5 cm, that is, well below normal seasonal changes in beach elevation, which typically varies by 1–2 m (3–6 ft) (Shih and Komar, 1994; Ruggiero and others, 2005).

**Figure 5.** Static GPS occupations were used as part of a site calibration on selected benchmarks to derive a local coordinate system in the Rockaway littoral cell. GPS site calibration procedures involved occupying a benchmark for 180 epochs (typically at least 3 minutes or longer) and then processing the data in Trimble Geomatics Office software.

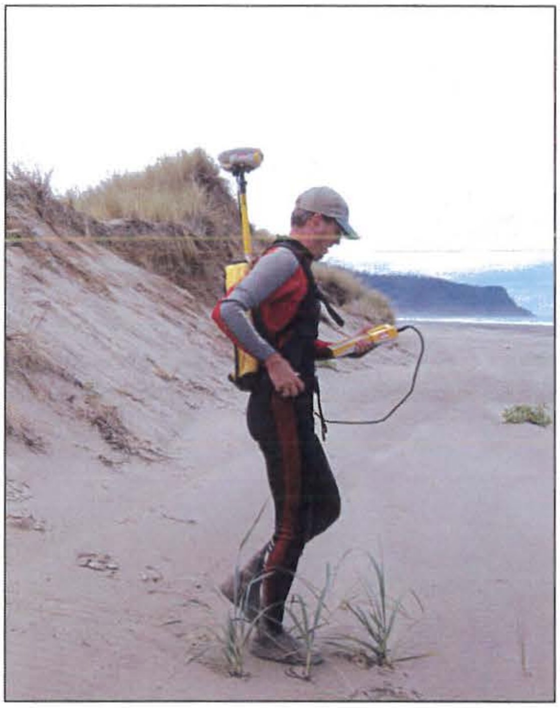

**Figure 6.** Profile survey undertaken near Neskowin using a Trimble 5800 GPS rover mounted on a backpack.

The collected GPS data were subsequently processed using the Trimble Geomatics Office™ suite of software. The first stage involved a re-examination of the site calibration undertaken on the TSCe computer. A three-parameter least-square fit was then applied to adjust all data points collected during the survey to the local coordinate system established for the particular study area in order to reduce any errors that may have occurred as a result of the GPS units. The reduced profile data were then exported for subsequent analysis.

Analysis of the beach survey data involved several stages. Data were first imported into the Mathworks MATLAB® computer programming environment using a customized script. A least-square linear regression was then fit to the profile data. The purpose of this script is to examine the reduced data and eliminate data points that exceed a ±0.5-m threshold on either side of the predetermined profile line. The data were then exported into a Microsoft Office Excel™ database for archiving purposes. A second MATLAB script was applied to the Excel profile database to plot the latest survey data (relative to the earlier surveys) and to output the generated figure as a Portable Network Graphics (.png) file. A third script examined the profile data and quantified the changes that occurred at selected contour elevations; for this study, temporal trends were developed for all contours between the 1-m and 6-m elevations and for all available data. Finally, the reduced contour data were plotted against time and exported as a .png file for additional analysis. After data analysis, the graphic images were displayed on the OBSMAP website for online viewing (http://www.oregongeology.org/sub/nanoos1/index.htm).

## RESULTS

A variety of approaches may be used to view and analyze beach morphology measured by surveys. In the traditional approach, one simply examines the temporal and spatial variability of graphed beach profiles. Other approaches include examining changes at specific contour elevations (also known as excursion distance analysis, or EDA), undertaking volumetric calculations, or examining alongshore changes that occurred.

Beach profiles provide the most important information concerning the spatial variability in the shape of a beach section over time. The information derived from repeated surveys provides a measure of the response of the beach to variations in the wave energy (e.g., winter versus summer wave conditions), which is reflected in accretion of the beach during the summer and erosion in winter. These data may also contain important information on how the beach responds to major storms, such as during the extreme 1997-1998 and 1998-1999 winters, including dune or bluff erosion (i.e., how much dune or bluff retreat occurred), data that are extremely useful when designating hazard zones along the coast. Given the short period in which beach changes in the Rockaway cell have been monitored, information derived from lidar topographic surveys has been used to supplement the beach monitoring data, extending the data set back to at least October 1997. Along the Rockaway cell, airborne lidar data were obtained in October 1997 (pre El Niño), April 1998 (post El Niño), and in September 2002 (Allan and Hart, 2005). When combined, the lidar and RTK-DGPS data provide almost a decade of information on beach changes in the Rockaway littoral cell.

Results presented here focus primarily on changes that have taken place in the Rockaway cell and on the Clatsop Plains during the past decade. (A similar assessment was previously undertaken for the Neskowin cell by Allan and Hart [2007].) This report concludes with an examination of beach changes that took place over the 2007-2008 winter, particularly in response to the extreme December 2-3, 2007, event and another event on January 5, 2008, and the associated beach responses that took place at Neskowin and in Rockaway and at Twin Rocks.

## Rockaway cell beach changes

The Rockaway littoral cell extends from Cape Meares in the south to Neahkahnie Mountain in the north. The length of the cell is about 26 km (16 mi), and can be further subdivided into three subcells that include Bayocean Spit, Rockaway, and Nehalem spit, with each of the subcells separated at the mouths of Tillamook and Nehalem bays. Within this cell, the most concentrated area of coastal development occurs along the Rockaway subcell (i.e., the area includes the towns of Twin Rocks, Rockaway, and Nedonna Beach). Intense development is also occurring in the north at Manzanita.

### Bayocean Spit

The Bayocean Spit subcell extends from Cape Meares in the south to the south jetty that bounds Tillamook Bay. Site Bay1, located at the south end of Bayocean Spit is characterized by a wide (~50 m wide [164 ft]) low-lying (5.8 m high [19 ft]) barrier berm comprised of pebbles and cobbles, which extends from the Cape Meares headland in the south to about 270 m (900 ft) north of Bay 1. North of Bay1, the shore is backed by a high (10 to 12 m [33 to 39 ft]) frontal foredune (primary dune) that extends from Bay2 to Bay5. North of Bay5, the foredune decreases in height to about 8 m (26 ft) in elevation. Between Bay4 and Bay5, the backshore is characterized by a remnant parabolic dune and transverse dunes that have been truncated due to the erosion of Bayocean Spit following construction of the north Tillamook jetty in the early 1900s (Cooper, 1958; Komar, 1997). South of Bay3 and north of Bay1, the backshore is low lying and is characterized by a wetland and lake that formed from the breaching of Bayocean spit in 1952. Seaward of the cobble berm and foredune, the beach is wide and gently sloping ($\tan \beta = 0.021$). Grain-size statistics determined by Peterson and others (1994) indicate that the mean grain size is 0.167 mm (i.e., fine sand).

Beach morphological changes for four of the study sites located along Bayocean Spit are presented in Figure 7. The measured changes indicate that over the past decade the beach has been relatively stable. In the far south at Bay1, the beach has experienced little change (Figure 7), a testament to the resilience of the cobble beach that protects the community of Cape Meares. Nevertheless, due to its relatively low crest elevation (~ 5 to 6 m [16 to 20 ft]) this particular shore section is periodically overtopped by ocean waves, carrying flotsam and cobbles landward of the cobble berm. Hence, this section of shore remains subject to major hazards associated with ocean flooding (storm surge plus high wave runup) that may accompany large storms, as well as from ballistics associated with the transport of cobbles and tree trunks inland against the houses that have been built parallel to the beach.

In response to the extreme winter storms of 1997-1998 and again in 1998-1999, parts of the spit did experience some erosion, particularly along the south-central section of the spit (north of Bay1 and south of Bay3), with the foredune eroding landward by about 5 to 7 m (16 to 23 ft) (Figure 8). However, since those events the monitoring data indicate that the Bay2 site has been gradually recovering, while the Bay3 site has not. In contrast, monitoring data from the remainder of the spit (north of Bay4) indicate that the upper part of the beach and frontal foredune have been aggrading (building vertically) over time, causing the beach-dune face (measured at an elevation of about 6 m [20 ft]) to advance (prograde) seaward by about 31.6 m (104 ft) at Bay5 and 37.8 m (124 ft) at Bay 7 at the north end of the spit (Figure 8). Much of this phase of beach building and dune growth has occurred since 2002. Although beach building has occurred at higher elevations on the beach face, the position of the lower beach face near the MHHW mark (~ 3 m [9 ft] elevation) has continued to erode landward over time, north of Bay2 and south of Bay5, causing the beach in the central part of the spit to steepen over time. For example, beach changes measured at the peak of the 2007-2008 winter revealed the beach in its most eroded state since monitoring commenced. In contrast, the beach along the northern one third of the spit revealed little to no change on the lower beach face. Nevertheless, as can be seen in Figure 8, the lower beach face at Bay7 was generally in the positive (i.e., had more sand on it relative to previous years).

### Rockaway

The Rockaway subcell extends from Tillamook Bay in the south to Nehalem Bay in the north. Along much of its shore, significant property development has occurred, particularly in the areas of Twin Rocks, Rockaway, and Nedonna Beach. As a result of these developments having been allowed to be built too close to the beach, and because of the relatively narrow beach widths present in this subcell (compared with other

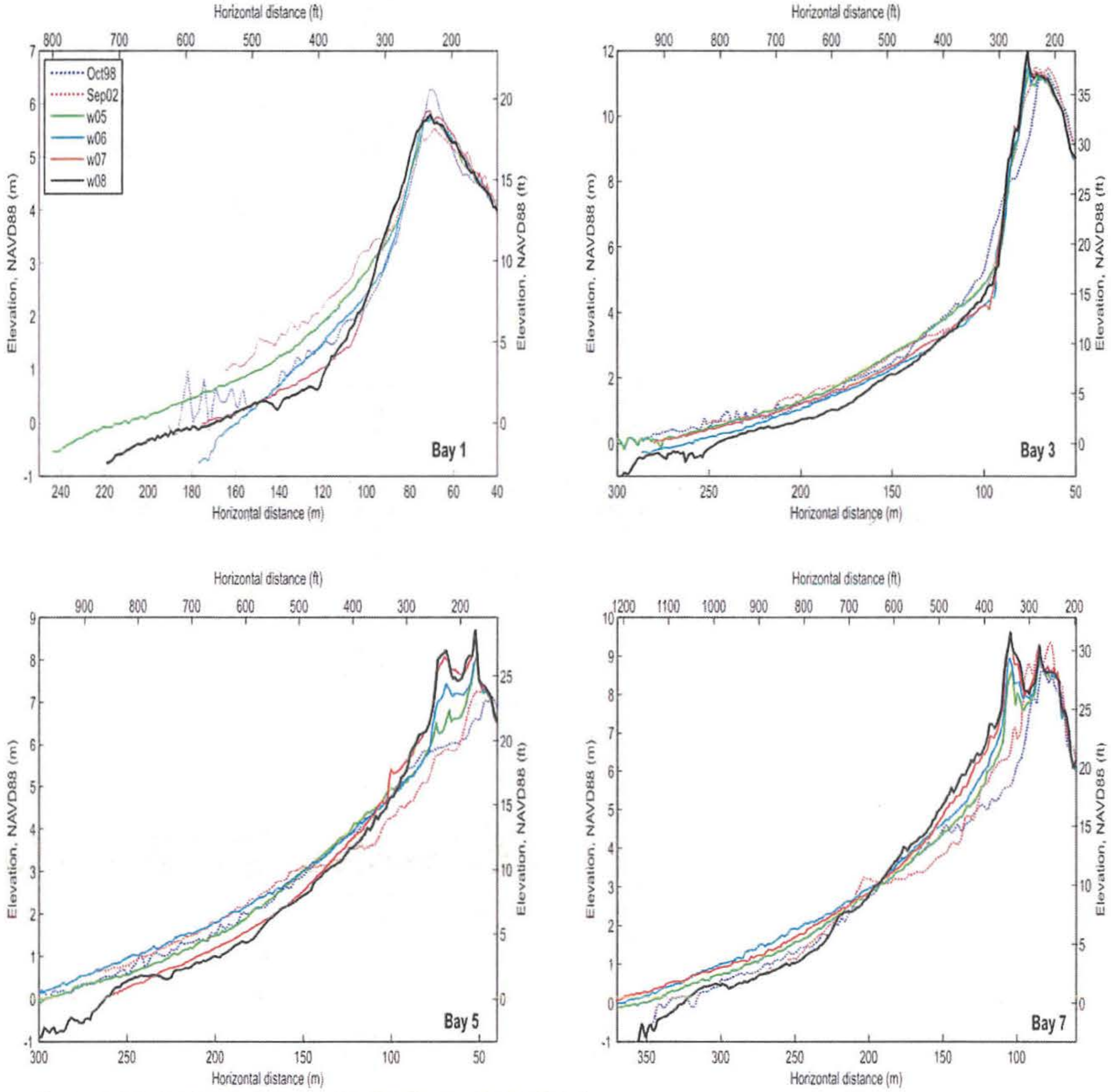

**Figure 7.** Measured beach morphological changes carried out between 1997 and 2008 along Bayocean Spit. Morphological changes shown in the figure are based on only the winter surveys undertaken in each year. Note: w in the legend signifies winter; beach surveys typically occurred in March. NAVD88 is North American Vertical Datum of 1988.

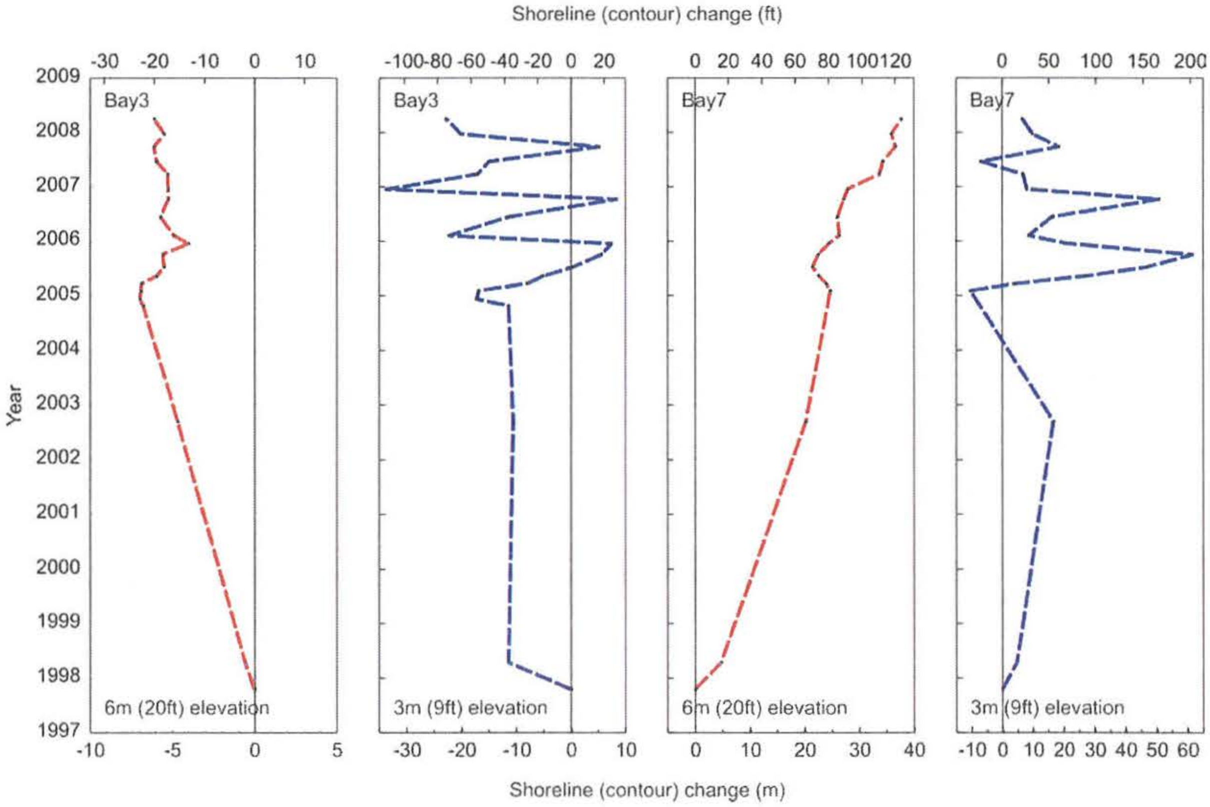

**Figure 8.** Shoreline "contour" changes determined for the upper (red) part of the beach at the 6 m (20 ft) elevation and for the lower (blue) beach face (3 m [9 ft] elevation) near the mean higher high water (MHHW) mark. Data presented here incorporate all the measured responses. Negative values indicate erosion, positive values indicate accretion, and zero indicates no change. Note figure top indicates units in feet, while the units on the bottom of the plot are metric.

beach sites), the Rockaway subcell has become one of several erosion "hotspots" on the Oregon coast, requiring expensive coastal engineering (riprap revetments) to combat the beach and dune erosion that has taken place in recent years. In particular, riprap structures have been constructed along much of the township of Rockaway, north of profile Rck5 and south of Rck8, as well as in the south between Rck2 and Rck3 (Figure 1).

Grain-size statistics indicate that the mean sand size is slightly coarser (0.21 mm) at Rockaway than at Bayocean Spit, but the sand is still classified as fine sand. Where creeks and streams flow out onto the beach, gravels can also be identified, though the quantities are very small. Due to the slightly coarser nature of the sediments, the beach in the Rockaway subcell tends to be generally steeper (tan $\beta = 0.021$) than Nehalem and Bayocean Spit beaches.

Since construction of the Tillamook and Nehalem jetties, the shoreline has changed considerably. In the south, the mean shoreline position has prograded seaward by up to 300 m (1000 ft) (Allan and Priest, 2001). Shore progradation also characterizes the beach response in the area of Nedonna Beach, which has been gradually accumulating sand since the late 1960s.

Figure 9 shows the responses of the Rockaway beach since the extreme storms of the late 1990s. Unlike the beach changes identified on Bayocean Spit, changes along the Rockaway subcell have been far more dramatic. Beach and dune erosion dominates the bulk of the shoreline, with the greatest amount of erosion having occurred north of the Tillamook jetties and south of about Rck8 (Figure 1). Without doubt, much of the erosion can be attributed to the extreme storms that impacted this section of the coast during the 1997-

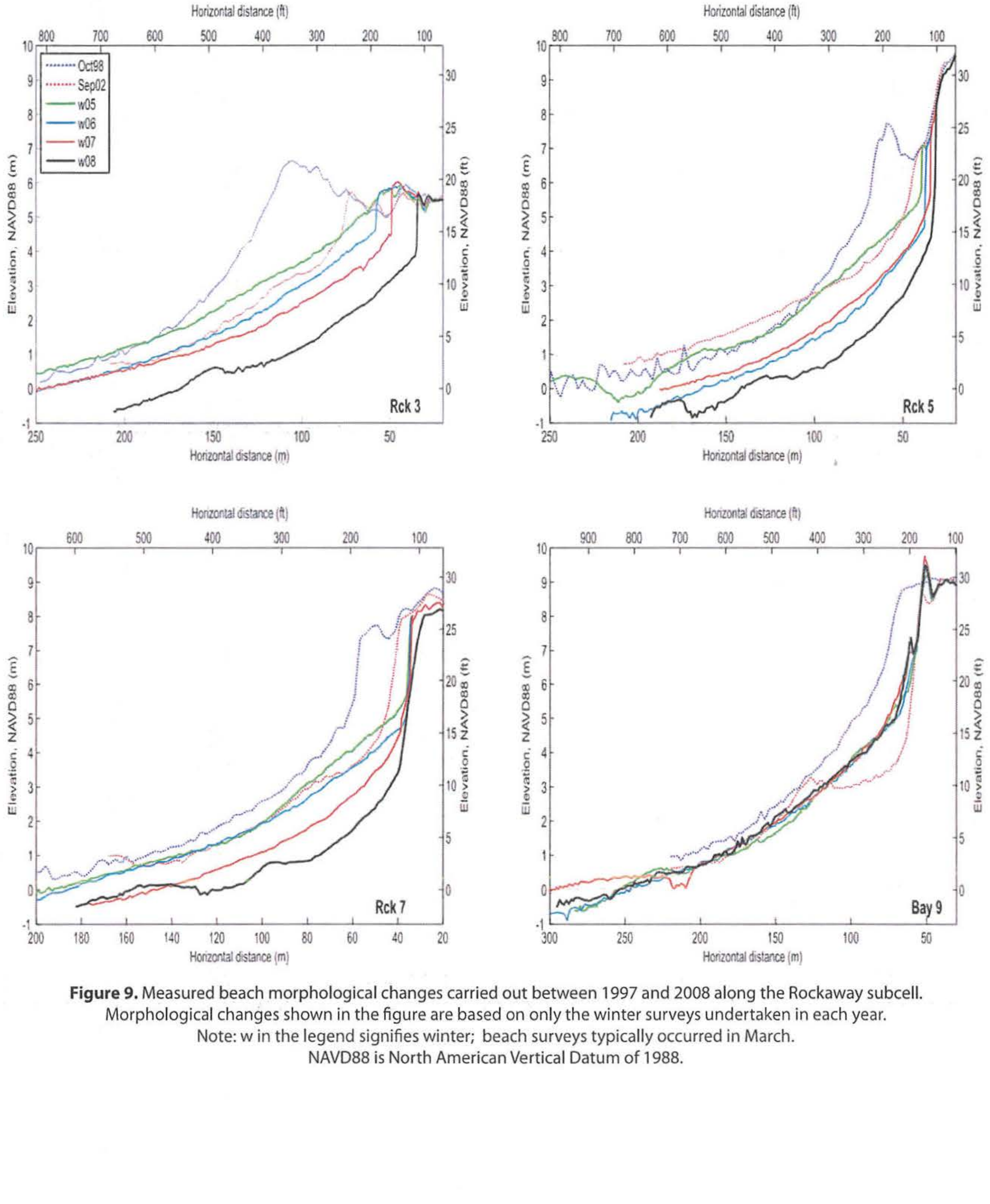

**Figure 9.** Measured beach morphological changes carried out between 1997 and 2008 along the Rockaway subcell. Morphological changes shown in the figure are based on only the winter surveys undertaken in each year. Note: w in the legend signifies winter; beach surveys typically occurred in March. NAVD88 is North American Vertical Datum of 1988.

1998 and 1998-1999 winters. For example, by the end of the 1998-1999 winter season the dune toe at Rck1 had receded landward by 38.2 m (125 ft). Recent beach monitoring efforts along this shore has revealed that this section of beach has continued to retreat landward, with Rck1 having now eroded by 46.9 m (154 ft) since 1997. It is likely that some of the beach erosion at the south end of the Rockaway subcell can be attributed to "hotspot" erosion effects that take place during major El Niños (Komar, 1998; Allan and others, 2003). Because the predominant storm tracks are shifted to the south during major El Niños, so that the storms cross the central/northern California coast, wave heights along the Oregon coast tend to be much larger. Furthermore, because of the proximity of the storm systems to the south, the arrival of waves on the Oregon coast tend to occur at strongly oblique angles relative to the shore, contributing to greater erosion at the south ends of the littoral cells (i.e., north of the headlands and jetties).

As shown in Figure 9, Rck3 has also experienced fairly significant beach and dune retreat. Between 1997 and 2002 (i.e., the period that spans the extreme storms of the late 1990s) the beach receded landward by 46.5 m (152.6 ft). Since 2002, the beach has eroded an additional 41 m (134.5 ft), bringing the total beach and shoreline retreat to 87.5 m (287 ft). Further north at Rck5, Figure 9, the beach eroded 26 m (85 ft) between 1997 and 2002. Our recent monitoring efforts have revealed that the Rck5 eroded an additional 5 m (16 ft) between 2002 and 2004, and was relatively stable up through early 2006. Since then, this section of Rockaway beach has retreated landward by an additional 7.9 m (26 ft), bringing the total amount of beach erosion since 1997 to 39.2 m (128.6 ft). Much of this recent phase of erosion can be attributed to a storm in early 2006, and most recently in December 2007. As can be seen in Figure 9, the erosion can be easily tracked over time, initially as small 1.2 m (3.9 ft) high erosion scarp that has increased in height (now about 4 m [13.1 ft]) over time as the dune has receded landward.

Similar changes can be identified for the Rck7 profile site, which retreated landward by about 20.6 m (-67.6 ft), between 1997 and 2002. By October 2004, when we commenced our surveys of the beach, the Rck7 site had eroded an additional 6.6 m (22 ft). While our other beach monitoring sites south of Rck7 continued to be characterized by ongoing beach and dune recession, the Rck7 site did not change much between 2004 and 2007. However, in January 2008 the beach cut back about 4 m (12 ft) (Figure 10); due to the close proximity of several homes to the beach, OPRD granted permission for emergency riprap to be installed. The

**Figure 10.** Dune erosion scarp that formed at Rck7 in January 2008. Note the two people having to use a ladder to get off the beach.

erosion that occurred at Rck7 was in fact exacerbated by the presence of a large rip embayment that formed over the winter. The presence of the rip embayment was identified in our summer survey; over the course of the winter, the embayment broadened and migrated north. Due to the presence of the rip embayment, large waves were able to break much closer to the shore in the throat of the channel, with minimal loss of energy. As a result of these processes as well as currents that form in response to circulation in the nearshore, the waves were able to rapidly lower the beach elevation and directly attack the dune face.

Finally, unlike south of Rck8, the Nedonna Beach area to the north has been relatively free of erosion problems. Although the Rck9 site shown in Figure 9 did experience fairly significant erosion between 1997 and 1998, since then the beach and dune has been gradually accreting. As a result, the dune has prograded seaward by about 4.4 m (14.4 ft). Such a response has likely been aided by the northward transport of sediments eroded from the beaches south of Rck8. Although the north end of the Rockaway subcell has gained new material over the past decade, the actual volume is relatively small compared with the total amount of sand that has been eroded from the beach south of Rck8. Further discussion of this is provided below.

### Nehalem Spit

The Nehalem Spit subcell spans the region between the Nehalem jetties in the south and Neahkahnie Mountain in the north. The beach along Nehalem Spit is significantly wider than beaches in the Rockaway subcell, in part because this shore is appears to be presently gaining sand, albeit at slow rates, and because the Rockaway subcell has experienced so much erosion in recent years. Along much of the spit, the beach is backed by a high foredune that averages about 12 to 14 m (39.4 to 45.9 ft) in height, with a maximum height of 17.6 m (57.8 ft) at Neh4, located midway along the cell. North of Neh6, the foredune crest decreases in elevation to a low of 8.4 m (27.6 ft) at Neh8. While the bulk of the spit is managed by the OPRD, residential development has occurred in the northern portion of the cell, from just south of Neh6 all the way north to Neahkahnie Mountain. Like the beaches along Bayocean Spit and at Rockaway, the Nehalem Spit beaches are gently sloping and are characterized by a wide dissipative surf zone. Grain-size statistics determined by Peterson and others (1994) indicate that the mean grain size is 0.195 mm (i.e., fine sand).

Morphological changes for selected beach profile sites are shown in Figure 11. For the most part, the identified pattern of responses are consistent with changes observed on Bayocean Spit. Thus, in general, the beach south of and including Neh4 (Figure 1), experienced quite a bit of erosion during the extreme winter storms of the late 1990s. For example, the mean beach and dune retreat between 1997 and 2002 was 18.2 m (59.7 ft), while the maximum amount of erosion was 28.3 m (92.9 ft) measured at the Neh2 profile site. Since then, two of the sites (Neh1 and Neh4) have almost fully recovered, while the Neh2 and Neh3 sites continue to experience low beach volumes relative to their condition in 1997 prior to the major El Niño.

Neh5 marks the transition between the southern region that has been subject to erosional changes and the northern portion of the cell that has been steadily aggrading over time. As can be seen for Neh5 (Figure 11) this particular site has undergone some recent beach building. Between 2002 and 2008, the foredune aggraded vertically by about 2.5 m (8.2 ft) (Figure 12), the section of dune above about 8 m (25 ft) prograded seaward by about 21 m (68.9 ft), and the dune toe measured at the 6 m (20 ft) contour elevation advanced seaward by about 12.6 m (41.3 ft). These changes suggest that the bulk of the dune sand is accumulating up in the dune itself, probably aided by the presence of European beach grass that helps trap sand blown inland from the beach. In contrast, sand accumulation around the 6 m (20 ft) contour elevation is likely to be more ephemeral, as it is moved about by ocean waves and the wind. These types of responses are broadly similar to measured beach changes observed in the Neskowin littoral cell (Allan and Hart, 2007). Further north at Neh7 and Neh8, the measured beach responses indicate very subtle changes. While there has been some sand accumulation on the upper beach face at Neh7 and to a lesser extend Neh8, both sites indicate considerable variability on the lower beach face as the beach varies between erosion and accretion. In essence, neither of these sites has changed significantly in the last decade.

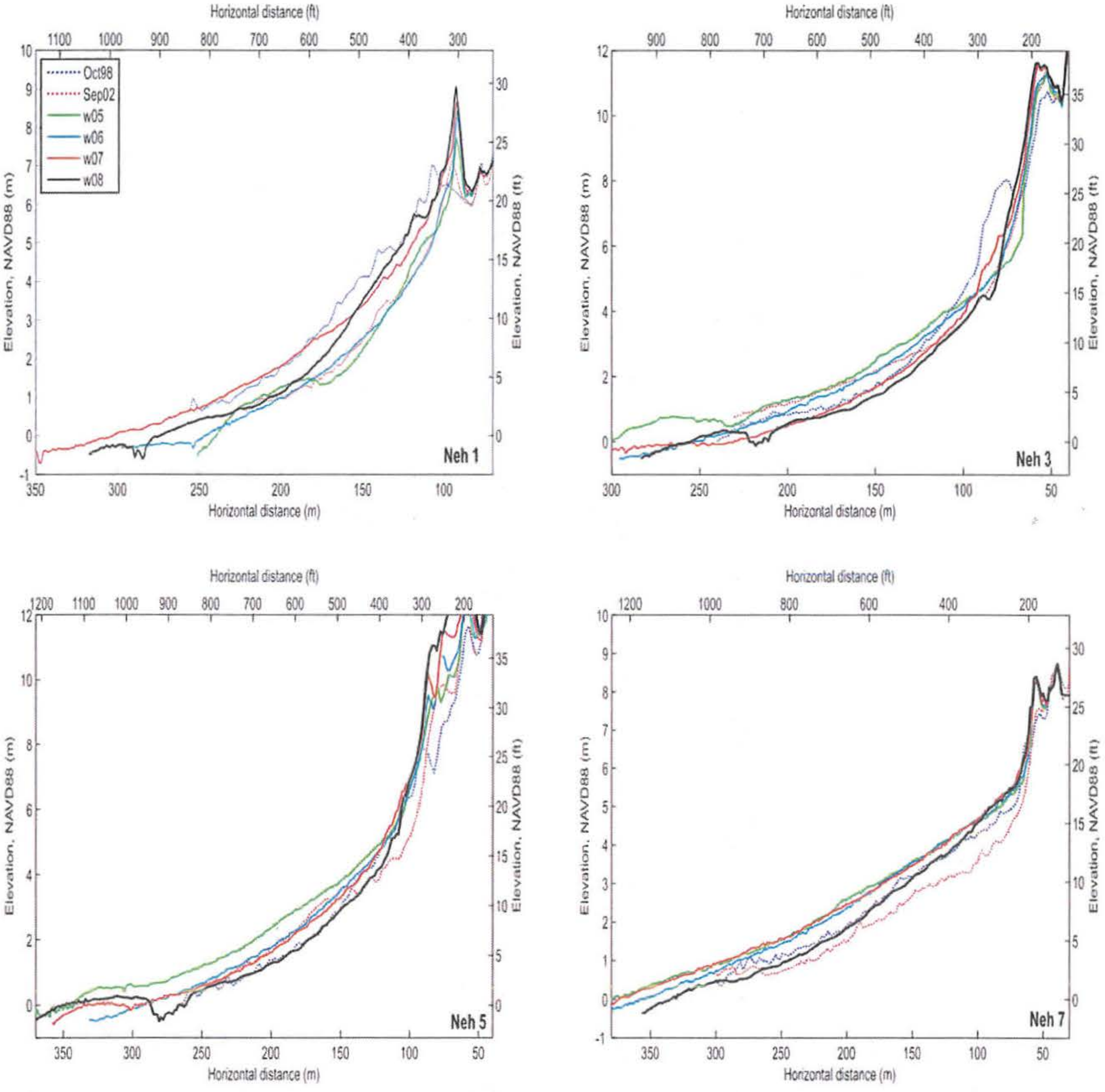

**Figure 11.** Beach morphological changes from surveys carried out between 1997 and 2008 along the Nehalem Spit subcell. Morphological changes shown in the figure are based on only the winter surveys undertaken in each year. Note: w in the legend signifies winter; beach surveys typically occurred in March. NAVD88 is North American Vertical Datum of 1988.

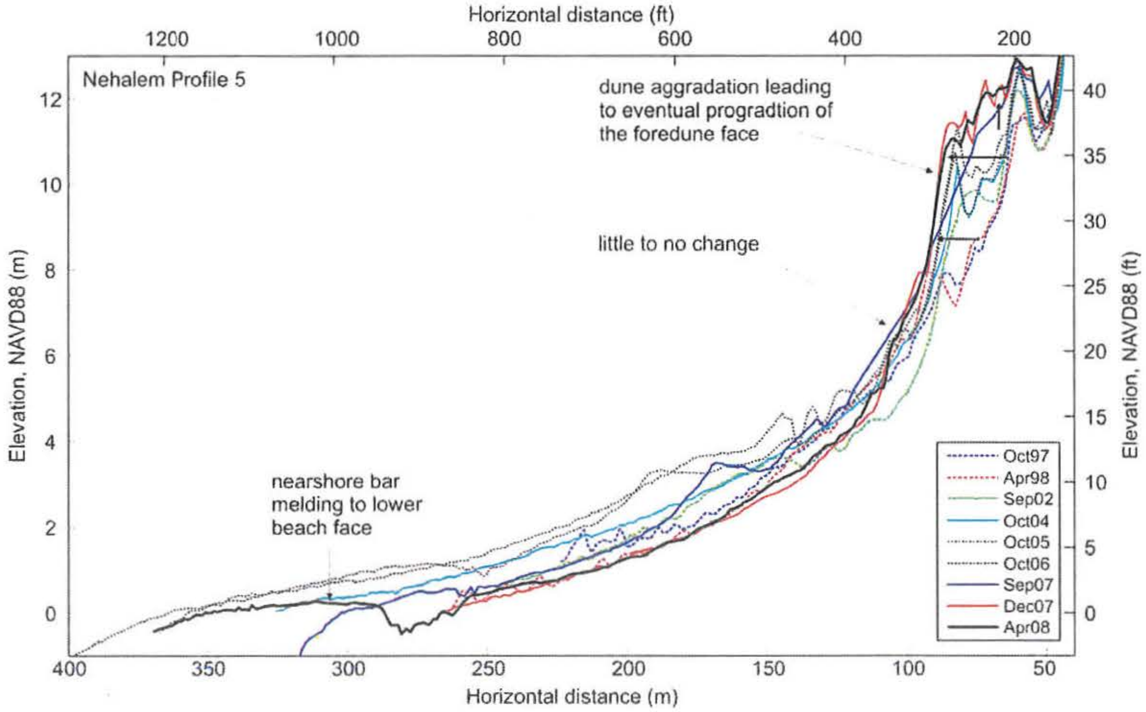

**Figure 12.** Summer beach profile measurements from surveys undertaken at site Neh5 on Nehalem Spit documenting buildup of sand on the foredune. NAVD88 is North American Vertical Datum of 1988.

### Volume changes and alongshore responses

Analyses of volume changes along the Rockaway littoral cell indicate that the cumulative effect of the 1997-1998 El Niño and 1998-1999 winters resulted in considerable erosion along much of the cell (Figure 13). These changes were derived from an analysis of lidar data undertaken by Allan and Hart (2007), which were based on a GIS beach profile database spaced at 100-m (300 ft) intervals along the shore. As can be seen in Figure 13, greatest sand volume losses occurred at mid-cell, between Tillamook and Nehalem bays near the towns of Twin Rocks, Rockaway, and Nedonna Beach, and along the southern end of Nehalem Spit. In contrast, the northern end of Bayocean and Nehalem spits gained sand, probably due to some northward migration of the sand. Nevertheless, sediment volume gains in the north are offset by the substantial net losses observed along the bulk of the shore. Summing the volume changes along the entire littoral cell indicates that the cumulative erosion of the beach and dune as a result of both winters resulted in the removal of 1,439,600 m$^3$ (1,883,000 yd$^3$) of sand from the beaches, the bulk of which was probably carried offshore, with some sand possibly carried into the bays.

As described above, recent surveys of the beaches in the Rockaway littoral cell indicate that the shore continues to erode, primarily in the region between Tillamook and Nehalem bays. Figure 14 shows the alongshore response of the beach determined at the 5-m (16 ft) contour elevation, representative of the juncture between the dune face and the beach crest. Included in the plot are data for the period 1997 to 2002, essentially capturing those beach changes that took place during the extreme winter storms of the late 1990s. As can be seen in Figure 14, the upper portion of the beach face/dune toe area continues to recede landward, with the most significant changes having taken place along the southern half of the Rockaway subcell, between the north jetty and the Rck5 beach profile site. Erosion has also occurred north of Rck5 and south of Rck7 to such a degree that much of this section of shore has now been hardened with riprap. In contrast, beach changes talking place on Bayocean and Nehalem Spits suggest some level of beach recovery. For example, the 5-m (16

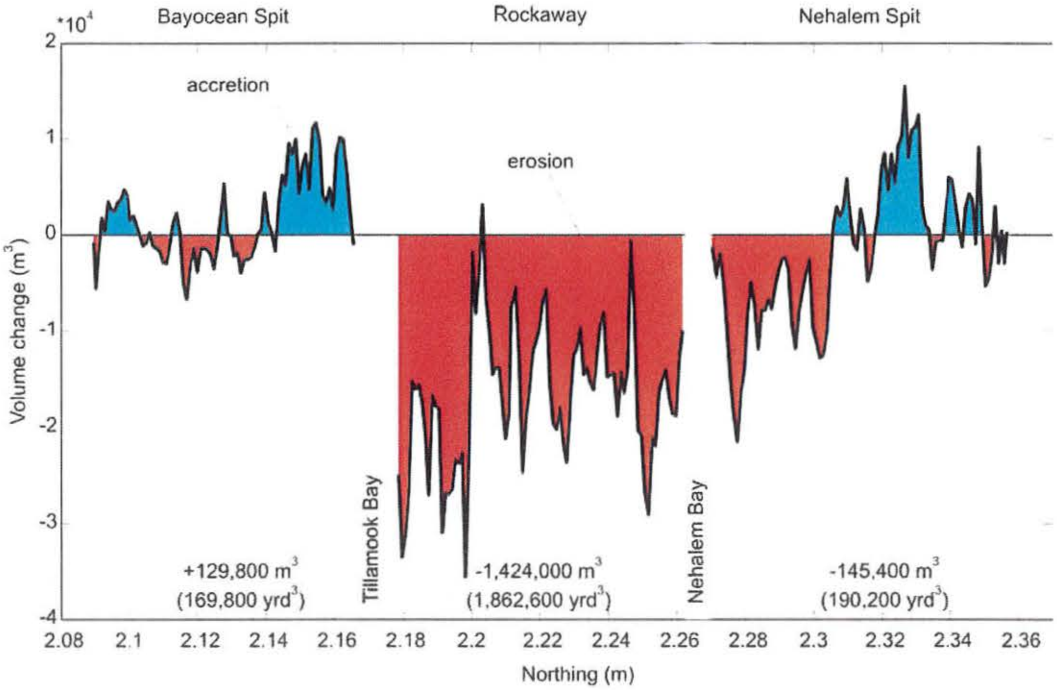

**Figure 13.** Alongshore beach volume changes (in cubic meters) derived from an analysis of available lidar data for the period 1997–2002. Data were derived from a re-analysis of lidar beach profile changes originally developed by Allan and Hart (2005, 2007). Red shading indicates erosion, blue shading indicates accretion.

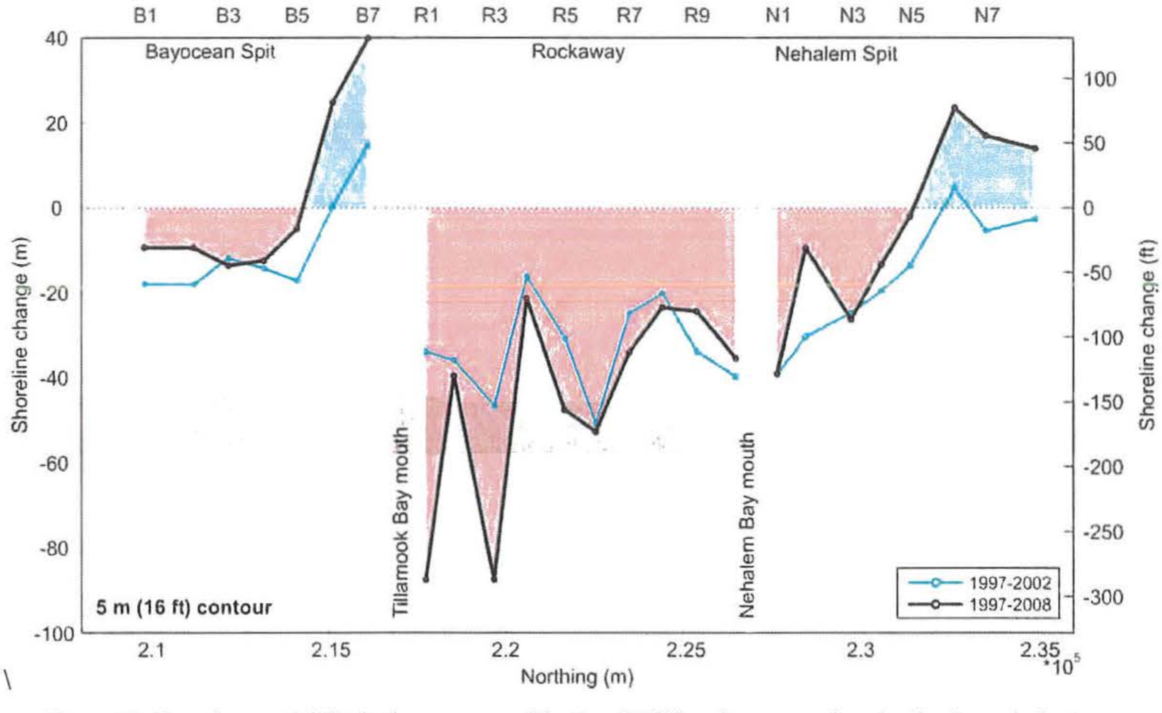

**Figure 14.** Alongshore variability in the response of the 5-m (16 ft) beach contour elevation for the periods 1997–2002 (derived from lidar) and 1997–2008 (lidar plus GPS surveys). Note the letters B, R, and N followed by a number denote the locations of profile sites. Red shading indicates erosion, blue shading indicates accretion.

ft) contour has begun to prograde seaward along the northern one third of Bayocean Spit, and the northern half of Nehalem Spit, with the sand tending to migrate up onto the dune face. From these ongoing changes, it is highly likely that the net volume of sand along the entire littoral cell remains in a state of net deficit compared to conditions in 1997, with the total loss of sand as of March 2008 estimated to be about 2 million cubic meters of sand (2.6 million cubic yards).

In summary, the measured responses identified by the combined lidar and RTK-DGPS survey data indicate that the beaches along the Rockaway subcell have continued to erode over time, with little to no evidence of recovery as of March 2008. Conversely, beaches along Bayocean and Nehalem Spits have recovered somewhat, while the northern ends of these two subcells have gained sand, relative to our lidar baseline measured in 1997. However, as was observed by Allan and Hart (2007), accretion in these two areas has been largely confined to a gradual buildup of sand on the primary frontal dune, raising its crest elevation over time. Thus, although these two sections of shore have accreted slightly over the past decade, the shoreline has not prograded seaward. Furthermore, the beaches along the littoral cell remain in a state of net deficit compared to their condition in 1997, with the estimated loss of sand as of March 2008 to be about 2 million cubic meters (2.6 million cubic yards) of sand. Whether the beach recovers fully and how long it takes remain important and interesting scientific and management questions, which can be answered only as the beaches continue to be monitored.

### Clatsop Plains beach changes

The Clatsop Plains are an arcuate shaped coastline that extends from Tillamook Head in the south to the mouth of the Columbia River (MCR) (Figure 1). The plains form part of a smaller subcell (34 km long) located within the much larger Columbia River littoral cell (CRLC), a 165-km coastal system that extends from Tillamook Head, Oregon, to Point Grenville, Washington.

The coastline of the Clatsop Plains is characterized by wide surf zones and prominent longshore bars in the nearshore, while the beaches are backed by an extensive dune sequence (Cooper, 1958; Woxell, 1998). The frontal foredunes that immediately back the beaches range in height from several meters to over 16 m (up to 53 ft high). These dunes increase in height from Seaside to Kyle Lake, and then decrease in height toward Clatsop Spit (Ruggiero and Voigt, 2000). The beaches are gently sloping (mean slope [*S*] of 0.032 ± 0.007), and have a somewhat lower beach slope when compared with slopes identified along the Tillamook County coastline (Allan and Priest, 2001). The sediments that comprise the beaches range in size from 0.14 to 0.25 mm (classified as medium- to fine-grained sand).

For the past few thousand years, the shorelines of the CRLC, including the Clatsop Plains, have accreted, causing the coastline to prograde seaward by a few hundred to several thousand meters. This process is thought to have begun around 4000 years ago, as the rate of sea-level rise slowed (Woxell, 1998). Woxell (1998) estimated that the Clatsop Plains historically accreted at an average rate of 0.7 m/yr (2.3 ft/yr) from about 4000 years BP to AD 1700. Between 1700 and 1885, accretion rates along the Clatsop Plains fell slightly to around 0.5 m/yr (1.6 ft/yr). The year 1885 is significant because this was when construction of the south jetty began.

The seaward advance of the Clatsop Plains shoreline has continued throughout the past 120 years, but at rates exceeding several meters per year due to large supplies of sand from the Columbia River, and as a result of jetty construction at the MCR (Gelfenbaum and others, 1999). Of particular significance has been the construction and subsequent extensions of the south jetty, which caused a dramatic increase in the rate of shoreline advance. According to Woxell (1998), since the late 1800s accretion rates along the Clatsop Plains have ranged from 2.0 to 5.8 m/yr (6.6 to 19 ft/yr), with an average rate of 3.3 m/yr (10.8 ft/yr), with the highest accretion rates identified near the MCR. However, since about the mid-1920s the rate of coastal advance has slowed, while erosion has been the dominant shoreline response along the northern end of Clatsop Spit. These latter adjustments may suggest a change in the overall sediment budget of the Columbia River cell, which could have important implications to the future stability of coastal shorelines adjacent to the MCR.

To better understand the changes taking place within the CRLC, the Washington Department of Ecology (WDoE) and the U.S. Geological Survey (USGS) initiated a joint study, the Southwest Washington Coastal Erosion Study (SWCES), to examine the causes of erosion hotspots that had begun to appear along the CRLC.

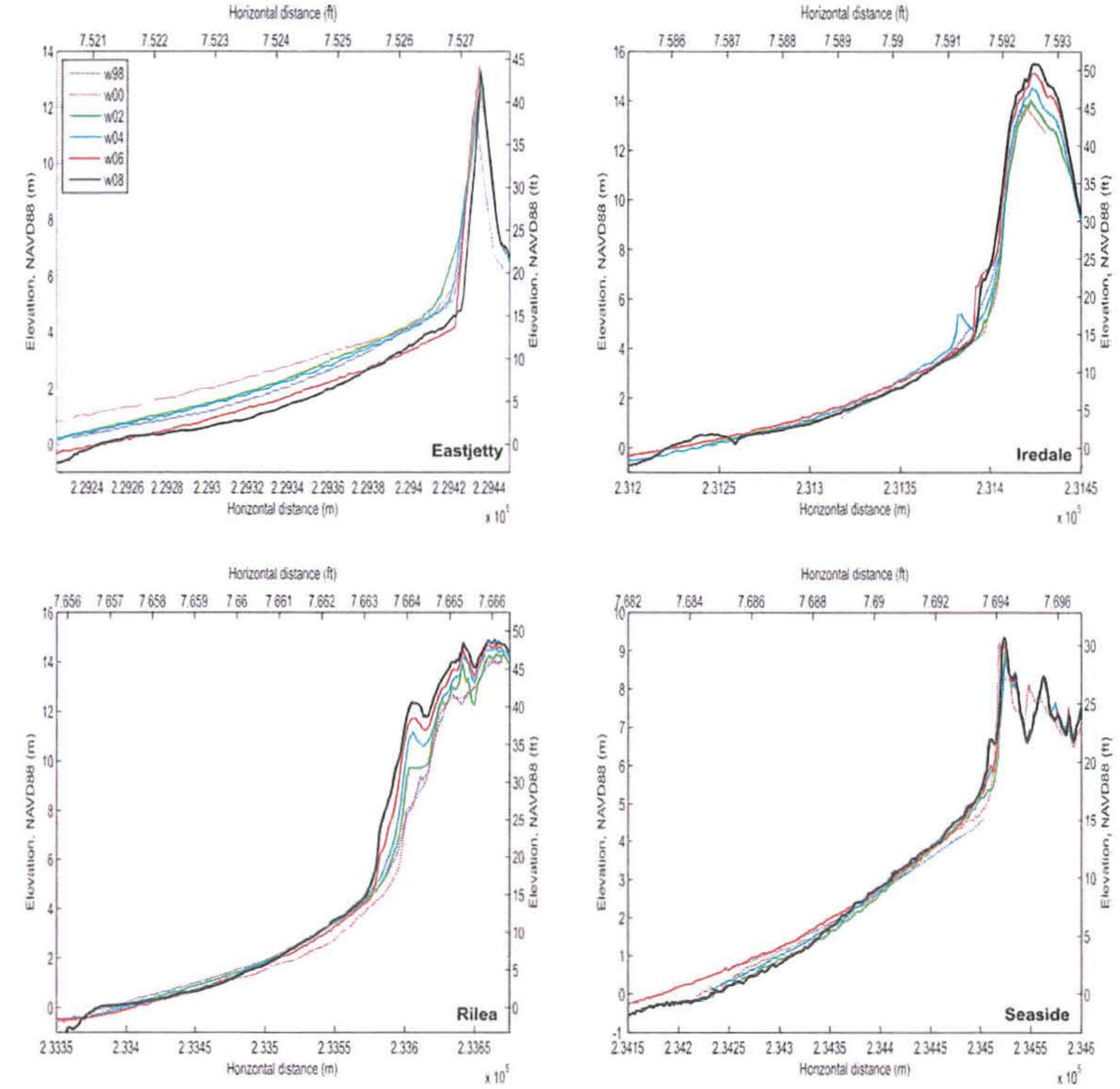

**Figure 15.** Beach morphological changes from surveys carried out between 1997 and 2008 along the Clatsop Plains subcell. Morphological changes shown in the figure are based on only the winter surveys undertaken in each year. Note: w in the legend signifies winter; beach surveys typically occurred in March. NAVD88 is North American Vertical Datum of 1988.

As part of this effort, the WDoE and the USGS developed and implemented a beach monitoring program along the full length of the CRLC. Within the Clatsop Plains subcell, six beach monitoring sites were established in 1997 (Figure 1) and have been surveyed on a seasonal basis since their inception. In 2005, a "technology transfer" was implemented between the WDoE and DOGAMI staff that resulted in DOGAMI staff taking over the monitoring of the beach profile sites.

Figure 15 shows the profile changes measured at four of the transect sites: Seaside, Rilea, Iredale, and Eastjetty. Beginning in the north at the Eastjetty site, Figure 15 indicates that the Eastjetty site eroded landward as a result of the storms of the late 1990s. One caveat here is that the winter 1998 survey is quite different from the other surveys and may reflect a survey that was carried out at the wrong location. By the late 2002 winter, the beach and dune had effectively rebuilt itself. However, since then the Eastjetty site has been steadily eroding (Figure 16), causing the foredune width to narrow over time. The current foredune width is 14 m (45.9 ft), down from 19 m (62.3 ft) in the winter of 2002. As a result, additional erosion of this shore section could easily breach the dune. Farther south at the Iredale site, morphological changes of the beach again indicate the impact of the storms of the late 1990s, which caused the beach to initially erode. However, since then the beach has been gradually rebuilding and by 2005 had essentially rebuilt itself. Probably the most significant change taking place at the Iredale site is the degree of aggradation occurring on the crest of the foredune (Figure 15). As can be seen in the figure, between 1997 and 2008 the foredune grew vertically by about 1.6 m (5.2 ft), resulting in a net gain of 90 $m^3$ of sand per meter of beach ($m^3 \times m^{-1}$) or 118 $yd^3$ per yard of beach. With progress south along the plains, aggradation on the foredune becomes even more significant, while changes on the beach face tend to be relatively minor. For example, net volume gains were measured at Kim (135 $m^3 \times m^{-1}$ [177 $yd^3 \times yd^{-1}$]), Rilea (259 $m^3 \times m^{-1}$ [339 $yd^3 \times yd^{-1}$]) and at Delray (159 $m^3 \times m^{-1}$ [208 $yd^3 \times yd^{-1}$)]). From these values and the length of shore between the transects a conservative estimate of the net sediment volume gain between 1997 and 2008 is 3.4 million cubic meters (4.5 million cubic yards) of sand. Given that the mean shoreline position at each of the beach profile sites has not changed substantially (i.e., prograded seaward), the bulk of the sediment gains reflect net gains on the foredune.

**Figure 16.** Surveying at the Eastjetty site on December 20, 2007. High waves associated with the December 2-3, 2007, storm eroded the dune toe, leading to its destabilization. Given the current foredune width of 14 m (45.9 ft), further erosion of this site will not take much to "punch" a hole through dune.

## THE 2007-2008 WINTER STORMS

This section examines erosion and flood hazards that occurred over the 2007-2008 winter season. Here we briefly discuss changes that took place in the Neskowin and Rockaway littoral cells.

The 2007-2008 winter season was characterized by at least seven major storms (Figure 17), where a major storm is defined as an event in which the significant wave heights exceeds 6 m (20 ft) for a period of 9 hours or greater (Allan and Komar, 2000). By far the most significant of these events was the December 2-3, 2007, storm, which was the largest not only in terms of measured significant wave heights but also because the waves exceeded 10 m (33 ft) for a total period of 18 hours. As can be seen in Figure 17, the significant wave heights peaked at 14.6 m (47.9 ft) and are associated with a 1.1-m (3.6 ft) storm surge (the difference between the measured and predicted tides). Figure 17C also shows the estimated total water level for this event, which reflects the calculated wave runup plus the measured tide. The wave runup was determined using the Stockdon and others (2006) equation (19), which relies on knowledge of the deepwater wave height, peak spectral wave period, and beach slope. As shown in Figure 17C, the total water levels peaked at about 7.1 m (22.3 ft), effectively raising the mean shoreline elevation and thereby allowing the waves to attack the dunes directly and to erode them. GPS measurements of rack/strandline deposits along Neskowin beach indicated total water elevations on the order of 6.5 to 7.4 m (21.3 to 24.3 ft), increasing our confidence in the calculated total water levels shown in Figure 17. Also apparent is a second major storm that occurred January, 5, 2008. Although this event did not produce large waves (the waves were on the order of 9 m (29.5 ft) relative to the

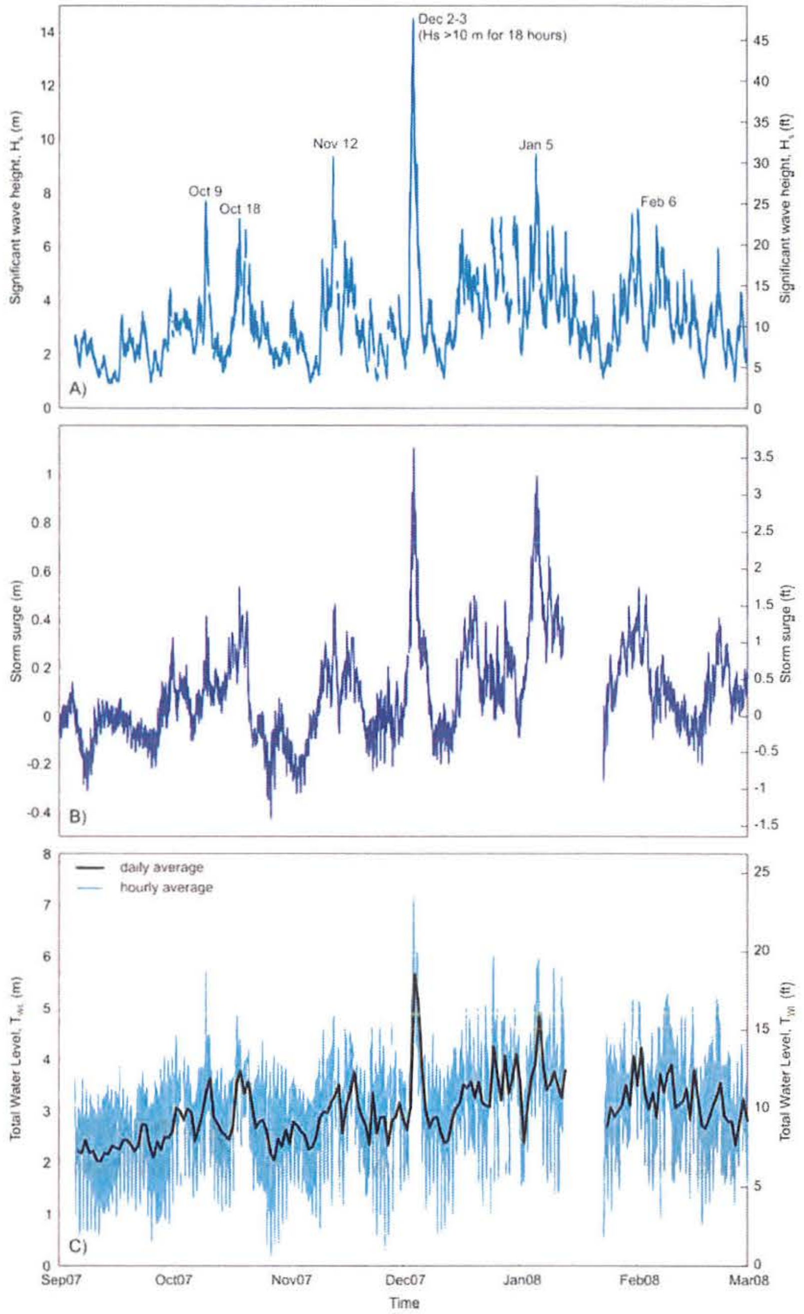

**Figure 17.** A) Significant wave heights measured by the Tillamook NDBC wave buoy (#46089) over the 2007-2008 winter. B) Storm surge derived by subtracting the predicted tide from the measured tide and based on the Garibaldi tide gauge. C) Hourly total water levels determined from the calculated wave runup plus the measured tide. Wave runup was calculated using the Stockdon and others (2006) equation (19) using a beach slope of 0.04.

December 2007 storm, the event did coincide with high tide that again helped to raise the elevation at which the wave swash could impact the shore. As a result, this event generated the second highest total water levels for the 2007-2008 winter, aided by the high storm surge (reaching 1 m [3.3 ft]) that characterized this event.

The effects of the 2007-2008 winter were widely felt along the Oregon coast, resulting in significant erosion in Neskowin, Netarts, Rockaway; the exhumation of a ship down on the north spit of Coos Bay and cannons at Cannon Beach; and erosion at Garrision Lake near Port Orford. At Neskowin, the storm contributed to as much as 25 m (82 ft) of dune retreat midway along the beach and north of the town of Neskowin. Slightly smaller erosion responses were observed to the north at Cape Lookout State Park, with the dune there retreating by 8.8 m (29 ft), eventually destroying a drain field constructed in the foredune that serves the park. At Neskowin, the formation of a rip embayment north of Proposal Rock during late summer 2007 broadened significantly over the course of the winter. In response to the combination of extreme waves, the high ocean water levels due to the occurrence of a storm surge, and the location of the rip embayment, wave breaking was able to occur close to shore, scouring down the beach face and eventually undermining the toe of a riprap structure and causing part of the structure to fail (Figure 18). Measurements of the beach elevation in April 2008 and obtained along the toe of the riprap indicated an extreme low beach elevation of 0.1 m (0.3 ft) above (mean lower low water (MLLW), while the beach elevation was typically less than 0.5 m (1.6 ft) along about 200 m (656 ft) of riprap. As a result, waves were able to impact the riprap wall at essentially all tidal elevations (Figure 19). During moderate wave events, green water was also observed to go over the top of the riprap wall, which has a crest elevation of 8.8 m (28.9 ft) affecting those properties built adjacent to the eroding shore (Figure 20).

Farther north in the Rockaway subcell, erosion issues were observed just south of Twin Rocks near an RV park built next to the ocean (Figure 21) as well as at the north end of Rockaway beach. In both cases, the problem was related to the presence of a rip embayment that lowered the beach elevation, decreasing its buffering capabilities. At the RV park, a survey of the shoreline

**Figure 18.** Erosion during a storm on January 5, 2008, eventually caused part of a riprap wall to fail in the town of Neskowin. (Photo courtesy of the The Breakers Condominiums, Neskowin, Oregon.)

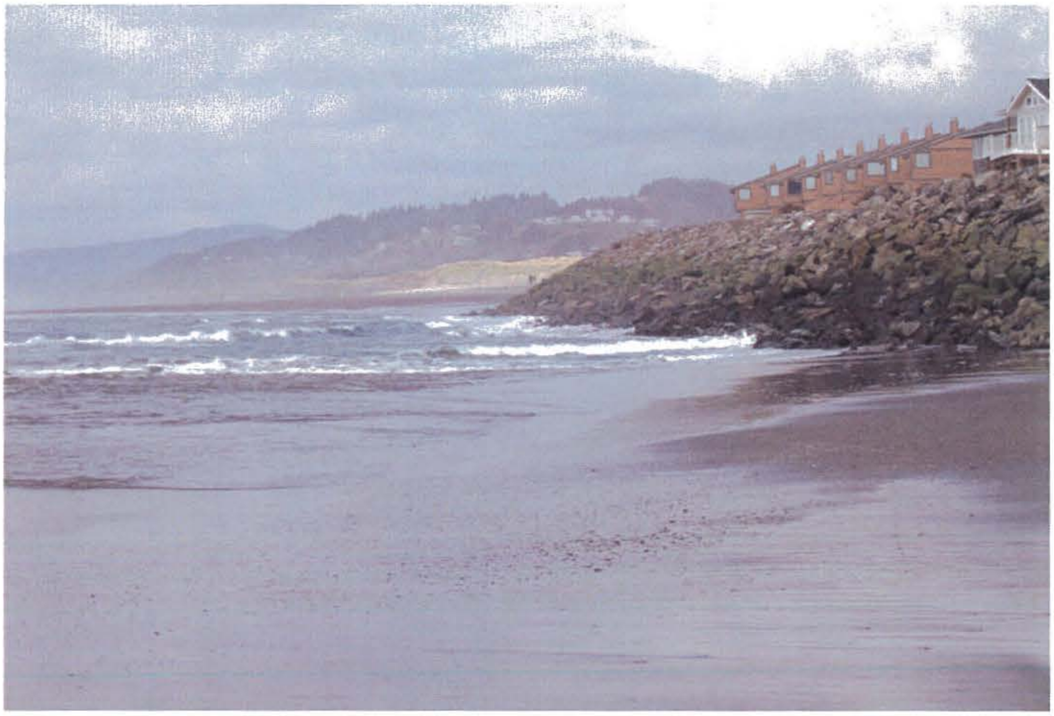

**Figure 19.** Development of a rip embayment north of Proposal Rock in Neskowin removed much of the fronting beach that would otherwise have protected the riprap structure shown above. Extreme lowering of the beach elevation means that the structure is being impacted by ocean waves at all tidal elevations. (Photo taken at low tide by J. C. Allan on April 15, 2008.)

**Figure 20.** Overtopping of waves during the January 5, 2008, storm caused flooding and damage to ground floor condominium units located in Neskowin. Note that the crest elevation of the graded dune is 8 m (26 ft), while the condominium units are located approximately 6 to 10 m (20 to 30 ft) from the top of the riprap revetment. (Photo taken on January 9 at high tide.)

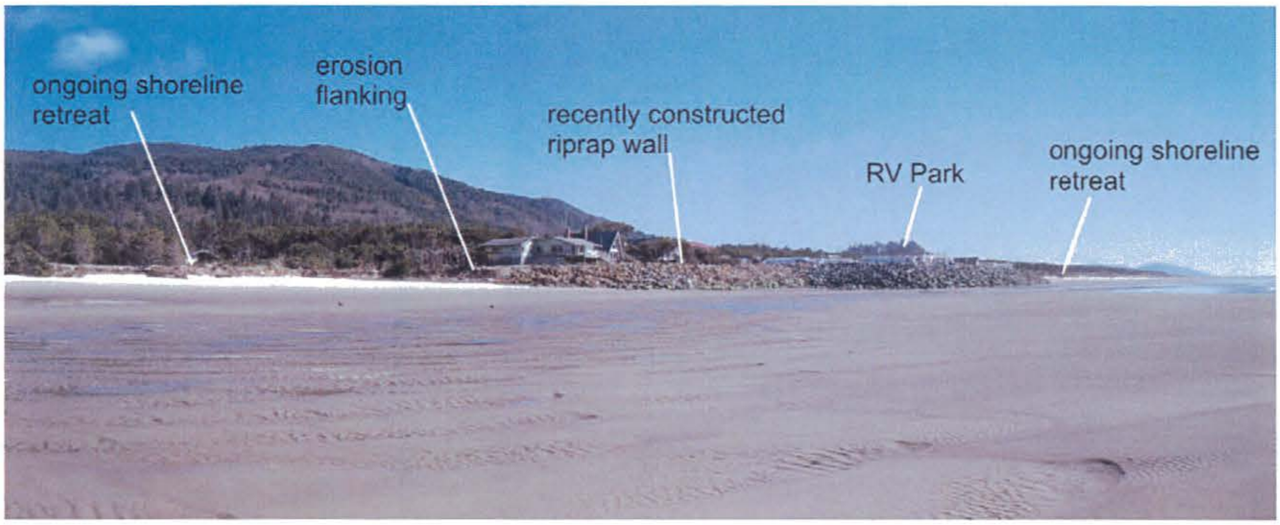

**Figure 21.** View south toward the RV park located south of Twin Rocks in the Rockaway subcell and erosion taking place to the north and south of the park.

undertaken at the end of the 2007-2008 winter highlights the changes that have taken place to the north and south of the RV park (Figure 22). As described previously, much of the Rockaway subcell has continued to erode landward following the extreme storms of the late 1990s. The erosion has been especially acute along the southern portion of the cell, south of about Rck4, including the area south of Rck4 and including the RV park shown in Figure 21. At the conclusion of the 2007-2008 winter, the RV park now stands out on the beach as the shoreline to the north and south of the park has receded landward (Figure 22). As can be seen in Figure 22, the beach north of the park receded landward by about 50 m (164 ft). In response to the erosion, an emergency permit for the construction and extension of a riprap revetment was issued for three homes north of the RV park. Since then, additional retreat of the shoreline north of northernmost home (Figure 21) has begun to flank the home (Figure 22). At this stage, the expectation is that the shore will continue to retreat to the north and south of these homes. Eventually, this could result in the need for these properties to be "ringed" by rock in order to protect the homes from erosion that is now occurring on all sides of the properties. The costs to maintain the riprap wall could become prohibitive and result in the property owner abandoning the site. At that point, all property owners would be at risk. This evolving situation also applies at several sites at Neskowin and at north Neskowin. Given the current state of low beach sand volumes along the much of the Neskowin and Rockaway shore, and ongoing concerns over climate change and more severe storms, the situation in these two areas alone remains extremely bleak.

To better understand the relative significance of the 2007-2008 winter compared with the previous 1998-1999 extreme winter, a wave-height frequency distribution analysis was performed. The wave-height data shown in Figure 23 were derived from the National Data Buoy Center (NDBC) buoy #46050 (average curve and 1998-1999 winter) and from the Tillamook buoy #46089 (2007-2008 winter) since buoy #46050 was out of commission. In all cases the waves heights analyzed reflect only the winter waves measured between October and March. The frequency values have been plotted on a log scale in order to emphasize the occurrence of the larger wave heights, which naturally have a much lower frequency of recurrence.

As can be seen in Figure 23, wave heights typically average about 3 m (9.8 ft) during winter, increasing to as much as 14 to 15 m for the most extreme storms. Of interest, conditions during the 2007-2008 winter averaged 3.4 m (11.2 ft), slightly above the long-term average, while the wave heights during the 1998-1999 winter averaged 3.8 m (12.5 ft). Of greater interest are the differences in the curves for the higher wave heights. As can be seen in Figure 23, measured wave heights during

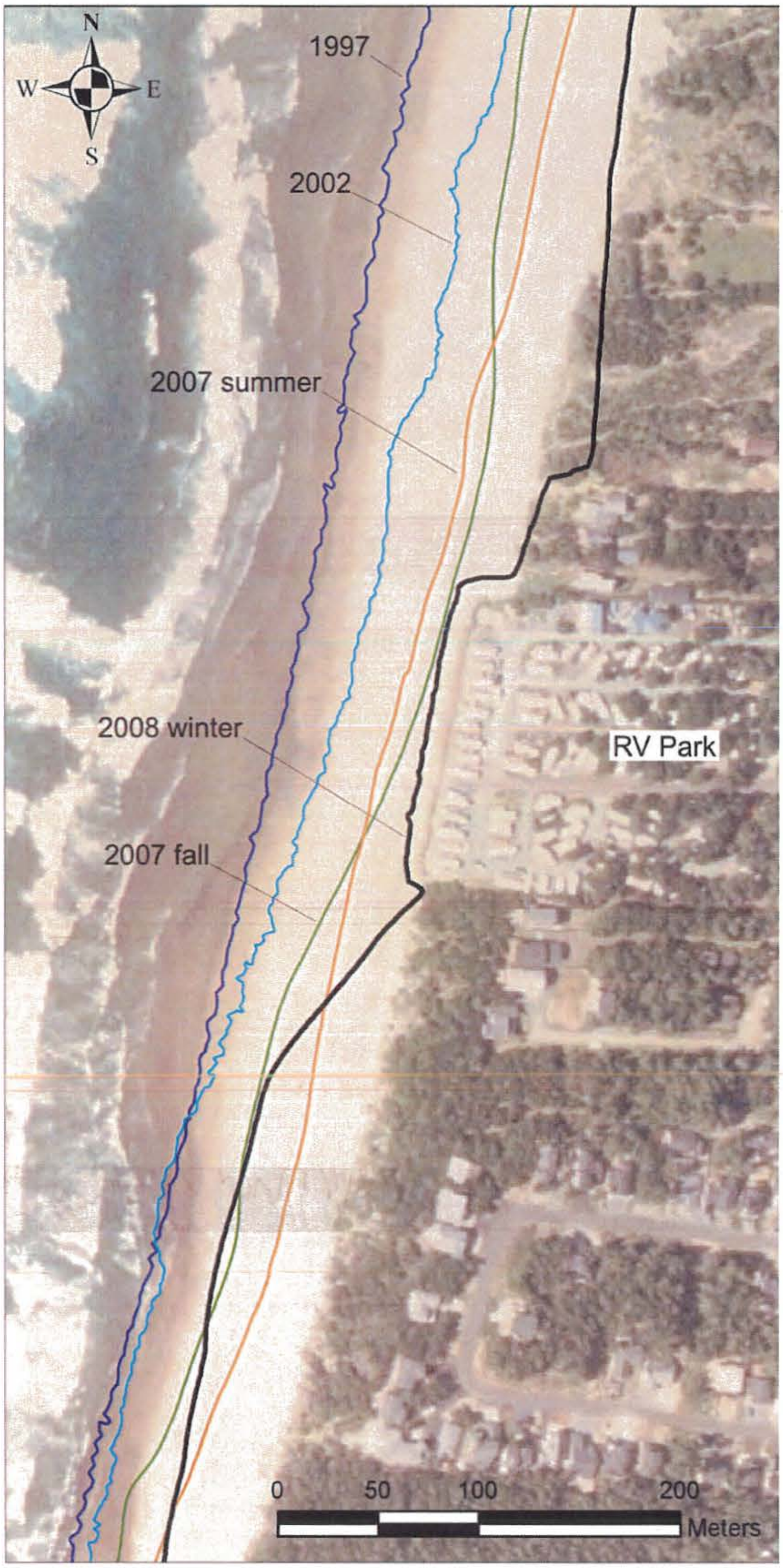

**Figure 22.** Plan view showing the extent of erosion along a portion of the Rockaway subcell. Mean Higher High Water (MHHW) shorelines derived from lidar (1997 and 2002) and from a Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) mounted on an ATV vehicle (post-2002) demonstrate the degree of erosion that has taken place at this site during the past decade. Total shoreline change at the RV park reflects approximately 300 feet of erosion.

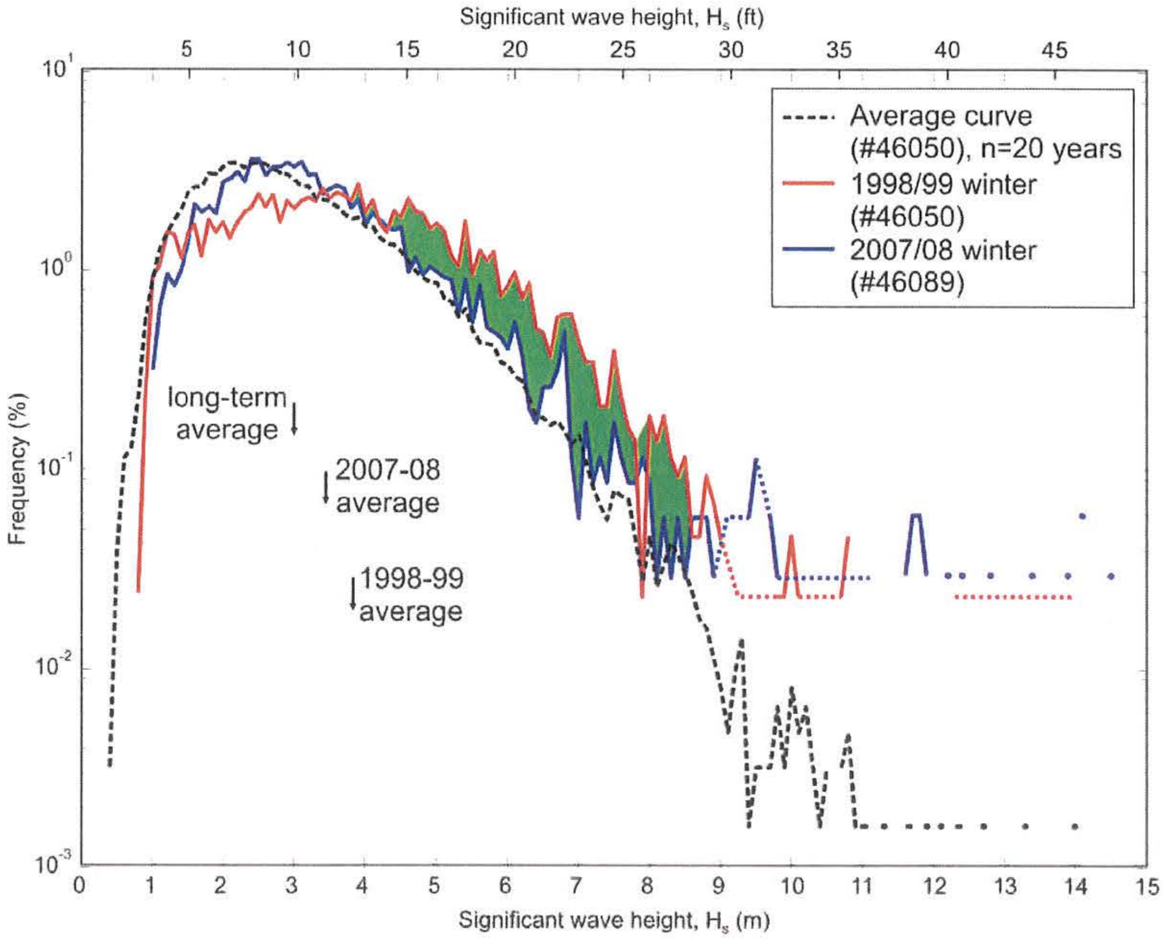

**Figure 23.** Comparison plot of 2007-2008 winter storm waves (blue) relative to the extreme 1998-1999 winter (red), and the long-term average curve for NDBC buoy #46050 (black). Green shading denotes a larger number of measured waves in the range of > 4 and < 9 m (>13 and < 29.5 ft) observed during the 1998-1999 winter, compared with the 2007-2008 winter.

the 1998-1999 winter well exceed the long term average curve, particularly for those wave heights > 4 and < 9 m (> 13 and < 29.5 ft). In contrast, 2007-2008 winter waves generally track close to the long-term average, and it is not until wave heights exceed 9 m (29.5 ft) that the curves begin to depart from the long-term average. These differences provide a stark reminder of the current level of risk facing many oceanfront property owners, particularly given that many of the beaches in Tillamook County have not recovered from the effects of past storms and hence the ability of the beaches to provide a buffering capacity against high waves is presently reduced. To that end, a worst-case scenario facing coastal communities in Tillamook County is a repeat of the 1998-1999 wave conditions, which would almost certainly result in significant damage to oceanfront property and infrastructure. Given the erosion responses observed in 2007-2008, and the state of the beach today, the prognosis remains bleak for beaches in Tillamook County for the immediate future.

# CONCLUSIONS

This report has presented the results of a collaborative effort by DOGAMI and the DLCD to maintain a comprehensive beach monitoring program on the Oregon coast, with the surveys used to document short- and long-term responses of the beaches. The establishment and repeated monitoring of beach and shoreline observing systems such as the those established at Rockaway, Neskowin, the Clatsop Plains and, more recently, in the Newport littoral cell, are capable of providing critical information to scientists and coastal resource managers concerning the response of Oregon's beaches to major storms, the effects of climate events such as the El Niño Southern Oscillation (ENSO) phenomena, sediment transport patterns, variations in the beach sediment budget, and longer-term impacts associated with climate change and sea level rise.

A major aspect of this study and of a similar beach monitoring efforts underway on the Oregon coast (http://www.oregongeology.org/sub/nanoos1/index.htm) is that as the beach survey data are collected, the information is placed on DOGAMI's website for rapid access and viewing by other state agency officials, researchers, and the public at large. This approach has received considerable support and is rapidly gaining ground with members of the geotechnical community, who are beginning to use the measured information in their studies. In this respect alone, the beach monitoring effort has begun to pay off: officials are now able to respond to various beach erosion issues on the basis of on sound scientific information.

Our beach monitoring efforts completed thus far along the Rockaway and Clatsop littoral cell have identified a number of interesting aspects of large-scale beach responses:

- The cumulative effect of the 1997-1998 and 1998-1999 winters resulted in extensive erosion along the Rockaway littoral cell and reflects some of the largest erosion responses observed on the Oregon coast. The degree of change observed and the level of beach rebuilding that has taken place since then varies along the shore.
    - Erosion continues to plague much of the Rockaway subcell, which has continued to recede landward up to the present. The area presently experiencing the highest beach erosion changes is occurring north of Tillamook Bay and south of the Rockaway High School;
    - North of Rockaway High School and south of the Nehalem jetties, beaches have been slowly gaining sand and, hence, are gradually rebuilding following the extreme storms of the late 1990s.
    - Erosion continues to affect the southern half of Bayocean Spit, while the northern third of the spit has effectively been rebuilt and is now beginning to prograde (advance) seaward;
    - Similarly, erosion continues to plague the southern half of Nehalem Spit, while the northern third has gained some sand.
- The beaches along the Rockaway littoral cell remain in a state of net deficit compared to 1997, with the loss of sand for the period 1997–2002 estimated to be about 1,439,600 m$^3$ (1,883,000 yd$^3$). Given that much of the Rockaway subcell has continued to erode and lose sand, we estimate that as of March 2008 the net sand loss from the cell is likely to be on the order of 2 million cubic meters of sand (2.6 million cubic yards). Whether the beaches recover fully and how long it takes remain important scientific and management questions, which in time will be answered by continued beach monitoring.
- Post-storm recovery has been slow, limited to the lower beach face, and restricted to parts of Bayocean Spit, Nedonna Beach, and at the north end Nehalem Spit. The lack of significant sand accumulation high on the beach face in recent years suggests that the present climate may not be conducive for transporting sand landward from the beach face.
- In contrast to the Rockaway cell, measured beach changes on the Clatsop Plains indicate that although this section of shore was also affected by the extreme storms of the late 1990s, the degree of impact was much less; beaches fully recovered within a matter of 1 to 2 years. The one exception are those shoreline changes taking place at the north end of the subcell and just south of the south jetty. Repeated beach surveys at the East-jetty profile site has revealed that the beach has

been slowly eroding landward. Given its narrow foredune width, it is likely that parts of this dune system could be breached in the near future.

- Beach monitoring on the Clatsop Plains indicates that the main foredune has steadily gained sand over the past several years. We estimate that the net sediment volume gain for the period 1997 to 2008 is about 3.4 million cubic meters (4.5 million cubic yards) of sand.
- The 2007-2008 winter caused severe erosion at selected sites in the Rockaway subcell (south end of the cell) and north of the town of Rockaway; erosion and damage to facilities at Cape Lookout State Park (including significant damage to the dynamic revetment constructed there to protect the park); damage to riprap revetments at multiple locations on the north coast but most notably at Neskowin; and exhumed cannons at Cannon Beach and a boat near Coos Bay. In the majority of the cases, erosion was enhanced due to the formation of rip embayments in those areas, allowing waves to break close to the shore with little loss in the incident wave energy.
- An analysis of the wave and water levels associated with the 2007-2008 winter compared with the long-term average and past extreme winters indicates that the 2007-2008 winter was not as severe as past winter seasons (e.g., the 1998-1999 winter). Despite this difference, the 2007-2008 winter was characterized by one major storm and several minor events, which resulted in significant erosion at Neskowin, Cape Lookout State Park, and in Rockaway, with the degree of erosion accentuated due to the lack of any post-storm beach recovery at those sites. As a result, given that many beaches in Tillamook County have continued to see very little post-storm recovery in the intervening years between successive winters (i.e., beaches today are narrower and have less sand volume compared with beaches in the mid 1990s), the communities of Neskowin and Rockaway in particular remain at high risk of being affected by both coastal erosion and ocean flooding in the ensuing winter seasons.

As additional surveys are completed and analyzed, patterns of sand transport within the littoral cells will become clearer. Of importance, we now have a system in place that can be used to better document and understand the changing beach morphodynamics, including the tracking of large-scale sand movements within the cell, the effects of future storms, and any post-storm recovery. In time, such information can be used to further evaluate and refine coastal hazard "setback" zones that are being developed by DOGAMI.

### ***Acknowledgments.***

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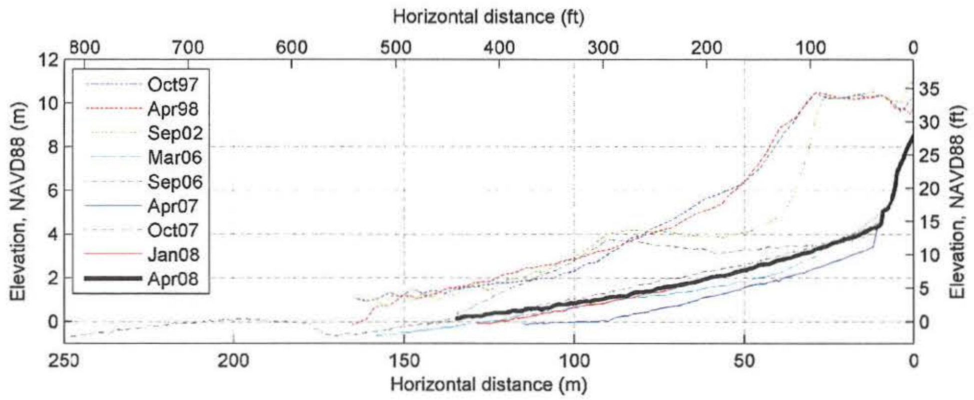
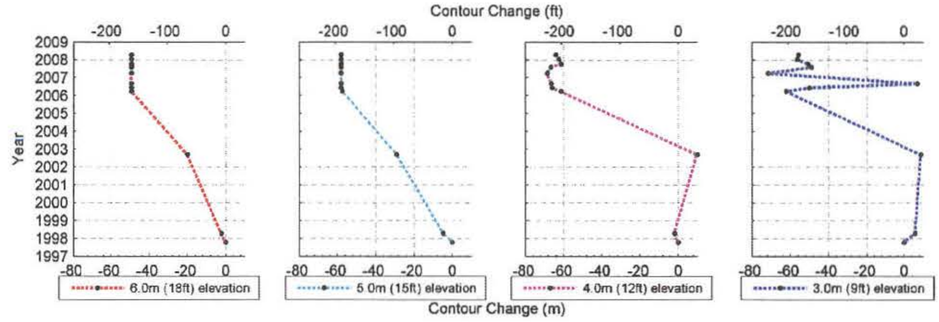
# APPENDIX A:
# COMBINED BEACH PROFILE AND EXCURSION DISTANCE ANALYSIS "CONTOUR" PLOTS

For each site shown, the upper plot is a conventional beach profile plot, which depicts the two-dimensional response of the beach to variations in the incident wave energy. The four lower plots reflect contours of greater interest due to their proximity to the dune toe (e.g., the 6.0-m and 5.0-m contours) or to Mean Higher High Water (MHHW) mark (e.g., the 3.0-m contour). The 1997 data have been used in the four lower plots as a baseline as this reflects the first comprehensive survey of the shape and position of the beach.

## Neskowin sites

### Nesk1:





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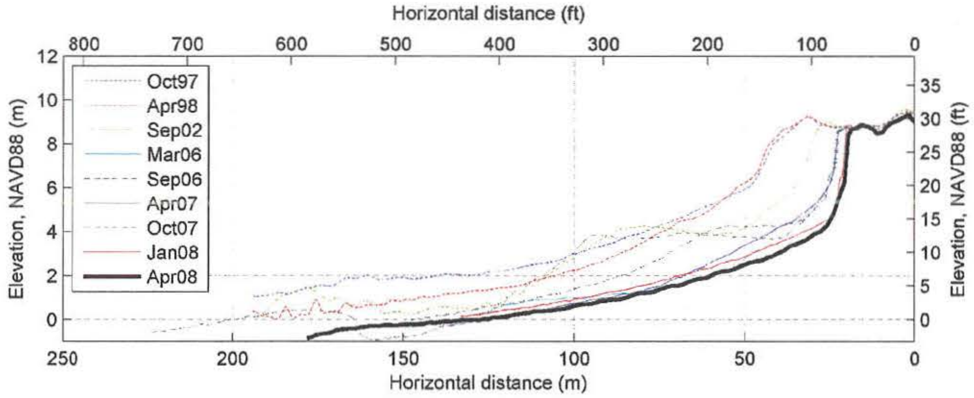
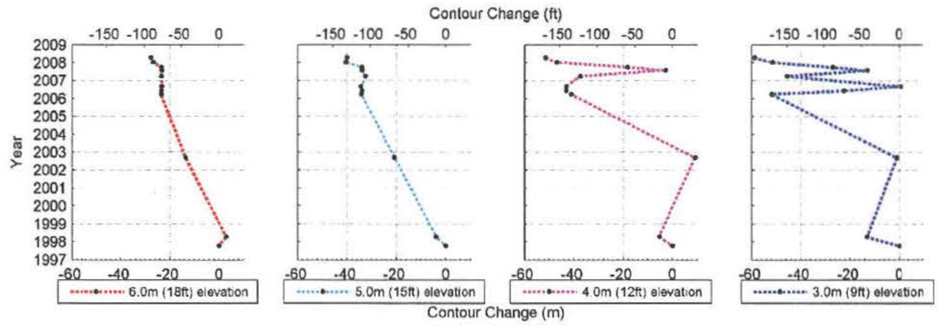
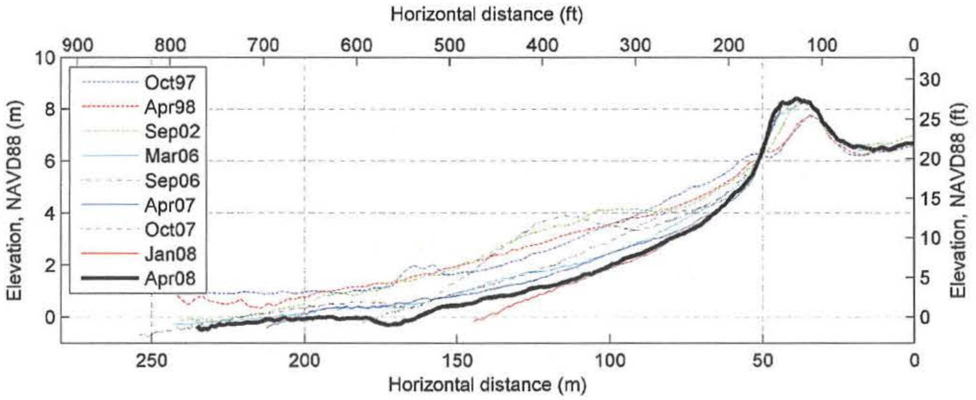
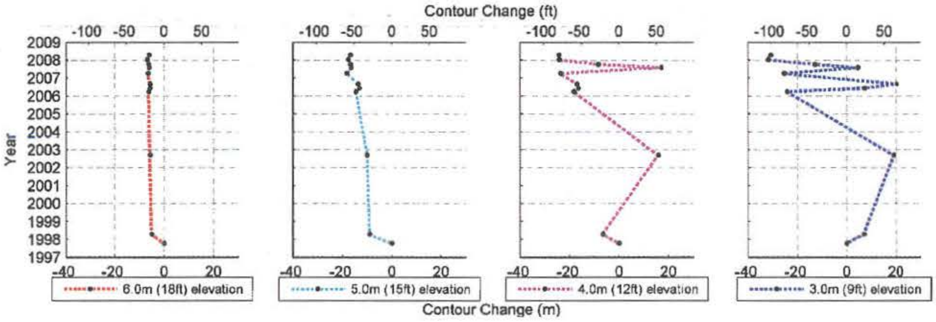


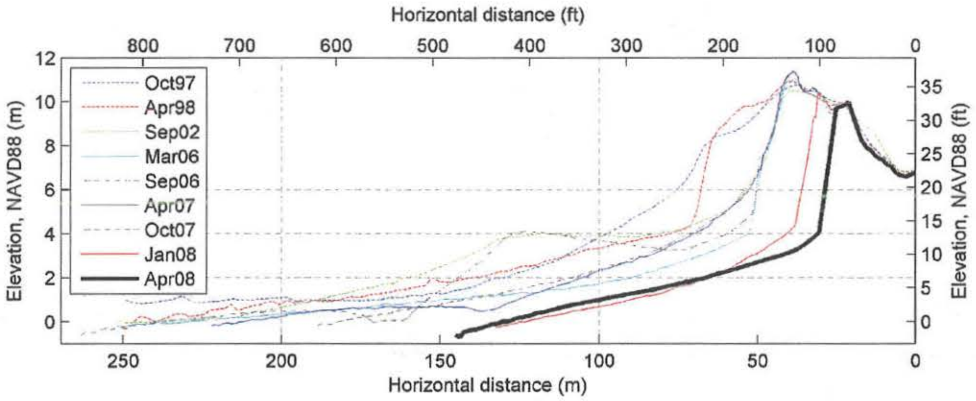


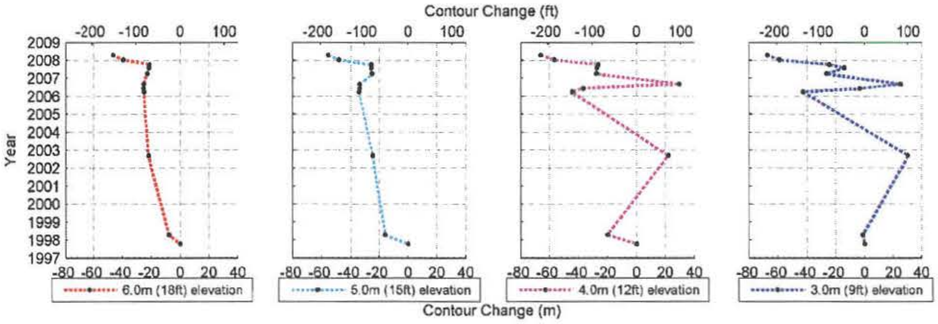
**Nesk3:**


Horizontal distance (ft)
900
800
700
600
500
400
300
200
100
0
Elevation, NAVD88 (m)
10
8
6
4
2
0
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
30
25
20
15
10
5
0
Elevation, NAVD88 (ft)
250
200
150
100
50
0
Horizontal distance (m)

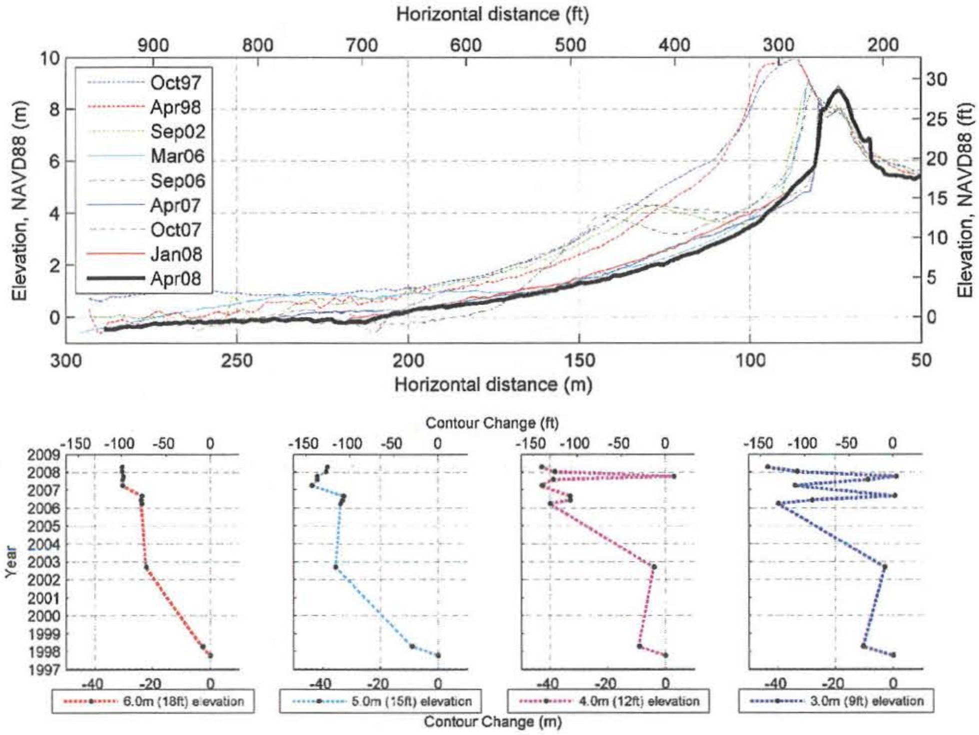

Contour Change (ft)
-100 -50 0 50
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-40 -20 0 20
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

**Nesk4:**

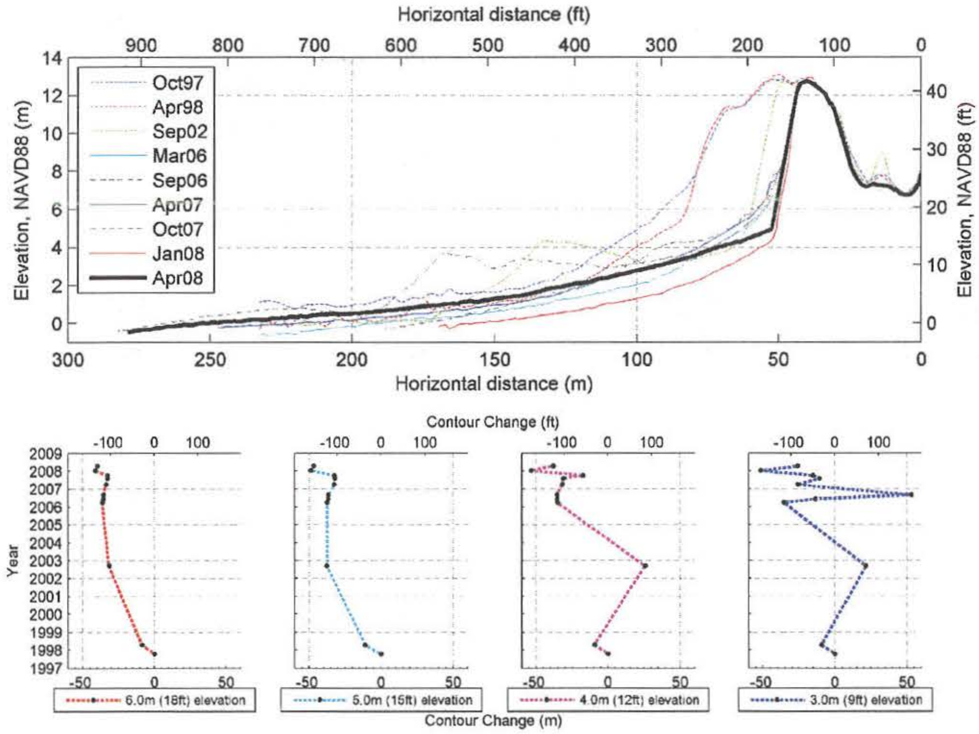

Horizontal distance (ft)
800
700
600
500
400
300
200
100
0
Elevation, NAVD88 (m)
12
10
8
6
4
2
0
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
35
30
25
20
15
10
5
0
Elevation, NAVD88 (ft)
250
200
150
100
50
0
Horizontal distance (m)


Contour Change (ft)
-200 -100 0 100
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-80 -60 -40 -20 0 20 40
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

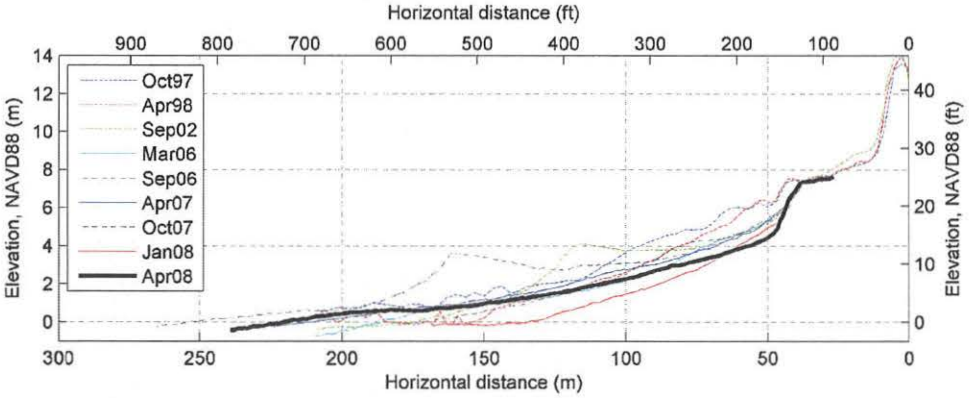
**Nesk5:**

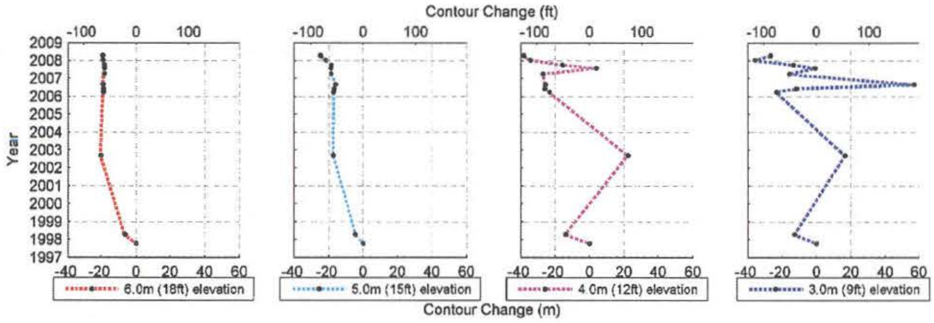

Horizontal distance (ft)
900
800
700
600
500
400
300
200
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
300
250
200
150
100
50
Horizontal distance (m)
Contour Change (ft)
Year
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

**Nesk6:**

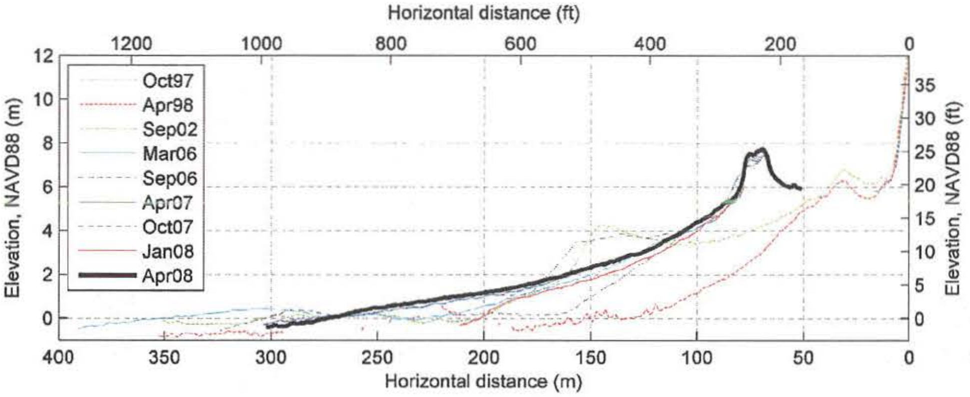

Horizontal distance (ft)
900
800
700
600
500
400
300
200
100
0
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
300
250
200
150
100
50
0
Horizontal distance (m)
Contour Change (ft)
Year
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

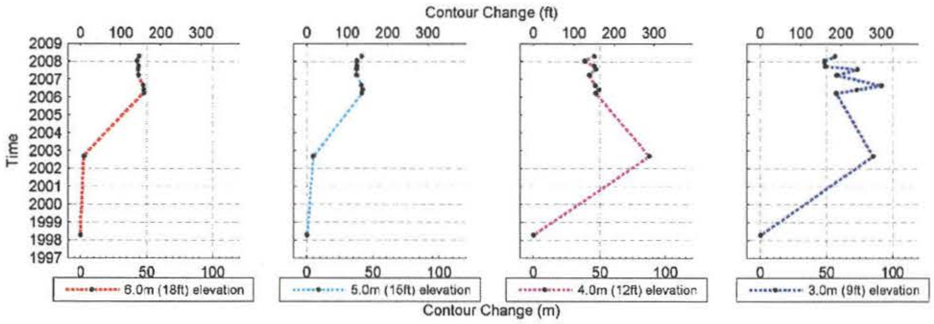
**Nesk7:**


Horizontal distance (ft)
900
800
700
600
500
400
300
200
100
0
Elevation, NAVD88 (m)
14
12
10
8
6
4
2
0
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
Elevation, NAVD88 (ft)
40
30
20
10
0
300
250
200
150
100
50
0
Horizontal distance (m)

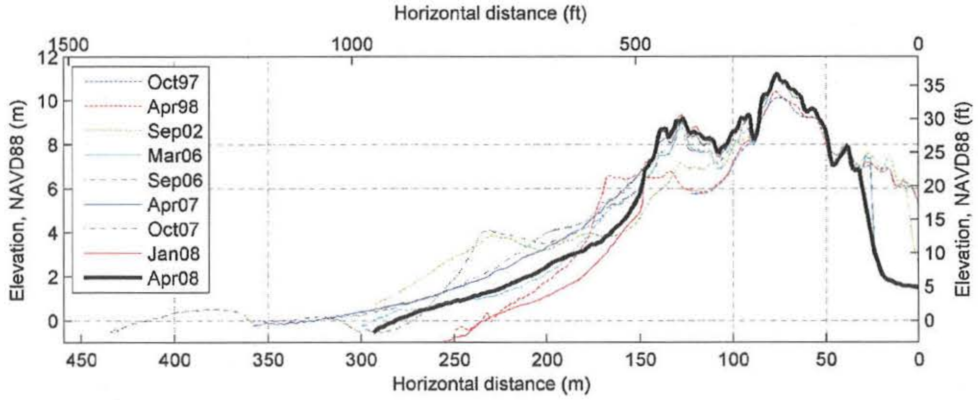

Contour Change (ft)
-100
0
100
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-40
-20
0
20
40
60
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

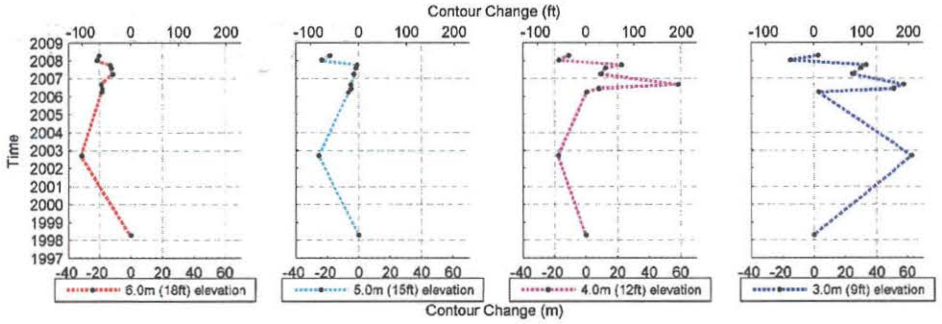
**Nesk8:**


Horizontal distance (ft)
1200
1000
800
600
400
200
0
Elevation, NAVD88 (m)
12
10
8
6
4
2
0
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
Elevation, NAVD88 (ft)
35
30
25
20
15
10
5
0
400
350
300
250
200
150
100
50
0
Horizontal distance (m)

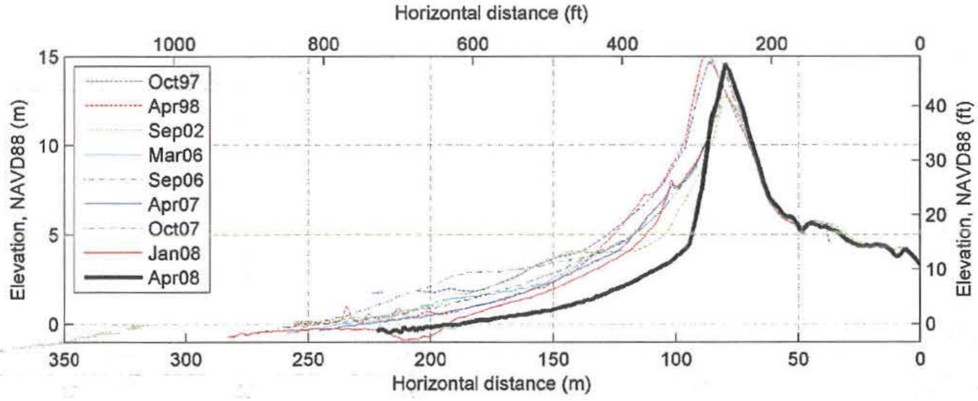

Contour Change (ft)
0
100
200
300
Time
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
0
50
100
6.0m (18ft) elevation
5.0m (16ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

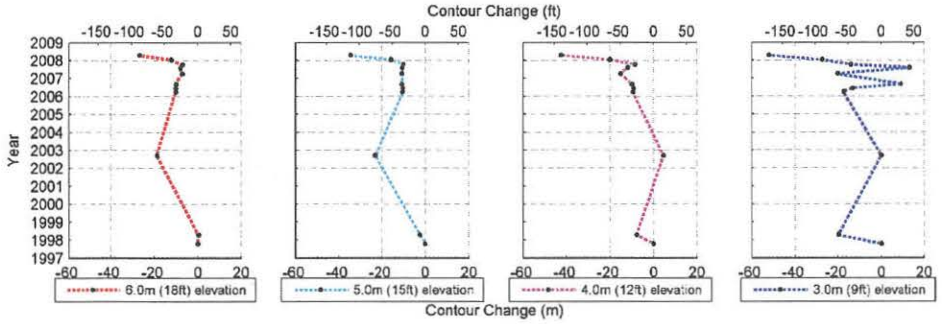
**Nesk9:**





**Nesk10:**





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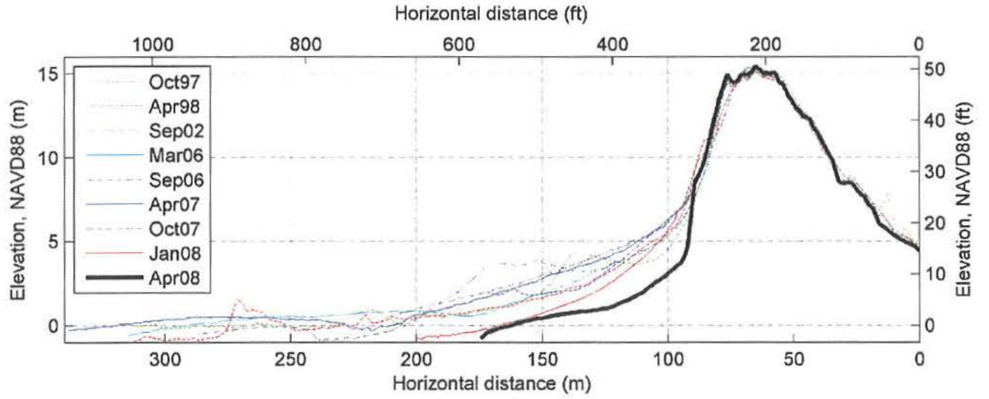
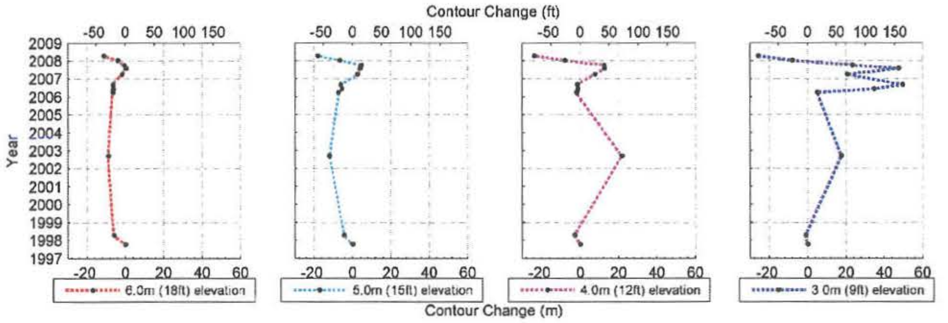
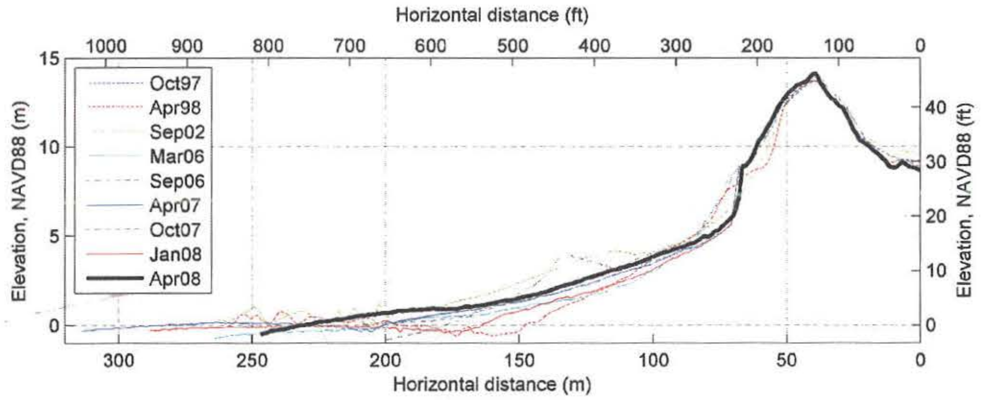
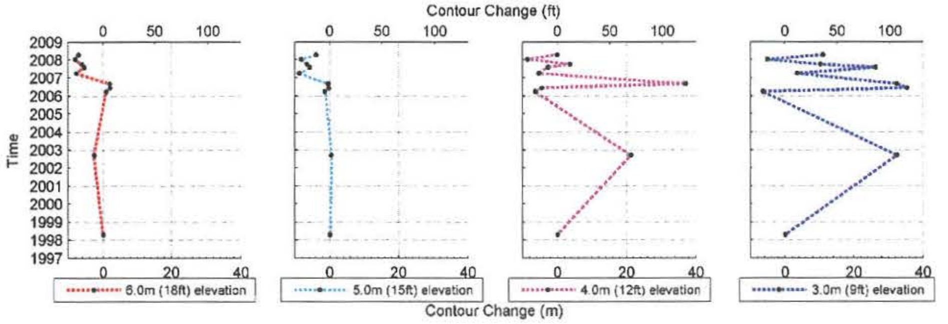


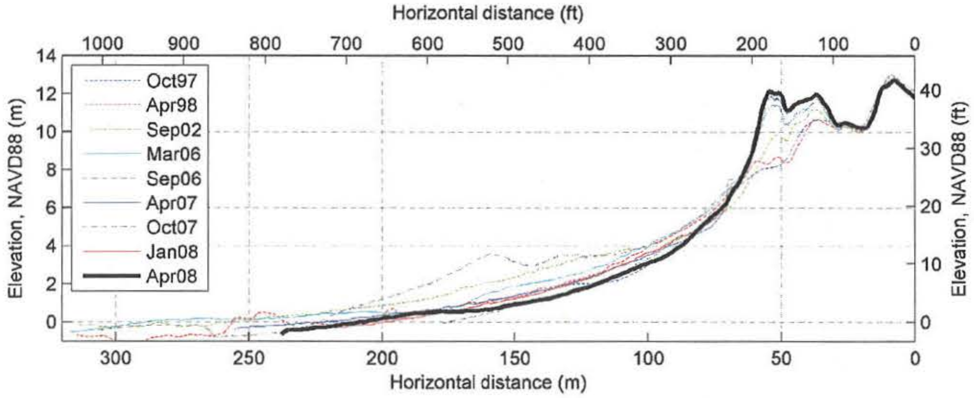


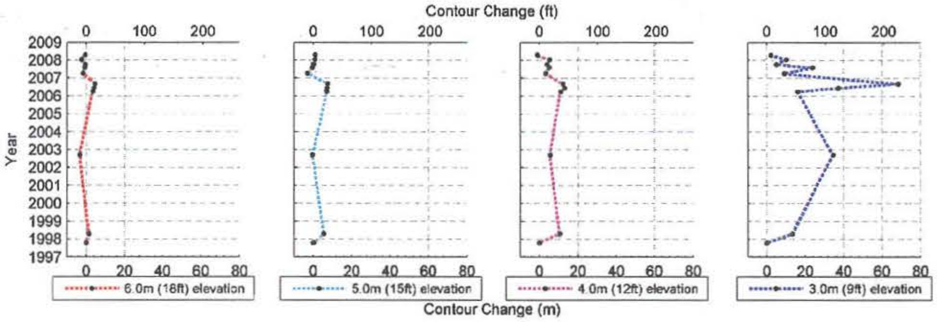
**Nesk12:**



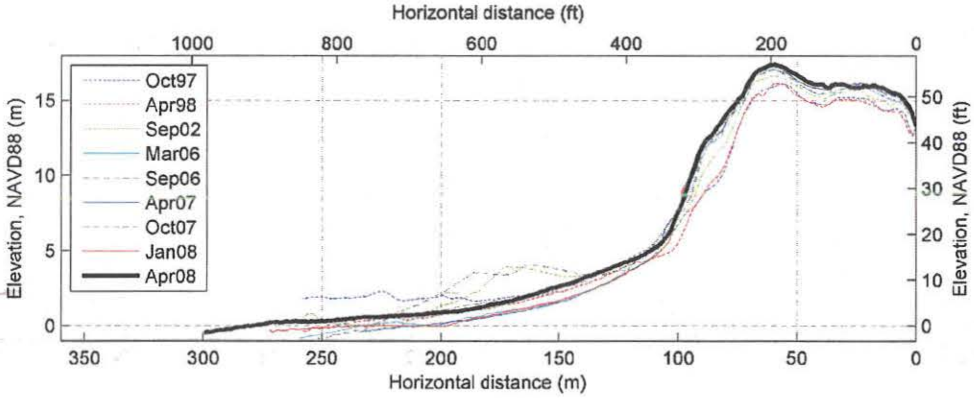


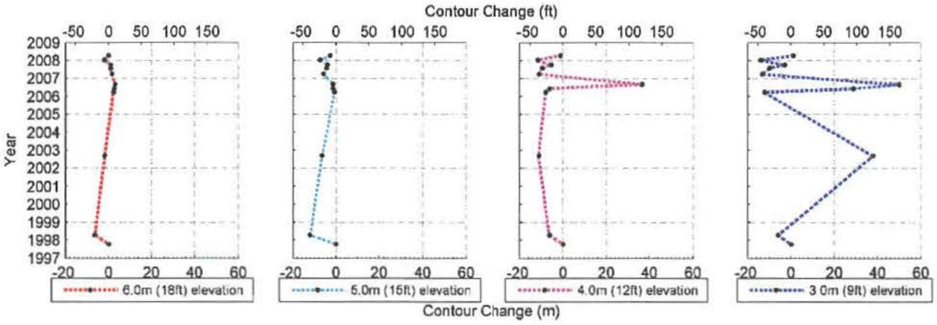
**Nesk13:**



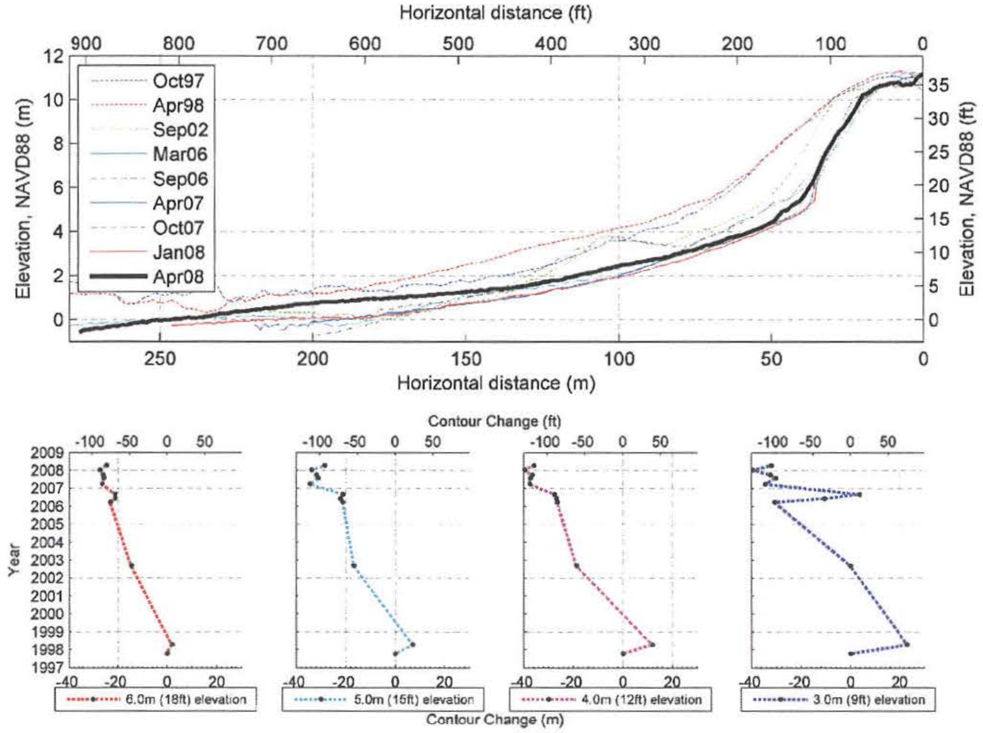


**Nesk14:**



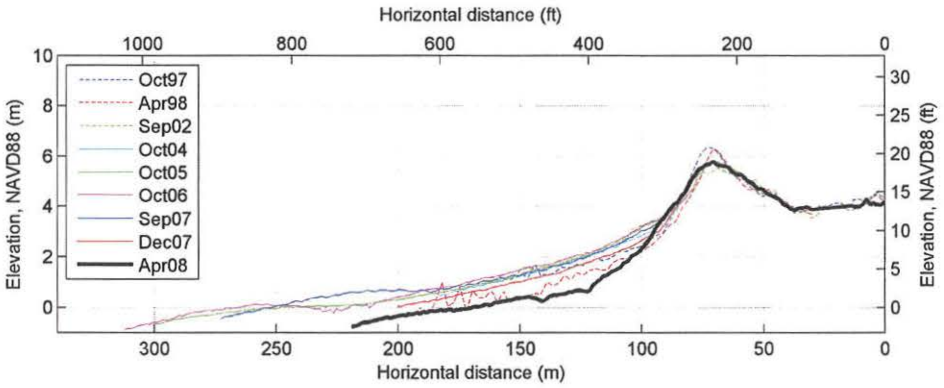


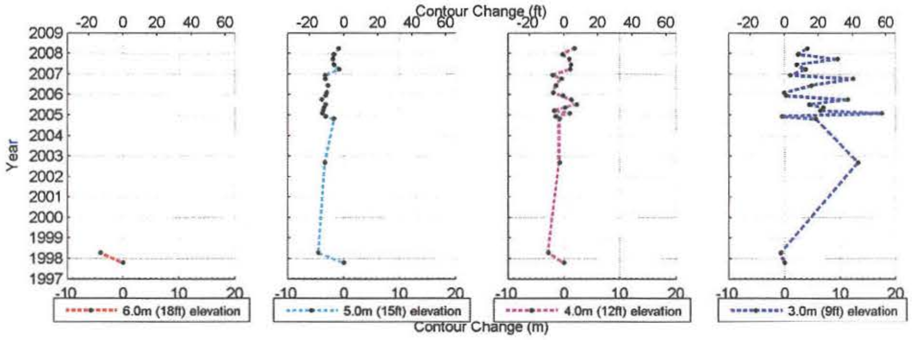
**Nesk15:**


Horizontal distance (ft)
900
800
700
600
500
400
300
200
100
0
Elevation, NAVD88 (m)
12
10
8
6
4
2
0
Oct97
Apr98
Sep02
Mar06
Sep06
Apr07
Oct07
Jan08
Apr08
35
30
25
20
15
10
5
0
Elevation, NAVD88 (ft)
250
200
150
100
50
0
Horizontal distance (m)
Contour Change (ft)
-100 -50 0 50
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-40 -20 0 20
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

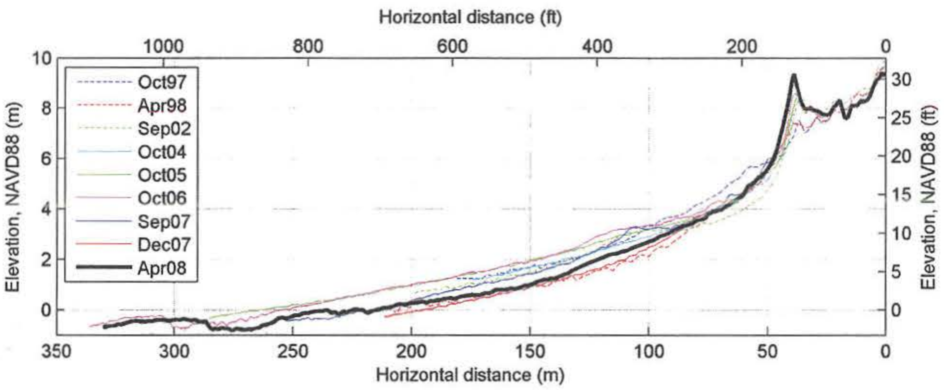
## Bayocean Spit sites

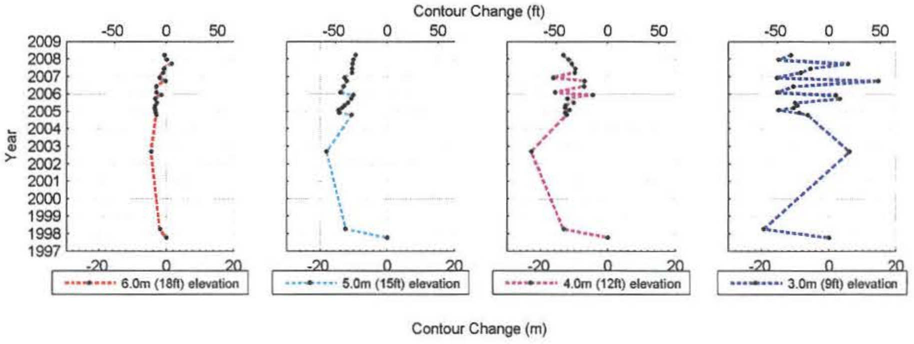
**Bay1:**



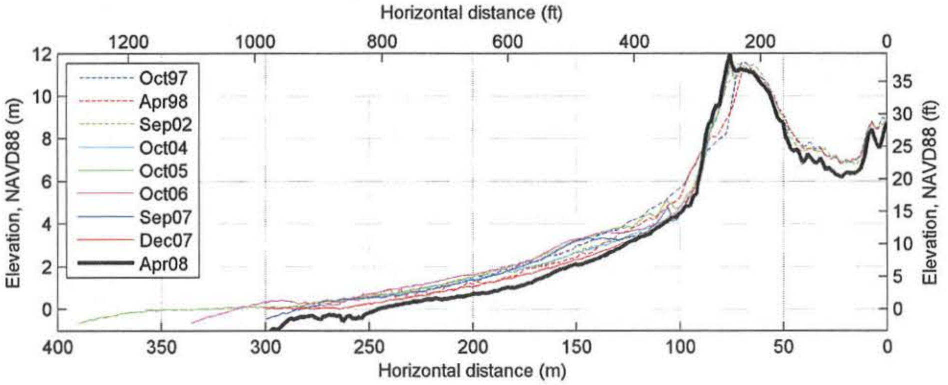


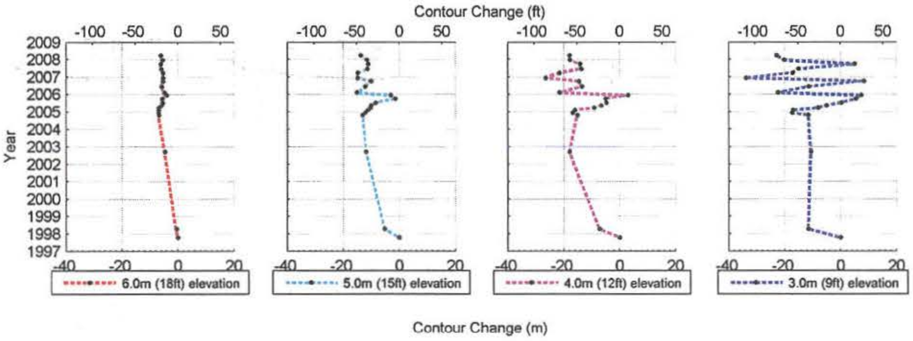
**Bay2:**



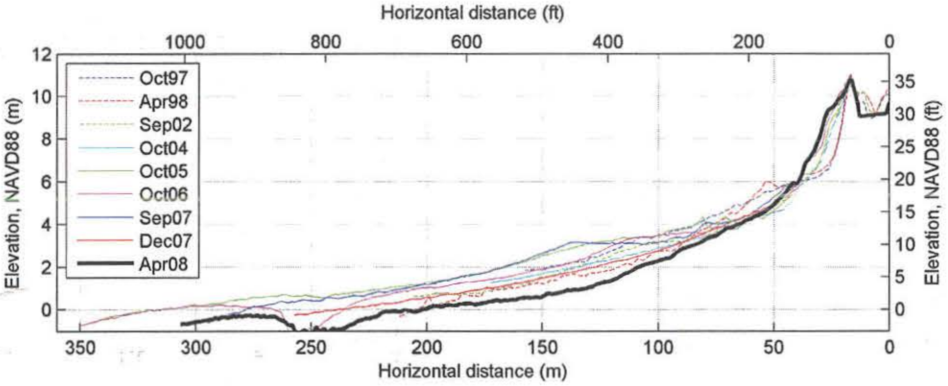


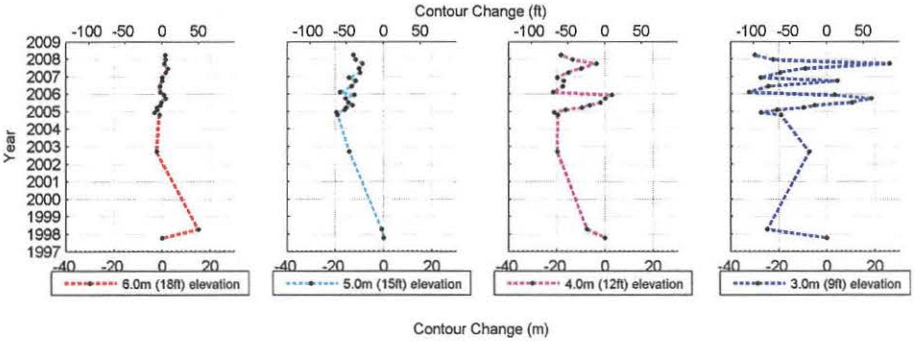
**Bay3:**


Horizontal distance (ft)
1200
1000
800
600
400
200
0
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Oct97
Apr98
Sep02
Oct04
Oct05
Oct06
Sep07
Dec07
Apr08
Horizontal distance (m)
400
350
300
250
200
150
100
50
0

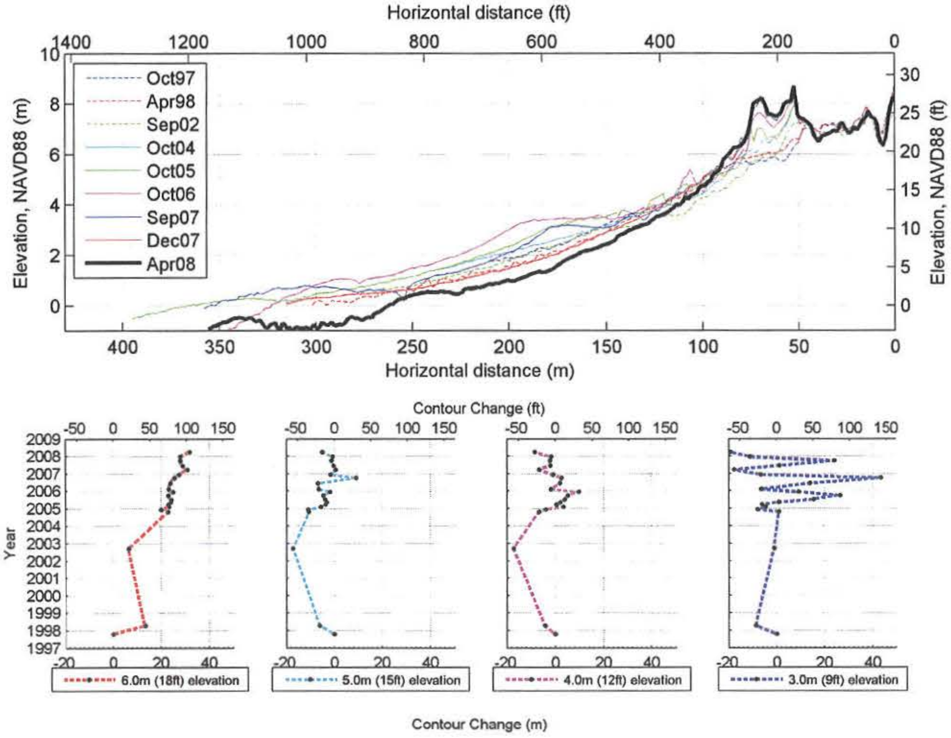

Contour Change (ft)
-100 -50 0 50
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-40 -20 0 20
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

**Bay4:**

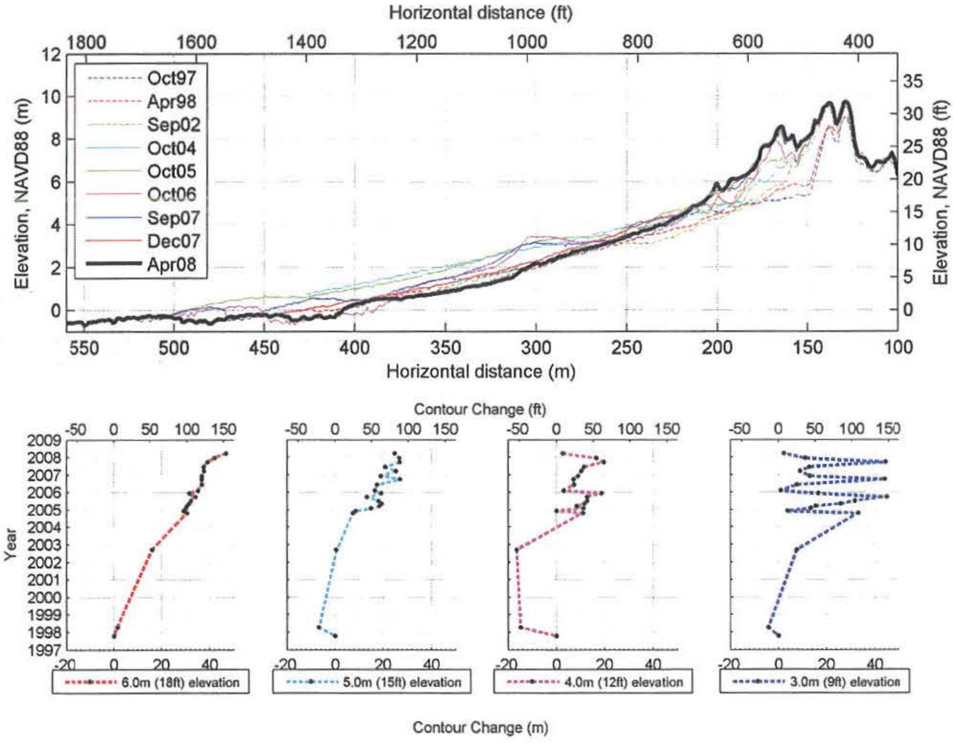

Horizontal distance (ft)
1000
800
600
400
200
0
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Oct97
Apr98
Sep02
Oct04
Oct05
Oct06
Sep07
Dec07
Apr08
Horizontal distance (m)
350
300
250
200
150
100
50
0


Contour Change (ft)
-100 -50 0 50
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-40 -20 0 20
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

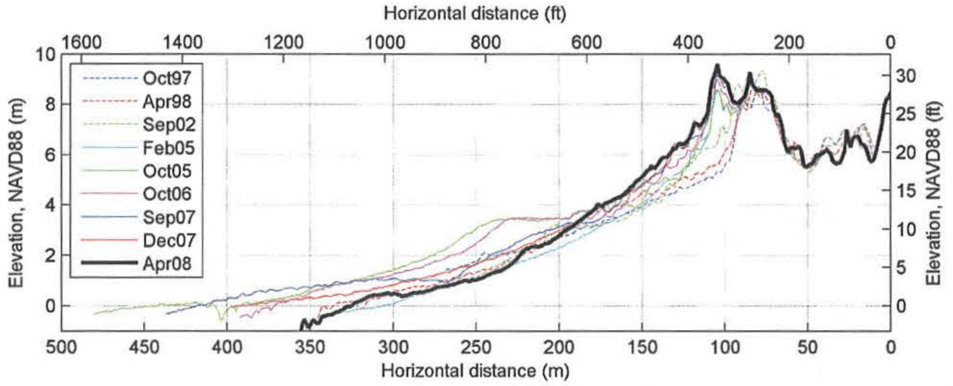
**Bay5:**

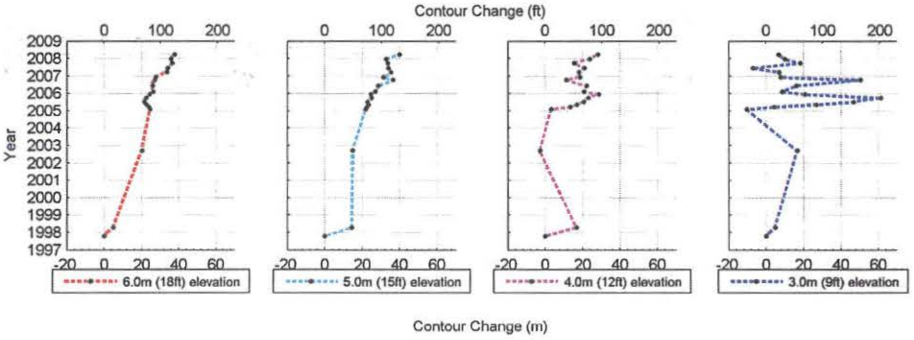

Horizontal distance (ft)
1400
1200
1000
800
600
400
200
0
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Oct97
Apr98
Sep02
Oct04
Oct05
Oct06
Sep07
Dec07
Apr08
Horizontal distance (m)
400
350
300
250
200
150
100
50
0
Contour Change (ft)
Year
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

**Bay6**


Horizontal distance (ft)
1800
1600
1400
1200
1000
800
600
400
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Oct97
Apr98
Sep02
Oct04
Oct05
Oct06
Sep07
Dec07
Apr08
Horizontal distance (m)
550
500
450
400
350
300
250
200
150
100
Contour Change (ft)
Year
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

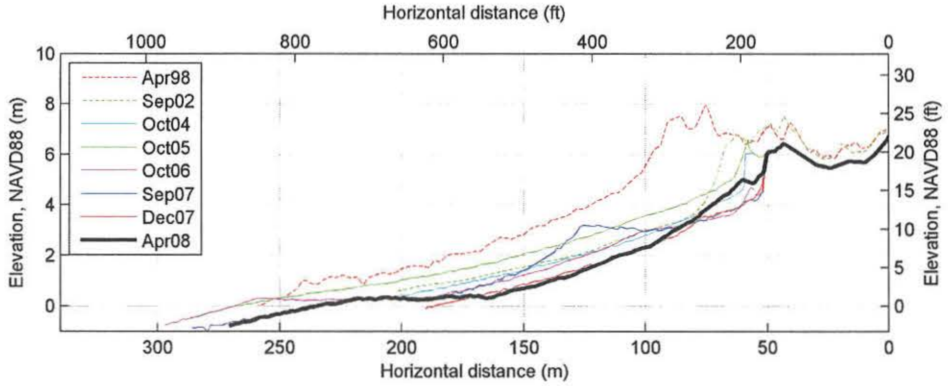
**Bay7**

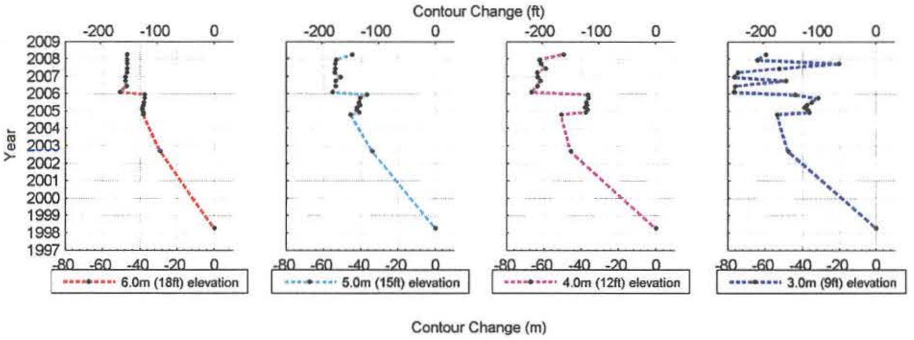

Horizontal distance (ft)
1600
1400
1200
1000
800
600
400
200
0
Elevation, NAVD88 (m)
10
8
6
4
2
0
Elevation, NAVD88 (ft)
30
25
20
15
10
5
0
Oct97
Apr98
Sep02
Feb05
Oct05
Oct06
Sep07
Dec07
Apr08
500
450
400
350
300
250
200
150
100
50
0
Horizontal distance (m)


Contour Change (ft)
0
100
200
Year
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
-20
0
20
40
60
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

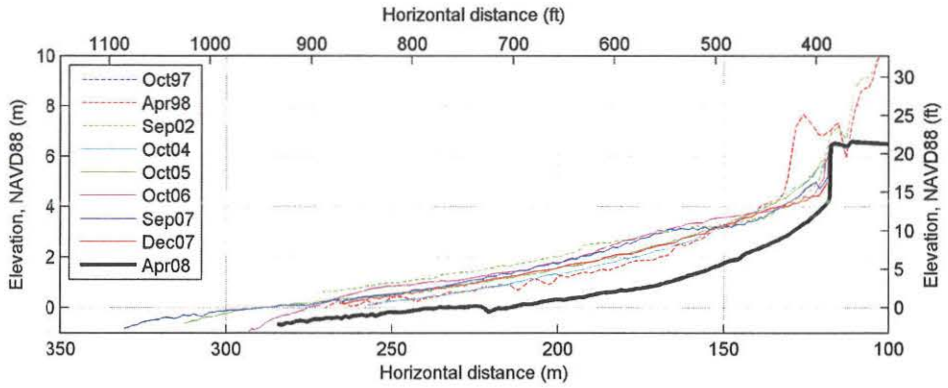
## Rockaway sites

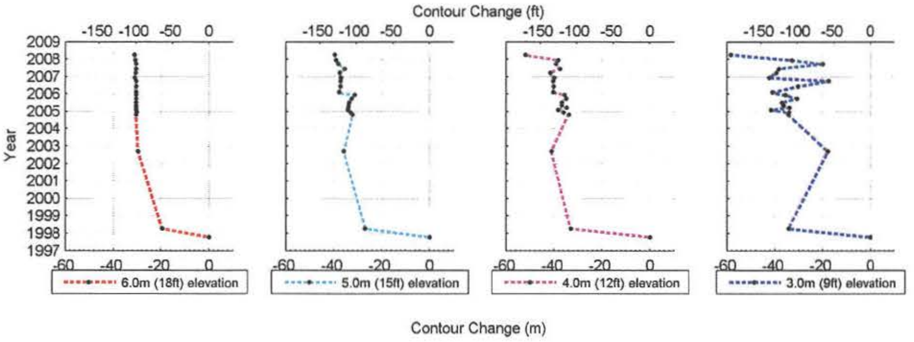
### Rck1:



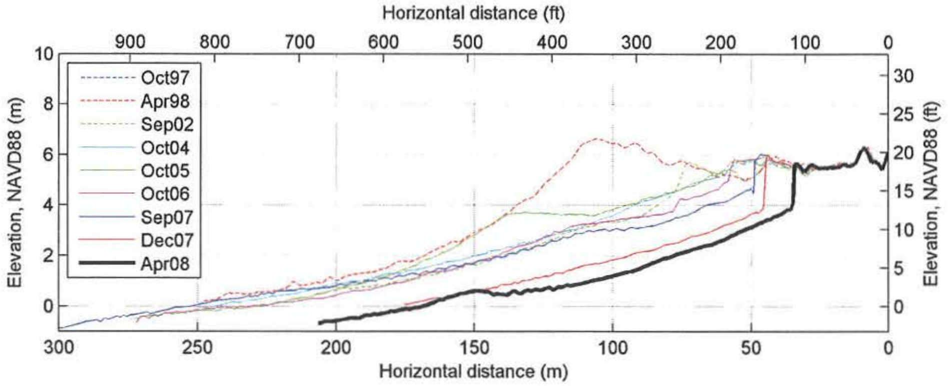


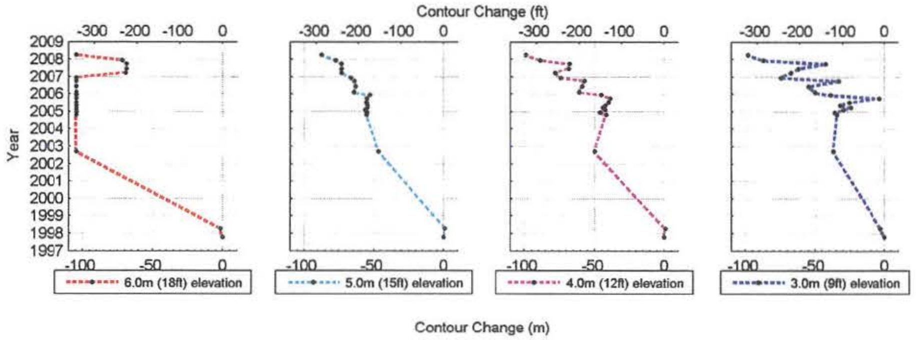
### Rck2:



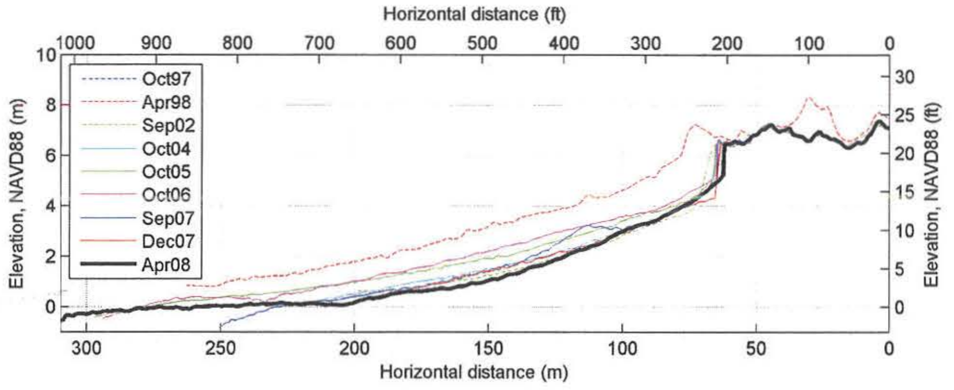


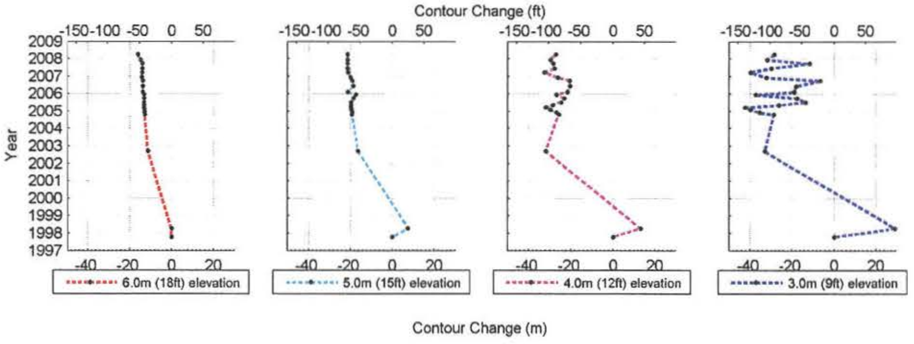
**Rck3:**


Horizontal distance (ft)
900 800 700 600 500 400 300 200 100 0
Oct97
Apr98
Sep02
Oct04
Oct05
Oct06
Sep07
Dec07
Apr08
Elevation, NAVD88 (m)
10 8 6 4 2 0
30 25 20 15 10 5 0
Elevation, NAVD88 (ft)
300 250 200 150 100 50 0
Horizontal distance (m)

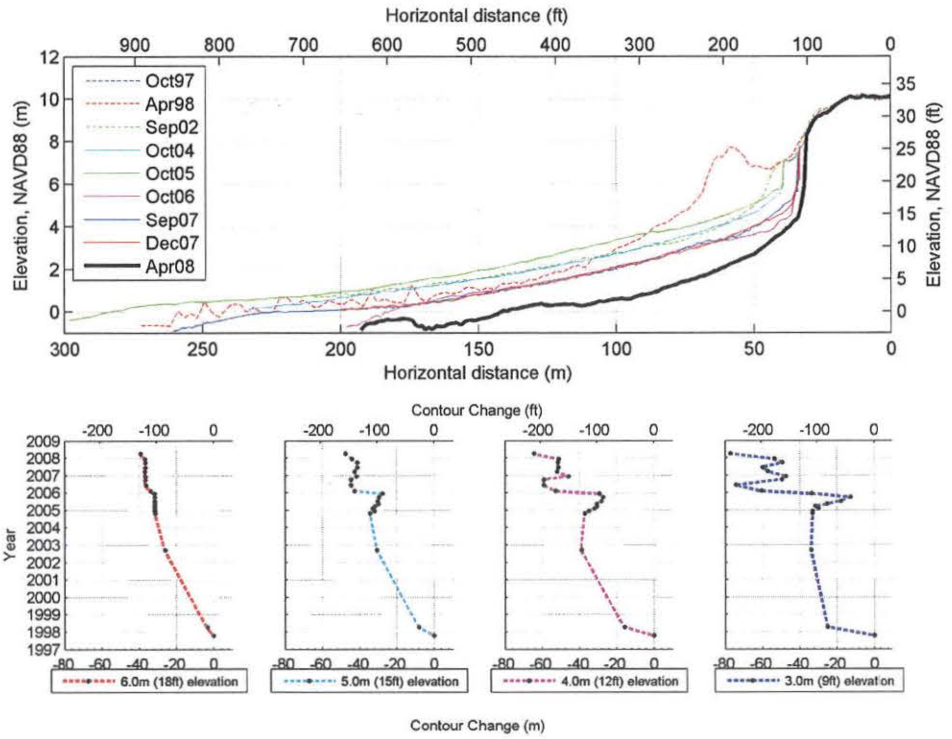

Contour Change (ft)
-300 -200 -100 0
Year
2009 2008 2007 2006 2005 2004 2003 2002 2001 2000 1999 1998 1997
-100 -50 0
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

**Rck4:**


Horizontal distance (ft)
1000 900 800 700 600 500 400 300 200 100 0
Oct97
Apr98
Sep02
Oct04
Oct05
Oct06
Sep07
Dec07
Apr08
Elevation, NAVD88 (m)
10 8 6 4 2 0
30 25 20 15 10 5 0
Elevation, NAVD88 (ft)
300 250 200 150 100 50 0
Horizontal distance (m)


Contour Change (ft)
-150 -100 -50 0 50
Year
2009 2008 2007 2006 2005 2004 2003 2002 2001 2000 1999 1998 1997
-40 -20 0 20
6.0m (18ft) elevation
5.0m (15ft) elevation
4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

**Rck5:**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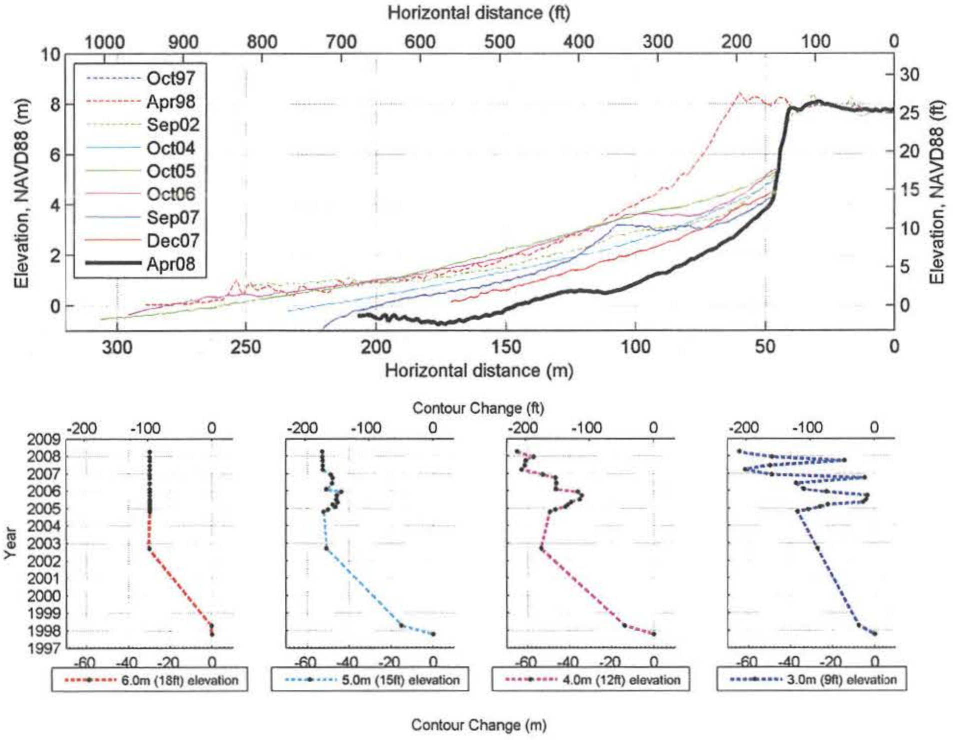
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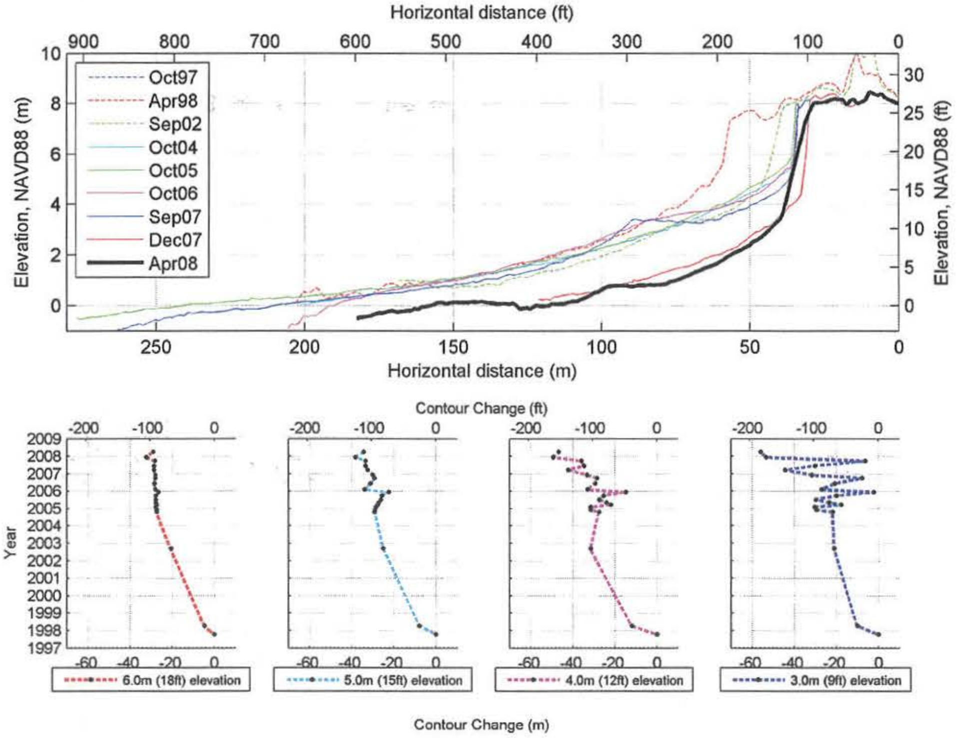
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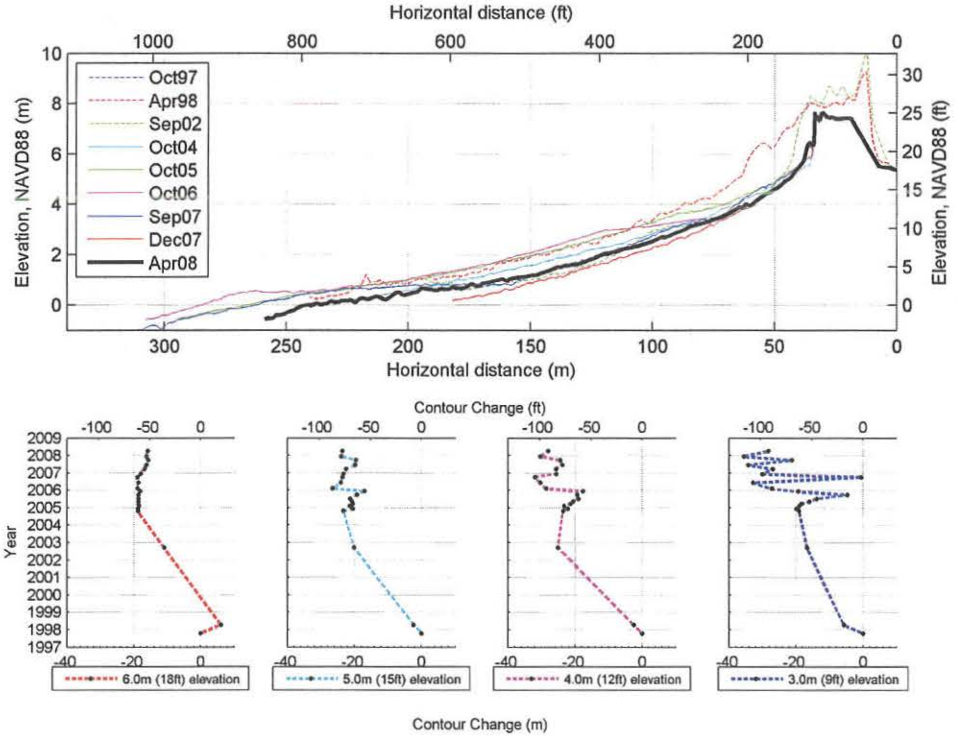
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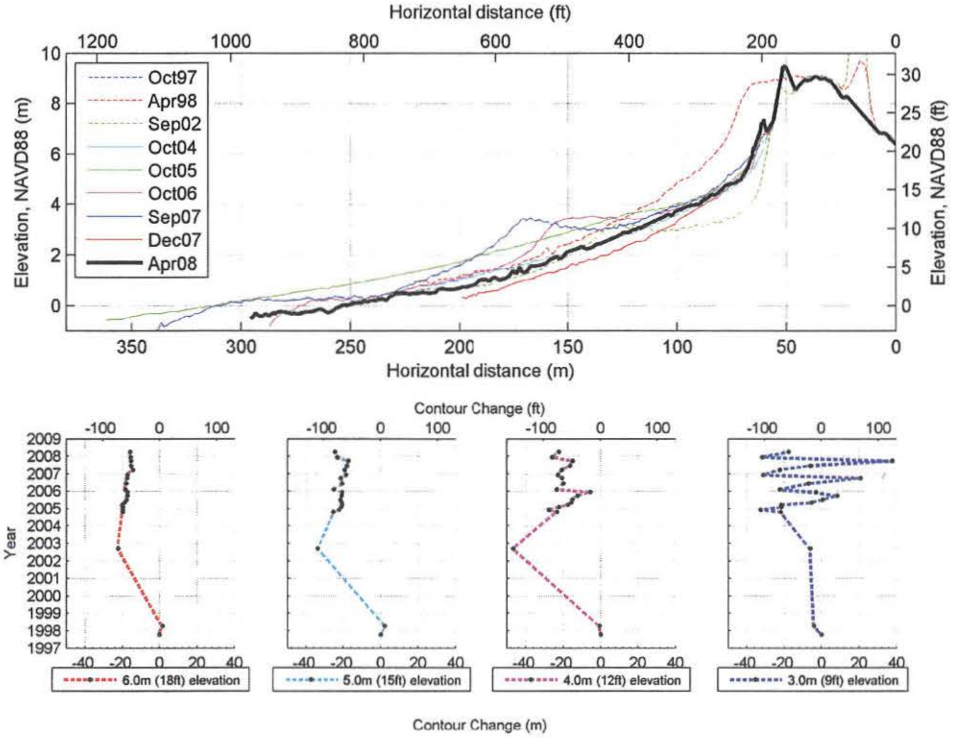
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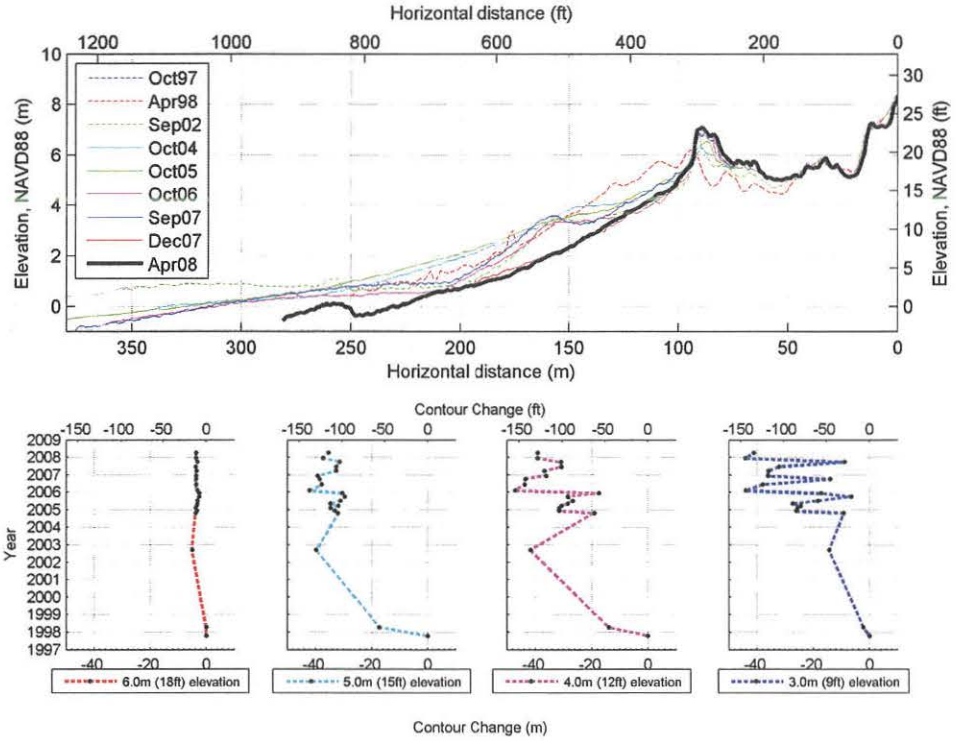
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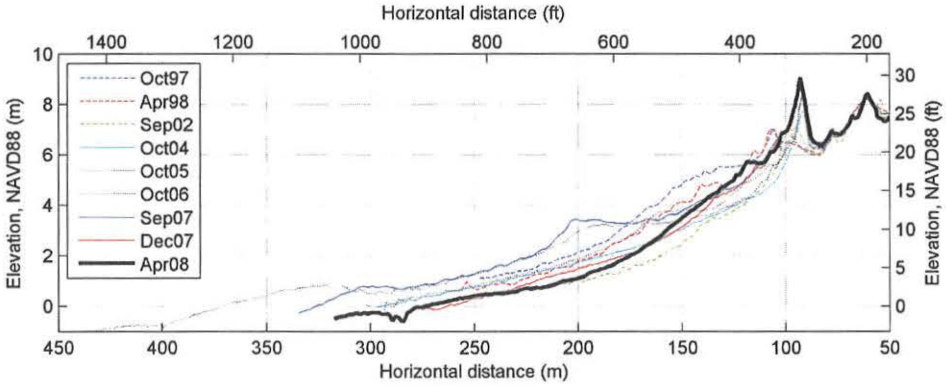

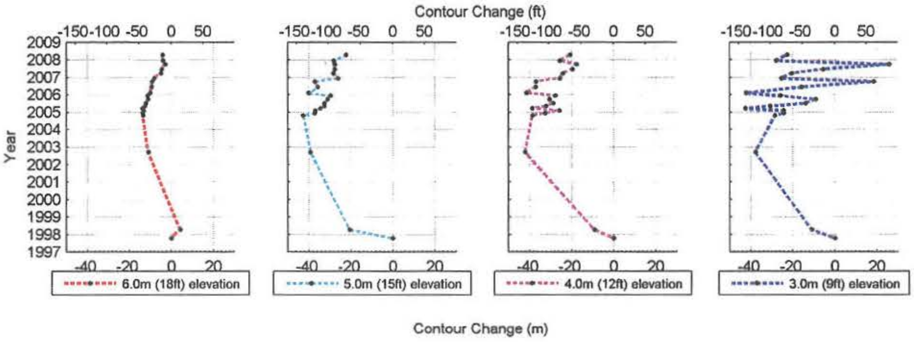

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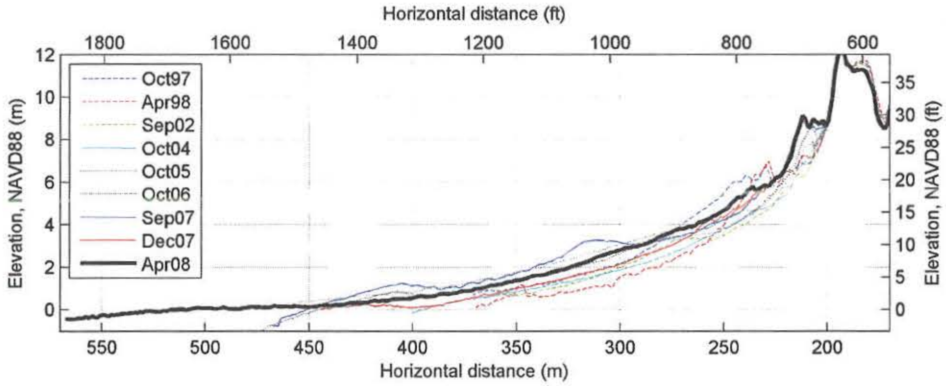

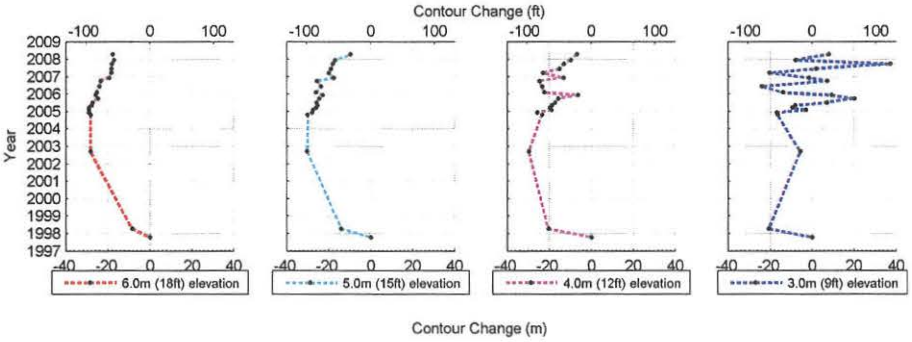

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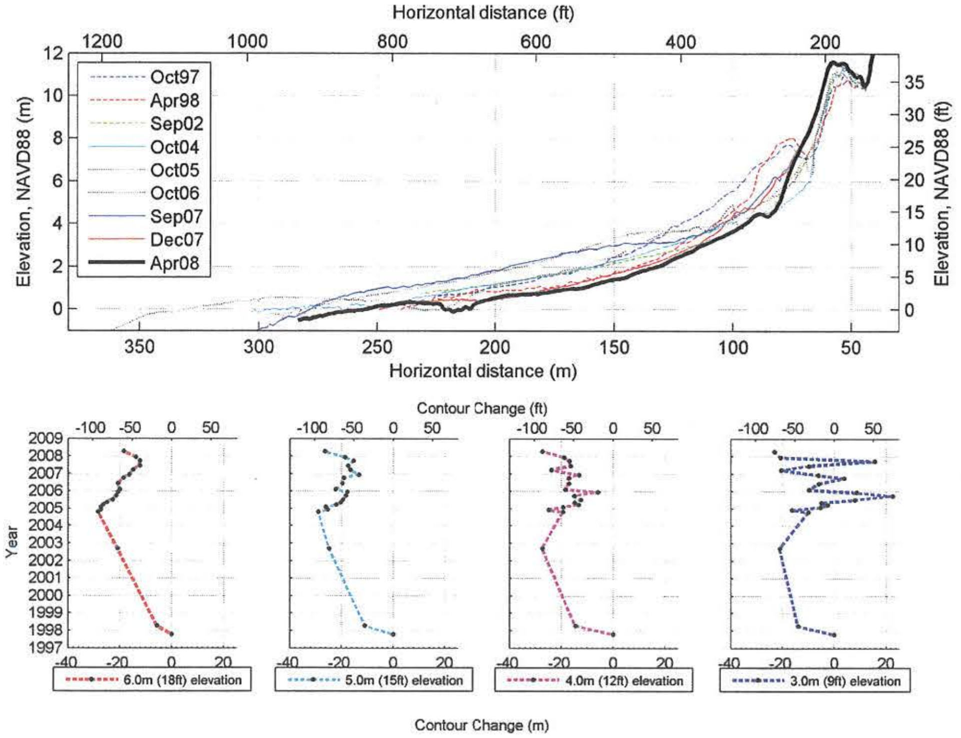
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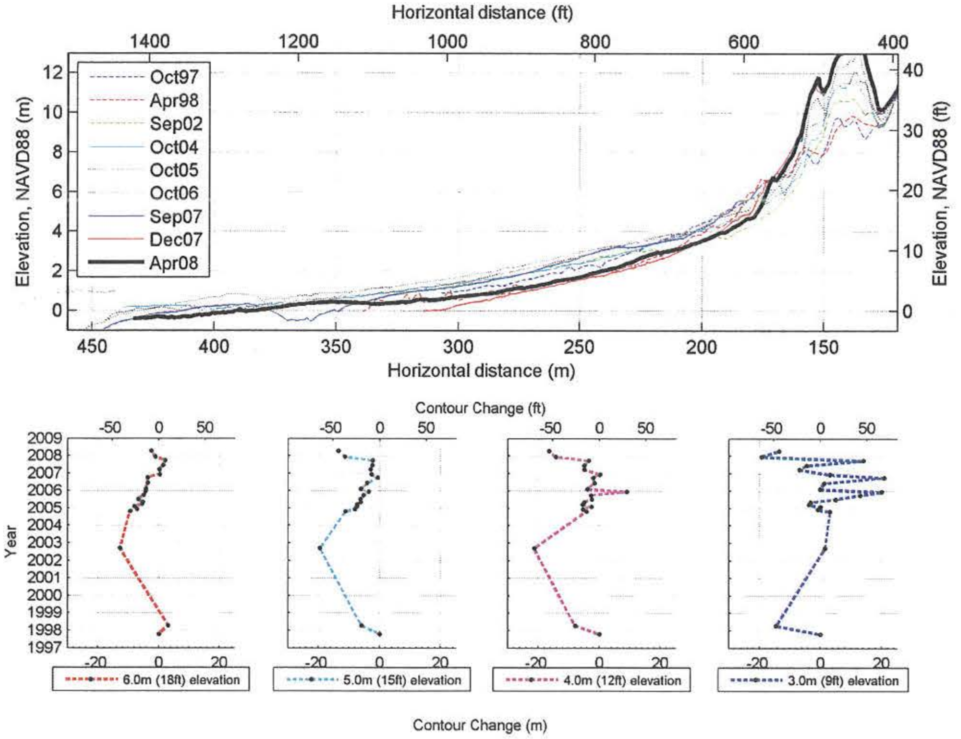
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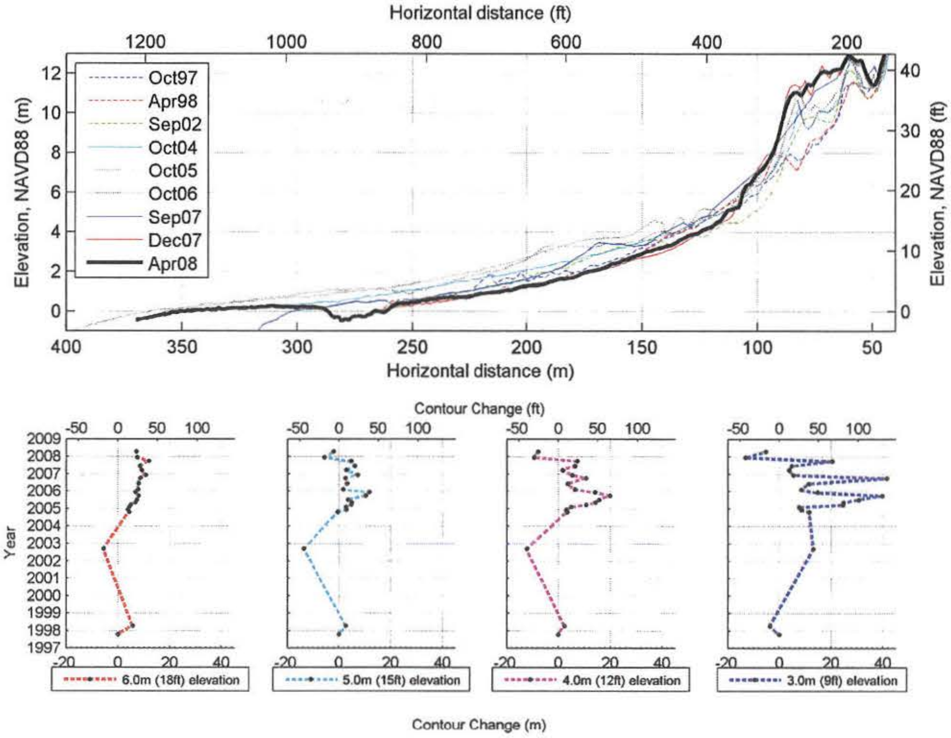
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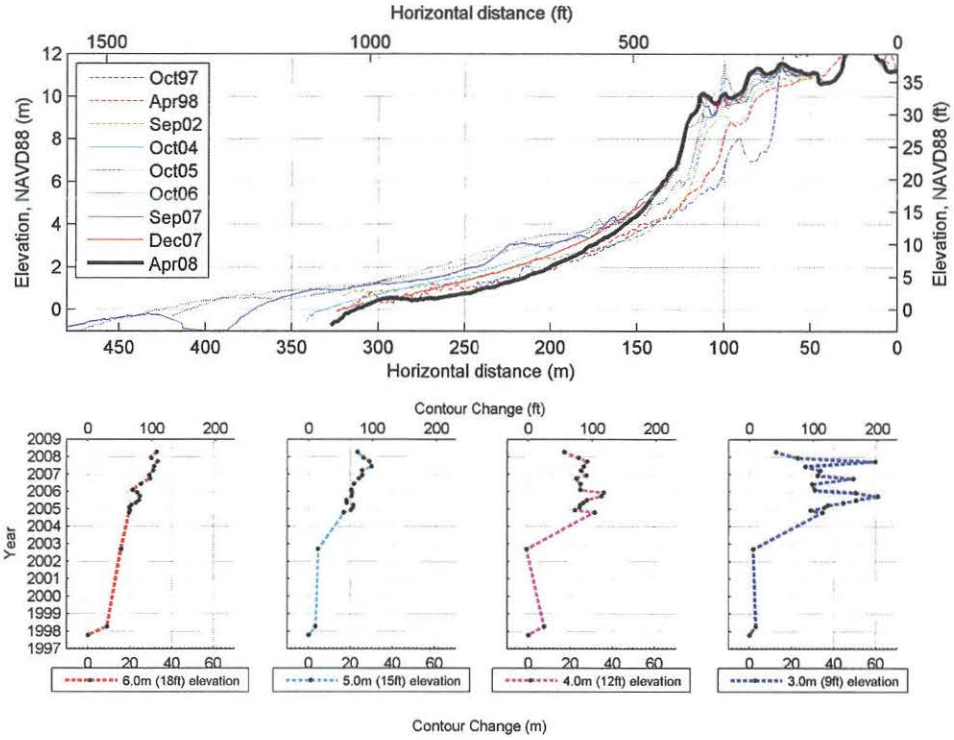
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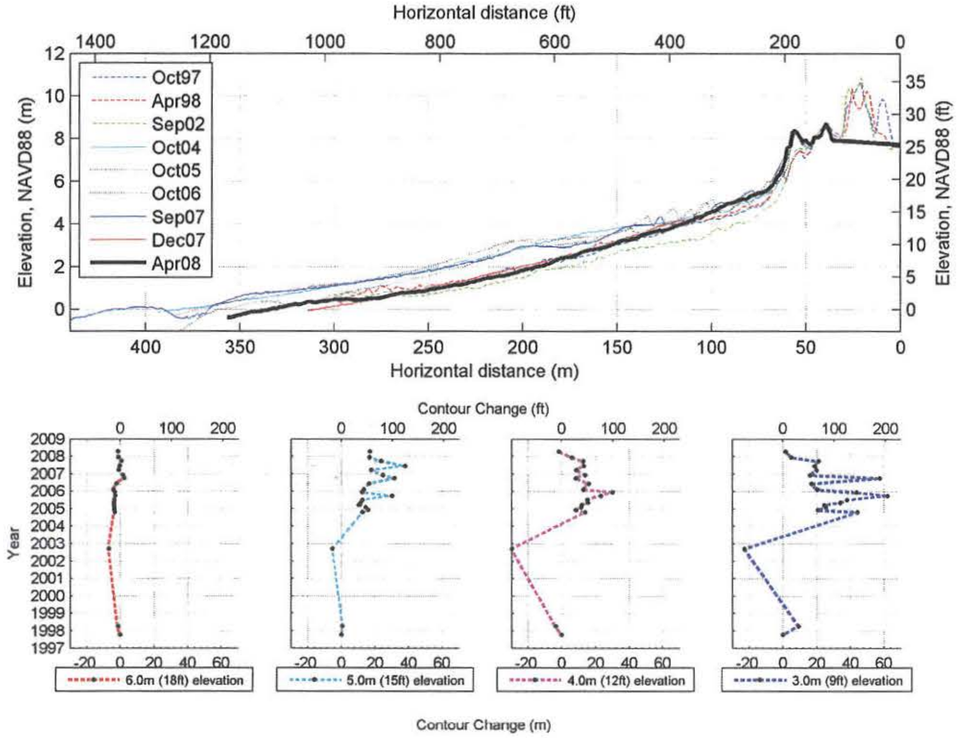
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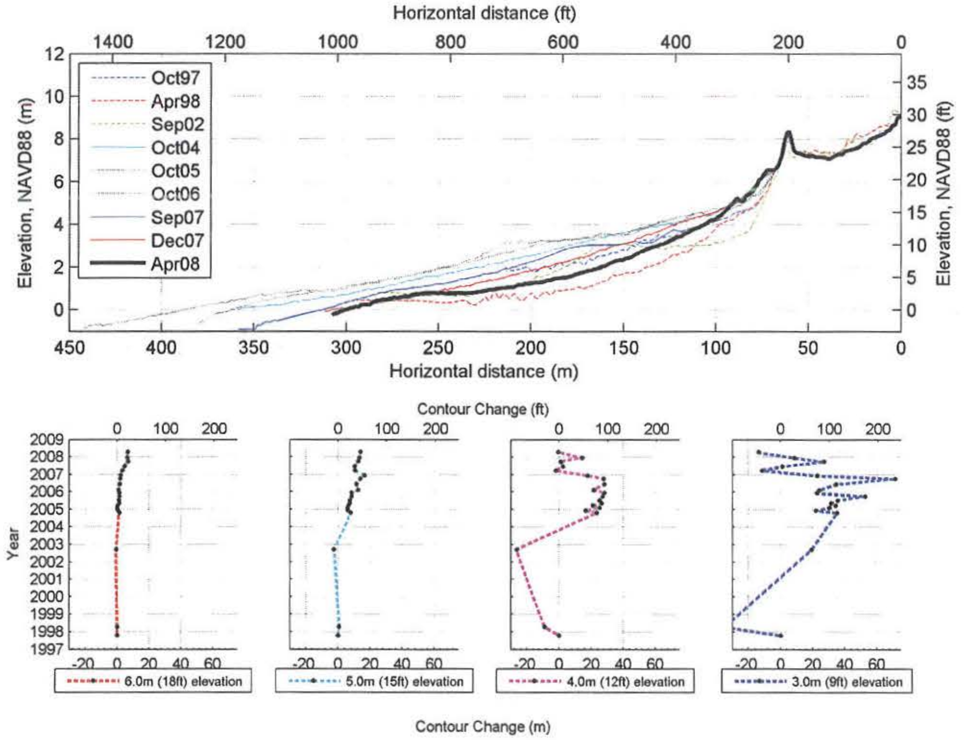
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4.0m (12ft) elevation
3.0m (9ft) elevation
Contour Change (m)

## Allison Hinderer

| | |
|---|---|
| **From:** | Sarah Mitchell <sm@klgpc.com> |
| **Sent:** | Tuesday, July 27, 2021 2:18 PM |
| **To:** | Sarah Absher; Allison Hinderer |
| **Cc:** | Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com |
| **Subject:** | EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 2 of 6) |
| **Attachments:** | Exh 2 - DOGAMI SP-47 Report_Part1.pdf |
| **Importance:** | High |

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 2 of 6.

**From:** Sarah Mitchell
**Sent:** Tuesday, July 27, 2021 2:16 PM
**To:** Sarah Absher <sabsher@co.tillamook.or.us>; Allison Hinderer <ahindere@co.tillamook.or.us>
**Cc:** Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and Lynda Cogdall (lcogdall@aol.com) <lcogdall@aol.com>; Brett Butcher (brett@passion4people.org) <brett@passion4people.org>; Dave and Frieda Farr (dfarrwestproperties@gmail.com) <dfarrwestproperties@gmail.com>; David Dowling <ddowling521@gmail.com>; David Hayes (tdavidh1@comcast.net) <tdavidh1@comcast.net>; Don and Barbara Roberts (donrobertsemail@gmail.com) <donrobertsemail@gmail.com>; Don and Barbara Roberts (robertsfm6@gmail.com) <robertsfm6@gmail.com>; evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com) <jeffklein@wvmeat.com>; Jon Creedon (jcc@pacifier.com) <jcc@pacifier.com>; kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net) <michaelmunch@comcast.net>; Mike and Chris Rogers (mjr2153@aol.com) <mjr2153@aol.com>; Mike Ellis (mikeellispdx@gmail.com) <mikeellispdx@gmail.com>; Rachael Holland (rachael@pacificopportunities.com) <rachael@pacificopportunities.com>; teriklein59@aol.com
**Subject:** 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 1 of 6)
**Importance:** High

Hi Sarah and Allison,

Please include the attached and forthcoming DOGAMI reports (Exhibits 1-3) in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. This email transmits part 1 of 6 of this submittal. Would you please confirm your receipt of

State of Oregon
Oregon Department of Geology and Mineral Industries
Ian P. Madin, Interim State Geologist

## SPECIAL PAPER 47

# COASTAL FLOOD HAZARD STUDY, TILLAMOOK COUNTY, OREGON

by Jonathan C. Allan[1], Peter Ruggiero[2], Gabriel Garcia[2],
Fletcher E. O'Brien[3], Laura L. Stimely[1], and Jed T. Roberts[3]

2015

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[3] Oregon Department of Geology and Mineral Industries, 800 NE Oregon St., Ste. 965, Portland, OR 97232

**DISCLAIMER**

*Cover photograph: Wave runup and overtopping during a moderate storm in Neskowin, Tillamook County. Photo taken by A. Thibault, January 9, 2008.*

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http://www.oregon.gov/DOGAMI/

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# 1.0 INTRODUCTION

The objective of the Tillamook County coastal flood hazard project is to develop a digital flood insurance rate map (DFIRM) and flood insurance study (FIS) report for Tillamook County, Oregon (**Figure 1-1**). A parallel effort is underway to convert the existing Tillamook County Federal Emergency Management Agency (FEMA) flood maps to a new countywide format in the North American Vertical Datum of 1988 (NAVD88); however, the scope of that project is strictly digital conversion and no new studies and/or updated floodplain boundaries are being incorporated. For this effort, the Oregon Department of Geology and Mineral Industries (DOGAMI) will be using available light detection and ranging data (lidar) to redelineate flood hazards within Tillamook County, produce revised DFIRMs and a revised FIS report, and produce other mapping products useable at the local, state, and federal level for mitigation planning, risk analysis, and disaster response.

As part of the redelineation, DOGAMI has been contracted to perform detailed coastal flood hazard studies for several stretches of beach along the Tillamook County shoreline of the Pacific Ocean. These analyses are to include assessments of the 1% annual probability, or 100-year, extreme storm wave event and the associated calculated wave setup, runup, and total water level (i.e., the wave runup superimposed on the tidal level) to help guide the determination of Special Flood Hazard Areas (SFHAs), the most significant being regions subject to high coastal flood risk (Zone VE), characterized with base flood elevations (BFEs) that are used to guide building practices. Additional modeling of the 0.2%, or 500-year, event will also be undertaken.

These detailed analyses will be limited to the following key areas (**Figure 1-1**):

- Neskowin littoral cell: extends from the north side of Cascade Head to Cape Kiwanda. This particular shore section includes the communities of Neskowin, North Neskowin, and Pacific City;
- Sand Lake littoral cell: extends from Cape Kiwanda north to Cape Lookout. This section includes the community of Tierra Del Mar;
- Netarts littoral cell: extends from Cape Lookout to Cape Meares. This sections includes Cape Lookout State Park and the communities of Happy Camp (Netarts), Oceanside, and Short Sand Beach; and
- Rockaway littoral cell: extends from the north side of Cape Meares to Neahkahnie Mountain in the north. This section includes the communities of Cape Meares, Twin Rocks, Rockaway, Nedonna Beach, Nehalem State Park, and Manzanita.

The communities noted above represent approximately 43% of the mapped Tillamook coastline; the remainder of the coast has been mapped as FEMA flood zone categories "D" (e.g., most of the spits) and "V" (e.g., Nehalem State Park). These latter areas reflect areas that were previously not mapped using detailed hydraulic analyses. As a result, this study will provide updated detailed coastal hydraulic analyses for the same communities, and will extend the detailed analyses by an additional 30% to encompass areas outside the existing areas. For the remaining 27% of the Tillamook County coast, the shoreline will be redefined as V zone (e.g., along the headlands) to better reflect the geomorphology of those areas.

The development of coastal flood maps is complicated due to its dependence on a myriad of data sources required to perform wave transformation, runup, and overtopping calculations. These challenges are further compounded by an equally wide range of potential settings in which the data and methods can be applied, which range from dune to bluff-backed beaches, sites that may be backed by coastal engineering structures such as sea walls, riprap revetments, or wooden bulkheads, to gravel and hard-rock shorelines. **Figure 1-2** broadly summarizes the steps described in the ensuing sections in order to provide a conceptual basis for the process that leads, ultimately, to the completed coastal flood hazard zones.

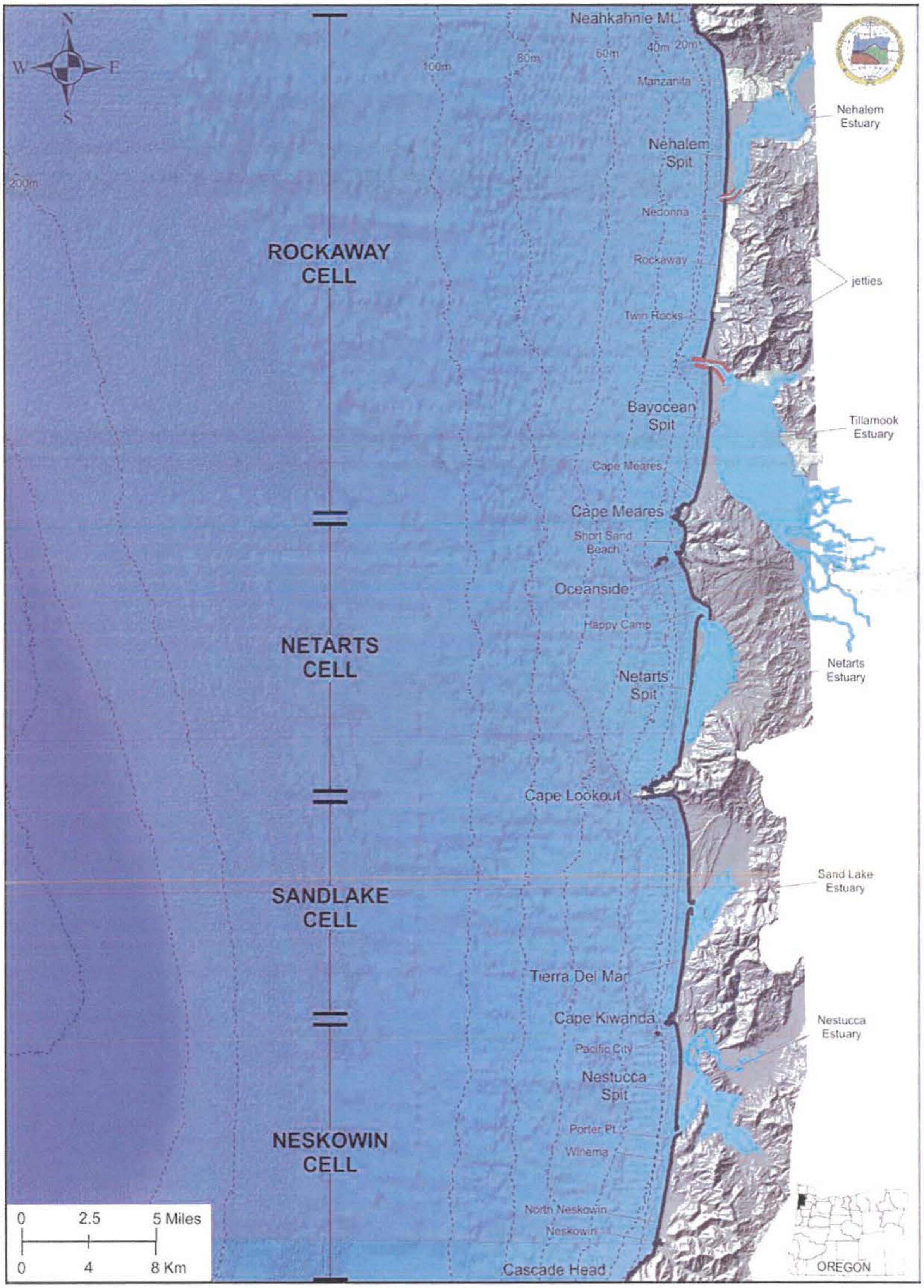

**Figure 1-1.** **Location map of the Tillamook County, Oregon coastline.**

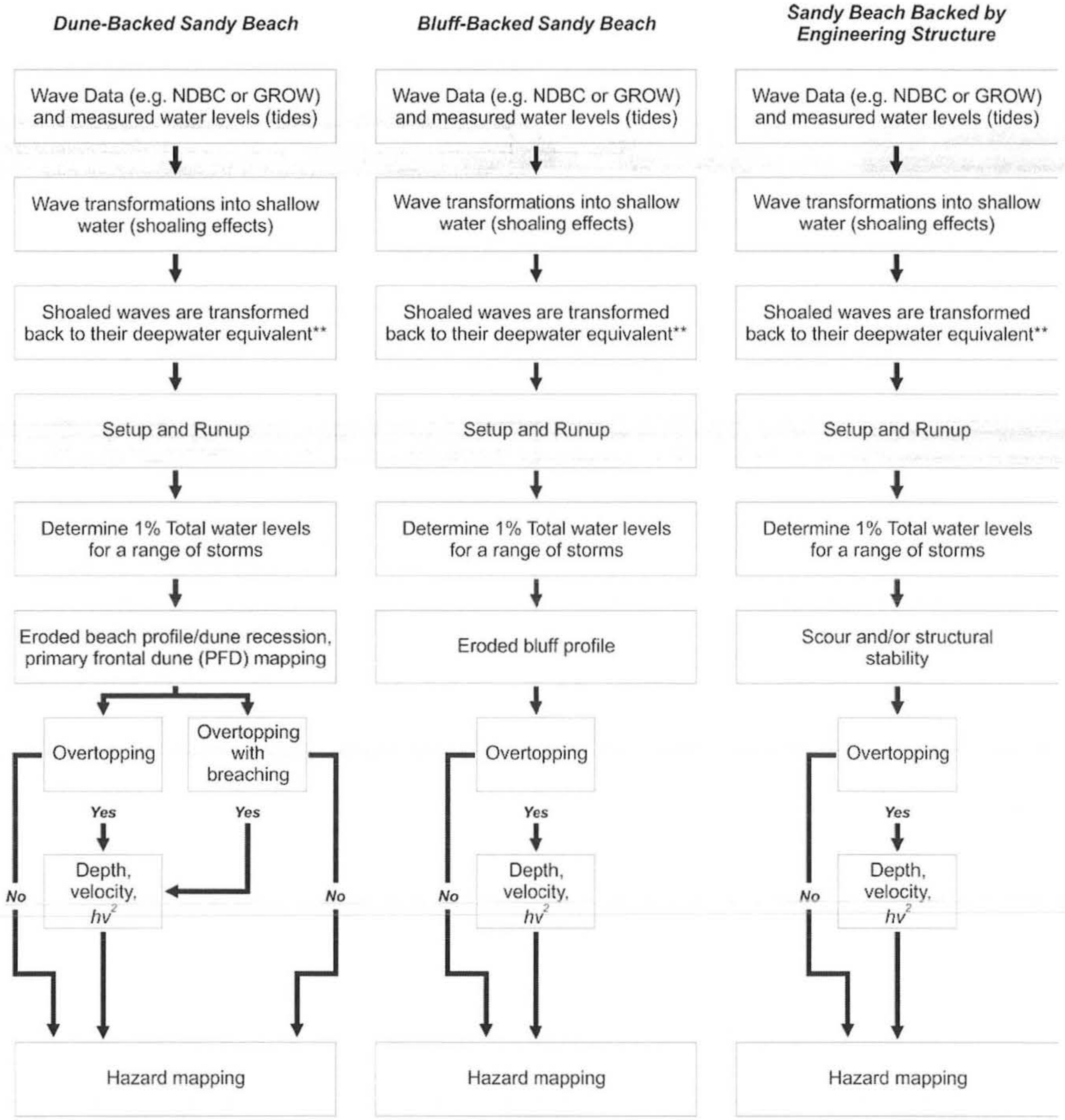

**Figure 1-2. Three representative examples of the steps that may be taken to derive coastal flood hazard maps on the Pacific Northwest coast. **Note: The waves are first shoaled using numerical models in order to account for the effect of wave changes (refraction/diffraction) that take place across the shelf and in the nearshore. Because many coastal engineering equations (e.g. wave runup) require deepwater inputs, the "shoaled" waves are then converted back to their deepwater equivalence.**

This report first examines the coastal geology and geomorphology of the Tillamook County shoreline, including a discussion of the erosion history of the coast. The results presented in this section will ultimately form the basis for defining the flood zones along the Tillamook coast. Section 3 presents the results of Real-Time Kinematic Differential Global Positioning Surveys (RTK-DGPS) of the detailed study sites established along the length of the Tillamook County shoreline, undertaken at the peak of the 2011-12 winter. These surveys are also compared with recent historical data derived from lidar data, which are used to help define the most eroded winter profile used in the runup calculations described in Section 6. Section 3 also documents various parameters associated with the measured beach profile data, including the beach/dune junction elevation, the beach slope and dune/bluff crest/top elevations.

Section 4 presents an examination of the tide data measured by the National Ocean Service (NOS) of the National Oceanographic Atmospheric Administration (NOAA) Garibaldi tide gauge (Tillamook Estuary) and the South Beach, Yaquina Bay tide gauges (including several other gauges), including an analysis of the 1% and 0.2% *still water levels* (SWL). Section 5 describes the steps undertaken to develop a synthesized wave climate, critical for developing the input wave statistics used in calculating the wave runup. Section 5 also examines the procedures used to refract the waves from deep water into the nearshore using the SWAN (Simulating Waves Nearshore) wave model. Analyses of the wave runup, including the calculation of the 1% and 0.2% total water levels (TWL), as well as any overtopping calculations, are presented and discussed in Section 6.

Section 7 discusses the steps used to determine the degree of erosion that might occur on the dune-backed beaches, including the approach used to define the duration-reduced erosion factor, important for further establishing the initial conditions on which the runup and overtopping calculations are ultimately performed. Similar discussions are provided describing observations of bluff erosion, characteristic of a few discrete sections of the Tillamook County shoreline. Finally, Section 8 synthesizes all of the information and describes the steps taken to draft new flood maps along the Tillamook County shoreline.

# 2.0 COASTAL GEOLOGY AND GEOMORPHOLOGY OF TILLAMOOK COUNTY

Tillamook County is located on the northwest Oregon coast, between latitudes 45° 45′ 49.49″ N (Cape Falcon) and 45° 3′ 54.88″ N (Cascade Head), and longitudes 124° 1′ 15.57″ W and 123° 17′ 59.88″ W. The terrain varies from low-elevation sandy beaches and dunes on the coast to elevations over 1,000 m (e.g., Rogers Peak reaches 1,130 m [3,706 ft]) farther inland. The coastal strip is approximately 104 km (65 miles) in length and varies in its geomorphology from broad, low-sloping sandy beaches backed by dunes, to beaches backed by engineered structures, cobble and boulder beaches adjacent to the headlands, and cliff shorelines. Prominent headlands formed of resistant basalt (e.g., Cascade Head, Cape Meares, Cape Lookout, and Neahkahnie Mountain) provide natural barriers to alongshore sediment transport (Komar, 1997), effectively dividing the county coastline into four littoral cells. These are:

- Neskowin littoral cell (~14.3 km), which extends from the north side of Cascade Head to Cape Kiwanda;
- Sand Lake (~13.2 km), which extends from Cape Kiwanda north to Cape Lookout;
- Netarts (~15.9 km), which extends from Cape Lookout to Cape Meares; and
- Rockaway littoral cell (~28.2 km), which extends from the north side of Cape Meares to Neahkahnie Mountain in the north.

Each of these cells is further divided into a series of subcells due to the presence of five estuaries (in order from south to north, Nestucca, Sand Lake, Netarts, Tillamook, Nehalem), two of which (Tillamook and Nehalem) are stabilized by prominent jetties (**Figure 1-1**). The county also is characterized by several major rivers (Nestucca, Nehalem, Miami, Tillamook, Trask, Kilchis, and Wilson Rivers) that terminate in the estuaries.

Due to their generally low flows and the terrain they are eroding, these rivers carry little beach sediment out to the open coast but instead deposit most of their sediment in the estuaries (Clemens and Komar, 1988; Komar and others, 2004). Hence, the beaches of Tillamook County receive very little sediment along the coast today other than from erosion of the backshore.

## 2.1 Local Geology

Along the Tillamook County coast the predominant geologic unit consists of latest Holocene beach sand present along the full length of the coastline (**Figure 2-1**) (Cooper, 1958). Interspersed between the sand are intrusive rocks (Tertiary age basalt), which characterize discrete areas, such as Neahkahnie Mountain at the northern end of the county coastline (**Figure 2-2**). Other volcanic rocks (Miocene age) form the prominent headlands such as at Cape Meares and Cape Lookout (Schlicker and others, 1972). These latter rocks are described as fine-grained. In all cases, rockfalls and landslides in these latter units are actively providing new material to the beaches, gravel and cobbles, albeit at relatively slow rates. These failures contribute to the formation of extensive cobble and boulder berms (**Figure 2-2**), which accumulate along their northern/southern flanks, where beaches have merged up against the headlands.

South of Cape Lookout and north of the Sand Lake estuary, much of the beach is backed by bluffs, which have an average height of 24 m (Allan and Harris, 2012) consisting of medium-grained sandstone and interbedded siltstone of the Astoria Formation (**Figure 2-3**). This particular rock formation also characterizes the geology of Cape Kiwanda, adjacent to Pacific City (**Figure 2-4**). Sandstone is also prominent along a small section of the coast adjacent to Porter Point (**Figure 1-1**), located just south of the Nestucca estuary mouth. These latter sediments are considered to be much older (Oligocene to Miocene) in age and are described as massive basaltic sandstone that is predominantly fine- to medium-grained (Schlicker and others, 1972).

Much of the beach sand present on the Oregon coast consists of grains of quartz and feldspar. The beaches also contain small amounts of heavier minerals (e.g. garnet, hypersthene, augite, and hornblende [**Figure 2-5**]), which can be traced to various sediment sources along the Pacific Northwest coast (Clemens and Komar, 1988). For example, garnet and hypersthene is derived from the Klamath Mountains located in southern Oregon and in North California. Because the headlands today extend well out in deep water, they effectively limit sand transport around their ends under the current process regime. This suggests that these heavier minerals were probably transported northward along the coast at a time when sea level was much lower, with few barriers to interrupt their northward movement (Komar, 1997). With distance from their source, the sediments combined with other minerals derived locally from erosion processes in the coast range. As shown in **Figure 2-5**, the concentrations of garnet and hypersthene decrease to the north, while concentrations of of augite increase significantly; augite is a mineral that is prevalent in the volcanic rocks present throughout Tillamook County. At Tillamook Head, the concentration of garnet is very small, suggesting that Tillamook Head reflects its most northerly transport. North of Tillamook Head, it can be seen that concentrations of hypersthene and hornblende increase again. These latter sediments are derived from the Columbia River, which contributed to the formation of the Clatsop Plains, Long Beach Peninsula, and Grayland Plains. Thus, sediments derived from the Columbia River were transported mainly to the north, supplying the Washington coast and shelf.

With the end of the last glaciations, sea level rose rapidly and the beaches began to migrate landward. New sediments were derived from erosion of the coastal plain that makes up the continental shelf today. At around 5,000–7,000 years ago, the rate of sea level rise slowed as it approached its current level today (Komar, 1997). At this stage the prominent headlands would have begun to interrupt sediment transport. Modern barrier spits and beaches began to form within the headland bounded littoral cells that make up the present coast today.

Along the Tillamook County coast, the beaches contain abundant concentrations of augite, indicative of their having been derived locally (**Figure 2-5**). This implies that at the time, rivers and streams were carrying these sediments out to the coast where they mixed with other sediments. These concentrations likely increased during the past 150 years as human settlement accelerated leading to increased deforestation (Peterson and others, 1984; Komar and others, 2004). This correspondingly contributed to increased sediment loads in the various rivers. However, analyses of the sediment characteristics in Tillamook Bay, the largest estuary in the county, indicated that while fine sediments pass through the estuary, the bulk of the coarser sediments remain behind where they accumulate as bars and shoals in Tillamook Bay (Komar and others, 2004). Furthermore, sediments within Tillamook Bay are predominantly of a marine origin (60%), while river sediments make up 40% of the sediment in the estuary. This finding is consistent with the work of Peterson and others (1984) and Clemens and Komar (1988), who observed that because of the combination of low river discharge and high tidal regime in Oregon estuaries, the majority of the estuaries are in fact natural "sinks" for the sediment. Thus, the beaches of Oregon receive very little sediment input from rivers and streams today. Accordingly, sediment supply is essentially confined to those areas backed by coastal bluffs, particularly those areas overlain by more erosive Pleistocene marine terrace sandstones (raised ancient beach and dune sands) and more recent Holocene dune sands that drape the landscape.

Prior to the 1940s, many of the barrier spits were devoid of significant vegetation. With the introduction European beach grass (*Ammophila arenaria*) in the early 1900s and its subsequent proliferation along the Oregon coast, the grass essentially resulted in the stabilization of the dunes and barrier spits. The product today is an extensive foredune system, which consist of large "stable" dunes containing significant volumes of sand. Accompanying the stabilization of the dunes, humans have settled on them, building in the most desirable locations, typically on the most seaward foredune. As will be shown throughout this report, construction of these homes and facilities in such areas poses a significant risk as periodically storms erode into the dunes. This has resulted in many cases where the foundations of the homes are undermined, eventually requiring riprap coastal engineering structures to mitigate the erosion problem.

**Figure 2-1. Looking north along Bayocean spit, the Tillamook jetties (Tillamook Bay to the right), Rockaway just north of the jetties, Nehalem Spit and Neahkahnie Mountain in the far distance (photo: E. Harris, DOGAMI, 2011).**

**Figure 2-2. Looking east at Neahkahnie Mountain. U.S. Highway 101 can be seen around mid photo tracking along the mountain. To the right and along the toe of the bluff is an extensive cobble/boulder berm that has formed as a result of rockfalls and landslides off the headland (photo: L. Stimely, DOGAMI, 2011).**

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**Figure 2-3. Looking south toward Cape Kiwanda in the distance. Coastal bluffs of the Astoria Formation characterize much of the shore north of Sand Lake. Note the presence of cobbles to the left of the photo, which serve to protect the bluff toe (photo: J. Allan, DOGAMI, 2011).**

**Figure 2-4.** Looking east across Cape Kiwanda toward the town of Pacific City. Cape Kiwanda is described as Astoria Formation sandstone. Immediately adjacent to the headland, latest Holocene dune sand have ramped up and over the headland (photo: L. Stimely, DOGAMI, 2011).

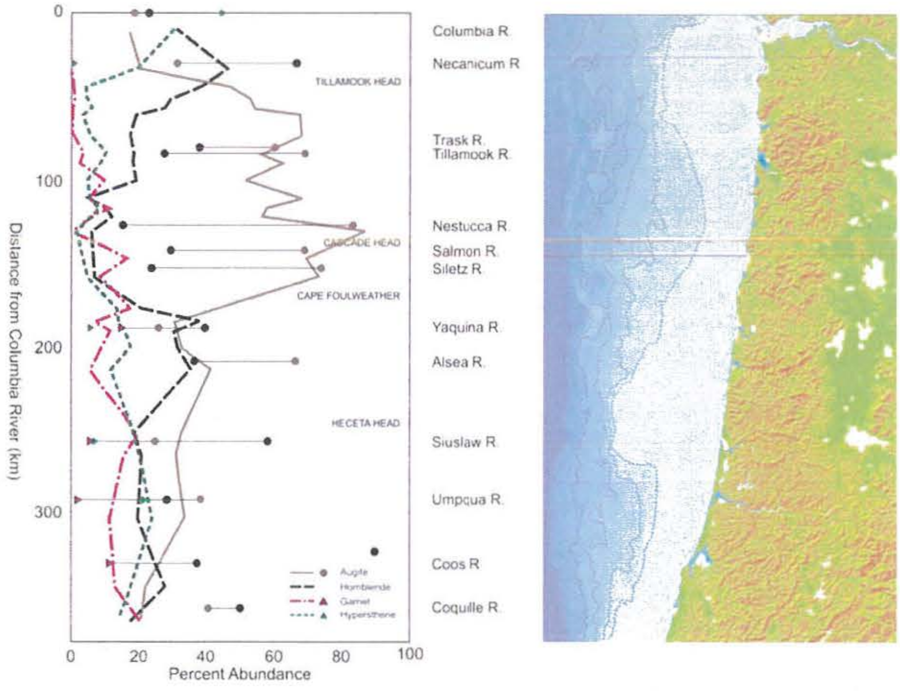


**Figure 2-5.** Variations in the percent abundances of various heavy minerals observed on the central to northern Oregon coast (after Clemens and Komar, 1988).

## 2.2 Tsunami Hazards Associated with the Cascadia Subduction Zone and from Distant Earthquake Sources

Considerable geologic data from estuaries and coastal lakes along the Cascadia subduction zone provides evidence for episodic occurrences of abrupt coastal subsidence immediately followed by significant ocean flooding associated with major tsunamis that swept across the ocean beaches and also traveled well inland through the bays and estuaries. Coastal paleoseismic records document the impacts of as many as 13 major subduction zone earthquakes and associated tsunamis over the past ~7,000 years (Witter and others, 2003; Kelsey and others, 2005; Witter and others, 2010), while recent studies of turbidite records within sediment cores collected in deep water at the heads of Cascadia submarine canyons provide evidence for at least 41 distinct tsunami events over the past ~10,000 years (Goldfinger and others, 2003; Goldfinger, 2009; Goldfinger and others, 2012). The length of time between these events varies from as short as a century to as long as 1,200 years, with the average recurrence interval for major Cascadia earthquakes (magnitude [$M_W$] > 9) estimated to be ~530 years (Witter and others, 2010).

The most recent Cascadia subduction zone earthquake occurred on January 26, 1700 (Satake and others, 1996; Atwater and others, 2005) and is estimated to have been a magnitude ($M_W$) 9 or greater based on the size of the tsunami documented along the coast of Japan. From correlations between tsunami deposits identified at multiple sites along the length of the PNW coast this event probably ruptured the full length (~1,200 km) of the subduction zone.

There is now increasing recognition that great earthquakes do not necessarily result in a complete rupture of the Cascadia subduction zone (i.e., rupture along the full 1,200 km fault zone), such that partial ruptures of the plate boundary have occurred in the paleo-records due to smaller earthquakes with magnitudes ($M_W$) < 9 (Witter and others, 2003; Kelsey and others, 2005). These partial segment ruptures appear to occur more frequently on the southern Oregon coast, determined from paleotsunami studies (stratigraphic coring, radiocarbon dating and marine diatom analyses) undertaken at several locations on the southern Oregon coast, including Bradley Lake located just south of Bandon, the Sixes River and the Coquille estuary. According to Kelsey and others (2005), initial estimates of the recurrence intervals of Bradley Lake tsunami incursion are typically shorter (~380–400 years) than the average recurrence intervals inferred for great earthquakes (~530 years). Furthermore, they have documented from those records that local tsunamis from Cascadia earthquakes recur in clusters (~250–400 years) followed by gaps of 700–1,300 years, with the highest tsunamis associated with earthquakes occurring at the beginning and end of a cluster.

Recent analyses of the turbidite records (Goldfinger, 2009; Goldfinger and others, 2012) suggest that of the 41 events in the geologic past:

- 20 events were probably associated with a rupture of the full Cascadia subduction zone, characterized by a magnitude ($M_W$) ~9 or greater earthquake;
- 2-3 events reflected a partial rupture (~75%) of the length of the subduction zone, characterized by an estimated earthquake magnitude ($M_W$) of ~8.5–8.8 earthquake;
- 10-11 events were associated with a partial rupture (~50%), characterized by an estimated earthquake magnitude ($M_W$) of ~8.3–8.5 earthquake; and
- 8 events reflected a partial rupture (~25%), with an estimated earthquake magnitude ($M_W$) of ~7.6–8.4.

These last 19 shorter ruptures are concentrated in the southern part of the margin and have estimated recurrence intervals of ~240–320 years. Goldfinger (2009) estimated that time-independent probabilities for segmented ruptures range from 7-9% for full margin ruptures, to ~18% in 50 years for a southern segment rupture; time dependent rupture analyses indicate that the probability increases to ~25% in 50 years for the northern zone.

Aside from local tsunamis associated with the Cascadia subduction zone, the Oregon coast is also susceptible from tsunamis generated by distant events, particularly along the coast of Japan, along the Aleutian Island chain, and from the Gulf of Alaska. The most recent distant tsunami event occurred on March

11, 2011, when a magnitude ($M_W$) 9.0 earthquake occurred 129 km (80 miles) offshore from the coast of Sendai, northeast Honshu, Japan (Allan and others, 2012a). This earthquake triggered a catastrophic tsunami that within minutes inundated the northeast coast of Japan, sweeping far inland; most recent reports indicate 15,854 dead and another 3,155 missing. Measurements derived from a tide gauge on the impacted shore (Ayukawa, Ishinomaki, Miyagi Prefecture) recorded a tsunami amplitude of 7.6 m, before the gauge was destroyed by the initial tsunami wave (Yamamoto, 2011), while post-tsunami surveys indicate that the tsunami water levels within the inundation zone reached as high as 19.5 m (64 ft) (Mori and others, 2011). The tsunami also propagated eastward across the Pacific Ocean, impacting coastal communities in Hawaii and along the west coast of the continental United States — Washington, Oregon, and California.

Damage in Oregon, Washington, and northern California from the tsunami was almost entirely confined to harbors, including Depoe Bay, Coos Bay, Brookings in Oregon, and in Crescent City, California, having been moderated by the arrival of the tsunami's highest waves during a relatively low tide (Allan and others, 2012a). At Crescent City, an open-coast breakwater, the to-and-fro surge of the water associated with the tsunami waves overturned and sank 15 vessels and damaged 47, while several boats were swept offshore. Flood damage also occurred during the early hours of March 12; for example, an RV park near the mouth of Elk Creek was flooded when a 1.05 m (3.4 ft) tsunami wave arrived, coinciding with high tide. The total damage to the Crescent City harbor and from the effects of the flooding has been placed at $12.5 million. At Brookings on the southern Oregon coast, 12 fishing vessels put to sea at about 6 am, prior to the arrival of the tsunami waves. However, the *Hilda*, a 220-ton fishing boat and the largest in the harbor, broke loose under the forces of the wave-induced currents, washing around the harbor and smashing into and sinking several other boats. Much of the commercial part of the harbor and about one third of the sports basin were destroyed; the total damage has been estimated at about $10 million.

Prior to the Tōhoku tsunami, the previous most significant distant tsunami occurred on March 27, 1964, when a magnitude ($M_W$) 9.2 earthquake occurred near Prince William Sound in Alaska. The earthquake generated a catastrophic local tsunami in Alaska, but the effects of the tsunami were also felt around the Pacific Basin. The tsunami caused significant damage to infrastructure in the coastal communities of Seaside and Cannon Beach, Oregon, and killed four people camping along Beverly Beach in Lincoln County, Oregon.

In 2009, the Oregon Department of Geology and Mineral Industries (DOGAMI) initiated a multi-year study to accelerate remapping of the Oregon coast for tsunami inundation using state of the art computer modeling and laser based terrain mapping (lidar). The outcome of this effort was the creation of new and more accurate tsunami evacuation maps for the entire length of the coast. DOGAMI, in collaboration with researchers (Zhang and Baptista) at the Oregon Health and Science University (OHSU), Oregon State University (Goldfinger) and the Geological Survey of Canada (Wang), developed a new approach to produce a suite of next-generation tsunami hazard maps for Oregon (Priest and others, 2010; Witter and others, 2010). Modeling tsunami inundation on the southern Oregon coast was initiated late in 2009 and consisted of a range of scenarios, including 15 Cascadia events and two distant earthquake source events (e.g., 1964 Prince William Sound earthquake magnitude [$M_W$] 9.2 earthquake [Witter, 2008]). The last of the suite of new evacuation maps (TIM series) was released in 2013; the maps are also available in an online tsunami hazard portal (http://nvs.nanoos.org/TsunamiEvac).

Associated with great Cascadia earthquakes is a near instantaneous lowering (subsidence) of the coast by ~0.4 m (1.3 ft) to as much as 3 m (9.8 ft) (Witter and others, 2003). This process equates to raising sea level by the same amount along the entire Pacific Northwest coastline. Following the earthquake, coastal erosion is expected to accelerate everywhere as the beaches and shorelines adjusted to a new equilibrium condition that, over time, would likely decrease asymptotically (Komar and others, 1991). On the southern Oregon coast, Komar and others have suggested that the extensive development of sea stacks offshore from Bandon may be evidence for that erosion response following the last major subduction zone earthquake in 1700. Over the past century, the erosion appears to have stabilized as there is little evidence for any progressive erosion trend. This suggests that the south coast is now being uplifted (estimated to be ~0.6 to 1.1 m) due to the Cascadia subduction zone having become locked again, such that strain is now building toward the next major earthquake. With the release of that energy and land subsidence, cliff erosion along the Bandon shore (and elsewhere on the Oregon coast) would be expected to begin again.

## 2.3 Coastal Geomorphology

On the basis of geology and geomorphology the Tillamook County shoreline can be broadly divided into five morphological beach types. These are depicted in **Figures 2-6** to **2-10** and include:

1. ***Dune-backed beaches:*** Dune-backed beaches make up the bulk (50.9%) of the Tillamook County shoreline, much of which is associated with the barrier spits (e.g., Nestucca, Sand Lake, Netarts, Bayocean, and Nehalem Spits, **Figures 2-6** to **2-10**). The geomorphology of the beaches can be generalized as having wide, dissipative surf zones with low sloping foreshores that are backed by high dunes containing significant sand volume (**Figure 2-1**). Dune crest elevations reach their highest peak along Bayocean (39 m [128 ft]) and Netarts Spit (25 m [82 ft]) (**Figure 2-11**). However, these dunes are in part ancient parabolic dunes that are now being truncated by wave erosion. Dune crest elevations are generally lowest in the Rockaway subcell (Twin Rocks, Rockaway, and Nedonna Beach) (**Figure 1-1**). Along the length of the county, mean dune crest heights are 10.5 m (35.5 ft), with most dunes being in the range of 5 to 16 m (16 to 54 ft). The average beach slope (tan $\beta$) for dune-backed beaches is summarized in **Figure 2-12** where it is apparent that slopes vary significantly along the coast, with the lowest mean slopes occurring in the vicinity of Oceanside (mean = 0.032), and are generally steepest in the Neskowin littoral cell (mean = 0.06).
2. ***Cliffed shore:*** Cliffed shores make up the second largest (30.5%) geomorphic "type" in the county (**Figure 2-2**). Examples exist around each of the major headlands. This particular shore type generally consists of near-vertical cliffs that plunge directly into the ocean, but in some cases, the cliffs may be fronted by rock platforms and/or talus.
3. ***Bluff-backed beaches:*** Bluff-backed beaches fronted by wide, dissipative sand beaches are the third most prominent geomorphic type in Tillamook County, comprising approximately 14.3% of the shore (**Figure 2-3**). This particular geomorphic type dominates the shoreline in the vicinity of Oceanside and Short Sand Beach, south of Cape Lookout, the south end of Cape Lookout State Park, north of Cape Kiwanda and south of Tierra Del Mar, and adjacent to the mouth of Nestucca Bay. The bluffs that back the beaches vary in height from ~7 m (23 ft) to greater than 50 m (164 ft). Beach slopes (tan $\beta$) seaward of the bluffs are similar to those observed throughout Tillamook County, averaging about 0.037 ($\sigma = 0.009$). Geomorphically, these beaches may be characterized as "composite" using the terminology of Beaulieu (1973) and Jennings and Shulmeister (2002), such that the beaches consist of a wide dissipative sandy beach, backed by a steeper upper foreshore composed of gravels and cobbles. In addition, several of the bluff-backed sections are characterized by well-vegetated faces, indicating that they have not been subject to significant wave erosion processes along the toe of the bluffs for many decades.
4. ***Bluff-backed beaches fronted by gravel and sand:*** This particular geomorphic type makes up approximately 3.3% of the Tillamook County shoreline and is prevalent on the south side of Neahkahnie Mountain (north of Manzanita), immediately north of Cape Meares, Short Sand Beach (**Figure 2-13**), and immediately north of Cape Lookout. The overall morphology is essentially the same as described for bluff-backed beaches, with the only differ-

ence being the presence of a gravel berm along the toe of the bluff.

5. ***Gravel/boulder berm fronted by sand:*** In the community of Cape Meares (south end of Bayocean Spit, **Figure 2-7**), a substantial gravel/boulder beach abuts against the Cape Meares headland, where they form prominent, steep natural barriers to wave erosion (**Figure 2-14**). The berm is approximately 0.8 km (0.6 miles) long. Crest elevations of the cobble/boulder beach reach a maximum of 8.7 m (29 ft), while the mean crest elevation is 6.7 m (22 ft). The slope of the gravel berm is steep (mean = 0.187 [($\sigma$ = 0.060]), while the sand beach has a mean slope of 0.047, which is typical of much of the Tillamook County coast. Considerable flotsam exists along the crest of the berm and significant distant landward of the crest, indicating that this stretch of shore is subject to frequent wave overtopping and inundation.

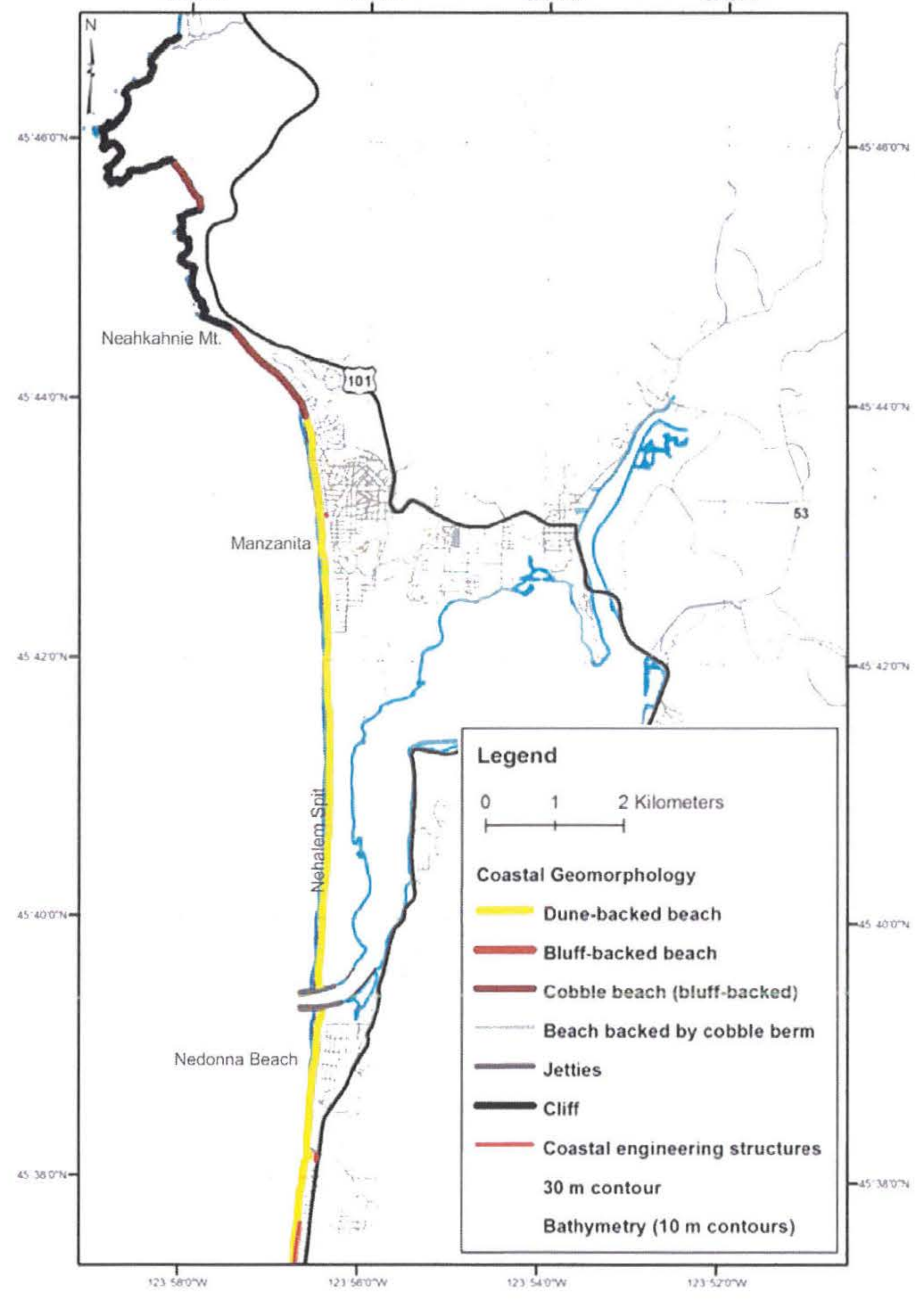


**Figure 2-6.** Geomorphic classification of northern Rockaway Beach/Nehalem Spit (Rockaway beach to Cape Falcon).

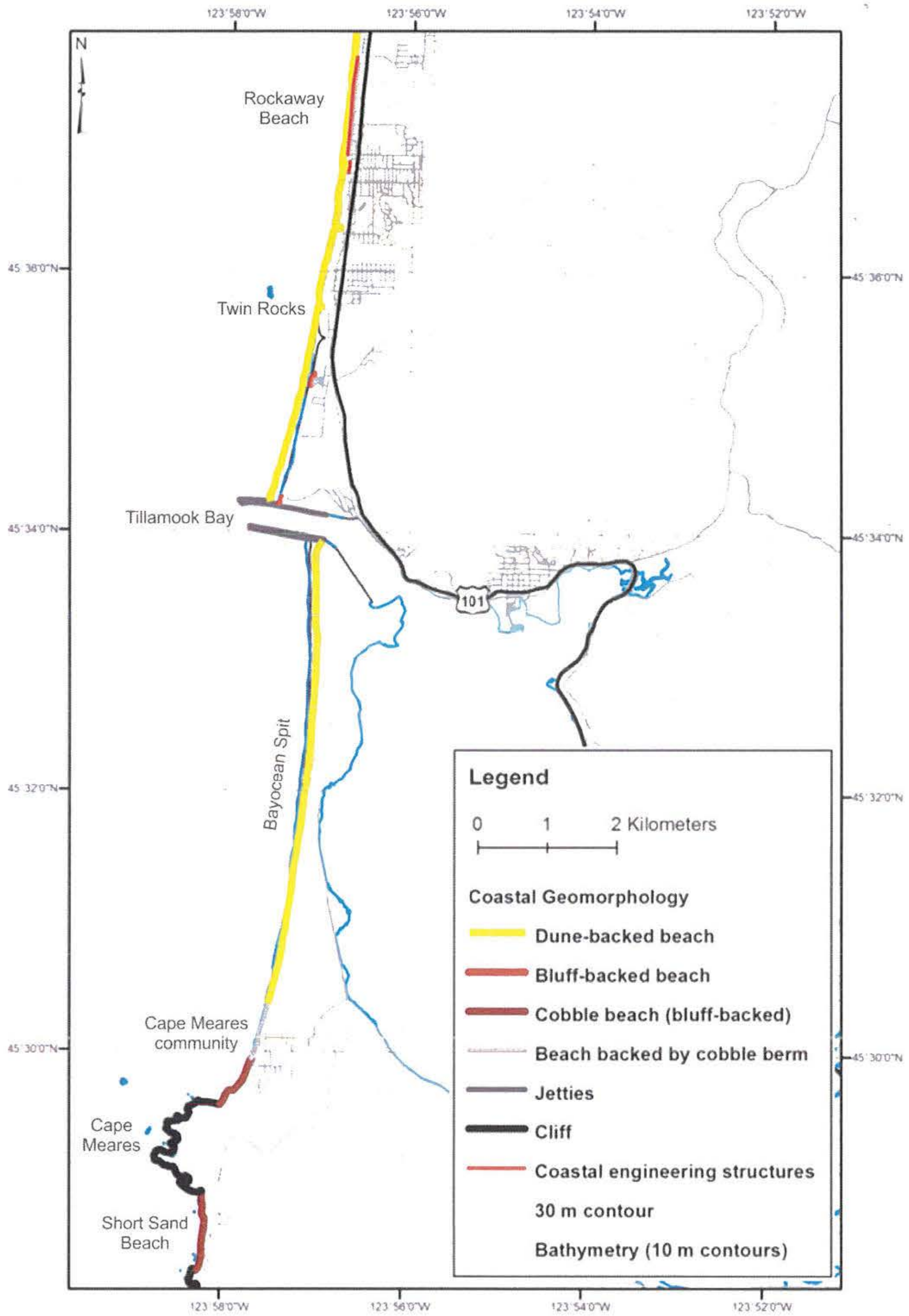


**Figure 2-7.** **Geomorphic classification of southern Rockaway Beach/Bayocean Spit (Cape Meares to Rockaway Beach).**

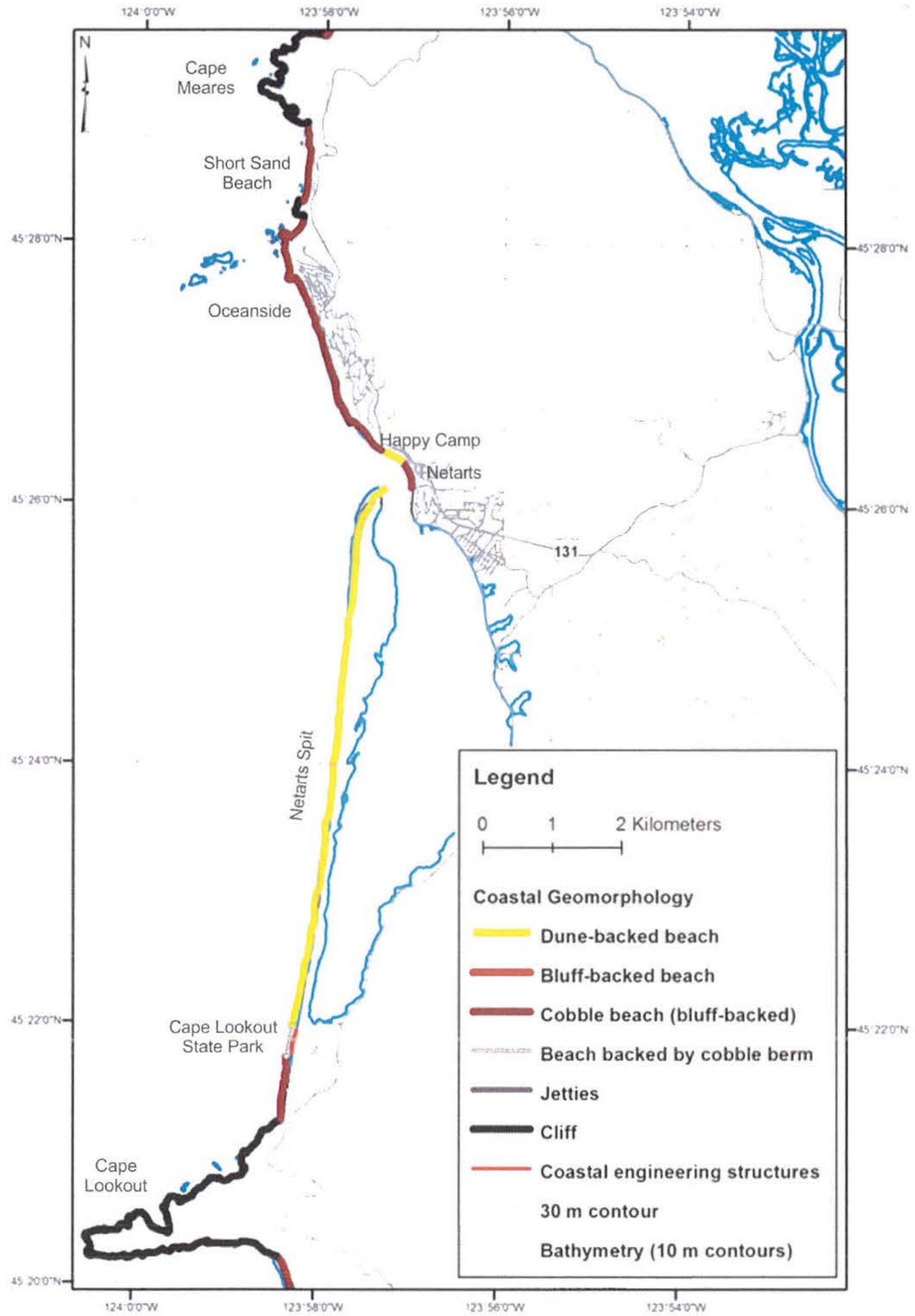


**Figure 2-8.** Geomorphic classification of the Netarts littoral cell (Cape Lookout to Cape Meares).

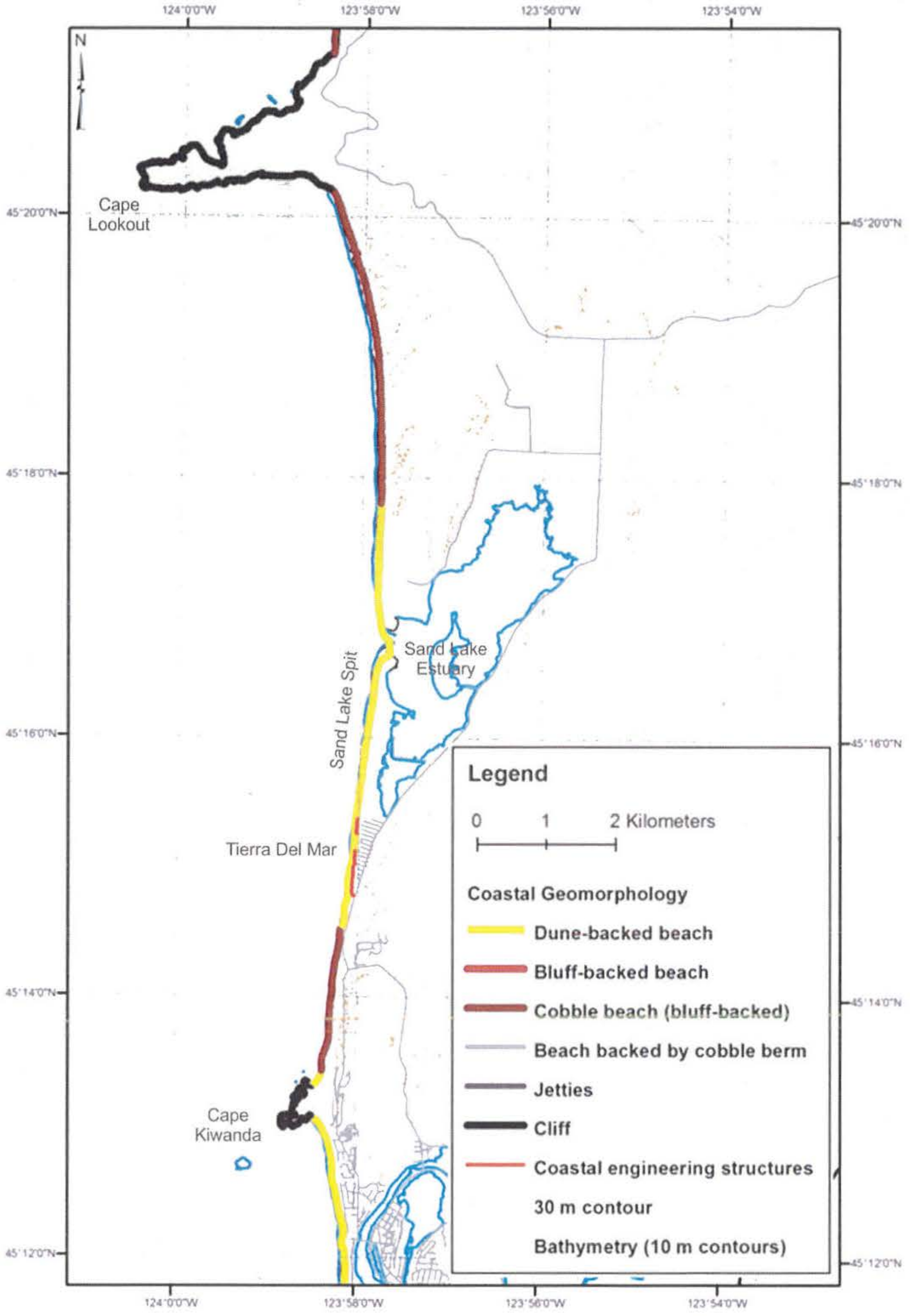


**Figure 2-9.** Geomorphic classification of the Sand lake littoral cell (Cape Kiwanda to Cape Lookout).

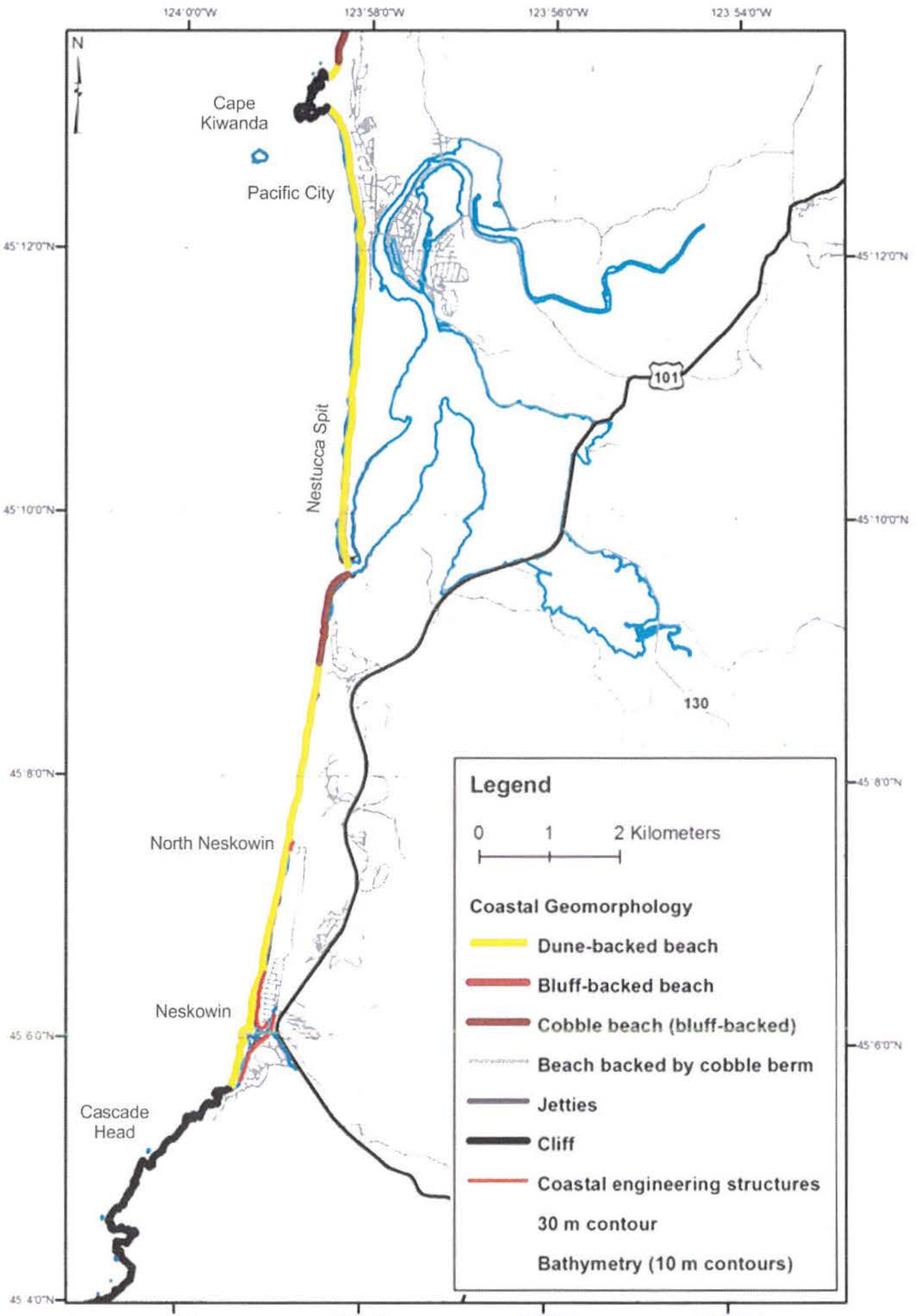


**Figure 2-10. Geomorphic classification of the Neskowin littoral cell (Cascade Head to Cape Kiwanda).**

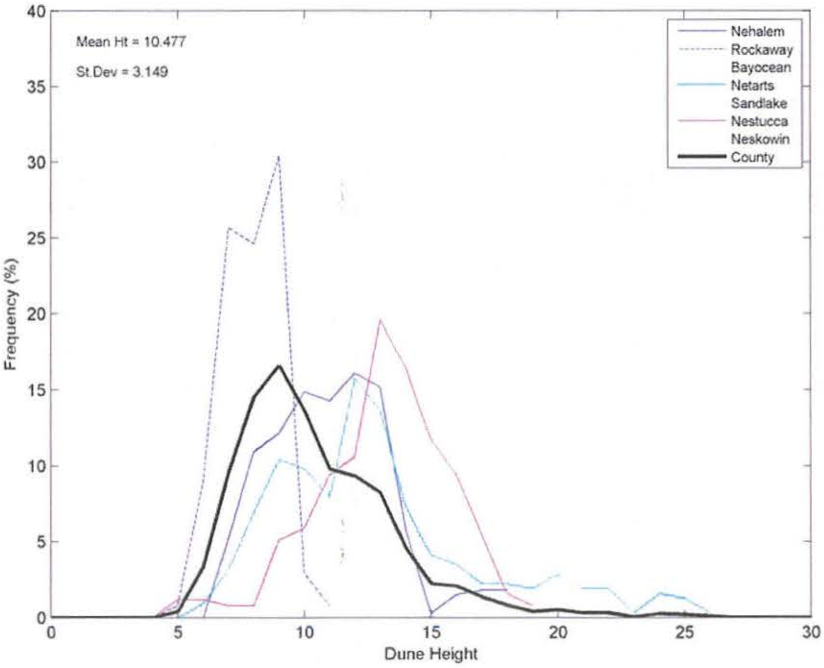


Figure 2-11. Tillamook County dune crests. Data from Allan and Harris (2012).

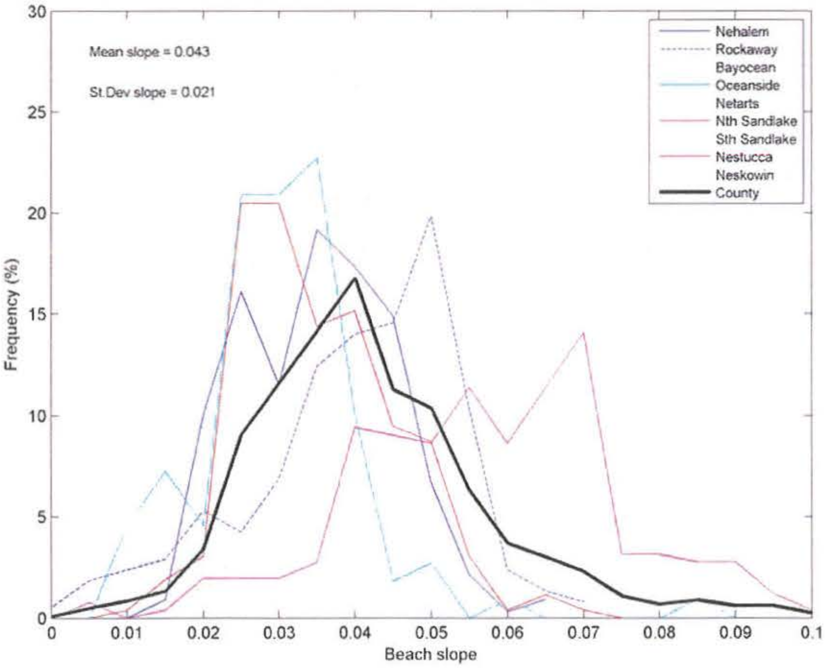


Figure 2-12. Tillamook County beach slopes. Data from Allan and Harris (2012).

**Figure 2-13. An extensive gravel berm fronted by a dissipative sand beach and backed by high bluffs at Short Sand Beach, north of the community of Oceanside. Note the extensive accumulation of woody debris along the crest of the berm, which has a crest elevation that averages ~5.8 m (σ = 1.6 m) (photo: J. Allan, DOGAMI, 2003).**

**Figure 2-14. An extensive gravel/boulder berm that backs a dissipative sand beach in the Cape Meares community. View is looking south toward the Cape Meares headland. An exposed tree stump located in situ is exposed due to lowering of the sand beach (photo: J. Allan, DOGAMI, 2008).**

## 2.4 Coastal Erosion and Flood History

### *2.4.1 Tillamook County historical shoreline positions*

This section presents a qualitative discussion of large-scale morphological changes derived from analyses of historical and contemporary shorelines derived for the Tillamook County coastline. This summary stems from work undertaken by researchers at DOGAMI and OSU over the past two decades (Priest and others, 1993; Allan and Priest, 2001; Allan and others, 2003; Allan and Hart, 2007, 2008; Allan and Harris, 2012; Allan and Stimely, 2013; Ruggiero and others, 2013).

National Ocean Service (NOS) Topographic (T)-sheet shoreline positions covering the 1920s and 1950s were previously obtained from NOAA (Allan and Priest, 2001). These lines reflect the mean high water (MHW) position mapped by early NOS surveyors, on an average tide typically in mid to late summer. Additional shorelines were derived from a variety of other sources including: 1967 digital orthophotos (Ruggiero and others, 2013), 1980s era U.S. Geological Survey topographic maps, 1994 digital orthophotos, and from 1997, 1998, and 2002 lidar data (Allan and Priest, 2001). Pre-lidar historical shorelines use the high water line (HWL) as a shoreline proxy. The HWL has been used by researchers for more than 150 years because it could be visually identified in the field or from aerial photographs. In contrast, shorelines derived from lidar data are datum-based and can be extracted objectively using a tidal datum, such as MHW or mean higher high water (MHHW). Studies by Moore (2000) and Ruggiero and others (2003) note that HWL-type shoreline proxies are virtually never coincident with datum-based MHW-type shorelines. In fact they are almost universally estimated to be higher (landward) on the beach profile when compared to MHW shorelines (Ruggiero and others, 2013). According to Ruggiero and others, the average absolute horizontal offset between the HWL and MHW ranges from ~6 m (~19 ft) to as much as 50 m (164 ft), while the average is typically less than 20 m (65 ft). Offsets are typically greatest on flat, dissipative beaches where the wave runup may be large and smallest where beaches are steep (e.g., gravel beaches).

Estimates of the uncertainty of HWL shoreline measurements have been assessed in a number of studies (e.g., Moore, 2000; Ruggiero and others, 2013). These uncertainties reflect the following errors: 1) mapping methods and materials for historical shorelines (including the offset between the HWL and MHW shoreline), 2) the registration of shoreline positions relative to Cartesian coordinates, and 3) shoreline digitizing, and are summarized in **Table 2-1**.

Shorelines measured by DOGAMI staff using Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) surveys of the beach are also available for the Neskowin and Rockaway littoral cells (Allan and Hart, 2007, 2008; Allan and Stimely, 2013). These latter data sets provide the most up-to-date assessments of the changes taking place along the Tillamook coastline and have been collected since 2007 in order to document the seasonal to interannual variability in shoreline positions along the county. In all cases, the GPS shorelines reflect measurements of the MHHW line located at an elevation of 2.3 m (7.5 ft). We have relied on the latter as opposed to the MHW line, because previous studies indicate that MHHW line most closely approximates the MHW line surveyed by early NOS surveyors. Errors associated with these various products are described by Moore (2000). GPS shoreline positioning errors, a function of the orientation of the GPS receiver relative to the slope of the beach, are estimated to be approximately ±0.1 to ±0.2 m (±0.3 to ±0.6 ft).

The approach adopted here is to describe the broad morphological changes identified along the

**Table 2-1. Average uncertainties for Pacific Northwest shorelines (Ruggiero and others, 2013).**

| | NOS T-Sheets (1800s to 1950s) | | DRGs (1940s to 1990s) | | Aerial Photography (1960s to 1990s) | | Lidar | |
|---|---|---|---|---|---|---|---|---|
| Total shoreline position uncertainty | 18.3 m | 60 ft | 21.4 m | 70 ft | 15.1 m | 50 ft | 4.1 m | 14 ft |

coast, beginning in the south at Neskowin, and progressing northward toward Cape Falcon.

#### *2.4.1.1 Neskowin Cell*

At Neskowin, the historical shoreline positions reveal little systematic pattern, with all of the identified shorelines falling within a few hundred feet of each other (**Figure 2-15**). Many of the shorelines reveal the presence of large embayments along the coast indicative of the formation of rip currents that can result in highly localized hotspot erosion (e.g., the April 2013 shoreline in **Figure 2-15**). Along much of the southern half of the cell, the 1920s era shoreline tends to track landward of the other shorelines. This suggests that beach conditions in the 1920s reflected an eroded state following a period of large storm events. Erosion appears to have dominated much of the early existence of the Neskowin community. Probably the most significant storm on record occurred in January 1939, which affected much of the Oregon coast and caused major coastal flood hazards as well as significant erosion problems. For example, **Figure 2-16** provides an example of the damage sustained in Neskowin; one home had its foundation eroded from under it, which resulted in the house collapsing onto the beach. Within a decade, however, this process had effectively reversed itself, with much of the shore having been rebuilt as sand migrated back on to the beach. This cycle of erosion followed by accretion is typical of shoreline changes on the Oregon coast. The 1967, 1980s era, and 1994 shorelines represent the most seaward positions, implying that significant accretion had occurred adjacent to Neskowin during those years, while the early 1960s, the 1982-83 El Niño winter, and the storms of the late 1990s represent eroded states.

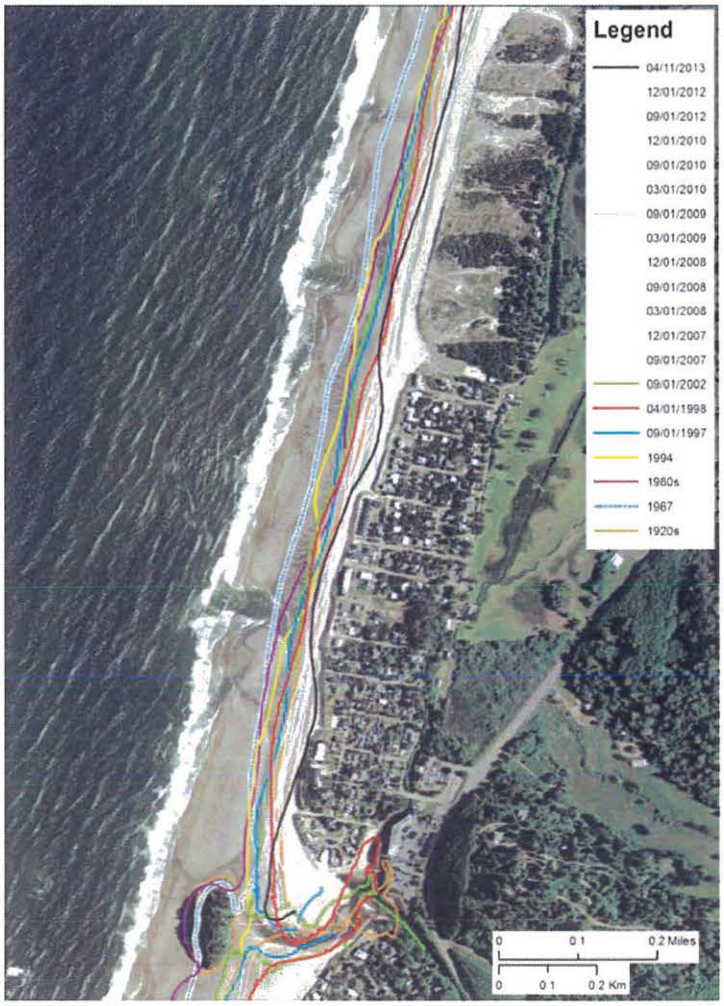


**Figure 2-15.** Historical and contemporary shoreline positions identified at Neskowin. Note: The 1920s (1927/28) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, 1997–2002 are derived from lidar, and post 2007 were measured using GPS.

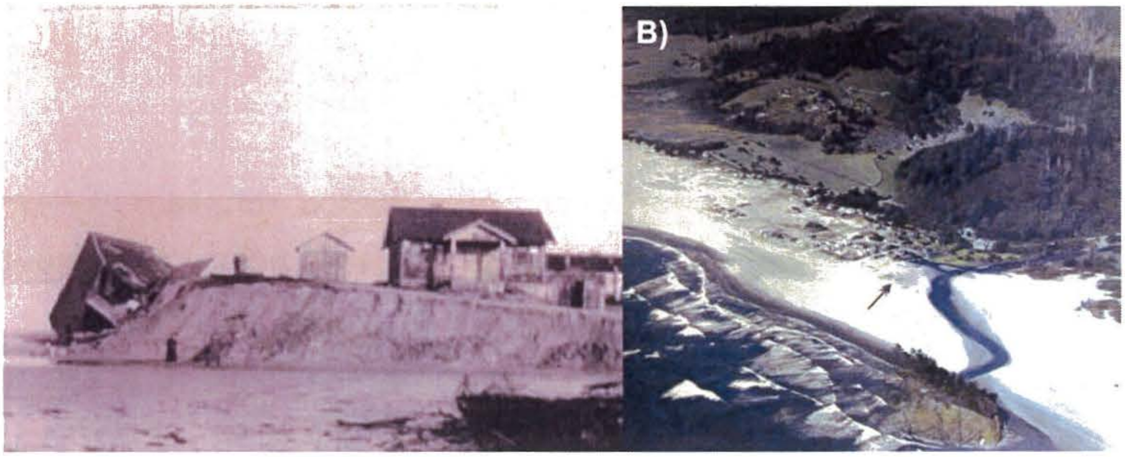


**Figure 2-16. Erosion and accretion at Neskowin. A) Erosion (adjacent to the juncture between Neskowin and Hawk Creeks) following the January 1939 storm; B) Rebuilding of the sandy beach at Neskowin in 1949. Note: the arrow indicates the approximate position of the erosion shown in A). (Photos courtesy of Neskowin community archives.)**

Following the major storms of the late 1990s, erosion hazards in the community of Neskowin have reached acute levels (Allan and others, 2003; Allan and Hart, 2007), with the beach and dune having eroded landward some 50 m (~150 ft) (**Figure 2-17**). Property owners responded to the hazard by installing riprap along much of the shore north of Proposal Rock. As of 2014, virtually the entire length of the community of Neskowin (including north Neskowin) is hardened with riprap. Monitoring of the beaches in Neskowin indicates that they have not fully recovered from the storms of the late 1990s (several areas have in fact continued to erode), such that the beaches today are narrower and have much less sand volume compared with the same beaches in the mid 1990s (Allan and Hart, 2008). Long-term erosion rates derived by Ruggiero and others (2013) indicate that the beaches of Neskowin have some of the highest rates of retreat in the state. Due to narrow beaches and lack of sand volume, the community of Neskowin today remains at high risk of being impacted by major winter storms and from ocean flooding.

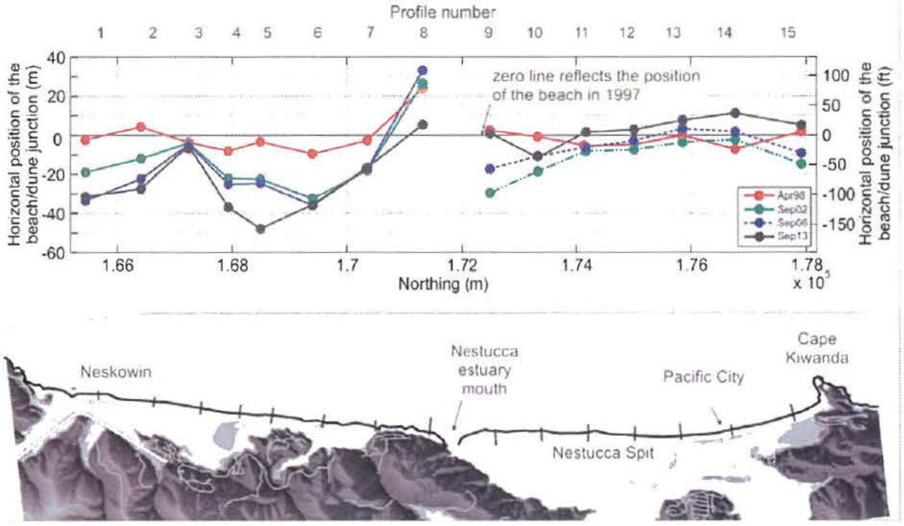


**Figure 2-17. Positional changes in the beach/dune toe (elevation of 6 m) along the Neskowin cell between 1997 and 2008 derived from lidar data and RTK-DGPS measured surveys of the beach. Circles and numbers correspond to the locations of the Neskowin beach monitoring network established by DOGAMI in 2006 (after Allan and others, 2009).**

Farther north along the coast, the 1994 shoreline tends to track well seaward of the other shorelines. This suggests a period of accretion and was most noticeable adjacent to Porter Point near the mouth of Nestucca Bay (**Figure 2-18** and approximate location of transect 8 in **Figure 2-17**). The pattern of accretion appears to be consistent with a general decline in wave energy and storm incidence observed during the early part of the 1990s (Allan and Komar, 2000). However, recent GPS surveys of this section of the coast by DOGAMI staff indicate a reversal from accretion back to erosion, with the shoreline now having retreated virtually back to the toe of the marine cliffs that back the beach.

Along Nestucca spit (**Figure 2-18**), the tip of the spit and the bay mouth have remained predominantly in the south, with some evidence of a northward migration in 1998. From inspection of the suite of shorelines available to us, the Nestucca spit tip has ranged over a distance of about 340 m (1,118 ft) between 1927 and 2008 and was at its most southerly position in 2008. Following the 1997-98 El Niño, the spit tip migrated northward, probably in response to a change in wave direction that is typical of El Niño events (e.g., Komar, 1986). Of interest also is the presence of a large bulge identified by the 1980s era shoreline on the eastern side of the spit (**Figure 2-18**). This feature is remnant from when the spit was breached during a major storm in February 1978 (see Figure 6.15 of Komar [1997]).

North of Nestucca spit, the 1980s era shoreline tracks landward of the other shoreline positions and extends all the way to Pacific City at the north end of the cell. This finding is likely to be a function of erosion that occurred during the 1982-83 El Niño event (P. Komar, personal communication 2001). In contrast, the 1994 and 2002 shoreline positions represent the most seaward extent of the MHWL (located some 45–76 m [150–250 ft] seaward of the 1985-1986 shoreline). This indicates that large volumes of sediment had accumulated along much of the northern half of the cell, the product of a persistent net drift of beach sediments to the north. It is highly likely that this pattern is a function of the persistent El Niño conditions that have characterized the Pacific Northwest (PNW) during the 1980s and 1990s. Similar observations of net accretion around Pacific City since about 1981 were also noted in a report by Shoreland Solutions (1998b). For example, considerable quantities of sand accumulated along much of the Pacific City shoreline, burying a large riprap revetment that was installed in 1978. Furthermore, the continued accumulation of sand at the north end of the Neskowin cell has presented major problems for homeowners since at least 1984. Of particular concern has been the inundation of homes and property by sand (Komar 1997; Shoreland Solutions, 1998b). As can be seen from **Figure 2-17**, much of the Nestucca spit has now recovered from the major storms of the late 1990s.

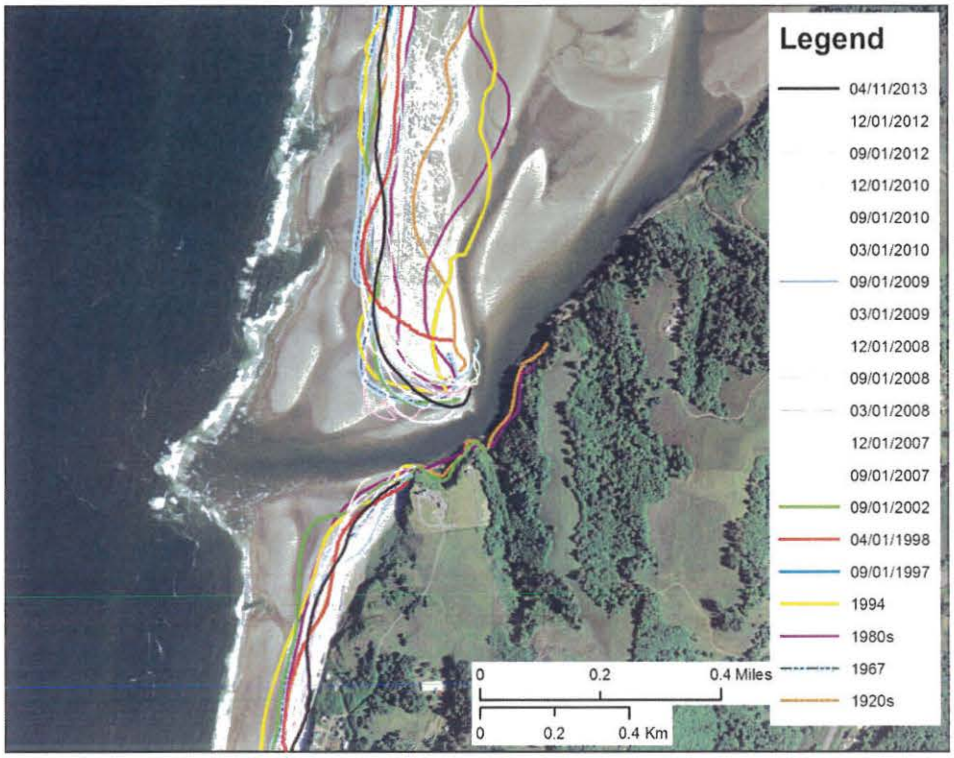


**Figure 2-18.** Historical and contemporary shoreline positions identified adjacent to the Nestucca Bay mouth. Note: The 1920s (1927/28) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, 1997–2002 are derived from lidar, and post 2007 were measured using GPS.

#### *2.4.1.2 Sand Lake Cell*

Along the Sand Lake cell, the 1920s and 1980s era shoreline positions represent the most landward extent of the MHWL (i.e., eroded state), while the 1967 and 1994 shorelines characterize the accreted state. For the most part, this pattern is broadly similar to that identified previously in the Neskowin cell. However, unlike the Neskowin cell, the 1980s era shoreline at Sand Lake indicates cell-wide coastal erosion.

Approximately 2.8 km (1.74 mi) north of Cape Kiwanda is the community of Tierra Del Mar. As with Neskowin, much of its shoreline has now been protected with coastal engineering structures (riprap). These structures appear to have been built in the early 1970s and were expanded further in 1984, probably in response to the effects of the 1982-83 El Niño. North of Tierra Del Mar, the entire spit is experiencing significant erosion. For example, analyses of lidar data from 1997 to 2009 indicate that the spit shoreline has eroded on average by 27.8 m (91 ft).

Some of the most interesting shoreline changes identified in the Sand Lake cell are found adjacent to the mouth of the estuary. As shown in **Figure 2-19**, the location of the estuary mouth has varied considerably over the past century. The 1920s era shoreline characterizes the most southerly extent of the estuary mouth (implying a period of net southerly sand transport), while the 2009 shoreline identifies its most northerly position. As a result, the estuary mouth has migrated some 0.5 km (~0.3 mi) during this period. These results clearly highlight the dynamic and unstable nature of spit ends. An examination of aerial photographs taken in 1939 (not shown) also reveals a southerly bay-mouth position, while the spit ends were much wider. These latter characteristics are broadly similar to the 1920s shoreline identified in **Figure 2-19**. In contrast, the 1980s shoreline indicates an extremely wide bay mouth (~0.5 km [~0.3 mi] wide), so that much of the inner bay was probably fully exposed to the sea. Since the 1990s the estuary mouth has migrated north up against the northern spit tip, causing the tip to be truncated, while also eroding a section of the shoreline within the estuary adjacent to Sand Lake Recreation Area park (**Figure 2-19**).

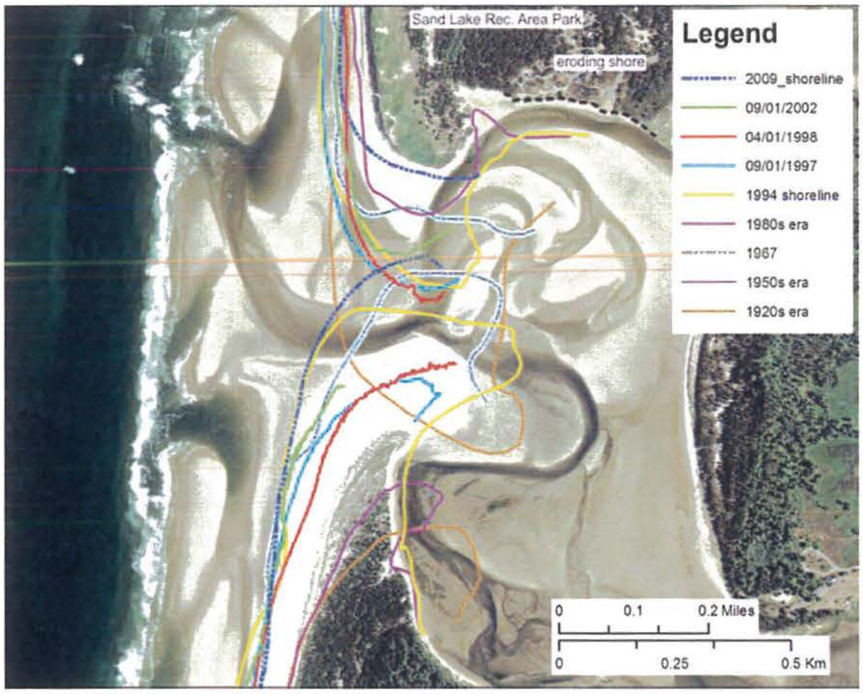


**Figure 2-19. Shoreline variability adjacent to the Sand Lake estuary mouth. Note: The 1920s (1927/28) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar.**

#### *2.4.1.3 Netarts Cell*

The Netarts littoral cell is one of the smallest cells on the Oregon coast. As a result, it is particularly susceptible to variations in wave approach, particularly changes in the predominant wave direction caused by the El Niño/La Niña Southern Oscillation. The shoreline analyses presented here demonstrate a number of morphological changes that are less apparent in the other littoral cells. At Cape Lookout State Park (CLSP) located at the southern end of the cell (**Figure 2-20**), the shorelines track closely to each other. The exceptions to this are the 1994 and 2009 shorelines. The former shoreline identifies the accreted state (consistent with the other littoral cells in Tillamook County), while the 2009 shoreline reveals the most eroded state. The latter is the product of erosion along the spit that accelerated in the late 1990s, due to a series of large storms that impacted the area in the 1997-98 El Niño winter. In fact, subsequent storms over the 1998-99 La Niña winter caused even more extensive erosion of the park. In particular, a storm on March 2-3, 1999, eventually resulted in the foredune that protected the park being breached, and inundation of the campground that led to significant damage to its facilities.

According to Komar and others (1989), El Niño events have produced large spatial changes in the configuration of the Netarts cell coastline and the morphology of the beaches, especially during the 1980s and 1990s. Allan and others (2003) analyzed terrestrial lidar measured in 1997 (pre 1997-98 El Niño) and 1998 (post El Niño) in order to quantify the alongshore variance in El Niño shoreline responses (**Figure 2-21**). As can be seen in the figure, the largest extent of shoreline retreat occurred along the southern 3 km (1.86 miles) of the cell, immediately north of Cape Lookout. Erosion in that area during both the 1982-83 and 1997-98 El Niños significantly damaged Cape Lookout State Park, eroding away a high ridge of dunes that protected the park (Komar and others, 1989; Komar, 1998a). The lidar results in **Figure 2-21** also capture the northward displacement of sand during the El Niño winter. In the hotspot zone in the south, the maximum shoreline retreat reached 18 m (59 ft). Shoreline accretion otherwise prevailed along the remainder of the cell, on average 5 to 10 m (~16–33 ft), a result of sand acquired by its northward displacement from the eroded hotspot zone at the south end of the cell. There was also an occurrence of hotspot erosion along the north shore of the inlet to Netarts Bay, which threatened the loss of condominiums perched overlooking the estuary mouth on the north side of the bay (Komar, 1998a).

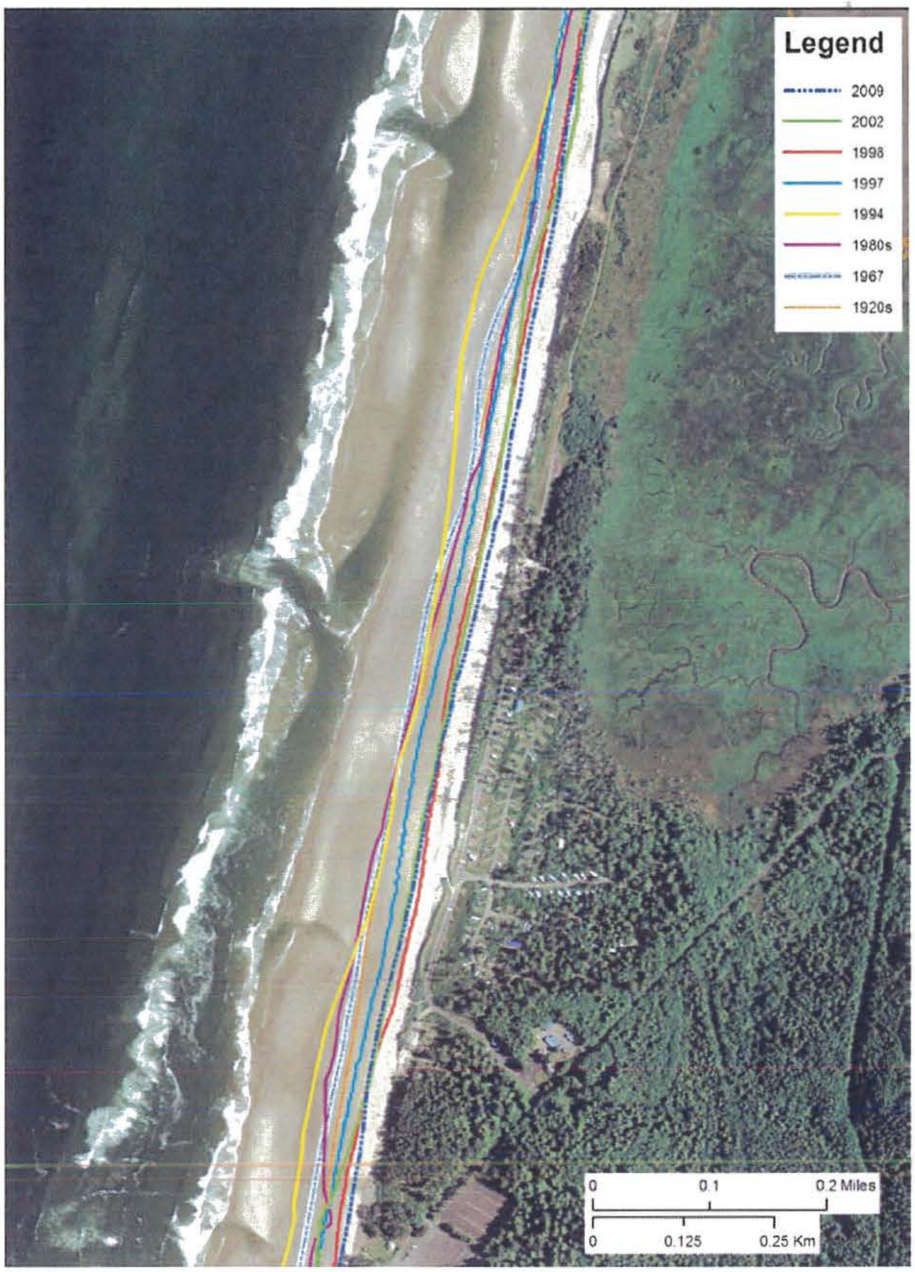


**Figure 2-20. Historical and contemporary shoreline positions identified along the southern end of Netarts Spit, adjacent to Cape Lookout State Park. Note: The 1920s (1927/28) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar.**

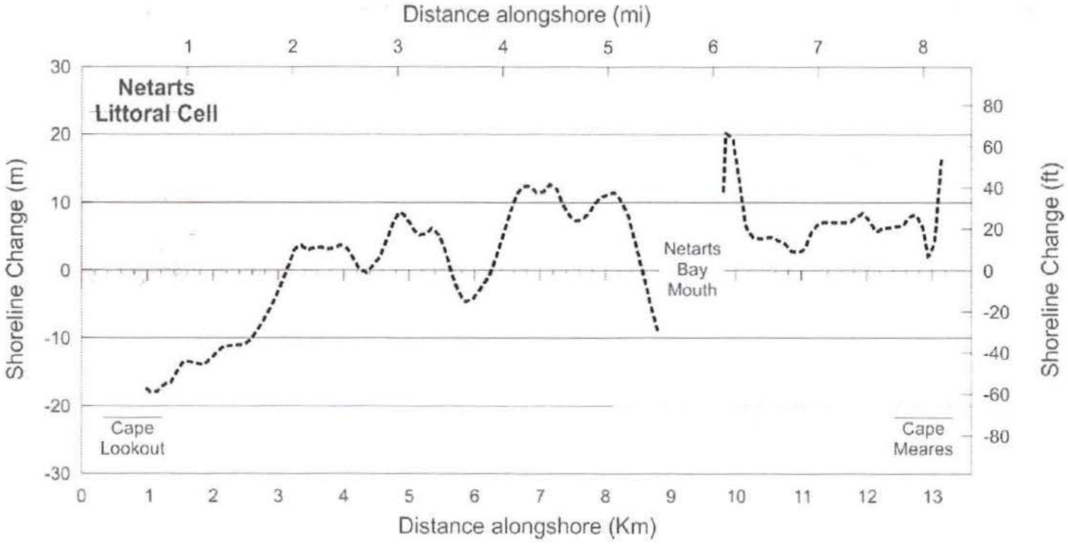


**Figure 2-21. De-meaned shoreline changes in the Netarts cell derived by subtracting the 1998 lidar shoreline from the 1997 shoreline (after Allan and others, 2003).**

Prior to the 1982-83 El Niño, erosion on Netarts Spit had been minimal (Komar and others, 1989). As a result, significant erosion of CLSP did not begin to occur until the 1982-83 El Niño and was very advanced by the 1987-88 El Niño erosion event. Interestingly, the 1980s era and 1994 shorelines presented in **Figure 2-20** indicate a relatively broad beach in front of the park, suggesting that the beach had reformed somewhat after the 1982-83 El Niño. This is consistent with observations reported by Komar and others (1989). However, they noted further that although some of the sand had returned, the volume of sand contained on the beach was still depleted when compared with the period prior to the 1982-83 El Niño. Extensive areas of gravel exposed on the beach and the presence of rock outcrops in the shallow offshore were evidence for their conclusion. Because the beach was in such a depleted state, its capacity to act as a buffer against storm waves during subsequent winter seasons was severely reduced. This was especially the case during the 1987-88 El Niño event, which eventually caused the destruction of a wooden bulkhead emplaced along the beach foredune during the late 1960s (**Figure 2-22**). By April 1998 the width of the beach in front of CLSP had narrowed significantly, from about 50–91 m (170–300 ft) wide in 1994, to around 12–24 m (40–80 ft) wide in 1998 (**Figure 2-20**). Furthermore, the area affected by the erosion extended about 1.4 km (0.9 mi) north and 1.1 km (0.7 mi) south of the campground. In an effort to mitigate the erosion problems, the Oregon Parks and Recreation Department responded by installing a dynamic revetment structure in the area most affected (**Figure 2-23**). Such structures are a "soft" form of engineering (when compared with basaltic rip rap revetments), because they are less intrusive on the coastal system and are designed to respond dynamically to wave attack.

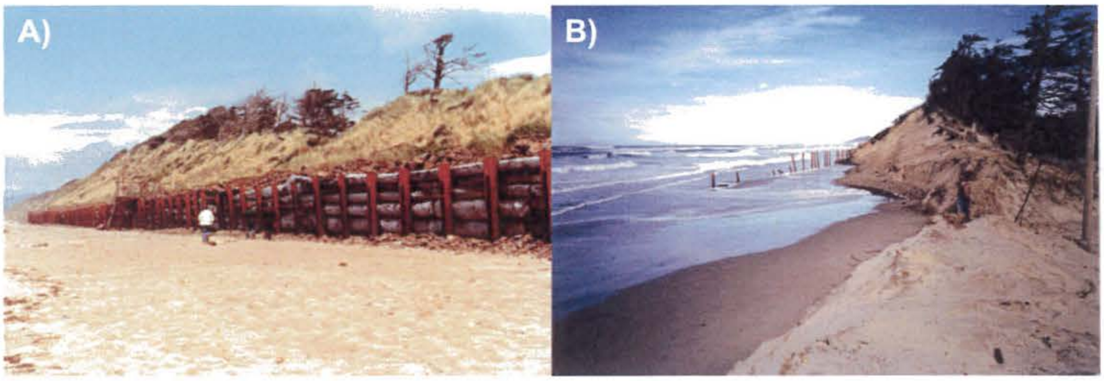


Figure 2-22. Cape Lookout State Park. A) A wooden bulkhead constructed at CLSP [Photo OPRD, June 1978]; B) The same area in February 1998 (photo: P. Komar, February 1998).

Figure 2-23. Dynamic revetment "cobble beach" constructed at Cape Lookout State Park. The cobble beach is backed by an artificial dune, which periodically is overtopped during major storms (photo: J. Allan, DOGAMI, 2008).

Farther north along Netarts Spit (about 2.9 km [1.8 mi] north of CLSP), erosion of the high foredune remains acute. For the most part, the 1980s shoreline shifts landward with progress along the spit, tracking close to the vegetation line and indicating significant erosion along much of the northern end of Netarts Spit (**Figure 2-24**). This is characterized by the position of the 1980s shoreline and by the presence of a prominent erosion scarp. In contrast, the 1994, 1997, and 1998 shorelines shift seaward and track about 60 to 75 m (196 to 246 ft) seaward of the 1980s shoreline (**Figure 2-24**). Such a change is analogous to a pivot point in which one set of processes (erosion), gives way to another (accretion). In other words, the coastal response along Netarts Spit reflects a reorientation of the entire shoreline toward the direction of wave attack, with erosion occurring along the southern end of the cell and accretion in the north (Komar and others, 1989; Revell and others, 2002). Recent measurements by DOGAMI staff using RTK-DGPS to document beach and shoreline changes along Netarts Spit have revealed that the foredune periodically undergoes 10 to 15 m (33 to 49 ft) of dune retreat during single storm events, highlighting the intensity of the erosion processes that dominate much of this coastline.

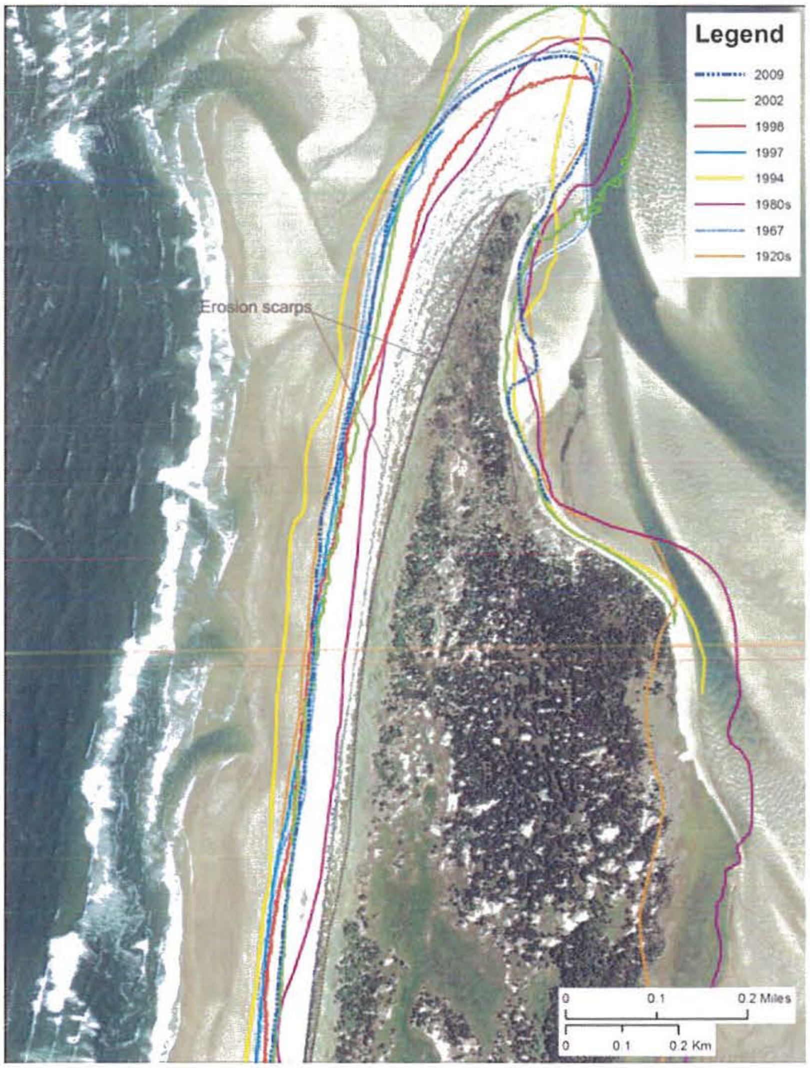


**Figure 2-24. Historical and contemporary shoreline positions identified along the northern end of Netarts Spit, adjacent to Cape Lookout State Park. Note: The 1920s (1927/28) shoreline is derived from NOS T-sheets, 1967 and 1994 from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar. Black dashed line on the dune denotes an erosion scarp.**

**Figure 2-25** compares the historical shoreline positions adjacent to the end of Netarts Spit; here we include one additional shoreline (1950s), which was derived from a NOS T-sheet not available south of Netarts Spit. Apart from the 1950s shoreline, which shows the spit end having re-curved into the bay and a much narrower mouth, the morphology of Netarts Spit has remained broadly the same. In keeping with the Nestucca and Sand Lake estuary mouths, the spit tip migrated northward some 122 m (400 ft) between the 1980s and 1994 shorelines. Part of this response is probably related to the prevalence of El Niños throughout the 1980s, which would have helped shift the mouth of Netarts Bay to the north in response to the increase in waves from the southwest typical of El Niño conditions. However, by 1998 the spit tip had returned to the south. These changes again highlight the dynamic nature of spit ends.

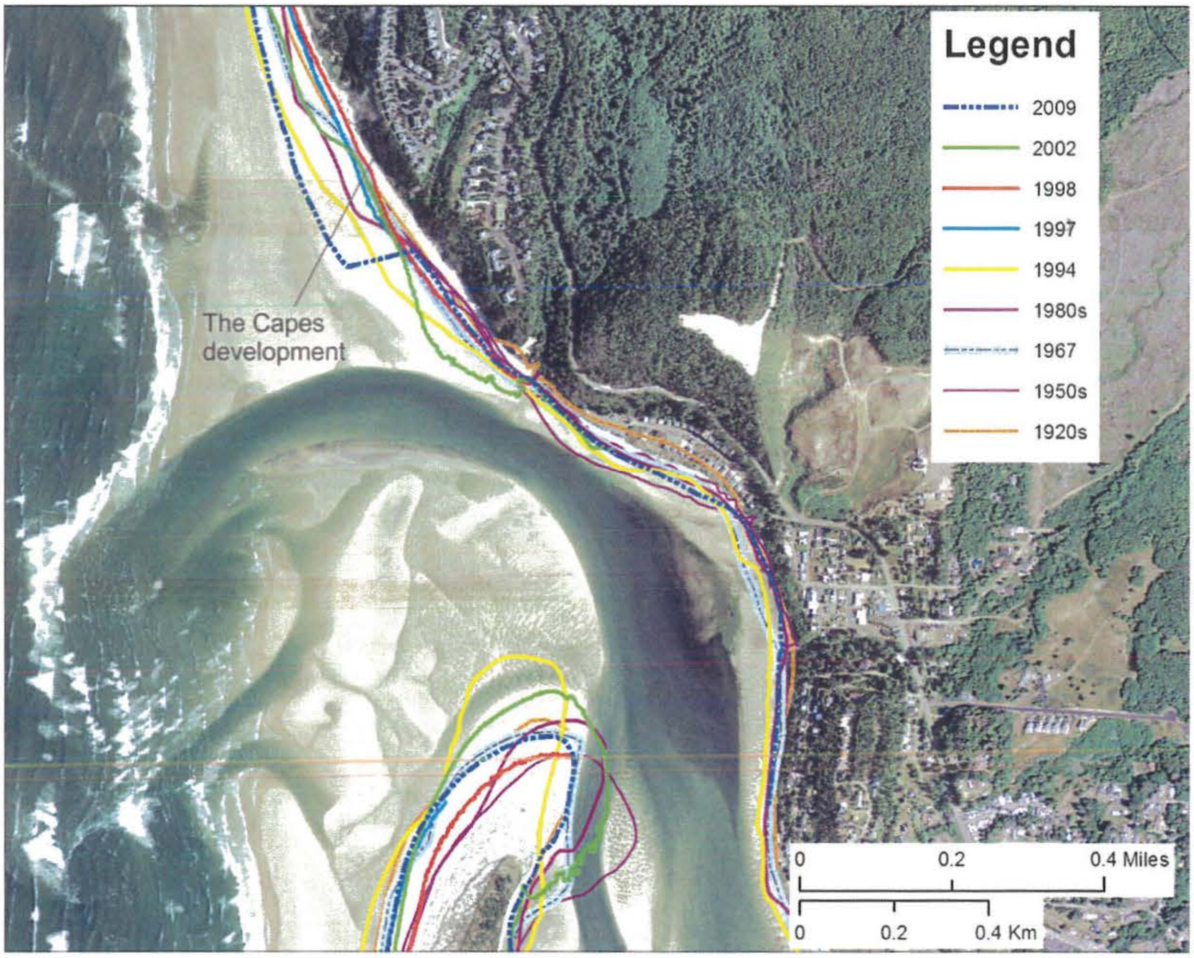
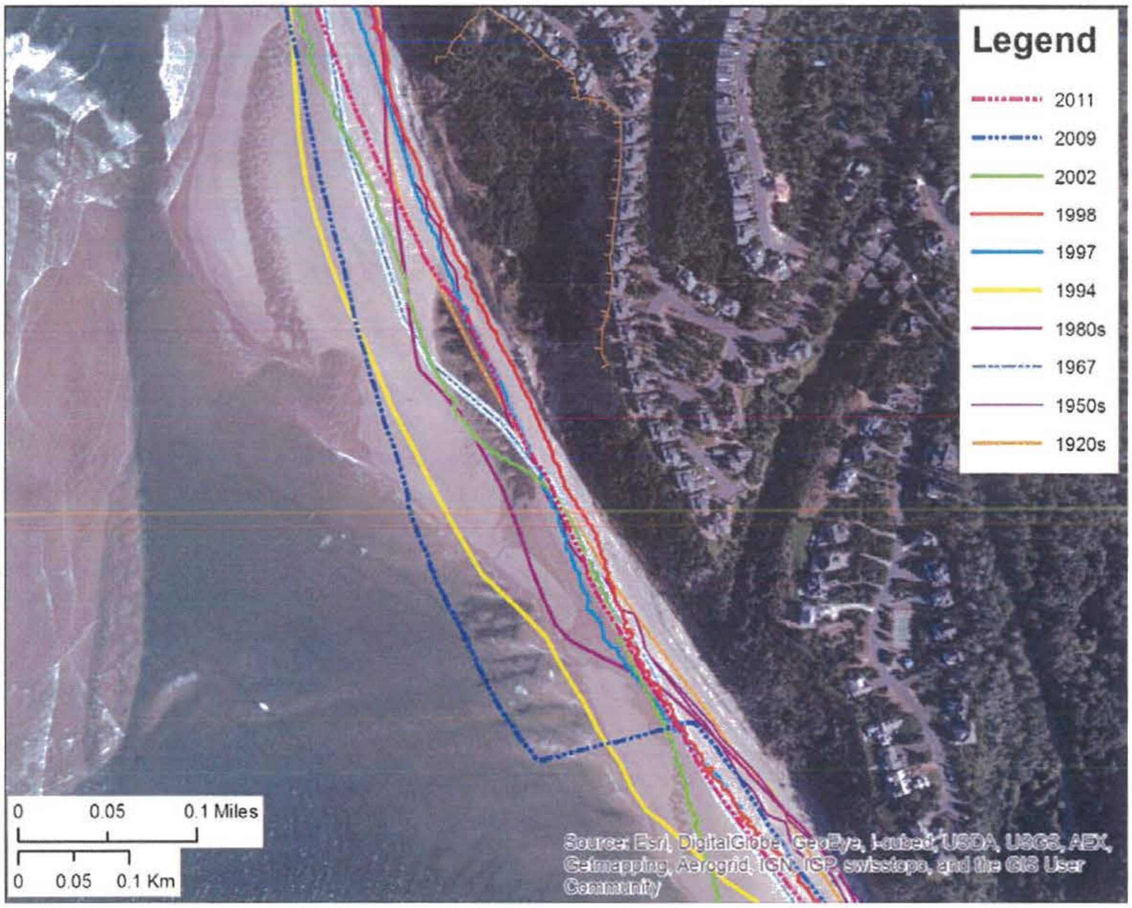


Figure 2-25. Historical shoreline positions identified at the end of Netarts Spit.

On the north side of Netarts Bay is The Capes development, which consists of homes built along the head scarp of a large landslide (**Figure 2-25** and **Figure 2-26**). During the 1997-98 El Niño, homeowners observed movement on the slide immediately seaward of homes built adjacent to the head scarp (**Figure 2-26**). The movement accelerated over the winter, resulting in several cracks opening up landward of a few of the homes. The cause of the movement was attributed to extensive wave erosion along the toe of the landslide, the product of the northward movement of the mouth of the estuary. The erosion essentially removed the toe supporting structure, which effectively enhanced the lateral movement of the landslide material.

Our analyses of shoreline data reveal that the width of the beach in front of The Capes has varied considerably (**Figure 2-25** and **Figure 2-26**). For example, the width of the beach at the toe of the slide in 1994 was some 106 m (350 ft) wide, while small dunes had developed along a 1.1 km (0.6 mi) section of the beach. This suggests the accumulation of a significant volume of sand in the area. However, as a result of the 1997-98 El Niño, the beach eroded back about 98 m (320 ft), eroding into the toe of the slide (**Figure 2-26**). This process has been repeated over the years (e.g., 1950s shoreline) and most recently in the mild 2009-10 El Niño. During this last event, the sand beach in front of The Capes narrowed significantly, almost approaching the position of the shoreline in 1998. **Figure 2-26** shows the magnitude of change characterized by the shift in the shoreline from 2009 and 2011, as the mouth of the bay once again shifted north.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

**Figure 2-26. Historical shoreline positions identified along the toe of The Capes development near the mouth of Netarts Bay. Here we include one additional shoreline (2011) surveyed using GPS. Brown hashed line depicts the landslide headscarp.**

Finally, **Figure 2-27** shows the spread of shorelines adjacent to Oceanside. The 1920s and 1950s shorelines reveal the presence of an extremely narrow beach at Oceanside. This suggests a period of extensive erosion during those years. However, as can be seen from **Figure 2-28**, although the beach may have been narrow the bluff face is covered in vegetation with little sign of erosion. In fact, comparisons between historical and modern photos reinforce the perception that this section of shore is essentially stable.

Of interest also is the 1980s shoreline, which highlights significant differences between Oceanside and Short Sand Beach to the north. At Oceanside, the 1980s shoreline is located in the approximate same location as the 1994, 1997, and 1998 shorelines and indicates a relatively broad beach (**Figure 2-27**). In the two pocket beaches to the north, the 1980s shoreline tracks close to the base of the bluff, indicating a very narrow beach. The latter is not surprising given that this particular beach consists of gravels and as noted previously, the shorelines tend to track much closer to each other on steep beaches. Overall, variations in the shoreline positions along this section of coast may reflect a lag in the transport of sediment around the bluff headlands that bound the smaller pocket beaches. Furthermore, erosion events similar to what occurred at the Capes likely contribute large slugs of sediment that progressively move northwards along the coast, producing the apparent shoreline fluctuations seen at Oceanside and in the smaller pocket beaches to the north. Overall, these findings clearly highlight a very dynamic and complex coastal environment, in which a wide range of different processes are operating over a broad range of spatial and temporal scales.

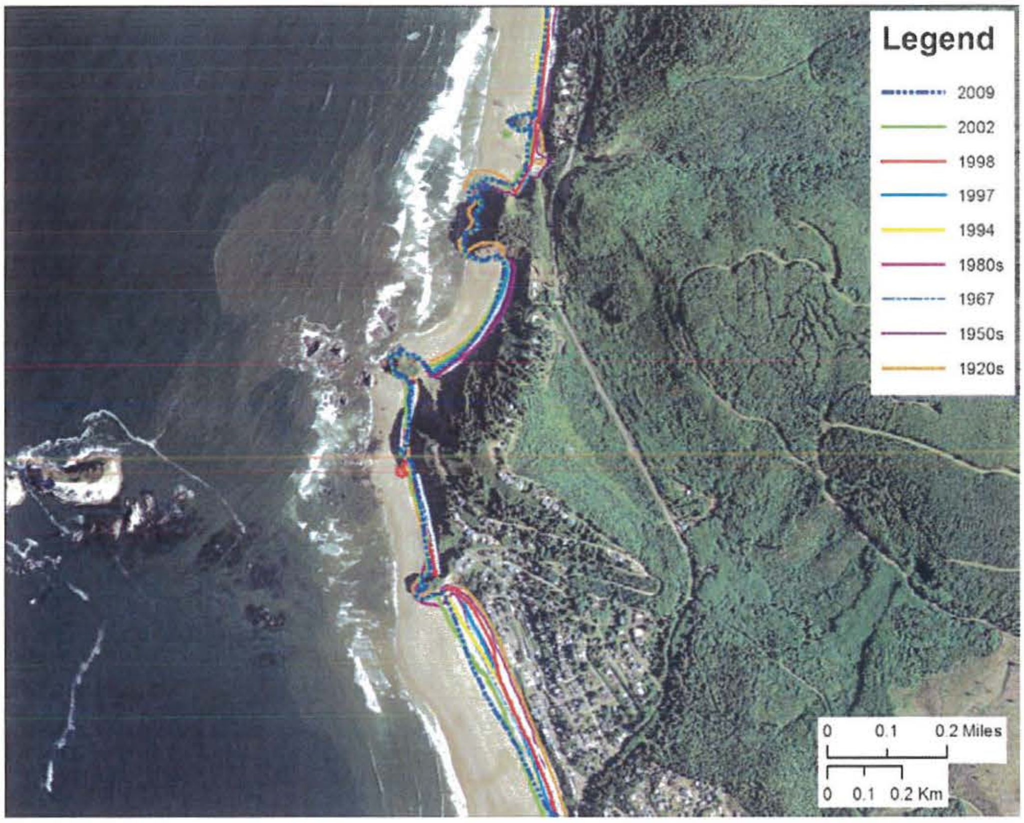


**Figure 2-27. Historical shoreline positions identified at the mouth of Netarts Bay, Oceanside and along Short Sand Beach. Note: The 1920s and 1950s (1927/28, 1953/55) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar. Black dashed line on the dune denotes an erosion scarp.**

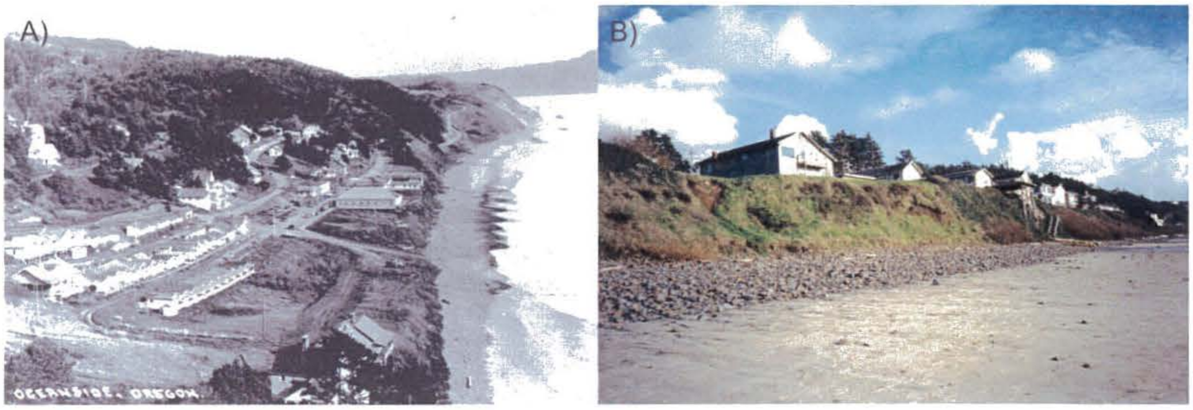


**Figure 2-28. Stable shorelines at Neskowin and Oceanside. A) A 1920s era photo of the community of Neskowin looking south toward the entrance to Netarts Bay. Note well vegetated bluffs and the presence of the gravel berm along the toe of the bluffs (photos courtesy of Neskowin community archives); B) Oceanside in March 1998 following the 1997-98 El Niño winter. Note again the well vegetated bluff and gravel berm at the back of the beach (photo courtesy of P. Komar).**

#### *2.4.1.4 Rockaway Cell*

Some of the most dramatic shoreline changes identified on the Oregon coast have occurred in the Rockaway littoral cell, particularly in response to the construction of the north jetty at the mouth of Tillamook Bay (**Figure 2-29** and **Figure 2-30**). Previous descriptions of the response of Tillamook Bay mouth to jetty construction are given by Terich and Komar (1974), while (Komar, 1997) provides a historical summary of the destruction of Bayocean spit.

Construction of Tillamook's north jetty was completed in October 1917. During the construction phase, changes in the inlet channel and the adjacent shorelines soon became evident (**Figure 2-29**). North of the jetty, sand began to accumulate rapidly and the shoreline advanced seaward at a rate almost equal to the speed at which the jetty was being constructed (Komar, 1997). Between 1914 and 1927, the coastline just north of the jetty advanced seaward by ~1 km (0.62 mi). However, by 1920 the rate of sand accumulation on the north side of the jetty had slowed dramatically, so that the position of the shoreline was much the same as it is today (**Figure 2-30**). According to (Komar and others, 1976), the volume of sand that accumulated north of the jetty caused some to speculate that the predominant net sand transport was to the south. However, Komar and others argued that this was not the case. They observed that if a net southward drift of sediment was occurring, why was there no evidence of an accumulation of sand adjacent to Cape Meares, located at the southern end of the Rockaway littoral cell. Instead, the Cape Meares beach is narrow and is composed mainly of cobbles and gravels.

## Allison Hinderer

**From:** Sarah Mitchell <sm@klgpc.com>
**Sent:** Tuesday, July 27, 2021 2:19 PM
**To:** Sarah Absher; Allison Hinderer
**Cc:** Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
**Subject:** EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 3 of 6)
**Attachments:** Exh 2 - DOGAMI SP-47 Report_Part2.pdf

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 3 of 6.

**From:** Sarah Mitchell
**Sent:** Tuesday, July 27, 2021 2:17 PM
**To:** sabsher@co.tillamook.or.us; 'Allison Hinderer' <ahindere@co.tillamook.or.us>
**Cc:** Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and Lynda Cogdall (lcogdall@aol.com) <lcogdall@aol.com>; Brett Butcher (brett@passion4people.org) <brett@passion4people.org>; Dave and Frieda Farr (dfarrwestproperties@gmail.com) <dfarrwestproperties@gmail.com>; David Dowling <ddowling521@gmail.com>; David Hayes (tdavidh1@comcast.net) <tdavidh1@comcast.net>; Don and Barbara Roberts (donrobertsemail@gmail.com) <donrobertsemail@gmail.com>; Don and Barbara Roberts (robertsfm6@gmail.com) <robertsfm6@gmail.com>; evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com) <jeffklein@wvmeat.com>; Jon Creedon (jcc@pacifier.com) <jcc@pacifier.com>; kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net) <michaelmunch@comcast.net>; Mike and Chris Rogers (mjr2153@aol.com) <mjr2153@aol.com>; Mike Ellis (mikeellispdx@gmail.com) <mikeellispdx@gmail.com>; Rachael Holland (rachael@pacificopportunities.com) <rachael@pacificopportunities.com>; teriklein59@aol.com
**Subject:** RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 2 of 6)
**Importance:** High

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 2 of 6.

**From:** Sarah Mitchell
**Sent:** Tuesday, July 27, 2021 2:16 PM
**To:** Sarah Absher <sabsher@co.tillamook.or.us>; Allison Hinderer <ahindere@co.tillamook.or.us>
**Cc:** Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and

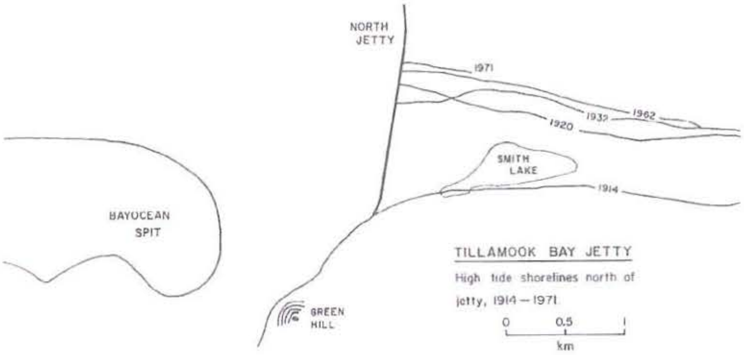


**Figure 2-29. Shoreline positions north of Tillamook Bay jetty, 1914-1972 (From Terich 1973 in Komar 1997).**

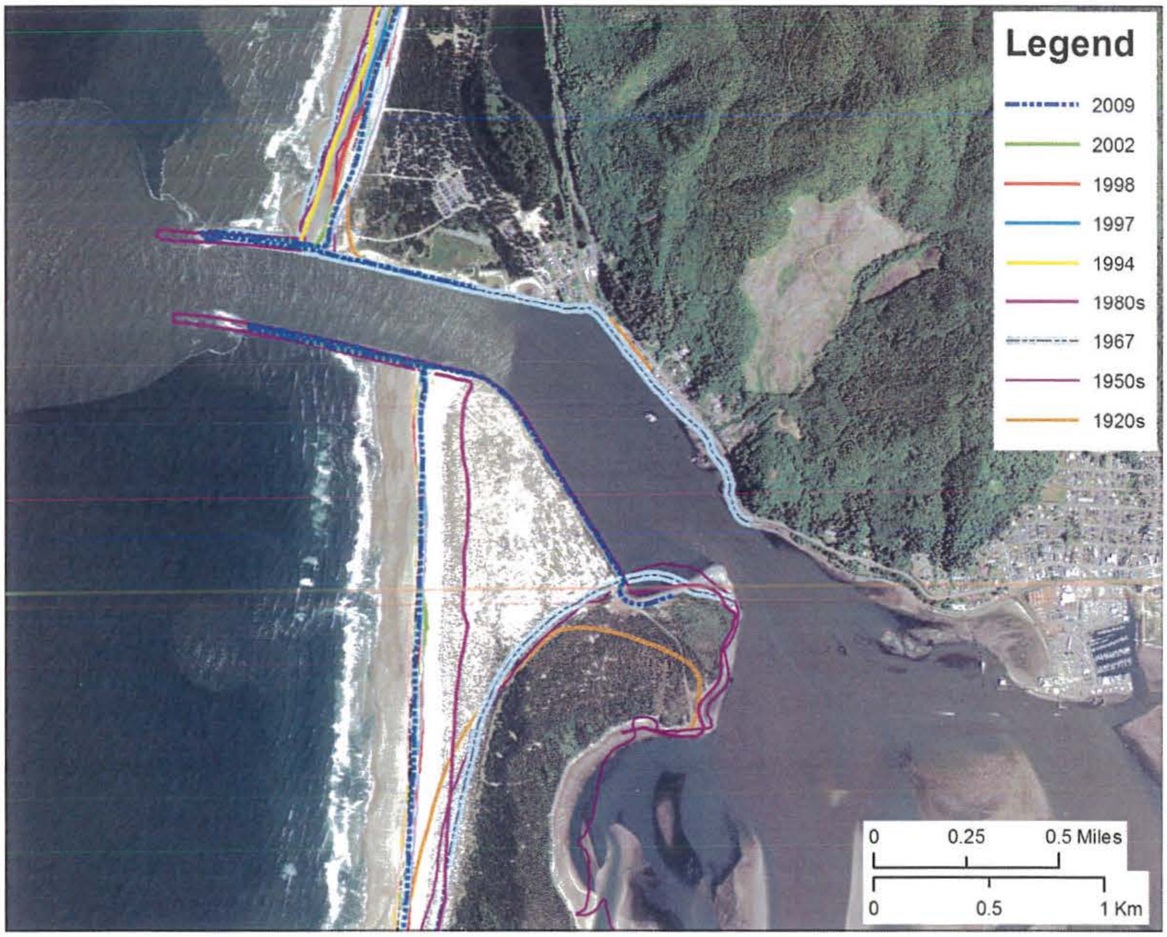


**Figure 2-30. Historical shoreline positions identified adjacent to the mouth of Tillamook Bay in the Rockaway littoral cell. Note: The 1920s and 1950s (1927/28, 1953/55) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar.**

Although the coastline from Rockaway to Manzanita experienced some erosion (discussed below) due to jetty construction, the most dramatic changes were in fact observed farther south along Bayocean Spit. In particular, significant coastal retreat occurred at the south end of the Rockaway cell in the vicinity of the Cape Meares community (**Figure 2-31**). As shown in the figure, the 1927 shoreline previously extended well seaward (up to 260 m [850 ft]) of the present-day shoreline; when visiting the community of Cape Meares, 3rd Street is the most seaward street with 1st and 2nd Streets having been located out on what is now the beach. Over time the shoreline has progressively retreated landward to its present position. Between 1920s and 1950s the shoreline retreated by about 67 to 85 m (220 to 280 ft) at an average erosion rate of ~2 to 3 m/yr (6 to 10 ft/yr). In particular, significant coastal erosion occurred in the vicinity of the Cape Meares community as a result of a major storm during January 3–6, 1939 (Komar, 1997). Additional large storm wave events during the winter of 1940 continued to erode the spit. This process was repeated throughout the 1940s and culminated with the removal of a 1.2 km (0.75 mi) section of Bayocean spit on November 13, 1952, breaching the spit (**Figure 2-32**).

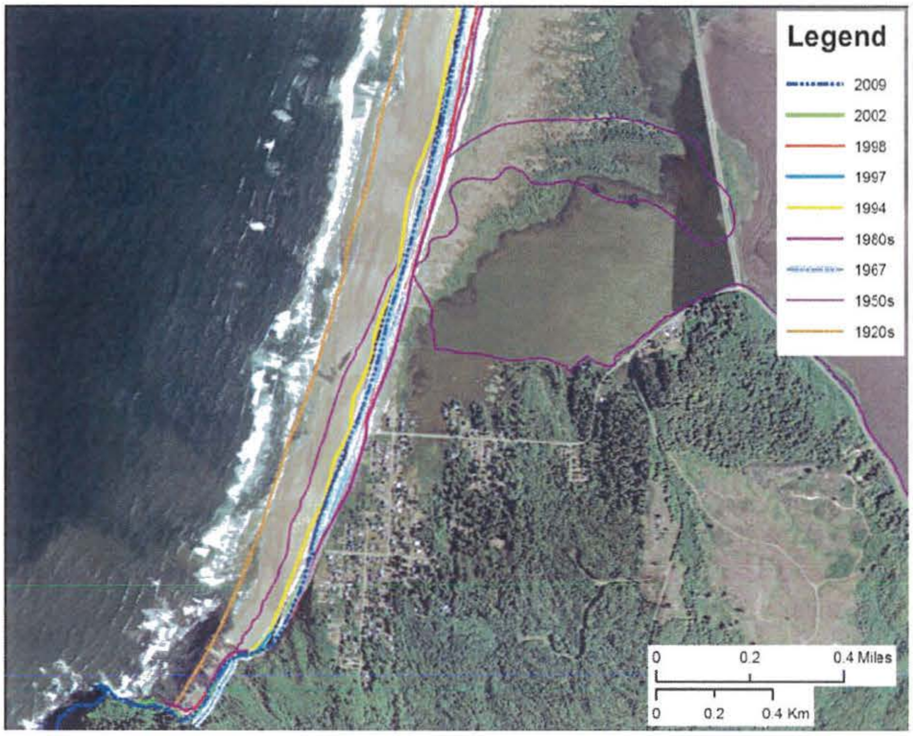


**Figure 2-31.** Historical shoreline positions identified at the southern end of the Rockaway littoral cell in the vicinity of the Cape Meares community.

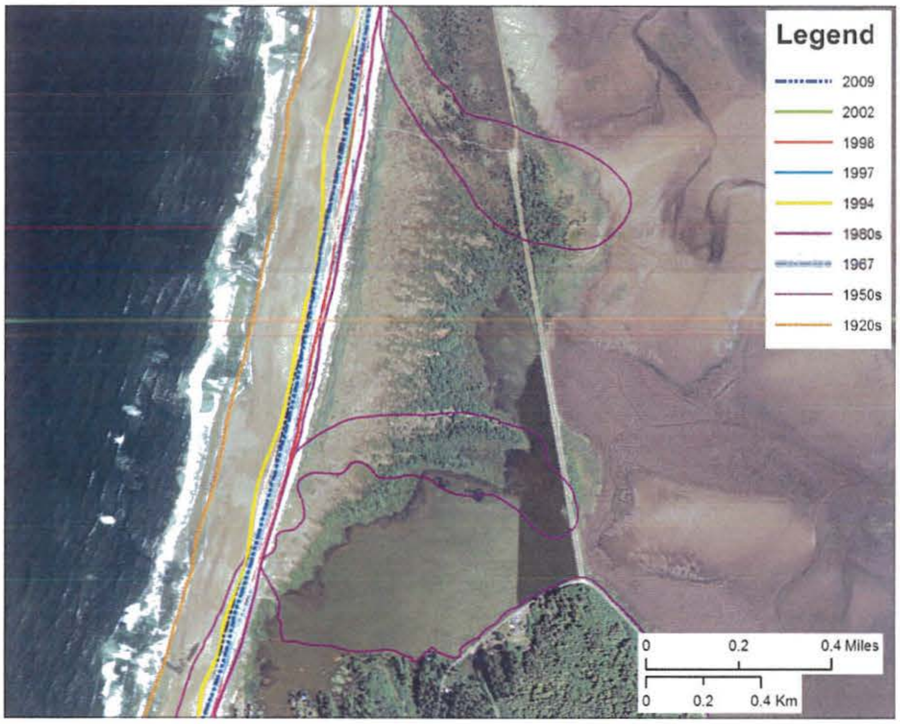


**Figure 2-32.** The breach of Bayocean Spit on November 13, 1952. Note: The 1920s and 1950s (1927/28, 1953/55) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar.

The estimated erosion rate (~2 to 3 m/yr [6 to 10 ft/yr]) for the area around Cape Meares appears to have been maintained between the 1950s to the 1980s, as the shoreline continued to retreat landward by an additional 91 m (300 ft, **Figure 2-28**). However, since then the lidar and GPS shorelines indicate that the shoreline may have stabilized, because it appears to be oscillating around its present location. The absence of a south jetty at Tillamook Bay prior to 1974 probably enhanced the erosion of Bayocean spit, as a lot of sediment accumulated as shoals at the spit end or was washed into the bay (Komar, 1997). However, with the completion of the south jetty in November 1974, sand quickly began to accumulate at the north end of the spit, causing the shoreline to prograde seaward by some 300 to 760 m (1,000 to 2,500 ft; **Figure 2-27**). Since then, the shoreline along Bayocean Spit has stabilized, so that it now responds in a manner similar to other littoral cells on the Oregon coast (Komar, 1997), with the pair of jetties on the inlet acting more like a headland. Repeat GPS surveys of Bayocean Spit undertaken by DOGAMI staff since 2004 indicate that the southern end of the spit is stable (http://www.oregongeology.org/¬nanoos/data/img/lg/Bay1 6mchangc.png), while the northern one third of the spit has been accreting at an average rate of ~+0.7 to +1 m/yr (+2.3 to +3.3 ft/yr) (http://www.oregongeology.org/nanoos/data/img/lg/Bay6 6mchange.png).

Farther north along the Rockaway-Manzanita coastline, the 1920s and 1950s shorelines were positioned well landward of contemporary shorelines (**Figure 2-33** and **Figure 2-34**). This type of pattern is a direct response to construction of the north Tillamook jetty. However, the erosion that occurred along the Rockaway-Manzanita beaches was generally much less then on Bayocean Spit (Komar, 1997). This is because the length of shoreline along the Rockaway-Manzanita coastline is much greater than along Bayocean spit. As a result, only a small amount of sand had to be eroded from those beaches, per unit length of shoreline, to supply sand to the accreting area around the north jetty. Erosion along the Rockaway-Manzanita coastline probably stabilized sometime after the 1950s, enabling the coastline to enter an accretionary phase. As shown in **Figure 2-33** and **Figure 2-34**, the 1994 and 1997 shorelines characterize the seaward extent of this rebuilding phase. This view is also supported from observations of dune growth around Manzanita, culminating with the initiation of a dune management program to control the growth of the foredunes (Dr. J. Marra, personal comm., 2001). While the historical patterns of change suggest overall stability, this is in fact not the case. Commencing in the late 1990s, the beach between the Tillamook and Nehalem jetties have been subject to a number of major storms that have resulted in chronic erosion hazards. This latest response is described in Section 3.3.1.

In summary, this section has presented information on the historical shoreline changes that have occurred along the Tillamook County coastline over the past century. The analyses indicate that for the most part the dune-backed shorelines respond episodically to such processes as the El Niño/La Niña Southern Oscillation, and as a result of rip current embayments that cause highly localized "hotspot erosion" of the coast. Accordingly, the coastline undergoes periods of both localized and widespread erosion, with subsequent intervening periods during which the beaches and dunes slowly rebuild. Perhaps the most significant coastal changes identified in Tillamook County have occurred in response to human activity, particularly as a result of jetty construction during the early part of last century. In particular, jetty construction has had a dramatic influence on the morphology of Bayocean Spit and, to a lesser extent, between the north Tillamook jetty and the Rockaway-Manzanita beaches to the north. Finally, the present analyses have shown that the mouths of the estuaries and the spit ends are extremely dynamic features, migrating over large distances in response to changes in both the sediment supply and the predominant wave conditions, making these areas hazardous for any form of development.

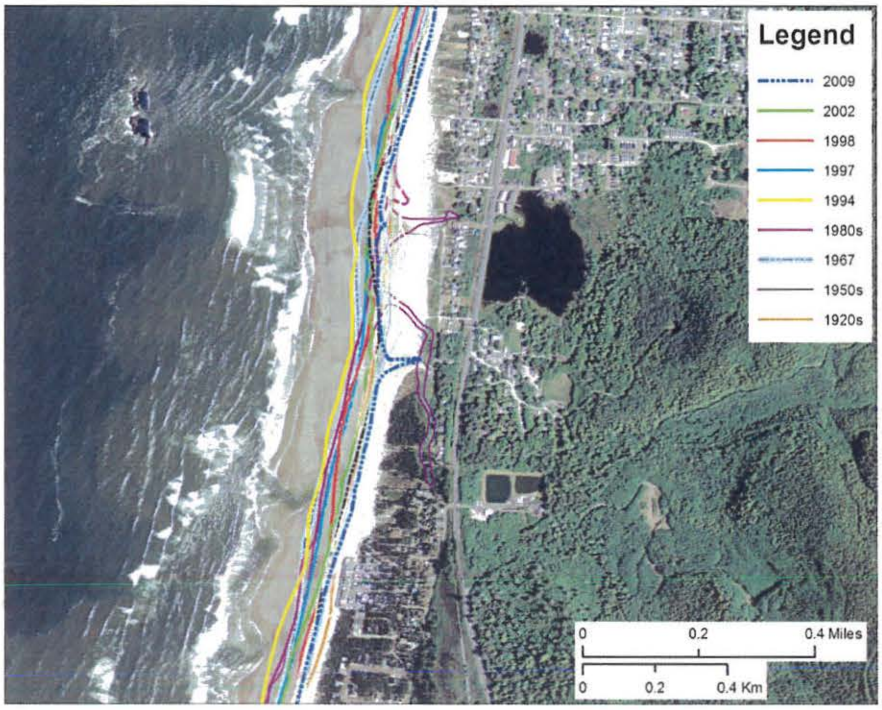


Figure 2-33. Historical shoreline positions identified near Twin Rocks. Note: The 1920s and 1950s (1927/28, 1953/55) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar.

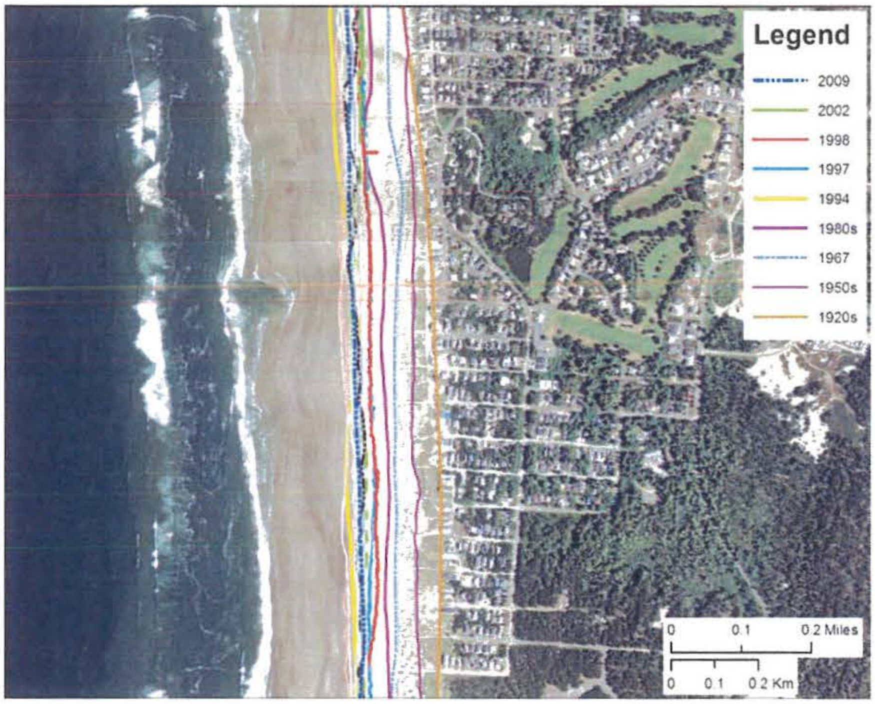


Figure 2-34. Historical shoreline positions at Manzanita. Note: The 1920s and 1950s (1927/28, 1953/55) shoreline is derived from NOS T-sheets, 1967 and 1994 are from orthorectified aerial photographs, 1980s (1985/86) is from U.S. Geological Survey topographic maps, and 1997–2009 are derived from lidar.

# 3.0 BEACH AND BLUFF MORPHOLOGY ASSESSMENTS

Field surveys were undertaken throughout Tillamook County in summer 2011 and again in winter 2012 in order to better define the seasonal variability. These surveys serve two important objectives:

1. To establish beach profile transects along discrete but representative sections of the shoreline's geomorphology/geology, including sections of coast where coastal engineering structures have been constructed, for the purposes of coastal hydraulic analyses.
2. To provide representative measurements, derived from lidar or GPS data, of the beach in its winter state, in order to define the morphology, elevations, and slope of the beach face for use in subsequent wave runup and overtopping computations.

Surveying along the Tillamook County coast was initially carried out in August and September 2011, and again in February/March 2012. The surveys were completed late in the winter season when Oregon beaches are typically in their most eroded state (Aguilar-Tunon and Komar, 1978; Komar, 1997; Allan and Komar, 2002; Allan and Hart, 2008). A total of 178 beach profile transects were established along the length of Tillamook County (**Figure 3-1** to **3-3**) and can be subdivided according to the following littoral cells:

- Neskowin: 28 sites;
- Nestucca spit/Pacific City: 14 sites;
- Tierra Del Mar/Sand Lake: 32 sites;
- Netarts Spit/Oceanside: 29 sites;
- Short Sand Beach: 3 sites;
- Bayocean Spit: 11 sites;
- Twin Rocks/Rockaway/Nedonna Beach: 40 sites; and
- Nehalem Spit/Manzanita: 21 sites.

Appendix B provides a table that describes the naming conventions used by DOGAMI, which is linked to the transect database in the final DFIRM for Tillamook County.

## 3.1 Survey Methodology

Beach profiles that are oriented perpendicular to the shoreline can be surveyed using a variety of approaches, including a simple graduated rod and chain, surveying level and staff, total station theodolite and reflective prism, lidar airborne altimetry, and Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) technology. Traditional techniques such as leveling instruments and total stations are capable of providing accurate representations of the morphology of a beach, but are demanding in terms of time and effort. At the other end of the spectrum, high-resolution topographic surveys of the beach derived from lidar are ideal for capturing, within a matter of hours, the three-dimensional state of the beach over an extended length of coast; other forms of lidar technology are now being used to measure nearshore bathymetry out to moderate depths but are dependent on water clarity. However, the lidar technology remains expensive and is impractical along small segments of shore and, more importantly, the high costs effectively limits the temporal resolution of the surveys and hence the ability of the end-user to understand short-term changes in the beach morphology (Bernstein and others, 2003).

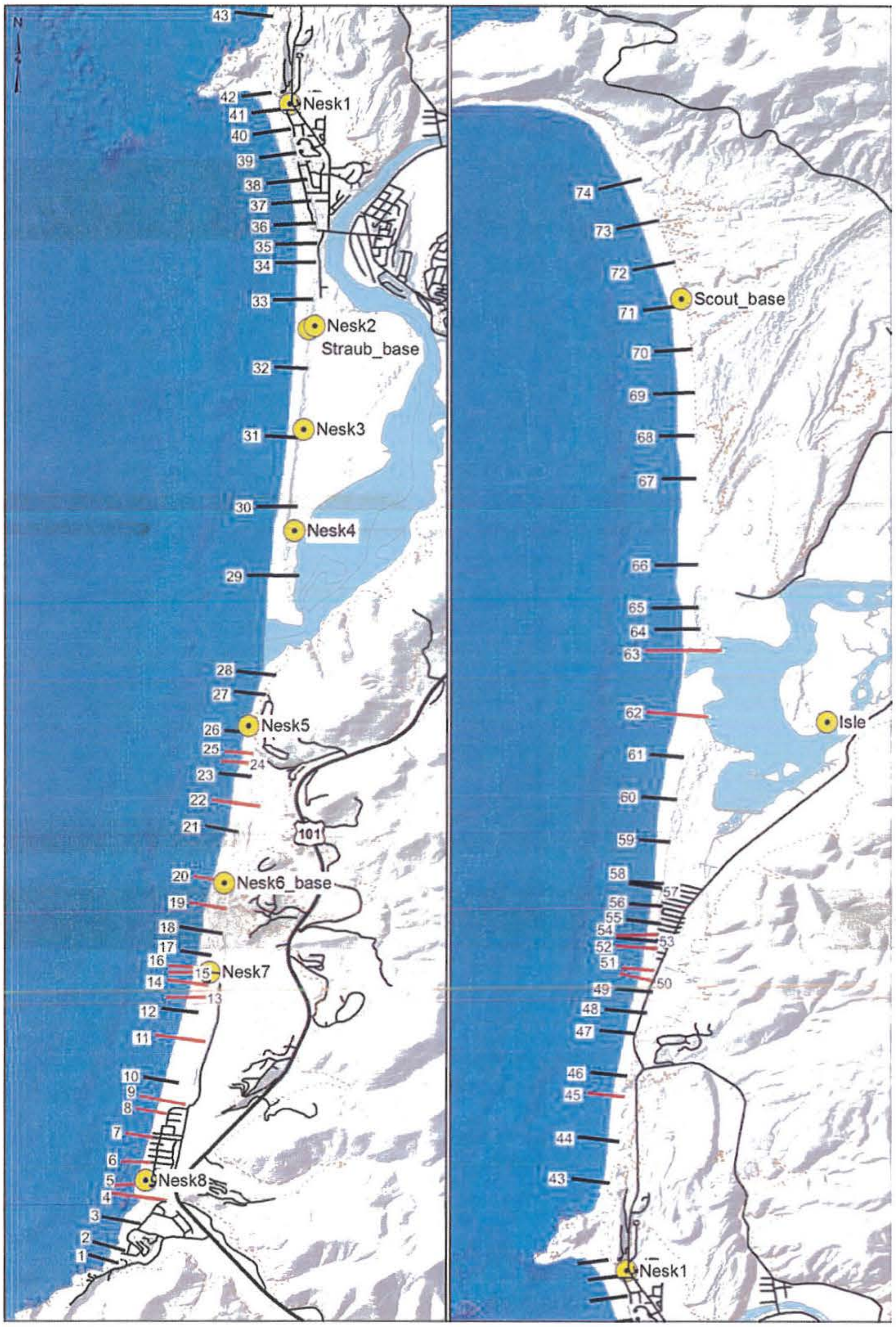


**Figure 3-1.** Location map of beach profiles in southern Tillamook County. Left) Beach profiles measured along the Neskowin shoreline (transects 1–28), Nestucca spit and adjacent to Pacific City (transects 29–42); Right) and within the Sand Lake littoral cell in Tillamook County (transects 43–74). Red lines denote transects where overtopping has been identified. Yellow circles denote the locations of benchmarks used in local site calibrations.

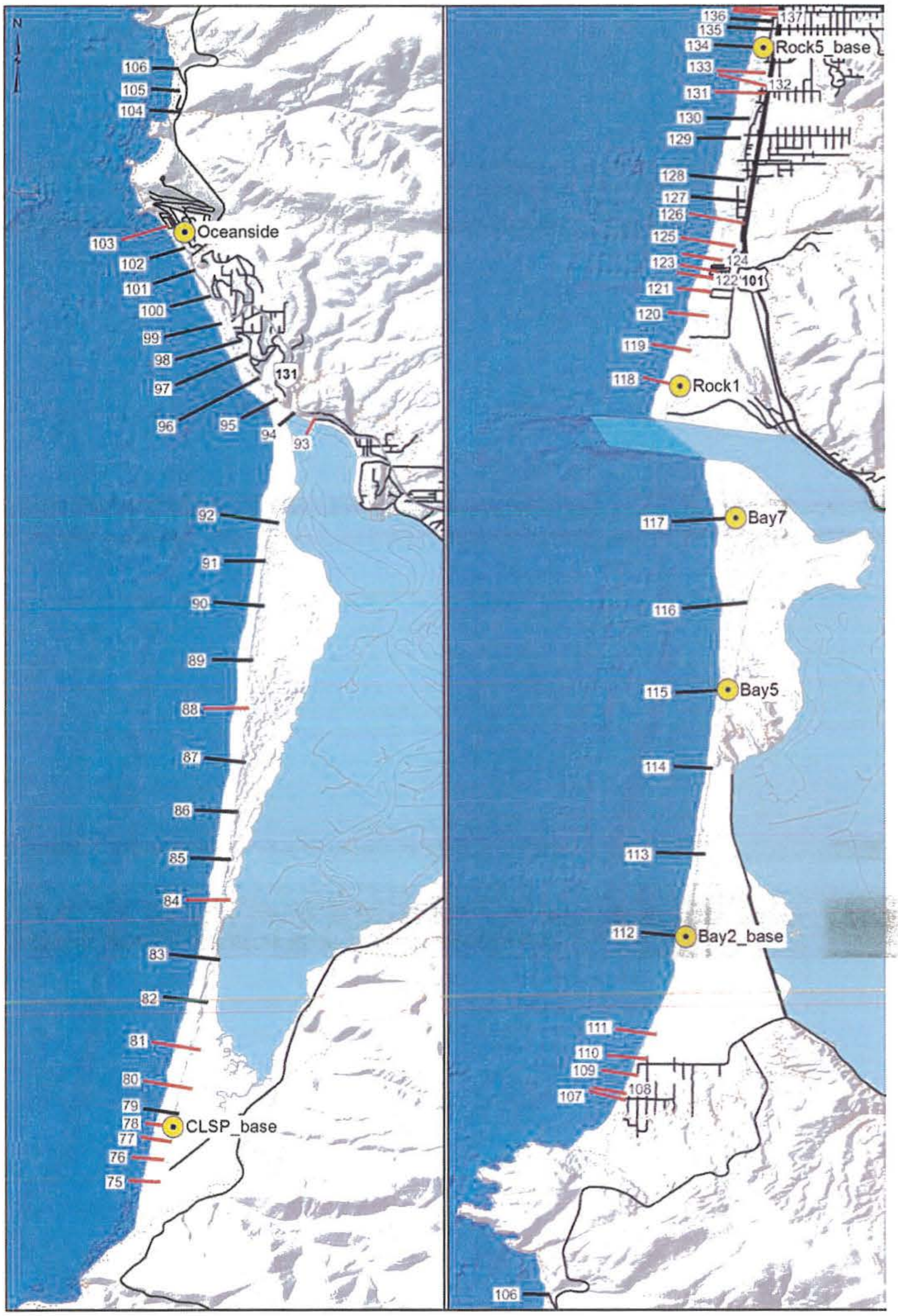


**Figure 3-2.** Location map of beach profiles in central Tillamook County. Left) Location map of beach profiles measured along Netarts Spit (transects 75–92), at Oceanside (transects 93–103) and at Short Sand Beach (transects 104–106); Right) along Bayocean Spit (transects 107–117), and in the Twin Rocks area (transects 118–137) in Tillamook County. Red lines denote transects where overtopping has been identified. Yellow circles denote the locations of benchmarks used in local site calibrations.

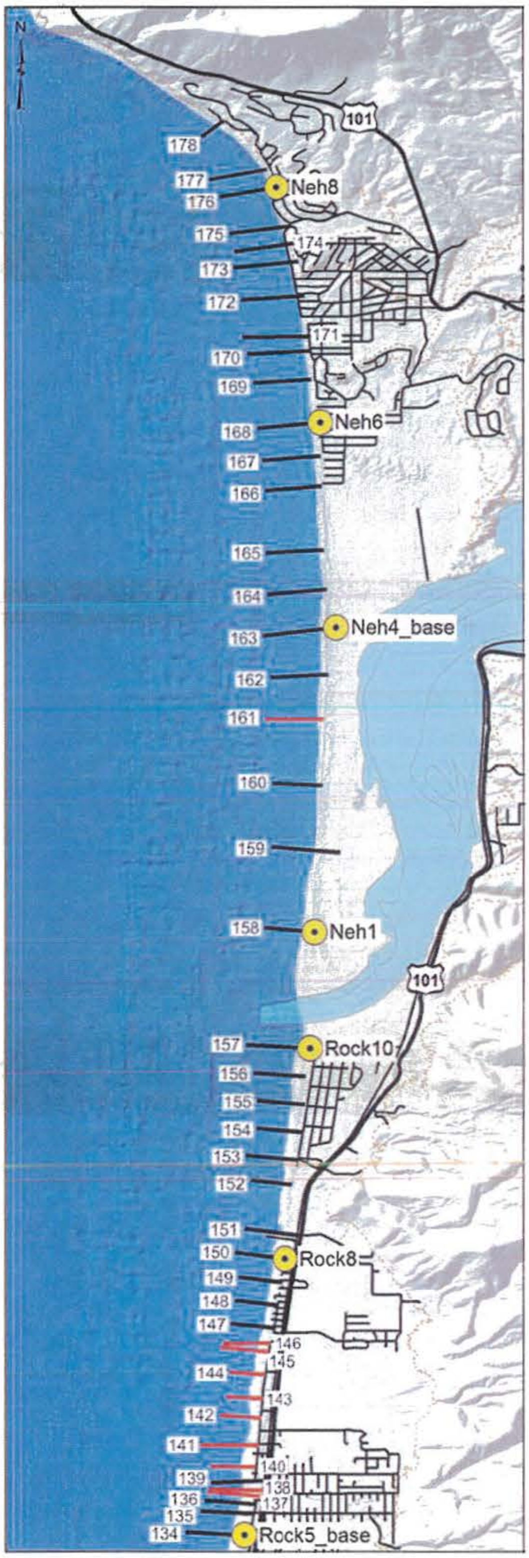


**Figure 3-3.** Location of map of beach profiles in northern Tillamook County showing profiles measured along Rockaway/Nedonna Beach (transects 134–157), Nehalem Spit (transects 158–166), and in the Manzanita area (transects 167–178) in Tillamook County. Red lines denote transects where overtopping has been identified. Yellow circles denote the locations of benchmarks used in local site calibrations.

Within this range of technologies, the application of RTK-DGPS for surveying the morphology of both the subaerial and subaqueous portions of the beach has effectively become the accepted standard (Morton and others, 1993; Ruggiero and Voigt, 2000; Bernstein and others, 2003; Ruggiero and others, 2005) and is the surveying technique used in this study. The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations, originally developed by the U.S. Department of Defense; in 2007 the Russian Government made their GLONASS satellite network available increasing the number of satellites to ~46 (as of February 2011).

In its simplest form, GPS can be thought of as triangulation with the GPS satellites acting as reference points, enabling users to calculate their position to within several meters (e.g., using inexpensive off the shelf hand-held units), while survey grade GPS units are capable of providing positional and elevation measurements that are accurate to a centimeter. At least four satellites are needed mathematically to determine an exact position, although more satellites are generally available. The process is complicated because all GPS receivers are subject to error, which can significantly degrade the accuracy of the derived position. These errors include the GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere and multipath effects (where the signals bounce off features and create a poor signal). For example, hand-held autonomous receivers have positional accuracies that are typically less than about 10 m (<~30 ft), but can be improved to less than 5 m (<~15 ft) using the Wide Area Augmentation System (WAAS). This latter system is essentially a form of differential correction that accounts for the above errors, which is then broadcast through one of two geostationary satellites to WAAS-enabled GPS receivers.

Greater survey accuracies are achieved with differential GPS (DGPS) using two or more GPS receivers to simultaneously track the same satellites, enabling comparisons to be made between two sets of observations. One receiver is typically located over a known reference point, and the position of an unknown point is determined relative to that reference point. With the more sophisticated 24-channel dual-frequency RTK-DGPS receivers, positional accuracies can be improved to the sub-centimeter level when operating in static mode and to within a few centimeters when in RTK mode (i.e., as the rover GPS is moved about). In this study we used Trimble® 24-channel dual-frequency R7/R8 and 5700/5800 GPS receivers. This system consists of a GPS base station (R7 and/or 5700 unit), Zephyr Geodetic™ antenna (model 2), HPB450 radio modem, and R8 (and/or 5800) "rover" GPS (**Figure 3-4**). Trimble reports that both the R7/R8 and 5700/5800 GPS systems have horizontal errors of approximately ±1 cm + 1 ppm (parts per million × the baseline length) and ±2 cm in the vertical (Trimble, 2005).

To convert a space-based positioning system to a ground-based local grid coordinate system, a precise mathematical transformation is necessary. While some of these adjustments are accomplished by specifying the map projection, datum, and geoid model prior to commencing a field survey, an additional transformation is necessary whereby the GPS measurements are tied to known ground control points (**Figure 3-5**). This latter step is called a GPS site calibration, such that the GPS measurements are calibrated to ground control points with known vertical and horizontal coordinates using a rigorous least-squares adjustment procedure. Performing the calibration is initially undertaken in the field using the Trimble TSC2 GPS controller and then re-evaluated in the office using Trimble's Business Office software (version 2.5).

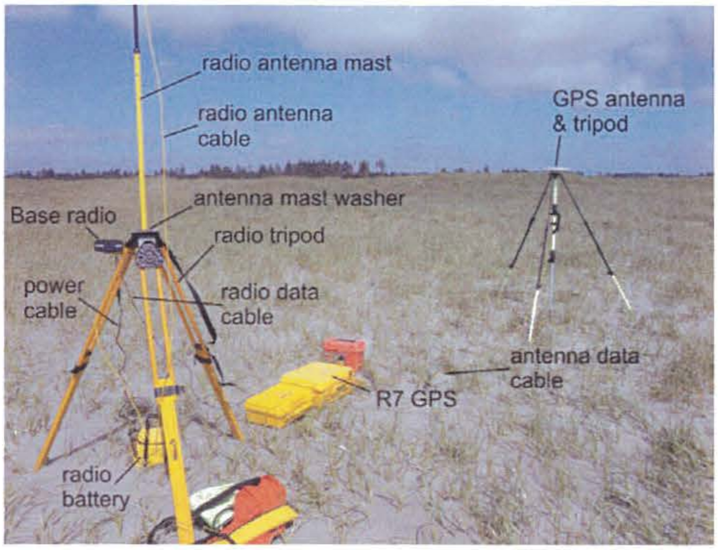


Figure 3-4. The Trimble R7 base station antenna in operation on the Tillamook Plains. Corrected GPS position and elevation information is transmitted by an HPB450 Pacific Crest radio to the R8 GPS rover unit (photo: J. Allan, DOGAMI, 2010).

Figure 3-5. A 180-epoch calibration check is performed on a survey monument (Rock7) established in the Rockaway littoral cell in Tillamook County. This procedure is important for bringing the survey into a local coordinate system and for reducing errors associated with the GPS survey (photo: J. Allan, DOGAMI, 2004).

### 3.1.1 Tillamook County survey control procedures

Survey control (Table 3-1) along the Tillamook County shore was provided by occupying multiple benchmarks established by the Coastal Field Office of DOGAMI. The approaches used to established the benchmarks are fully described in reports by Allan and Hart (2007, 2008).

Coordinates assigned to the benchmarks (**Table 3-1**), were derived by occupying a Trimble R8 GPS receiver over the established benchmark, which then receives real-time kinematic corrections via the Oregon Real Time GPS Network (ORGN) (http://www.theorgn.net/). The ORGN is a network of permanently installed, continuously operating GPS reference stations established and maintained by ODOT and partners (essentially a CORS network similar to those operated and maintained by the National Geodetic Survey [NGS]) that provide real-time kinematic (RTK) correctors to field GPS users over the internet via cellular phone networks. As a result, GPS users that are properly equipped to take advantage of these correctors, such as the Trimble system used in this study, can survey in the field to the one centimeter horizontal accuracy level in real time. Each benchmark was observed on at least two occasions, at different times of the day or on alternate days; the derived values were reviewed and, if reasonable, were averaged.

Furthermore, additional checking was undertaken for each of the GPS base station sites (**Table 3-1**), by comparing the multi-hour GPS measurements to coordinates and elevations derived using the Online Positioning User Service (OPUS) maintained by the NGS (http://www.ngs.noaa.gov/OPUS/ [Soler and others, 2011]). OPUS provides a simplified way to access high-accuracy National Spatial Reference System (NSRS) coordinates using a network of continuously operating GPS reference stations (CORS, http://www.ngs.noaa.gov/CORS/). In order to use OPUS, static GPS measurements are typically made using a fixed height tripod for periods of 2 hours or greater. OPUS returns a solution report with positional accuracy confidence intervals for adjusted coordinates and elevations for the observed point. In all cases we used the Oregon State Plane coordinate system, northern zone (meters), while the vertical datum is relative to the North American Vertical Datum of 1988 (NAVD88).

For each of the discrete shore reaches, the R7 GPS base station was located on the prescribed base station monument (i.e., NEH4, ROCK5, BAY2, CLSP, SCOUT, STRAUB, NESK6; **Table 3-1**), using a 2.0-m fixed height tripod. Survey control was provided by undertaking 180 GPS epoch measurements (~3 minutes of measurement per calibration site) using the calibration sites indicated in **Table 3-1**, enabling us to perform a GPS site calibration that brought the survey into a local coordinate system. This step is critical in order to eliminate various survey errors that may be compounded by factors such as poor satellite geometry, multipath, and poor atmospheric conditions that in combination increase the total error to several centimeters. **Table 3-2** shows the relative variability identified when comparing the mean derived benchmark coordinate and the original ORGN/OPUS derivations. As can be seen from **Table 3-2**, differences in the horizontal and vertical values at the benchmarks were typically less than 2 cm (i.e., within one standard deviation [σ]).

**Table 3-1. Survey benchmarks used to calibrate GPS surveys of the beach along the Tillamook County coastline. Asterisk signifies the location of the GPS base station during each respective survey. NGS denotes National Geodetic survey monument, ORGN signifies Oregon Real Time GPS Network.**

| Study Area | Primary Identification (PID) Name[1] | Northing (m) | Easting (m) | Elevation (m) |
|---|---|---|---|---|
| **Nehalem Spit** | NEH8 - DOGAMI/ORGN | 2232106.115 | 234997.630 | 9.101 |
| | NEH6 - DOGAMI/ORGN | 2232318.132 | 232654.396 | 11.201 |
| | NEH4 - DOGAMI/ORGN* | 2232342.755 | 230612.045 | 8.703 |
| | NEH1 - DOGAMI/ORGN | 2232062.218 | 227586.204 | 12.828 |
| Rockaway | ROCK10 - DOGAMI/ORGN | 2231980.938 | 226431.232 | 8.400 |
| | ROCK8 - DOGAMI/ORGN | 2231714.373 | 224350.055 | 5.276 |
| | ROCK5 - DOGAMI/ORGN* | 2231306.182 | 221626.396 | 10.046 |
| | ROCK1 - DOGAMI/ORGN | 2230430.835 | 217674.746 | 6.732 |
| Bayocean Spit | BAY7 - DOGAMI/ORGN | 2230194.049 | 211189.992 | 9.440 |
| | BAY5 - DOGAMI/ORGN | 2230672.493 | 214089.934 | 8.155 |
| | BAY2 - DOGAMI/ORGN* | 2230827.791 | 216103.016 | 8.497 |
| Netarts Spit/ Oceanside | AJ1985 – NGS/ORGN | 2228840.68 | 205112.21 | 37.609 |
| | RD1459 – NGS/ORGN | 2239922.16 | 200302.4695 | 4.5265 |
| | CLSP - DOGAMI/ORGN* | 2228287.197 | 194592.782 | 4.763 |
| Sand Lake/ Tierra Del Mar | SCOUT - DOGAMI/ORGN* | 2228476.091 | 189282.575 | 8.261 |
| | ISLE - DOGAMI/ORGN | 2229478.034 | 184302.823 | 4.638 |
| | NESK1 - DOGAMI/ORGN | 2227540.749 | 177975.0305 | 12.367 |
| Nestucca spit/ Pacific City | NESK1 - DOGAMI/ORGN | 2227540.749 | 177975.0305 | 12.367 |
| | STRAUB - DOGAMI/ORGN* | 2227589.237 | 175343.511 | 12.936 |
| | NESK2 - DOGAMI/ORGN | 2227636.668 | 175375.163 | 7.085 |
| | NESK3 - DOGAMI/ORGN | 2227495.199 | 174174.595 | 4.437 |
| | NESK4 - DOGAMI/ORGN | 2227368.161 | 173001.673 | 4.827 |
| Neskowin | NESK5 - DOGAMI/ORGN | 2226885.830 | 170740.992 | 4.12 |
| | NESK6 - DOGAMI/ORGN* | 2226603.997 | 168908.419 | 8.215 |
| | NESK7 - DOGAMI/ORGN | 2226438.263 | 167871.992 | 6.504 |
| | NESK8 - DOGAMI/ORGN | 2225802.096 | 165471.981 | 9.529 |

Notes: Coordinates are expressed in the Oregon State Plane Coordinate System, northern zone (meters), and the vertical datum is NAVD88.

[1]Control provided using both horizontal and vertical values derived by averaging multiple separate GPS occupations with survey control provide by the ORGN.

**Table 3-2. Comparison of horizontal and vertical coordinates (expressed as a standard deviation) at each of the benchmark locations, compared to the final coordinates referenced in Table 3-1. Asterisk signifies the location of the GPS base station during each respective survey.**

| Study Area | Primary Identification (PID) Name[1] | Northing (m) σ | Easting (m) σ | Elevation (m) σ |
|---|---|---|---|---|
| **Nehalem Spit** | NEH8 | 0.001 | 0.016 | 0.029 |
| | NEH6 | 0.004 | 0.001 | 0.020 |
| | NEH4* | 0.012 | 0.004 | 0.010 |
| | NEH1 | 0.010 | 0.011 | 0.001 |
| **Rockaway** | RCK10 | 0.010 | 0.049 | 0.141 |
| | RCK8 | — | — | — |
| | RCK5* | 0.012 | 0.005 | 0.024 |
| | RCK1 | 0.020 | 0.007 | 0.006 |
| **Bayocean Spit** | BAY7 | 0.003 | 0.011 | 0.002 |
| | BAY5 | 0.012 | 0.000 | 0.003 |
| | BAY2* | 0.010 | 0.007 | 0.025 |
| **Netarts Spit** | AJ1985 | 0.019 | 0.011 | 0.036 |
| | RD1459 | 0.021 | 0.013 | 0.012 |
| | CLSP* | 0.015 | 0.006 | 0.010 |
| **Sand Lake** | SCOUT* | 0.010 | 0.005 | 0.034 |
| | ISLE | 0.029 | 0.000 | 0.003 |
| | NESK1 | 0.014 | 0.006 | 0.001 |
| **Nestucca spit** | STRAUB* | 0.003 | 0.001 | 0.020 |
| | NESK2 | 0.011 | 0.003 | 0.001 |
| | NESK3 | 0.005 | 0.004 | 0.044 |
| | NESK4 | 0.008 | 0.021 | 0.000 |
| **Neskowin** | NESK5 | — | — | — |
| | NESK6* | 0.014 | 0.007 | 0.013 |
| | NESK7 | 0.008 | 0.023 | 0.049 |
| | NESK8 | 0.015 | 0.037 | 0.004 |

After local site calibration (**Figure 3-5**), cross-shore beach profiles were surveyed with the R8 GPS rover unit mounted on a backpack, worn by a surveyor (**Figure 3-6**). This was undertaken during periods of low tide, enabling more of the beach to be surveyed. The approach generally was to walk from the landward edge of the primary dune or bluff edge, down the beach face and out into the ocean to approximately wading depth. A straight line perpendicular to the shore was achieved by navigating along a predetermined line displayed on a hand-held Trimble TSC2 computer controller connected to the R8 receiver. The computer shows the position of the operator relative to the survey line and indicates the deviation of the GPS operator from the line. The horizontal variability during the survey is generally minor, typically less than about ±0.25 m either side of the line (**Figure 3-7**), which results in negligible vertical uncertainties due to the relatively uniform nature of beaches characteristic of much of the Oregon coast (Ruggiero and others, 2005). From our previous research at numerous sites along the Oregon coast, this method of surveying can reliably detect elevation changes on the order of 4-5 cm, that is, well below normal seasonal changes in beach elevation, which typically varies by 1–2 m (3–6 ft) (Ruggiero and others, 2005; Allan and Hart, 2007, 2008).

Analysis of beach survey data involved a number of stages. The data were first imported into the MathWorks® MATLAB® environment (a suite of computer programming languages) by using a customized script. A least-squares linear regression was then fit to the profile data. The purpose of this script is to examine the reduced data and eliminate data point residuals (e.g., **Figure 3-7**) that exceed a ±0.75-m threshold (i.e., the outliers) on either side of the predetermined profile line. The data are then exported into a Microsoft® Excel® database for archiving purposes. A second MATLAB script uses the Excel profile database to plot the survey data (relative to the earlier surveys) and outputs the generated figure as a Portable Network Graphics (png) file. Appendix C shows the reduced beach profile plots for the Tillamook County transects.

**Figure 3-6. Surveying the morphology of the beach at Bandon using a Trimble 5800 "rover" GPS (photo: J. Allan, DOGAMI, 2009).**

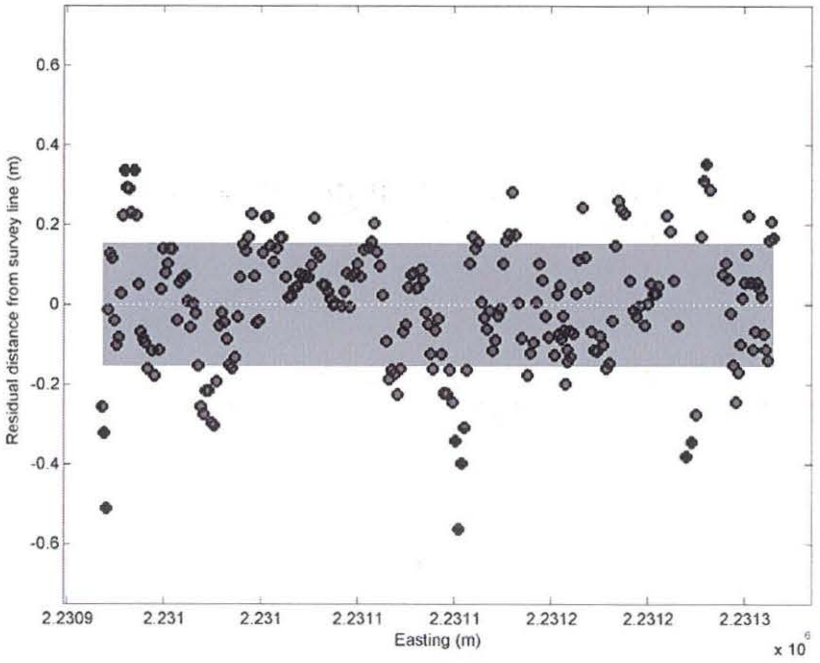


**Figure 3-7.** Residuals of GPS survey points relative to zero (transect) line. Example reflects the Cannon Beach 10 profile line. Dark grey shading indicates 68.3% of measurements located ±0.15 m (1σ) from the transect line, while 95.5% (2σ) of the measurements are located within ±0.30 m of the profile line (grey shading).

To supplement the GPS beach and bluff data, high-resolution lidar data measured by Watershed Sciences, Inc. (WSI) in 2009 for DOGAMI were also analyzed and integrated into the beach profile data set. This was especially important for backshore areas where it was not possible to easily survey with the GPS gear. In addition, lidar data flown by the U.S. Geological Survey (USGS)/National Aeronautics and Space Administration (NASA)/NOAA in 1997, 1998, and 2002 were used to extend the time series of the beach and bluff profile data. In particular, the 1998 lidar data measured at the end of the major 1997-98 El Niño were analyzed, providing additional measurements of the beach in an eroded state that can be compared with more recent winter surveys of the beach. The 1997, 1998, and 2002 lidar data were downloaded from NOAA's Coastal Service Center (http://coast.noaa.gov/dataregistry/search/collection/info/coastallidar) and were gridded in Esri® ArcGIS® by using a triangulated irregular network (TIN) algorithm; distance and elevation data were extracted from the grid lidar digital elevation models (DEMs).

## 3.2 Beach Characterization

Analyses of the beach profile data were undertaken using additional scripts developed in MATLAB. These scripts require the user to interactively locate the positions of the seaward edge and crest of the *primary frontal dune* (PFD) backing the beach, and then evaluate the beach-dune juncture ($E_j$) elevations and beach slopes (tan $\beta$) for the 1997, 1998, 2002, 2008/2009, 2011 and 2012 surveys along each of the profile sites. Beach slope was determined by fitting a linear regression through the measured profile data. In all cases, the slope of the beach face was determined to be the region of the beach located between mean sea level (~1.4 m, MLLW [mean lower low water]) and the highest observed tide (~3.8 m, MLLW), an approach that is consistent with methodologies adopted by Ruggiero and others, 2005; Stockdon and others (2006). Determination of the location of the beach-dune junctures ($E_j$) was accomplished interactively using the MATLAB scripts and from local knowledge of the area. In general, the beach-dune juncture (Ej) reflects a major break in slope between the active part of the beach face and the toe location of the primary dune or bluff. For most sites along the Oregon coast, the beach-dune juncture (Ej) typically occurs at elevations between about 4 and 6 m (NAVD88). **Figure 3-8** provides an example of the identified beach-dune juncture (Ej) for one site, TILL 21, located at the north end of the Neskowin shoreline (**Figure 3-1**) after it has been eroded (described in Section 7). In this example, it is apparent that the dune has experienced considerable erosion during the past two decades, with the dune face retreating landward by 32.6 m (107 ft) since 1997 as measured at the 7 m (23 ft) contour elevation.

Examination of the profile data indicates that the beach-dune juncture (Ej) has varied in elevation, a function of repeated phases of both erosion and accretion events. As of winter 2012, an erosion scarp had formed and the beach-dune juncture reflected the toe of the scarp, located at an elevation of 5.1 m (16.7 ft). **Figure 3-8** also includes the derived beach slope (tan $\beta$ = 0.049), the crest of the primary dune, as well as the landward boundary of the primary frontal dune. These latter data are used later to develop new Zone VE flood hazard zones along the Tillamook County coast. Recall that Zone VE is the flood insurance rate zone that corresponds to areas within the 1% annual chance coastal floodplain where wave erosion, overtopping, and inundation may take place.

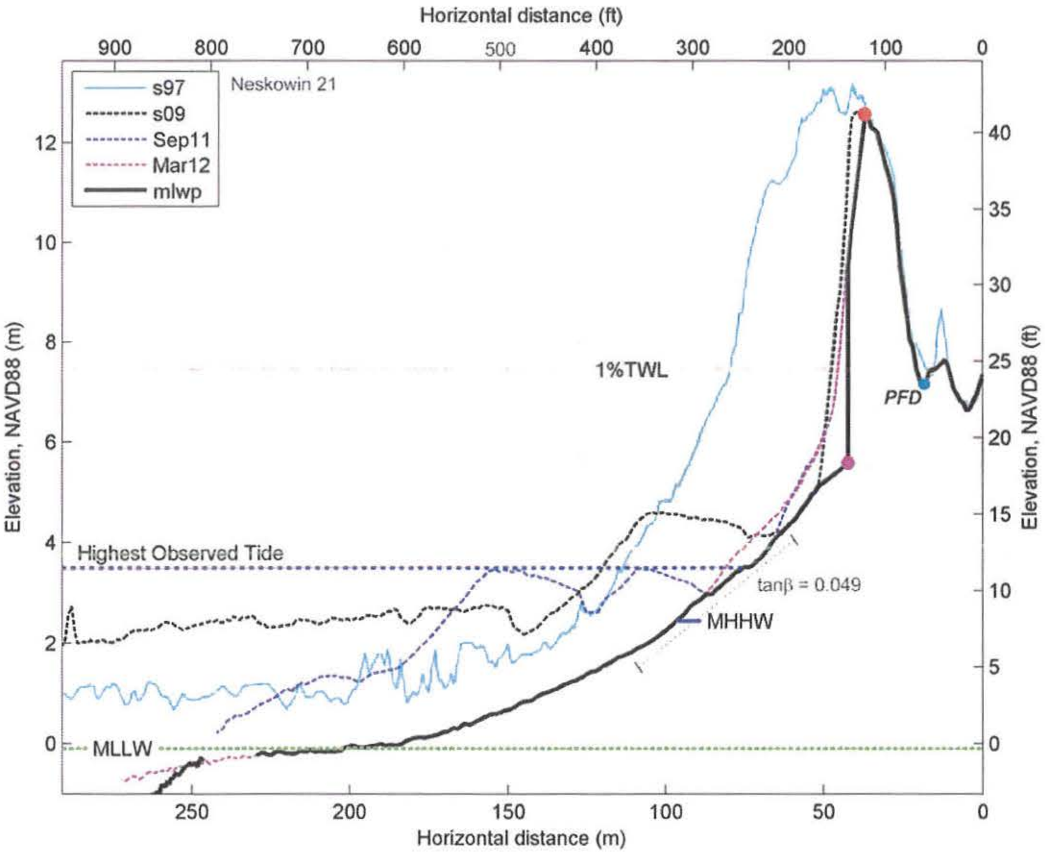


**Figure 3-8. Plot showing various beach cross-sections at the TILL 21 (aka Neskowin 21) profile site. In this example, the most likely winter profile (MLWP) is depicted as the heavy black line, the *eroded* beach-dune juncture location, dune crest, and primary frontal dune location (PFD) are characterized by magenta, red, and blue circles, respectively. The plot also provides a dramatic example of the extent of erosion that has taken place along this section of Neskowin beach. MLLW is mean lower low water. MHHW is mean higher high water. TWL is total water level. PFD is primary frontal dune.**

To estimate beach erosion and profile changes for a specific coastal setting that occurs during a particular storm, it is essential to first define the initial conditions of the morphology of the beach prior to the actual event of interest (Northwest Hydraulic Consultants, 2005). This initial beach profile is referred to as the *most likely winter profile* (MLWP) condition for that particular coastal setting and is depicted in **Figure 3-8** as the heavy black line. The MLWP was assessed from examination of the combined surveyed profiles and lidar data. In the **Figure 3-8** example, the 2009 lidar survey of the primary dune and backshore was found to best characterize the landward component of the MLWP, while our March 2012 survey best captured the state of the active beach and seaward edge of the foredune. Landward of the dune crest, information on the backshore topography was derived by incorporating the actual measured GPS data because those data provided the best representation of the actual ground surface. Where GPS survey data were not available, we used topographic data derived from the 2009 lidar flown for DOGAMI.

**Table 3-3** summarizes the various morphological parameters identified for each transect site along the Tillamook County coastline, including their geomorphic classification.

**Table 3-3. Identified beach morphological parameters from the most likely winter profile (MLWP) along the Tillamook County shoreline. Parameters include the beach-dune junction elevation (Ej_MLWP), beach slope (tan β), and a site description.**

| Reach | Transect | DFIRM Transect | Dune Crest/Bluff Top (m) | *Ej_MLWP* (m) | Beach Slope (tan *β*) | Description |
|---|---|---|---|---|---|---|
| **Salmon River** | LINC 308 | 1 | 6.251 | 5.058 | 0.084 | dune-backed cliff |
| **Cascade Head** | LINC 309 | 2 | 48.172 | 1.609 | 0.027 | plunging cliff |
| | LINC 310 | 3 | 43.56 | 1.207 | 0.028 | plunging cliff |
| | LINC 311 | 4 | 24.427 | 0.358 | 0.022 | boulder beach backed by bluffs |
| | LINC 312 | 5 | 93.24 | 2.125 | 0.026 | plunging cliff |
| | LINC 313 | 6 | 139.103 | 0 | 0.023 | plunging cliff |
| **Neskowin** | TILL 1 | 7 | 47.278 | 0.764 | 0.025 | sandy beach backed by riprap and high cliffs |
| | TILL 2 | 8 | 8.684 | 3.914 | 0.045 | sand beach backed by riprap |
| | TILL 3 | 9 | 8.452 | 3.914 | 0.042 | sand beach backed by riprap |
| | TILL 4 | 10 | 5.184 | 3.448 | 0.018 | sand beach backed by riprap |
| | TILL 5 | 11 | 8.312 | 2.712 | 0.049 | sand beach backed by riprap |
| | TILL 6 | 12 | 8.447 | 3.563 | 0.073 | sand beach backed by riprap |
| | TILL 7 | 13 | 8.169 | 1.904 | 0.062 | sand beach backed by riprap |
| | TILL 8 | 14 | 8.539 | 2.533 | 0.062 | sand beach backed by riprap |
| | TILL 9 | 15 | 7.075 | 5.888 | 0.06 | dune-backed |
| | TILL 10 | 16 | 8.897 | 6.235 | 0.054 | dune-backed |
| | TILL 11 | 17 | 6.679 | 5.604 | 0.041 | dune-backed |
| | TILL 12 | 18 | 8.374 | 5.521 | 0.044 | dune-backed |
| | TILL 13 | 19 | 7.126 | 5.709 | 0.049 | dune-backed |
| | TILL 14 | 20 | 8.118 | 5.086 | 0.099 | sand beach backed by riprap |
| | TILL 15 | 21 | 7.587 | 4.642 | 0.069 | sand beach backed by riprap |
| | TILL 16 | 22 | 6.767 | 6.014 | 0.052 | dune-backed |
| | TILL 17 | 23 | 9.986 | 4.326 | 0.039 | dune-backed |
| | TILL 18 | 24 | 8.387 | 5.512 | 0.074 | dune-backed |
| | TILL 19 | 25 | 6.014 | 6.014 | 0.059 | dune-backed |
| | TILL 20 | 26 | 7.648 | 7.066 | 0.098 | dune-backed |
| | TILL 21 | 27 | 12.562 | 5.582 | 0.049 | dune-backed |
| | TILL 22 | 28 | 6.241 | 4.489 | 0.034 | dune-backed |
| | TILL 23 | 29 | 14.334 | 6.819 | 0.088 | dune-backed |
| | TILL 24 | 30 | 7.792 | 7.185 | 0.06 | dune-backed |
| | TILL 25 | 31 | 7.642 | 5.627 | 0.061 | dune-backed |
| | TILL 26 | 32 | 32.562 | 3.877 | 0.059 | sandy beach backed by high cliffs |
| | TILL 27 | 33 | 28.194 | 4.519 | 0.088 | sandy beach backed by high cliffs |
| | TILL 28 | 34 | 39.31 | 6.292 | 0.084 | sandy beach backed by dunes and high cliffs |

| Reach | Transect | DFIRM Transect | Dune Crest/Bluff Top (m) | *Ej_MLWP* (m) | Beach Slope (tan *β*) | Description |
|---|---|---|---|---|---|---|
| **Nestucca spit/ Pacific City** | TILL 29 | 35 | 10.245 | 4.903 | 0.043 | dune-backed |
| | TILL 30 | 36 | 14.485 | 5.083 | 0.048 | dune-backed |
| | TILL 31 | 37 | 15.49 | 5.933 | 0.061 | dune-backed |
| | TILL 32 | 38 | 14.358 | 5.413 | 0.093 | dune-backed |
| | TILL 33 | 39 | 13.16 | 5.338 | 0.072 | dune-backed |
| | TILL 34 | 40 | 15.877 | 6.611 | 0.086 | dune-backed |
| | TILL 35 | 41 | 15.147 | 5.312 | 0.05 | dune-backed |
| | TILL 36 | 42 | 17.709 | 5.908 | 0.051 | dune-backed |
| | TILL 37 | 43 | 12.932 | 4.389 | 0.051 | sand beach backed by riprap? |
| | TILL 38 | 44 | 11.283 | 4.69 | 0.053 | sand beach backed by riprap? |
| | TILL 39 | 45 | 18.954 | 5.407 | 0.041 | dune-backed |
| | TILL 40 | 46 | 11.314 | 5.539 | 0.057 | sand beach backed by riprap? |
| | TILL 41 | 47 | 11.06 | 4.785 | 0.039 | sand beach backed by riprap? |
| | TILL 42 | 48 | 13.304 | 4.681 | 0.043 | sand beach backed by riprap and high bluffs |
| **Sand Lake/ Tierra Del Mar** | TILL 43 | 49 | 23.369 | 5.582 | 0.046 | sandy beach backed by high cliffs |
| | TILL 44 | 50 | 16.741 | 6.162 | 0.075 | sandy beach backed by high cliffs |
| | TILL 45 | 51 | 6.868 | 4.232 | 0.042 | sandy beach backed by cobbles - grades into bluff |
| | TILL 46 | 52 | 18.071 | 4.865 | 0.055 | sandy beach backed by high cliffs |
| | TILL 47 | 53 | 18.396 | 4.063 | 0.045 | sand beach backed by riprap |
| | TILL 48 | 54 | 7.412 | 6.555 | 0.048 | dune-backed |
| | TILL 49 | 55 | 8.24 | 6.197 | 0.044 | dune-backed |
| | TILL 50 | 56 | 6.931 | 5.891 | 0.041 | dune-backed |
| | TILL 51 | 57 | 6.317 | 4.554 | 0.05 | sand beach backed by riprap |
| | TILL 52 | 58 | 7.721 | 4.543 | 0.055 | sand beach backed by riprap |
| | TILL 53 | 59 | 8.141 | 5.026 | 0.056 | sand beach backed by riprap |
| | TILL 54 | 60 | 7.462 | 5.055 | 0.058 | sand beach backed by riprap |
| | TILL 55 | 61 | 8.094 | 5.159 | 0.045 | dune-backed |
| | TILL 56 | 62 | 8.357 | 4.652 | 0.046 | sand beach backed by riprap |
| | TILL 57 | 63 | 11.383 | 4.823 | 0.04 | sand beach backed by riprap |
| | TILL 58 | 64 | 10.224 | 6.18 | 0.042 | dune-backed |
| | TILL 59 | 65 | 12.153 | 5.72 | 0.052 | dune-backed |
| | TILL 60 | 66 | 9.595 | 5.355 | 0.041 | dune-backed |
| | TILL 61 | 67 | 9.37 | 6.193 | 0.048 | dune-backed |
| | TILL 62 | 68 | 6.573 | 6.26 | 0.052 | dune-backed |
| | TILL 63 | 69 | 3.38 | 3.324 | 0.009 | dune-backed |
| | TILL 64 | 70 | 18.524 | 6.915 | 0.111 | dune-backed |
| | TILL 65 | 71 | 18.296 | 5.556 | 0.053 | dune-backed |
| | TILL 66 | 72 | 15.211 | 5.34 | 0.049 | dune-backed |
| | TILL 67 | 73 | 19.042 | 8.385 | 0.069 | sandy beach backed by high cliffs |
| | TILL 68 | 74 | 24.72 | 6.441 | 0.044 | sandy beach backed by high cliffs |
| | TILL 69 | 75 | 29.519 | 5.96 | 0.051 | sandy beach backed by high cliffs |
| | TILL 70 | 76 | 30.293 | 4.588 | 0.045 | sandy beach backed by high cliffs |
| | TILL 71 | 77 | 37.153 | 4.979 | 0.055 | sandy beach backed by high cliffs |
| | TILL 72 | 78 | 30.575 | 4.844 | 0.037 | sandy beach backed by high cliffs |
| | TILL 73 | 79 | 28.571 | 6.625 | 0.048 | sandy beach backed by high cliffs |
| | TILL 74 | 80 | 20.692 | 5.762 | 0.038 | sandy beach backed by high cliffs |

| Reach | Transect | DFIRM Transect | Dune Crest/Bluff Top (m) | *Ej_MLWP* (m) | Beach Slope (tan *β*) | Description |
|---|---|---|---|---|---|---|
| **Netarts Spit/ Oceanside** | TILL 75 | 81 | 6.775 | 2.43 | 0.029 | sandy beach backed by low/high cliffs |
| | TILL 76 | 82 | 7.6 | 2.937 | 0.037 | sandy beach backed by cobbles/boulders and low cliff |
| | TILL 77 | 83 | 8.447 | 3.235 | 0.047 | sandy beach backed by dynamic revetment/artificial dune |
| | TILL 78 | 84 | 7.298 | 3.706 | 0.051 | sandy beach backed by dynamic revetment/artificial dune |
| | TILL 79 | 85 | 10.798 | 3.976 | 0.043 | dune-backed (+cobbles) |
| | TILL 80 | 86 | 9.131 | 5.381 | 0.082 | dune-backed (+cobbles) |
| | TILL 81 | 87 | 7.159 | 4.661 | 0.067 | dune-backed (+cobbles) |
| | TILL 82 | 88 | 11.562 | 5.04 | 0.056 | dune-backed |
| | TILL 83 | 89 | 12.413 | 5.492 | 0.056 | dune-backed |
| | TILL 84 | 90 | 7.322 | 6.012 | 0.046 | dune-backed |
| | TILL 85 | 91 | 11.621 | 5.37 | 0.044 | dune-backed |
| | TILL 86 | 92 | 11.763 | 6.361 | 0.047 | dune-backed |
| | TILL 87 | 93 | 19.722 | 4.114 | 0.043 | dune-backed |
| | TILL 88 | 94 | 6.567 | 5.72 | 0.057 | dune-backed |
| | TILL 89 | 95 | 10.543 | 5.754 | 0.048 | dune-backed |
| | TILL 90 | 96 | 12.156 | 4.768 | 0.046 | dune-backed |
| | TILL 91 | 97 | 9.61 | 6.516 | 0.052 | dune-backed |
| | TILL 92 | 98 | 8.324 | 6.36 | 0.05 | dune-backed |
| | TILL 93 | 99 | 4.971 | 4.855 | 0.069 | Cobble beach backed by low wall (estuary mouth) |
| | TILL 94 | 100 | 14.619 | 5.554 | 0.074 | sandy beach backed by high cliffs |
| | TILL 95 | 101 | 29.639 | 4.999 | 0.032 | sandy beach backed by high cliffs |
| | TILL 96 | 102 | 39.082 | 4.536 | 0.055 | sandy beach backed by high cliffs |
| | TILL 97 | 103 | 55.206 | 4.631 | 0.065 | sandy beach backed by dune and high cliffs |
| | TILL 98 | 104 | 60.658 | 5.832 | 0.073 | sandy beach backed by dune and high cliffs |
| | TILL 99 | 105 | 33.925 | 4.907 | 0.044 | sandy beach backed by high cliffs |
| | TILL 100 | 106 | 36.465 | 4.585 | 0.041 | sandy beach backed by high cliffs |
| | TILL 101 | 107 | 13.733 | 5.191 | 0.045 | sandy beach backed by poor riprap and low cliffs |
| | TILL 102 | 108 | 18.353 | 5.953 | 0.05 | sandy beach backed by moderately high cliffs |
| | TILL 103 | 109 | 8.241 | 4.068 | 0.057 | sandy beach backed by moderately high cliffs |
| **Short Sand Beach** | TILL 104 | 110 | 33.582 | 3.026 | 0.056 | sandy beach backed by gravels and high cliffs |
| | TILL 105 | 111 | 26.461 | 3.932 | 0.075 | sandy beach backed by gravels and high cliffs |
| | TILL 106 | 112 | 47.152 | 5.674 | 0.109 | sandy beach backed by gravels and high cliffs |

| Reach | Transect | DFIRM Transect | Dune Crest/Bluff Top (m) | *Ej_MLWP* (m) | Beach Slope (tan *β*) | Description |
|---|---|---|---|---|---|---|
| **Bayocean Spit** | TILL 107 | 113 | 8.705 | 3.527 | 0.072 | sandy beach backed by cobble/boulder and low cliffs |
| | TILL 108 | 114 | 7.74 | 2.981 | 0.05 | sandy beach backed by cobble/boulder and low cliffs |
| | TILL 109 | 115 | 6.34 | 3 | 0.036 | sandy beach backed by cobble/boulder berm |
| | TILL 110 | 116 | 6.081 | 2.495 | 0.026 | sandy beach backed by cobble/boulder berm |
| | TILL 111 | 117 | 6.863 | 3.33 | 0.04 | sandy beach backed by cobble/boulder berm |
| | TILL 112 | 118 | 9.667 | 6.824 | 0.041 | dune-backed |
| | TILL 113 | 119 | 11.095 | 6.67 | 0.043 | dune-backed |
| | TILL 114 | 120 | 9.781 | 6.804 | 0.04 | dune-backed |
| | TILL 115 | 121 | 8.97 | 4.932 | 0.043 | dune-backed |
| | TILL 116 | 122 | 10.49 | 5.889 | 0.04 | dune-backed |
| | TILL 117 | 123 | 10.053 | 6.537 | 0.043 | dune-backed |
| **Rockaway** | TILL 118 | 124 | 5.932 | 5.932 | 0.048 | dune-backed |
| | TILL 119 | 125 | 6.332 | 4.905 | 0.043 | dune-backed |
| | TILL 120 | 126 | 6.72 | 5.37 | 0.049 | dune-backed |
| | TILL 121 | 127 | 6.749 | 5.178 | 0.058 | dune-backed |
| | TILL 122 | 128 | 6.518 | 5.388 | 0.047 | dune-backed |
| | TILL 123 | 129 | 7.242 | 3.13 | 0.029 | sand beach backed by riprap |
| | TILL 124 | 130 | 6.905 | 5.82 | 0.05 | dune-backed |
| | TILL 125 | 131 | 5.489 | 5.489 | 0.046 | dune-backed |
| | TILL 126 | 132 | 5.858 | 4.586 | 0.02 | dune-backed |
| | TILL 127 | 133 | 7.148 | 5.709 | 0.037 | dune-backed |
| | TILL 128 | 134 | 7.976 | 5.327 | 0.038 | dune-backed |
| | TILL 129 | 135 | 7.237 | 5.136 | 0.048 | dune-backed |
| | TILL 130 | 136 | 7.344 | 5.839 | 0.046 | dune-backed |
| | TILL 131 | 137 | 7.032 | 4.682 | 0.037 | dune-backed |
| | TILL 132 | 138 | 5.486 | 3.77 | 0.038 | sand beach backed by riprap |
| | TILL 133 | 139 | 7.133 | 5.593 | 0.038 | dune-backed |
| | TILL 134 | 140 | 10.147 | 5.68 | 0.043 | dune-backed |
| | TILL 135 | 141 | 8.387 | 7.085 | 0.052 | dune-backed |
| | TILL 136 | 142 | 7.062 | 5.92 | 0.032 | sand beach backed by low bluff |
| | TILL 137 | 143 | 6.827 | 4 | 0.034 | sand beach backed by riprap |
| | TILL 138 | 144 | 6.359 | 3.045 | 0.013 | sand beach backed by riprap |
| | TILL 139 | 145 | 8.67 | 5.263 | 0.034 | dune-backed |
| | TILL 140 | 146 | 8.923 | 3.759 | 0.051 | sand beach backed by riprap |
| | TILL 141 | 147 | 7.643 | 3.759 | 0.044 | sand beach backed by riprap |
| | TILL 142 | 148 | 8.305 | 3.759 | 0.057 | sand beach backed by riprap |
| | TILL 143 | 149 | 8.196 | 4.068 | 0.051 | sand beach backed by riprap |
| | TILL 144 | 150 | 8.305 | 3.312 | 0.051 | sand beach backed by riprap |
| | TILL 145 | 151 | 8.092 | 4.309 | 0.054 | sand beach backed by riprap |
| | TILL 146 | 152 | 8.176 | 4.029 | 0.047 | sand beach backed by riprap |
| | TILL 147 | 153 | 7.927 | 7.16 | 0.056 | dune-backed |
| | TILL 148 | 154 | 8.101 | 5.982 | 0.052 | dune-backed |
| | TILL 149 | 155 | 8.029 | 5.997 | 0.05 | dune-backed |
| | TILL 150 | 156 | 8.315 | 6.325 | 0.045 | dune-backed |
| | TILL 151 | 157 | 6.974 | 4.176 | 0.022 | sand beach backed by riprap |
| | TILL 152 | 158 | 8.688 | 6.358 | 0.068 | dune-backed |
| | TILL 153 | 159 | 8.773 | 4.786 | 0.037 | dune-backed |
| | TILL 154 | 160 | 8.966 | 6.457 | 0.051 | dune-backed |
| | TILL 155 | 161 | 8.448 | 6.267 | 0.042 | dune-backed |
| | TILL 156 | 162 | 8.409 | 6.061 | 0.04 | dune-backed |
| | TILL 157 | 163 | 6.833 | 5.548 | 0.031 | dune-backed |

| Reach | Transect | DFIRM Transect | Dune Crest/Bluff Top (m) | *Ej_MLWP* (m) | Beach Slope (tan *β*) | Description |
|---|---|---|---|---|---|---|
| **Nehalem Spit/ Manzanita** | TILL 158 | 164 | 7.752 | 6.112 | 0.049 | dune-backed |
| | TILL 159 | 165 | 12.218 | 6.616 | 0.053 | dune-backed |
| | TILL 160 | 166 | 8.676 | 6.254 | 0.063 | dune-backed |
| | TILL 161 | 167 | 7.828 | 5.901 | 0.056 | dune-backed |
| | TILL 162 | 168 | 15.433 | 5.338 | 0.042 | dune-backed |
| | TILL 163 | 169 | 13.023 | 5.823 | 0.043 | dune-backed |
| | TILL 164 | 170 | 14.069 | 5.912 | 0.055 | dune-backed |
| | TILL 165 | 170 | 15.75 | 5.514 | 0.051 | dune-backed |
| | TILL 166 | 172 | 12.088 | 4.356 | 0.034 | dune-backed |
| | TILL 167 | 173 | 12.772 | 5.616 | 0.039 | dune-backed |
| | TILL 168 | 174 | 13.313 | 6.617 | 0.038 | dune-backed |
| | TILL 169 | 175 | 10.635 | 7.807 | 0.075 | dune-backed |
| | TILL 170 | 176 | 9.226 | 4.313 | 0.022 | sand beach backed by riprap |
| | TILL 171 | 177 | 8.847 | 5.064 | 0.026 | dune-backed |
| | TILL 172 | 178 | 9.502 | 6.107 | 0.03 | dune-backed with road |
| | TILL 173 | 179 | 11.496 | 5.245 | 0.028 | dune-backed with road |
| | TILL 174 | 180 | 9.609 | 5.516 | 0.027 | dune-backed with road |
| | TILL 175 | 181 | 11.367 | 4.73 | 0.029 | dune-backed |
| | TILL 176 | 182 | 9.012 | 5.504 | 0.048 | sand beach backed by extensive cobble berm |
| | TILL 177 | 183 | 6.996 | 5.077 | 0.049 | sand beach backed by extensive cobble berm and bluff |
| | TILL 178 | 184 | 7.921 | 7.894 | 0.169 | sand beach backed by extensive cobble berm and bluff |
| **Falcon Cove** | CP 1 | 185 | 15.935 | 7.027 | 0.167 | sand, cobble berm backed by high bluff |

**Figure 3-9** provides a plot of the alongshore changes in beach slopes (tan $\beta$), mean sediment grain sizes ($M_z$), beach-dune juncture ($E_j$) elevations, and dune/bluff/structure crest heights. In general, the steepest slopes are confined to those beaches with coarse sediments on the foreshore (e.g., **Figure 2-13**), while sites containing finer sediments are characterized by generally lower beach slopes (e.g., **Figure 2-1**). Mean grain sizes in the Neskowin littoral cell are characterized as medium sand ($M_z = 1.3\phi$ (0.42 mm [Peterson and others, 1994]) and decrease to $M_z = 2.5\phi$ (0.18 mm, or fine sand) along the rest of the Tillamook County coastline. The steepest beach slopes are typically identified adjacent to the headlands, where the beach is composed predominantly of gravels and boulders and the sediment is locally sourced from the headlands as a result of landslides. At several beach study sites, sediment grain sizes vary in both along-shore and cross-shore directions. For example, beaches at Cape Lookout State Park, located at the south end of Netarts Spit, may be characterized as "composite" using the nomenclature of Jennings and Shulmeister (2002), that is, consisting of a wide dissipative sandy beach composed of fine sand (**Figure 3-9**), backed by an extensive gravel beach on the upper foreshore. In contrast, the beach at the north end of Manzanita exhibits a substantial cobble/boulder berm on the beach face that is fronted by a wide dissipative sand beach in the intertidal zone (**Figure 3-10**). The cobble/boulder berm provides significant protection to the backshore (Allan and others, 2005).

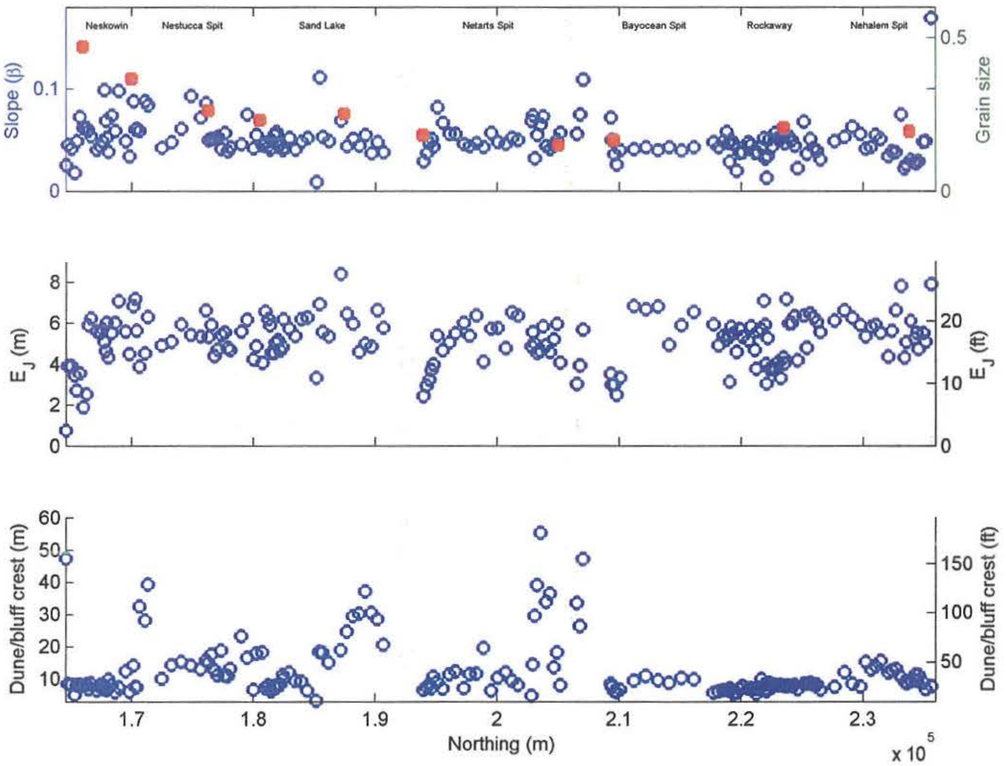


**Figure 3-9.** Alongshore changes in beach slopes (tan β), beach-dune juncture (Ej) elevations, and dune/bluff crest/tops along Tillamook County. Red squares indicate mean sediment grain sizes measured by Peterson and others (1994). Vertical blue shading denotes the location of estuary mouths, while the red shading denotes the location of headlands.

**Figure 3-9** also plots the beach-dune and beach-bluff juncture elevations (Ej) for the various study sites. Values for Ej vary significantly along the length of the Tillamook County coast. The lowest Ej values tend to occur along the toe of coastal engineering structures (e.g., the riprap structures that protect the community of Neskowin) and on beaches backed by gravel and boulders. In general, the highest beach-dune juncture elevations are found along Nehalem and Bayocean Spits, areas that are actively aggrading. In addition, **Figure 3-9** (bottom) indicates the dune/bluff/structure crest elevations. Because these heights are indicative of the potential for flooding, with higher crests generally limiting flood overtopping, it can be seen that the risk from coastal flooding and inundation is likely to be highest along much of the shores in Neskowin, Tierra Del Mar, Cape Meares, and Rockaway beach. Along the remainder of the shore, the beaches are protected by prominent bluffs (e.g., adjacent to the mouth of the Nestucca estuary, adjacent to Oceanside and at Short Sand Beach) and/or dunes (e.g., Nestucca and Nehalem Spit) with crest elevations that range from 10 to 18 m (33–59 ft) that effectively preclude wave overtopping and hence inundation in those areas. Nevertheless, some of these sites are subject to erosion hazards that likely will influence the extent of the flood zones in those areas, after factoring the potential for erosion from storms.

**Figure 3-10. Cobble/boulder beach located on the south side of Neahkahnie Mountain, north of Manzanita (photo: J. Allan, DOGAMI, July 2, 2003).**

## 3.3 Recent Coastal Changes in Tillamook County

This section briefly reviews beach profile changes that have occurred during the past decade, as documented by lidar and recent GPS surveys of the shore.

The overall approach used to define the morphology of the beach and dune system, including the location of the PFD along the length of county shoreline, and shoreline changes over the past decade, was based on detailed analyses of lidar data measured by USGS/NASA/NOAA in 1997, 1998, and 2002 and by DOGAMI in 2009. However, because lidar data flown by USGS/NASA/NOAA are of relatively poor resolution (~1 point/m$^2$) and reflect a single return (i.e., include vegetation where present), while the lidar data flown by DOGAMI have higher resolution (8 points/m$^2$) and are characterized by multiple returns enabling development of a bare-earth digital elevation model (DEM), our determination of the most critical beach/dune morphological features was based entirely on analysis of the 2009 lidar data.

Lidar data flown in 1997, 1998, and 2002 were downloaded from NOAA's Coastal Service Center and gridded in ArcGIS using a TIN algorithm (Allan and Harris, 2012); a similar approach was undertaken with the 2009 lidar data. Transects spaced 25 m apart were cast for the full length of the county coastline by using the Digital Shoreline Analysis System (DSAS) developed by the USGS (Thieler and others, 2009). For each transect, xyz values for the 1997, 1998, 2002, and 2009 lidar data were extracted at 1-m intervals along each transect line and saved as a text file using a customized ArcGIS script.

Processing of the lidar data was undertaken in MATLAB using a custom beach profile analysis script developed by DOGAMI. This script requires the user to interactively define various morphological features including the dune/bluff crest/top, bluff slope (where applicable), landward edge of the PFD, beach-dune juncture elevations for each year, and the slope of the beach foreshore.

### *3.3.1 Rockaway littoral cell changes*

As a result of the major storms of the late 1990s, the Rockaway littoral cell (Cape Meares to Neahkahnie Mountain) effectively experienced a "one-two punch" with successive winters of extreme erosion, commencing first with the unusually strong 1997-98 El Niño, followed immediately by the even more severe 1998-99 winter (see **Figure 3-11**). **Figure 3-11** was derived by analyzing topographic changes collected using airborne lidar flown in 1997 and 2002. The volume change estimated using this approach is confined to just the subaerial beach and hence excludes the vegetated foredune. The results indicate that the Rockaway subcell lost ~1.4 × $10^6$ $m^3$ (1.86*$10^6$ $yd^3$) of sand between 1997 and 2002 (**Figure 3-11**). Sand volume losses can also be seen for Nehalem Spit, which lost an estimated 1.45 × $10^5$ $m^3$ (1.90 × $10^5$ $yd^3$) of sand, while Bayocean Spit gained ~1.3 × $10^5$ $m^3$ (1.7 × $10^5$ $yd^3$) of sand. It is not clear where all the sand went. One hypothesis is that most of the eroded sand was removed offshore into deeper water; another potential sink is the estuaries. However, we speculate that the volume of sand removed into the estuaries is likely to be small compared to that carried offshore. As can be seen from **Figure 3-12**, which is derived from our repeated monitoring of the Rockaway cell beaches up to February 2014, the overall pattern of erosion within the Rockaway subcell has continued. In contrast, the northern half of Bayocean Spit (along with portions of the Nehalem Spit) has essentially recovered from the storms of the late 1990s and has gained significant amounts of sand (**Figure 3-12**). It is highly likely that a significant portion of the accumulated sand may be sediment eroded from Rockaway beach in the late 1990s. However, in all cases, the volume of sand gained along Bayocean and Nehalem Spit remains relatively small when compared to overall losses in the Rockaway subcell.

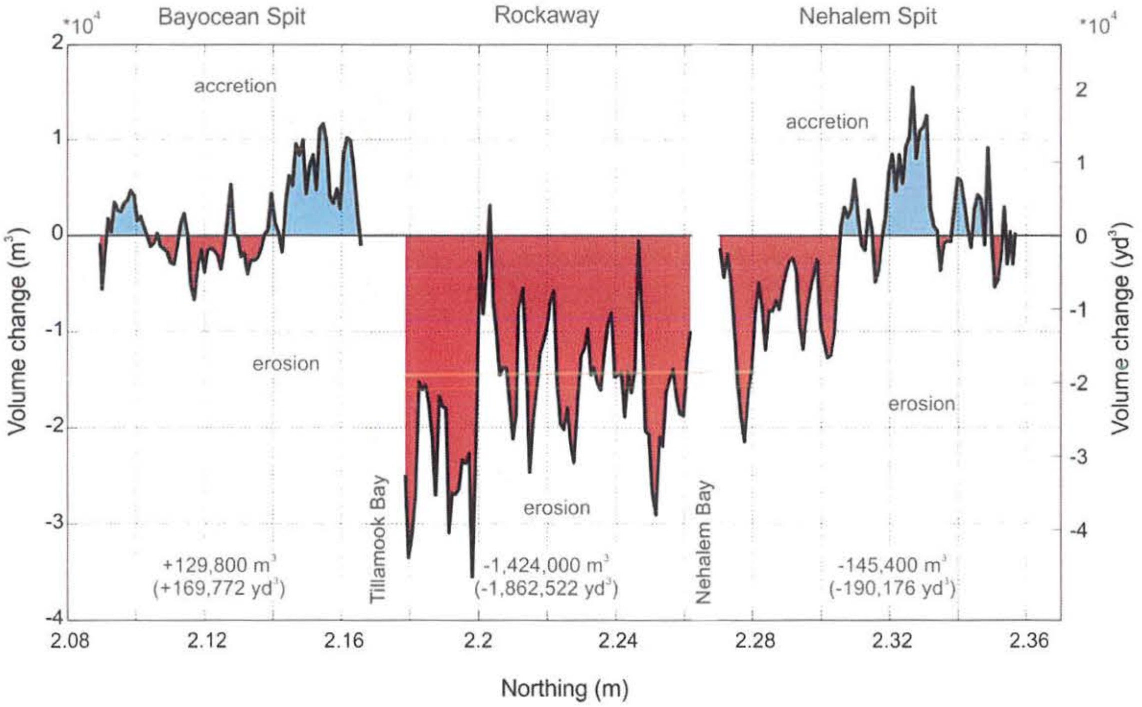


**Figure 3-11. Net beach sediment volume changes along the Rockaway littoral cell for the period 1997–2009. Gray bands denote the locations of the Tillamook and Nehalem Bay mouths (after Allan and others, 2009).**

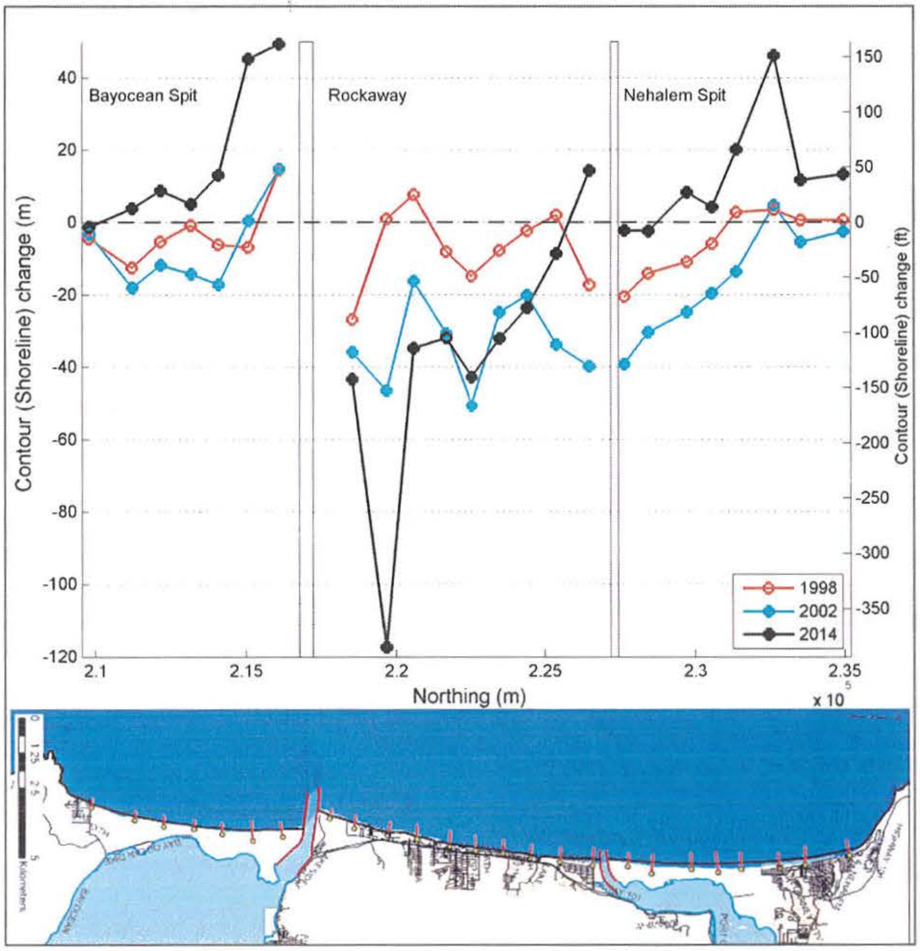


**Figure 3-12. The Rockaway cell beach monitoring network maintained by DOGAMI showing the measured changes in the position of the dune toe (6 m [19 ft] elevation) from 1997 to 2014.**

Figure 3-13, Figure 3-14, and Figure 3-15 show the profile changes measured at four representative transect sites located along Nehalem Spit, Rockaway beach, and Bayocean Spit, respectively. Beginning in the north on Nehalem Spit, Figure 3-13 indicates that apart from a brief period between 1997 and 2002, Nehalem Spit has essentially been in an accretional phase. As a result, the frontal foredune has aggraded vertically, and in some cases by several meters since 2002. This response is confined almost entirely to the southern two thirds of the spit (i.e., south of TILL 170, Figure 3-3). Erosion of the spit was especially significant between 1997 and 2002 along the southern one third of the spit (Figure 3-12), where recovery of the beach has taken some 10–14 years to fully rebuild. Shoreline erosion rates derived from GPS monitoring by DOGAMI staff indicate that the south end of Nehalem Spit is accreting at the fastest rate (~0.95 m/yr [3.1 ft/yr]), decreasing to ~0.2 m/yr (0.7 ft/yr) near Manzanita.

Farther south in the Rockaway subcell, the four transects highlight the contrasting responses observed along this particular subcell (Figure 3-14). In general, erosion rates are highest in the south (~-0.4 m/yr [-1.3 ft/yr]), and decrease toward the north. As can be seen in Figure 3-14, the TILL 120 transect site has retreated landward by about 40 m (130 ft) since 1997, with erosion dominating most of the transects. In essence, erosion dominates the entire section of coast south of about the TILL150 transect and extends all the way to the mouth of Tillamook Bay, while the beach and dune along Nedonna Beach are either stable or are slowly gaining sand.

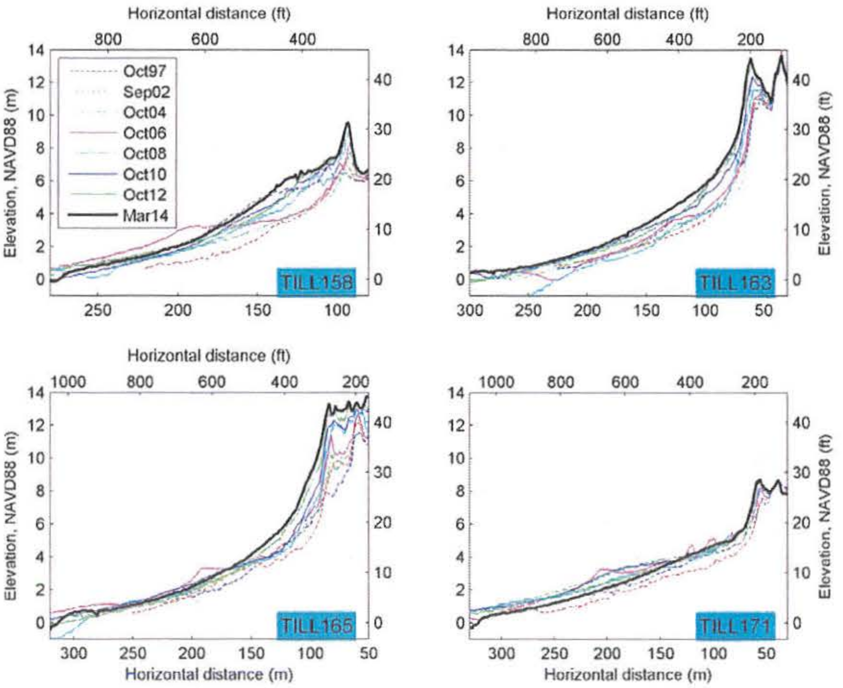


**Figure 3-13.** Measured beach morphological changes carried out between 1997 and 2014 for selected sites on Nehalem Spit from summer surveys undertaken by DOGAMI.

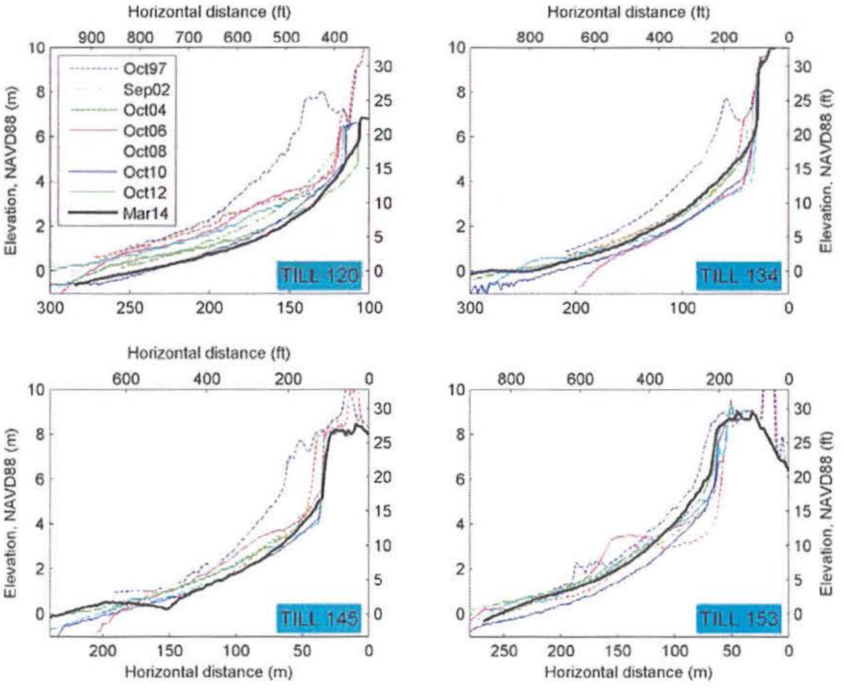


**Figure 3-14.** Measured beach morphological changes carried out between 1997 and 2014 for selected sites along the Rockaway subcell from summer surveys undertaken by DOGAMI.

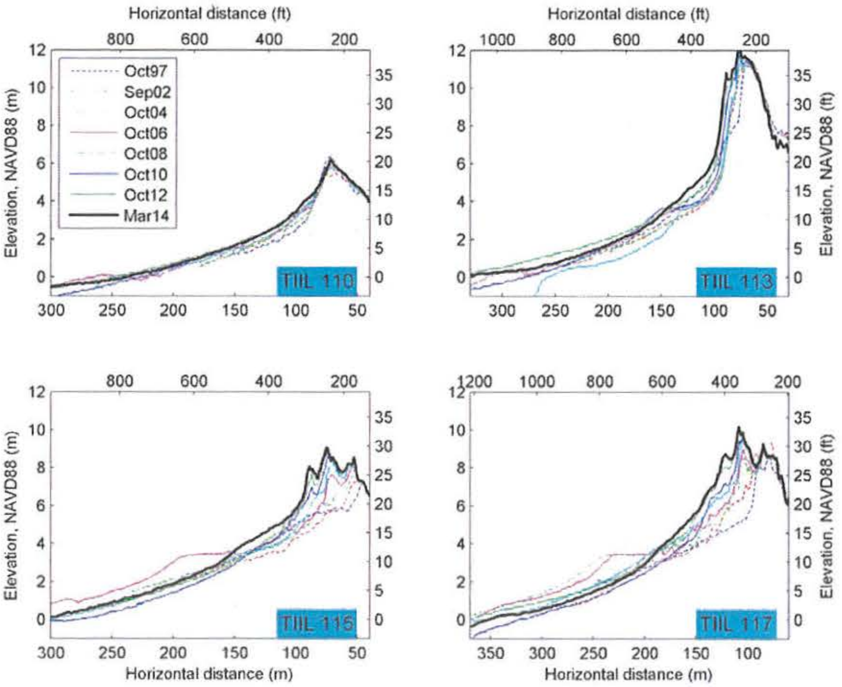


**Figure 3-15. Measured beach morphological changes carried out between 1997 and 2014 for selected sites along Bayocean spit from summer surveys undertaken by DOGAMI.**

As described previously in Section 2.4.1.4, Bayocean Spit has experienced dramatic change to its shorelines over the past century, much of which is directly a function of construction of the Tillamook Bay jetties. **Figure 3-15** depicts the changes that have taken place over the past 15 years. In the far south, the beach is backed by an extensive gravel beach that provides considerable protection from erosion to the backshore properties. As a result, this section of the beach is essentially stable, oscillating between minor bouts of erosion and accretion. With progress north along the spit, it is apparent that the dunes have fully recovered from the late 1990s winter storms (**Figure 3-12**) and are now actively aggrading along the length of the spit. Accretion rates are highest along the north end of the spit (reaching around +1m/yr [3.3 ft/yr]) and lowest in the south.

### *3.3.2 Tillamook County*

**Figure 3-16** summarizes the changes that have taken place along the full length of the county's shoreline since 1997. The analyses reflect the change in position of the 6 m (19.7 ft) contour elevation (essentially the dune/bluff toe) from 1997 (baseline) to 1998 (post El Niño), and from 1997 to 2009; the latter includes the updated lidar flight undertaken by WSI for DOGAMI. Several characteristics are apparent and worth highlighting:

- Erosion has continued along much of the shore to the north of the community of Neskowin;
- Along Nestucca spit, the beaches and dunes appear to have recovered slightly, although much of the remainder of the spit remains in a degraded state;
- Beach recovery is nonexistent in the vicinity of Tierra Del Mar and along the dunes to its immediate north. However, significant accretion has occurred on the south side of the Sand Lake estuary and farther north up to the south side of Cape Lookout;
- Erosion continues unabated on Netarts Spit, although there has been little to no change near Oceanside at the north end of this littoral cell. Considerable accretion has occurred on the south side of Netarts Bay, on the spit tip;
- Beach recovery is prevalent along Bayocean Spit, particularly along the northern half of the

spit where the dune face has clearly advanced (prograded) seaward by tens of meters;

- Erosion continues unabated along the bulk of the Rockaway subcell and, in many locations, is considered to be acute. This contrasts with significant aggradation along Nedonna Beach at the north end of the subcell and adjacent to the Nehalem jetties; and
- Beach recovery is occurring along the bulk of Nehalem Spit, with the area near Manzanita having prograded seaward.

Given these changes, we can conclude that the bulk of the Tillamook coast remains in a degraded or poor state, such that were we to experience storms comparable in magnitude to those experienced in 1998-99, it can be expected that massive erosion would again occur, potentially endangering many homes built adjacent to this coast.

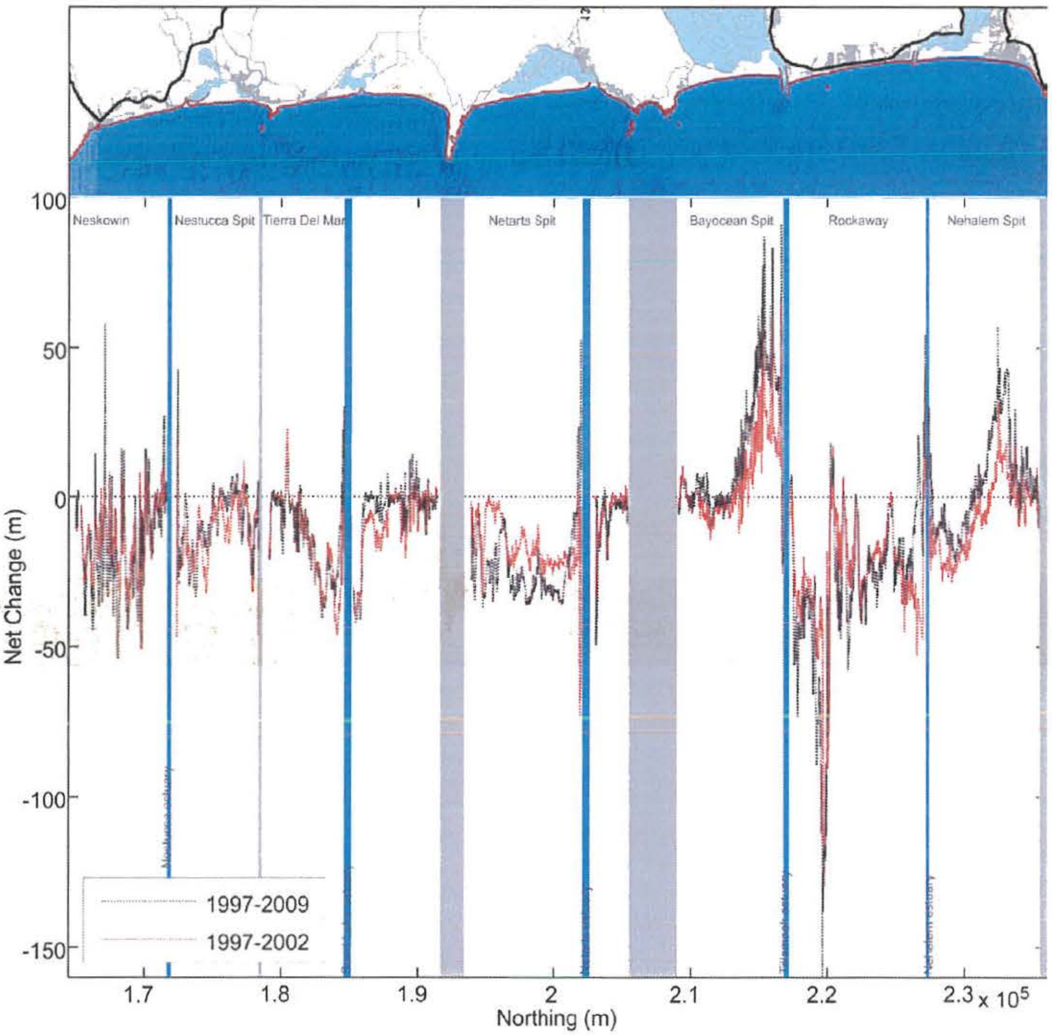


**Figure 3-16. Net shoreline response in Tillamook County as measured at the 6-m (19.7 ft) contour elevation for the period 1997–2002 and 1997–2009. Cyan bands denote the locations of estuary mouths; grey bands indicate the positions of headlands.**

## 3.4 Bathymetry

Important for calculating wave transformations and determining nearshore beach slopes is information on the local bathymetry seaward from the Tillamook County coast. For the purposes of this study we have adopted two approaches:

1. For the purposes of SWAN numerical wave modeling, we used bathymetric data compiled by the National Geophysical Data Center (NGDC), an office of NOAA, for the purposes of developing an integrated DEM for tsunami inundation modeling.
2. For erosion assessments and wave runup calculations, we used bathymetric data collected in late summer 2010 with the aid of personal watercrafts (Ozkan-Haller and others, 2009).

To develop an integrated bathymetric-topographic DEM that can be used for tsunami inundation modeling, the NGDC has compiled detailed bathymetric data across the continental shelf from multiple agencies. The synthesized bathymetric-topographic DEM (Astoria [http://www.ngdc.noaa.gov/dem/squareCellGrid/download/454], Garibaldi [http://www.ngdc.noaa.gov/dem/squareCellGrid/download/249], and Central Oregon Coast [http://www.ngdc.noaa.gov/dem/squareCellGrid/download/320]) is a 1/3 arc-second (approximately 10 m [~33 ft]) DEM of the north central Oregon coast that spans all of Tillamook County and includes the offshore rocks, small islands, and reefs that affect wave shoaling. The DEM was generated from a diverse suite of digital data sets that span the region (Carignan and others, 2009a, b, c). A summary of the data sources and methods used to synthesize the data to develop the Astoria and Garibaldi DEMs is described in the reports by Carignan and others. In general, the best available data were obtained by the NGDC and shifted to common horizontal and vertical datums: North America Datum 1983 (NAD 83) and Mean High Water (MHW).

NGDC used shoreline, bathymetric, and topographic digital data sets (**Figure 3-17**) from several U.S. federal, state, and local agencies (e.g., NOAA's National Ocean Service (NOS), Office of Coast Survey (OCS) and Coastal Services Center (CSC); the U.S. Geological Survey (USGS); the U.S. Army Corps of Engineers (USACE); and the Oregon Department of Fish and Wildlife/Marine Resource Program (ODFW). After all the data were converted to a common coordinate system and vertical datum, the grid data were checked for anomalous data and corrected accordingly. Because the data sets, particularly in deep water and near to the coast, were relatively sparse, further manipulation and smoothing was required to create a uniform grid. These products were then compared with the original surveys to ensure grid accuracy. According to Carignan and others (2009a) the final DEM is estimated to have an accuracy of up to 10 m (~33 ft), although some portions of the grid are more accurate (e.g., the coastal strip where high-resolution lidar data were available). The bathymetric portion of the data set is estimated to have an accuracy of between 0.1 m (0.33 ft) and 5% of the water depth, again depending on the type of survey data that was used to calibrate the final grid development.

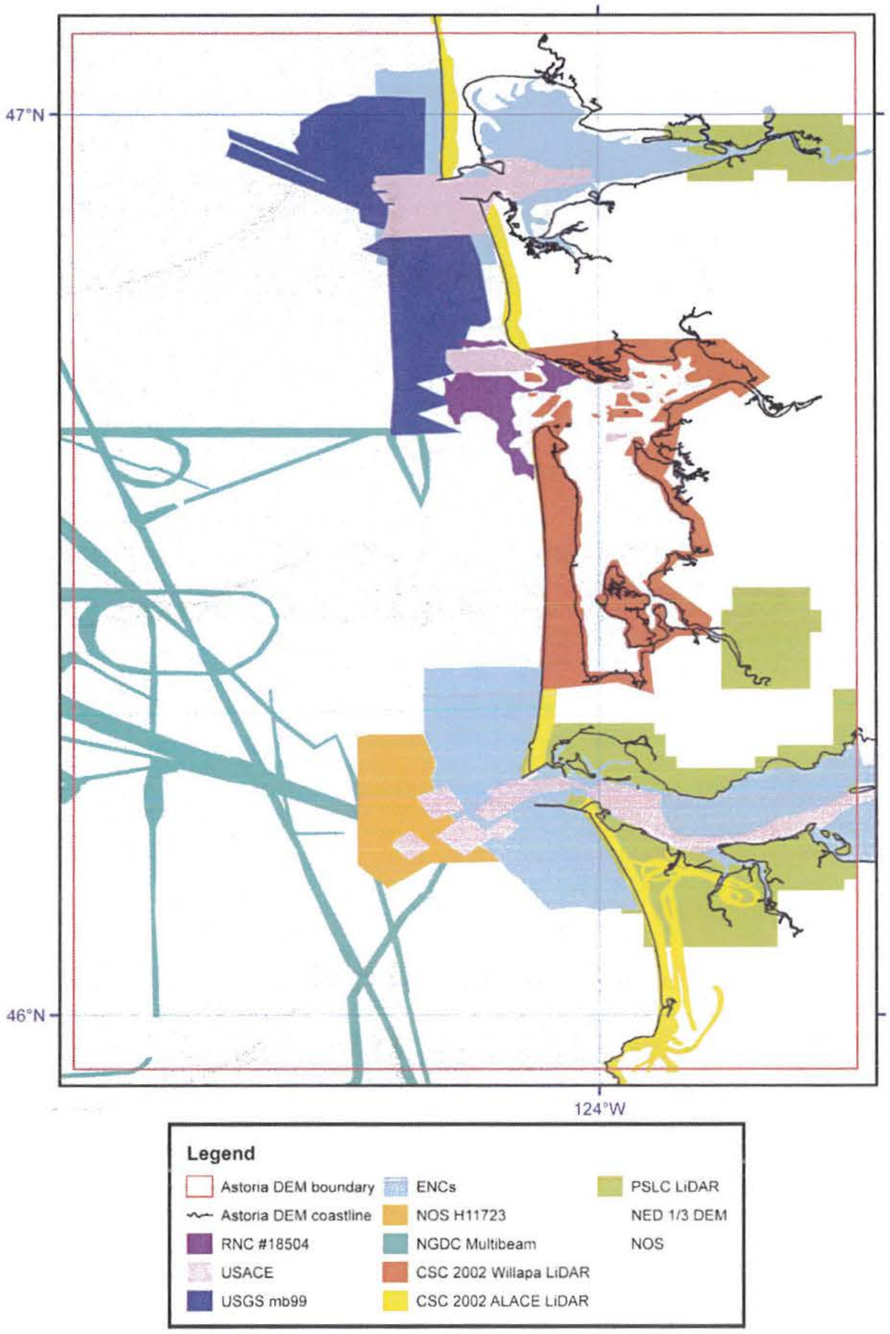


**Figure 3-17. U.S. federal, state, and local agency bathymetric data sets used to compile the Astoria digital elevation model (DEM) (Carignan and others, 2009b).**

Finally, despite all these efforts it is important to note that a limitation of the DEMs being developed by NGDC is the virtual absence of suitable bathymetric data in the nearshore (effectively landward of the 10 m (33 ft) bathymetry contour), because few survey boats are able to venture into this highly turbulent and dangerous portion of the surf zone. The exception to this is where surveys have been undertaken by the USACE in the entrance channels to estuaries where navigable water depths need to be maintained. Thus, there is some uncertainty about estimating nearshore slopes for the surf zone due to the absence of sufficient data for this region, with the user having to make assumptions based on the best available data that are present outside the surf zone and information at the shore face. This is a recognized problem with all coastal flood analyses. To resolve this problem, we used a Coastal Profiling System (CPS) that developed for nearshore bathymetric surveys by Dr. Peter Ruggiero (Department of Geosciences, Oregon State University [Ruggiero and others, 2005]). The CPS consists of a highly maneuverable personal watercraft equipped with a survey grade GPS receiver and antenna, an echo sounder, and an on board computer. Repeatability tests undertaken by Ruggiero and colleagues indicate sub-decimeter accuracy on the order of 0.15 m (0.5 ft) (Ozkan-Haller and others, 2009). **Figure 3-18** provides an example of the CPS system, while **Figure 3-19** and **Figure 3-20** present the mapped coverage of our bathymetric surveys undertaken in the summer 2009. An example of two of the bathymetric transects undertaken in Tillamook County is presented in **Figure 3-21**.

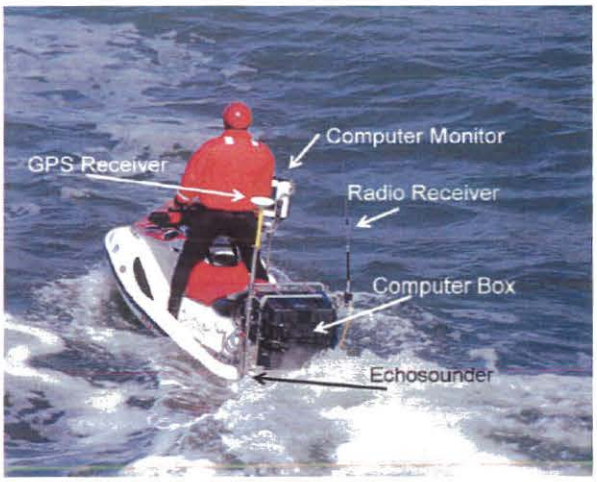


**Figure 3-18. Data acquisition boat and onboard equipment (photo: courtesy of P. Ruggiero, OSU).**

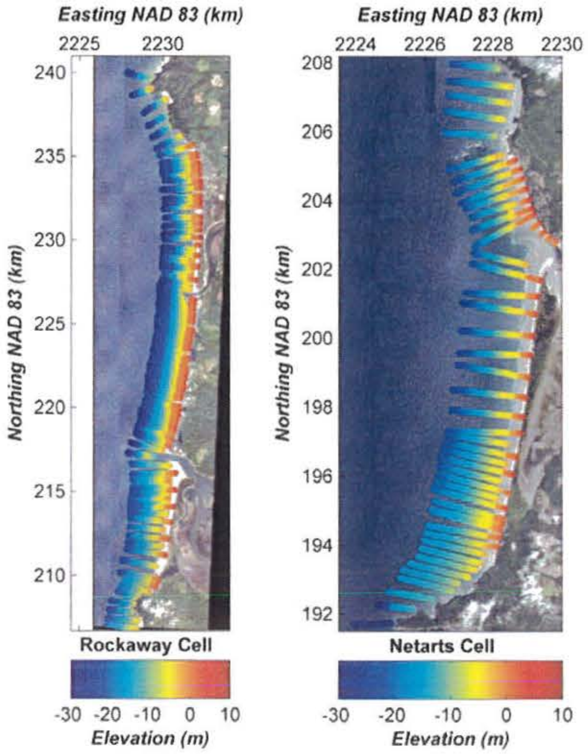


**Figure 3-19.** Collected bathymetry transects measured offshore the coast of the Rockaway and Netarts littoral cells, Tillamook County, Oregon.

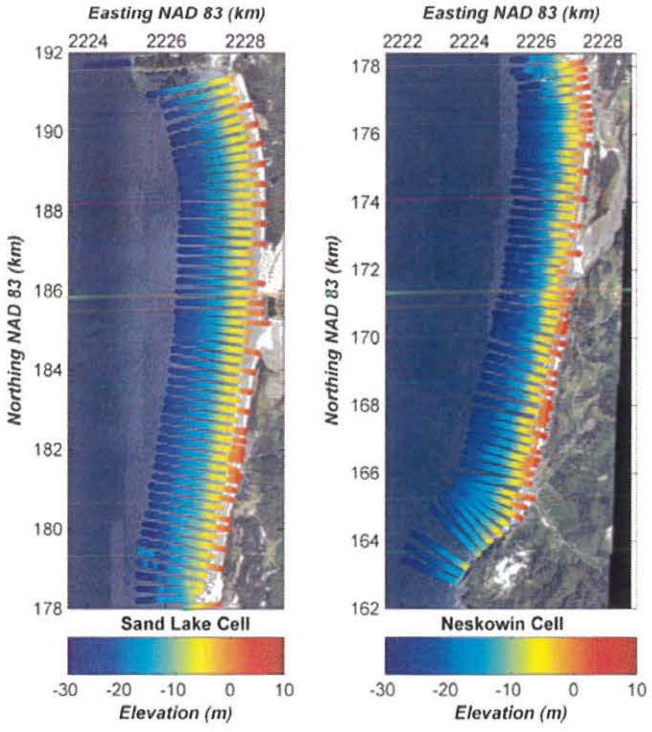


**Figure 3-20.** Collected bathymetry transects measured offshore the coast of the Rockaway and Netarts littoral cells, Tillamook County, Oregon.

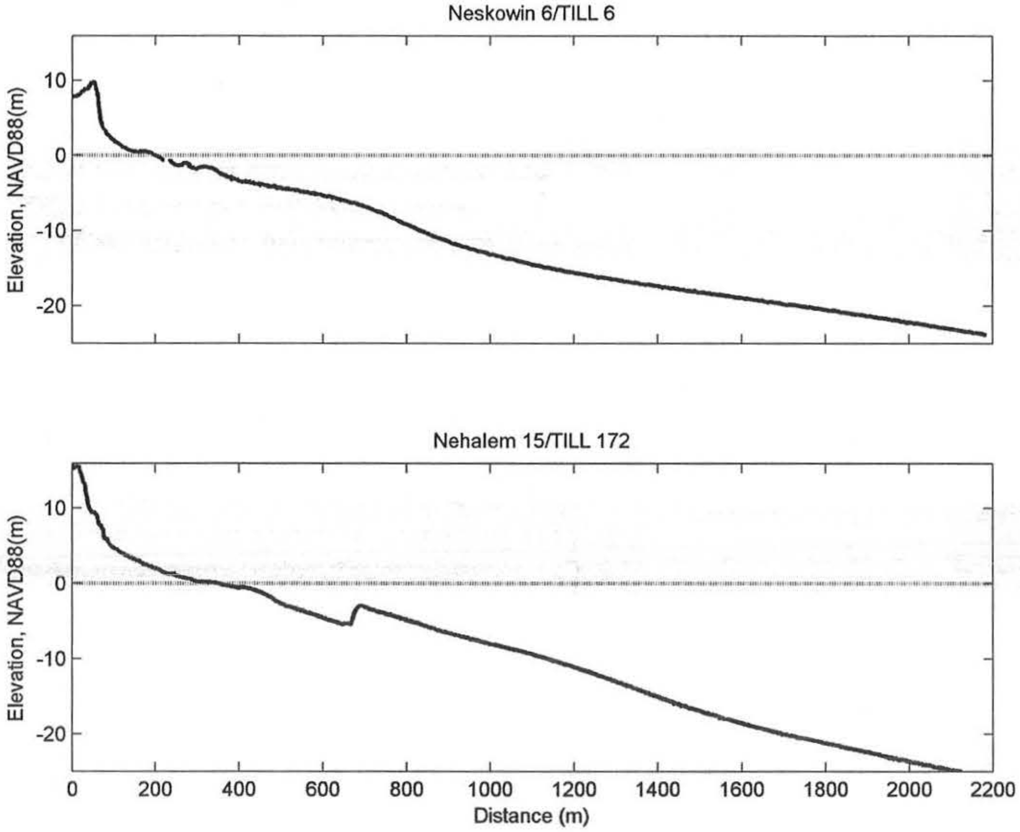


**Figure 3-21.** **Combined topographic and bathymetric cross-shore transects measured offshore from Neskowin and Nehalem Spit near the town of Manzanita (southern and northern Tillamook County, respectively) showing the presence of sand bars. Note the contrasting nearshore slopes between the two sites, with steeper topography observed at Neskowin and wider shallower topography offshore from Manzanita.**

# 4.0 TIDES

Measurements of tides on the Oregon coast are available from various tide gauges (http://www.tidesandcurrents.noaa.gov/map/index.shtml?type=PreliminaryData&region=Oregon) operated by NOS. Hourly tidal records are available from the following coastal sites (**Table 4-1**): Willapa Bay, Washington (Toke Point, #9440910), the Columbia River (Astoria, #9439040), Tillamook Bay (Garibaldi, #9437540), Newport (South Beach, #9435380), Coos Bay (Charleston, #9432780), and Port Orford (#9431647) on the southern Oregon coast. Long-term tidal records are also available from the Crescent City tide gauge (#9419750), located in northern California. The objective of this section is to establish which tide gauge would be most appropriate in applications directed toward FEMA wave and total water level analyses for the Tillamook coastline. Results presented here will also help guide future total water level (TWL) analyses scheduled for Lincoln County.

The tide gauges and their record intervals are listed in **Table 4-1**. **Figure 4-1** maps the locations of the most pertinent tide gauges present on the central to northern Oregon coast, along with the locations of various wave buoys operated by the National Data Buoy Center (NDBC) and the Coastal Data Information Program (CDIP), and Global Reanalysis of Ocean Waves (GROW) Fine Northeast Pacific wave hindcast data. These latter stations are pertinent to discussions of the wave climate and modeling described in Section 5 and, ultimately, in calculations of wave runup and overtopping.

As can be seen in **Table 4-1**, a number of the gauges have long records (30+ years) suitable for coastal flood analyses. The longest tide-gauge records (87 and 80 years, respectively) are from Astoria (AST), located 23.5 km up-channel from the mouth of the Columbia River, and at Crescent City (CC) in northern California. The South Beach (SB) and Toke Point (TP) gauges have moderately long records on the order of 45 and 43 years respectively (**Table 4-1**); the SB gauge is located within Yaquina Bay, ~2 km from the open coast, and the TP gauge is close to the mouth of Willapa Bay. The shortest record (~6 years), is that for Garibaldi (GB), located near the mouth of Tillamook Bay. All hourly tide data were purchased from NOS and were processed using various scripts developed in MATLAB. In addition to the measured tides, hourly tide predictions were calculated for all years using the NOS tide prediction program NTP4 (for NTP4, see the contact information at http://tidesandcurrents.noaa.gov/faq2.html#60).

**Table 4-1. Pacific Northwest NOAA tide gauges.**

| Gauge Site | Gauge Location | Record Interval | Years |
|---|---|---|---|
| **Washington** | | | |
| Toke Point (TP) | Willapa Bay, near the inlet mouth | Oct. 1968 – present | 43.6 |
| **Oregon** | | | |
| Astoria (AST) | Astoria | Feb. 1925 – present | 87.2 |
| Garibaldi (GB) | Tillamook Bay, near the inlet mouth | July 2005 – present | 6.8 |
| South Beach (SB) | Yaquina Bay, near the inlet mouth | Feb. 1967 – present | 45.2 |
| Charleston (CH) | Coos Bay, near the inlet mouth | Apr. 1970 – present | 42 |
| Port Orford (PO) | Port Orford, open coast harbor | Oct. 1977 – present | 34.6 |
| **California** | | | |
| Crescent City (CC) | Crescent City, open coast harbor | Sep. 1933 – present | 79.4 |

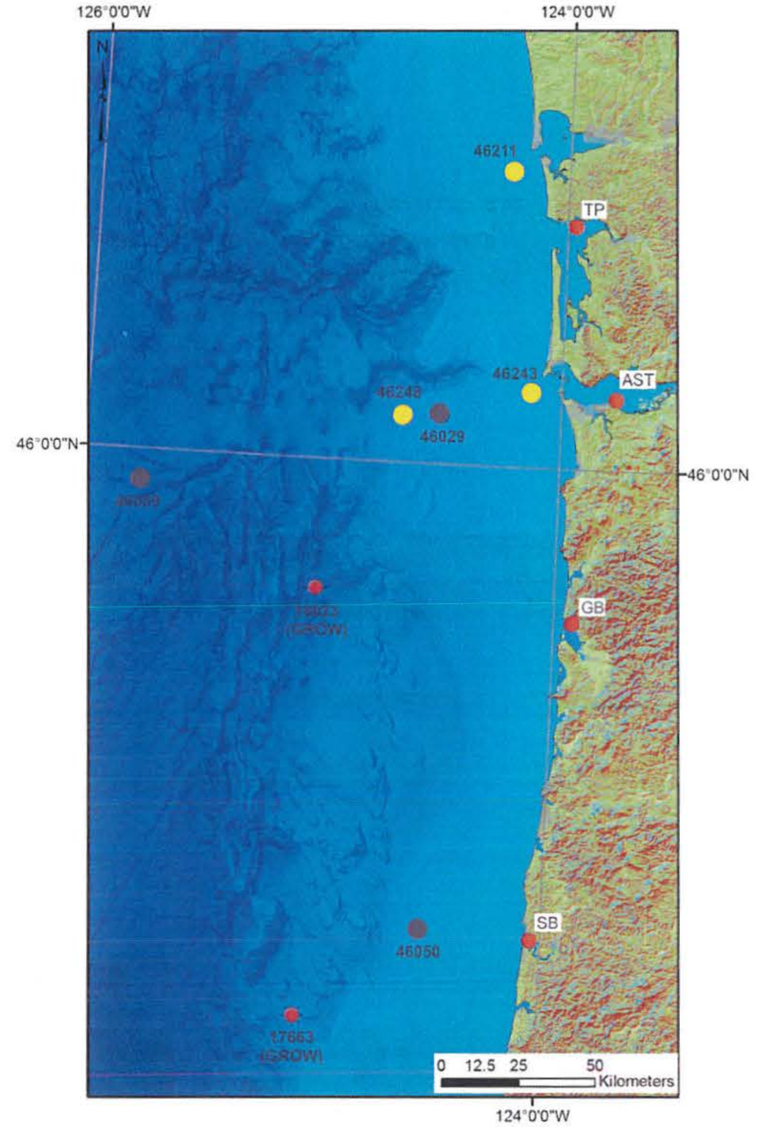


Figure 4-1. Location map of NDBC (black) and CDIP (yellow) wave buoys, tide gauges (red), and GROW wave hindcast stations (red suns). NDBC is National Data Buoy Center of NOAA and CDIP the Coastal Data Information Program (CDIP) of Scripps Institution of Oceanography. Note: NDBC Buoy #46005 referenced in this report is located 540 km (335 mi) west of the Columbia River mouth.

## 4.1 Tide Characteristics on the Central to Northern Oregon Coast

Tides along the Oregon coast are classified as moderate, with a maximum range of up to 4.3 m (14 ft) and an average range of about 1.8 m (6 ft) (Komar, 1997). There are two highs and two lows each day, with successive highs (or lows) usually having markedly different levels. Tidal elevations are given in reference to the mean of the lower low water levels (MLLW) and can easily be adjusted to the NAVD88 vertical datum. (MLLW to NAVD88 conversions may be performed by using values provided for a specific tide gauge by the NOS or by using the VDATUM (http://vdatum.noaa.gov/) tool developed by NOAA.) As a result, most tidal elevations are positive numbers with only the most extreme lower lows having negative values.

Initial analyses of the measured tides focused on developing empirical probability density function (PDF) plots of the measured tidal elevations for each tide gauge located between Newport, Oregon, and Willapa Bay, Washington. The objective here is to assess the measured tides along the Oregon and southwest Washington coasts in order to identify significant characteristics (including differences) between the gauges. **Figure 4-2** presents a series of PDF plots from each of the gauges. Because the gauges are characterized by varying record lengths, we have initially truncated the analyzed data to the period 2006–2011, when measurements were available from all four gauges.

As seen in the top plot of **Figure 4-2**, the gauges can be broadly characterized into two distinct regions. Those along the central and northern Oregon coast (SB and GB) indicate a slightly higher incidence of water levels between ~1.25 m and 2.25 m (4.1–7.4 ft, i.e., MSL [mean sea level] to MHW). In contrast, the AST and TP gauges, located in the Columbia River and in southern Washington, indicate a lower incidence of water levels in that same range. These differences are probably related to a combination of effects associated with the regional oceanography (upwelling, shelf currents, and Coriolis effects that deflect the currents toward the coast) and effects from the Columbia River plume (Legaard and Thomas, 2006). The lower plot in **Figure 4-2** shows the same PDF, but now clipped to span tidal elevations between 2 and 4 m (6.5–13 ft). In this latter plot, the higher water levels characteristic of TP clearly stand out. In terms of determining ultimately which tide gauge to use as a basis for the still water level time series, these initial results suggest strongly that we can effectively rule out Toke Point as a candidate site as it consistently yields much higher water levels and surges (described later), which are probably a function of its location at the mouth of a broad inlet and the potential for additional wind setup along the length of the bay. At the high water level end of the plot, differences between the three remaining gauges are relatively minor.

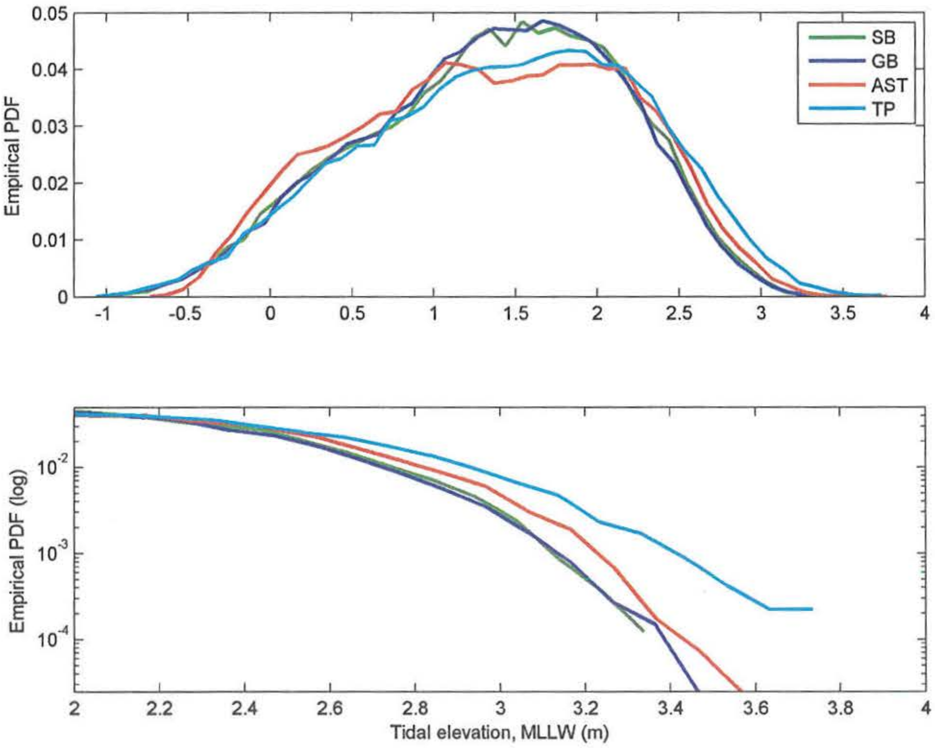


**Figure 4-2.** **Empirical probability density function (PDF) plots for various tide gauges for overlapping years of data (2006 – 2011). Top) PDF plots showing the complete range of tidal elevations, Bottom) truncated to higher water levels.**

**Figure 4-3** is broadly similar to **Figure 4-2**, with the exception that the PDFs now include the complete time series of data measured by the respective tide gauges. In general, the AST gauge is characterized by a higher incidence of water levels between about -0.18 and 1.0 m (-0.6–3.3 ft), and again between 2.1 and 3.5 m (6.9–11.5 ft). This contrasts with the SB and GB gauges, which show a higher incidence of water levels between ~1.0 and 2.0 m (3.3–6.6 ft). As noted previously, these differences are probably caused by regional oceanographic factors. Detailed examination of the hourly tides indicates that the higher incidence of AST water levels in the wings of the PDF reflect the fact that both the higher highs (HH) and lower highs (LH) are greatest at AST when compared with SB and GB, while the lower lows (LL) and higher lows (HL) are generally lower at AST compared with SB and GB.

At the extreme high end of the complete PDF plots (**Figure 4-3**), the highest water levels measured at AST, GB, and SB are, respectively, 3.76, 3.62, and 3.71 m (12.3, 11.9, and 12.2 ft). These results equate to a difference of 0.05 m (0.16 ft) between AST and SB and 0.14 m (0.46 ft) between AST and GB, while indicating the absence of any real latitudinal trend with the extreme water levels. Furthermore, differences between these values and those reported by NOS for the respective stations differ by no more than 2 cm. The larger difference between the GB and AST gauges when compared with the SB gauge is entirely due to the shortness of the Garibaldi measurement record (~6 years). Overall, the relative consistency in the PDF plots generated for each gauge, particularly at the more extreme end of the measured water levels, is indicative of the areal impact of major North Pacific extratropical storms, which can affect stretches of coast up to 1,500 km (932 mi, i.e., 3 times the length of the Oregon coast) in length (Davis and Dolan, 1993; Allan and Komar, 2002).

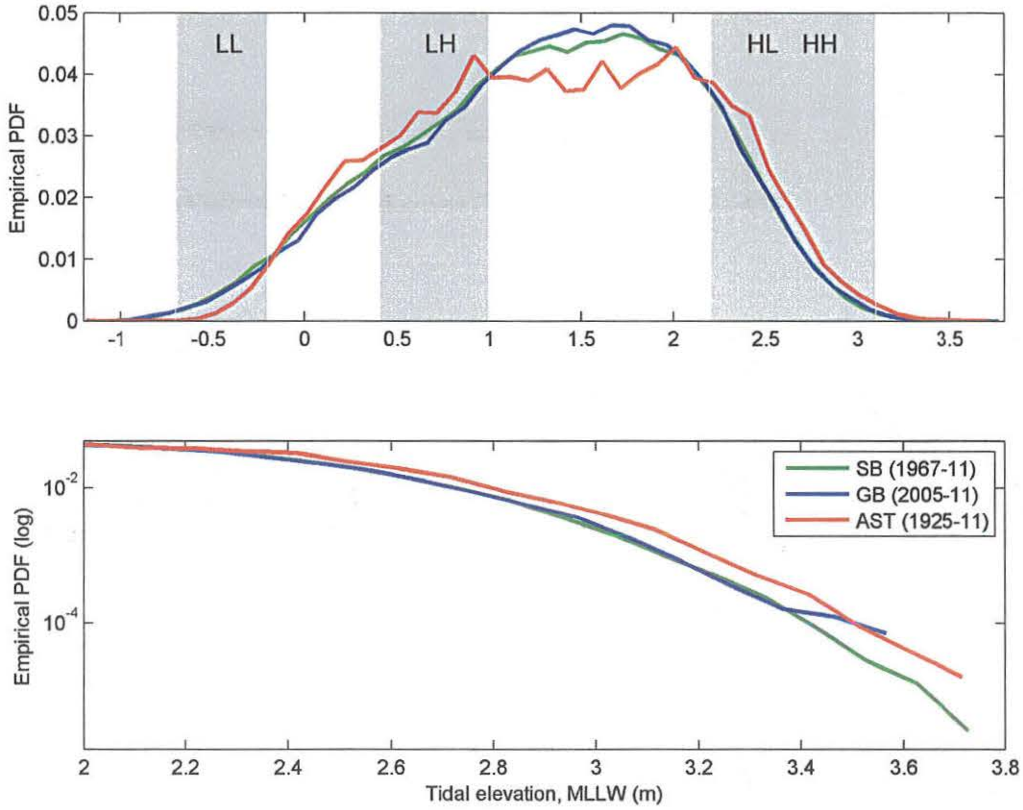


**Figure 4-3.** Empirical probability density functions (PDFs) for SB, GB, and AST based on all available data. Top) PDF plot showing the complete range of tidal elevations. LL, LH, HL, and HH denote, respectively, the lower lows, lower highs, higher lows, and higher highs in the tide data. Bottom) PDF truncated to higher water levels.

## 4.2 Seasonal Changes

**Figure 4-4** presents a plot of the characteristic seasonal cycles determined for the three gauges, AST, GB, and SB, to further examine their consistencies. All three gauges depict the typical seasonal cycle that reflects the combination of ocean upwelling effects along the coast, and seasonal reversals in the California current system. The Astoria gauge has been divided into two time periods that reflect conditions prior to Columbia River dam control (~mid 1960s, dotted line), and post dam conditions (solid black line). The reason for the latter is that the AST gauge exhibits seasonal characteristics that are not apparent in the other coastal tide gauges (including TP), which are entirely a function of Columbia River discharge flows (Sherwood and others, 1990; Burgette and others, 2009).

Prior to dam and irrigation control on the Columbia River, the seasonal cycle at the AST tide gauge was characterized by generally higher monthly mean sea levels from May through June (**Figure 4-4**), decreasing to a minimum between August and September. Between September and February, ocean water levels increase, reaching peaks in December and February. The high mean monthly sea levels observed between May and July are entirely due to the occurrence of spring freshets (i.e., high discharge flows due to spring snow melt [Sherwood and others, 1990]).

Following dam control, the incidence of high mean sea levels during spring at the AST tide gauge was clearly reduced (**Figure 4-4**), while the timing of these events remained essentially unchanged, although the period of higher spring mean sea levels was shortened slightly by about 1 month. In contrast, the seasonal pattern between October and March is essentially the same for AST as it is for SB and GB, with all three sites experiencing peak water levels in January, while the broad shape of the curve is effectively the same. As noted by Sherwood and others (1999), with the introduction of river control on the Columbia River in the mid 1960s for the purposes of flood control and for irrigation use, the incidence of spring freshets were reduced by up to 40% compared with the natural regime. This change is captured in **Figure 4-4** by the marked drop in monthly mean sea levels observed from May to July. Interestingly, under conditions today there is essentially little difference in the seasonal water levels between the three gauges during the critical winter period (October to March) when storms are affecting this northern part of the Oregon coast.

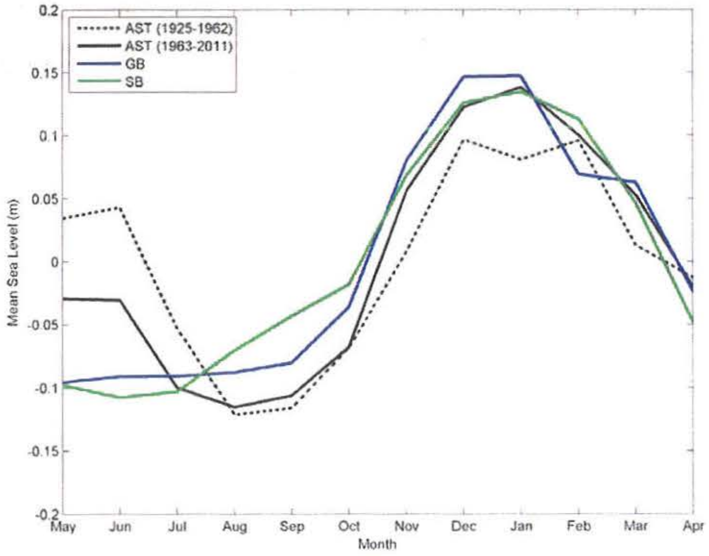


Figure 4-4. **Seasonal plot of tides along the central to northern Oregon coast.**

Finally, although not shown in **Figure 4-4**, all the tide gauges are strongly influenced by the El Niño Southern Oscillation phenomenon, which periodically causes mean sea levels along the U.S. West Coast to increase (Komar and others, 2011). This response is due to an intensification of the processes, especially enhanced ocean sea surface temperatures offshore from the Oregon coast. This occurred particularly during the unusually strong 1982-83 and 1997-98 El Niños, whereby mean sea levels increased by approximately 20–25 cm (~0.8 ft) above the normal seasonal cycle in mean sea level depicted in **Figure 4-4** (i.e., for a total mean sea level rise of up to 50 cm (1.6 ft) relative to the preceding summer). As a result, under these latter conditions, wave swash processes are able to reach much higher elevations on the beach, potentially eroding dunes and bluffs.

## 4.3 Oregon Storm Surges

The actual level of the measured tide can be considerably higher than the predicted tides provided in standard tide tables and is a function of a variety of atmospheric and oceanographic forces, which ultimately combine to raise the mean elevation of the sea. These latter processes vary over a wide range of time scales and may have quite different effects on the coastal environment. For example, strong onshore winds coupled with the extremely low atmospheric pressures associated with a major storm can cause the water surface to be locally raised along the shore as a storm surge, and such surges have been found in tide-gauge measurements to be as much as 1.5 m (4.9 ft) along the Pacific Northwest coast (Allan and Komar, 2002). However, during the summer months these processes can be essentially ignored due to the absence of major storm systems.

Analyses have been undertaken to examine the non-tidal residuals and ultimately the storm surges identified at the various tide gauges on the northern Oregon coast. The objective is to provide a better understanding of the spatial and temporal variabilities of storms as they track across the North Pacific, the magnitudes (and frequency) of the surges, and the potential differences in the non-tidal residuals between gauges due to variations in the storm tracks, barometric pressures, and winds. This last point is particularly important in terms of finalizing the tide gauge time series to be used in the Tillamook total water level analyses.

For the PNW, the measured water level ($h_t$) at a particular tide gauge is given by the following relationship:

$$h_t(t) = z_o + X_{at}(t) + X_{oc}(t) + S(t) \qquad \text{(Eq. 4-1)}$$

where $z_o$ is the mean water level, $X_{at}$ is the predicted astronomical tide, $X_{oc}$ is the altered mean water level due to ocean processes (water temperatures, currents and El Niño "sea-level" waves), and $S$ is the contribution by the storm surge at time $t$. The predicted astronomical tide for the specific tide gauge is calculated using its harmonic constituents:

$$X_{at} = \sum_{i=1}^{M} H_i \cos(\sigma_i t + \varphi_i) \qquad \text{(Eq. 4-2)}$$

where $H_i$ is the amplitude of the constituent $i$, $\sigma_i$ is its frequency, $\varphi_i$ is the phase of the constituent, and $M$ is the number of tidal constituents included in the analysis.

## 4.4 Non-Tidal Residual Analyses

The procedures used to analyze the non-tidal residuals and storm surge incidence follow those developed by Allan and others (2011), which used an harmonic analysis method of least squares (HAMELS) approach developed in MATLAB to estimate the amplitude and phase for any set of tidal constituents at each of the tide gauge sites (Boon, 2004). The purpose here is to develop a predicted time series of the water levels produced entirely by astronomic forces that excludes the seasonal component produced by oceanographic processes on the West Coast; the seasonal component can be integrated into tide predictions through the solar annual (Sa) and solar semiannual (Ssa) tide and is integrated as an *average term* in the predicted tides provided by NOS.

HAMELS analyses of tide gauge data have previously been completed for the SB and TP tide gauges (Allan and others, 2011). Thus, similar analyses were undertaken using the AST and GB tide gauges. The specific steps included the following:

1. HAMELS was used to derive an estimate of the amplitude and phase for the tidal constituents. This was initially done using just a spring/summer data set for testing purposes and then expanded to the full year of data;
2. After the tidal constituents were determined, HAMELS was used to derive the astronomic tide predictions for the entire record on a year-by-year basis (eliminating any long-term trend). The non-tidal residuals (NTRs) were calculated by subtracting the astronomic tide from the measured tides;
3. The NTR time series were then filtered using a moving average filter (averaged over ±30 days) with zero phase shift, and the seasonal cycle was removed from the NTRs;
4. The winter standard deviation was calculated, and those events exceeding $2*\sigma$ were used to define individual surge events (Zhang and others, 2001).

**Figure 4-5** presents a plot of the derived NTRs for the South Beach (SB), Garibaldi (GB), and Astoria (AST) tide gauges. These data reflect the corresponding NTRs associated with the higher highs and higher lows of the diurnal tidal cycle, which were determined using a peak detection algorithm in MATLAB. Analyses here span the period of record for the respective tide gauges. Correlation ($R^2$) values calculated for the three plots are 0.91, 0.69, and 0.79, respectively, with the strongest correlation found between the SB and GB tide gauges on the open coast, while the weakest correlation was between the SB and the AST tide gauges.

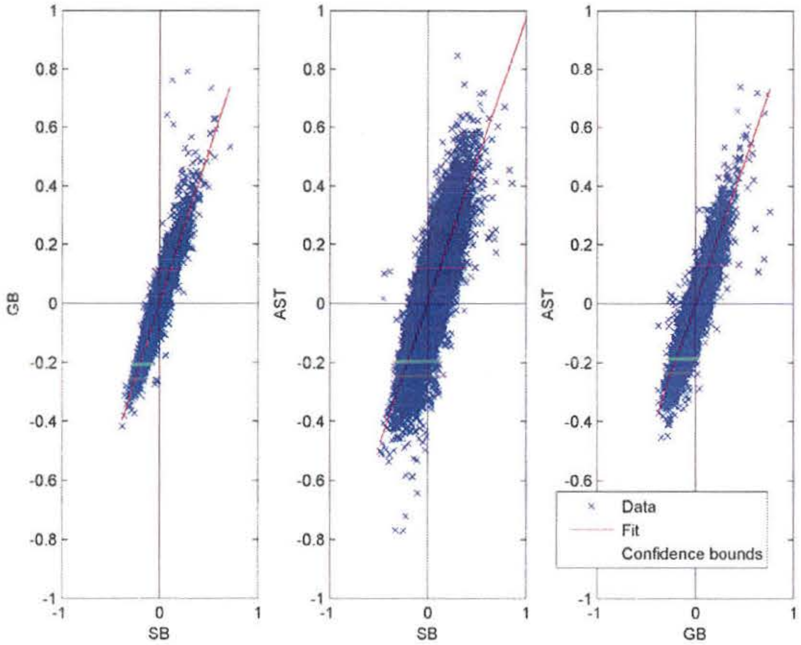


**Figure 4-5. Comparison of non-tidal residuals determined for South Beach (SB) versus Garibaldi (GB), SB versus Astoria (AST), and GB versus AST tide gauges. Values plotted here reflect the daily peak values.**

**Figure 4-6** presents the actual time series of de-seasoned NTRs derived for the SB, GB, and AST tide gauges for the 2005-06 winter. In this example, the NTRs have been time adjusted to a single station. As can be seen in this example, the SB and GB tide gauges tend to track very closely to each other, consistently capturing the same peaks and troughs. In contrast, the AST gauge shows larger fluctuations, when compared to the other tide gauges. These differences are further highlighted in the anomaly plot (**Figure 4-6** bottom), which indicates more subtle differences between SB and GB tide gauges, with both gauges characterized by anomalies that reach as much as 0.2 m (0.65 ft). In contrast, anomalies between the GB and AST tide gauges reveal much larger differences. While differences here to a large degree reflect differences in the position of the storms relative to the tide-gauges, the storm's barometric pressures, winds, and the associated wave forcing along the coast, the fluctuations shown for the AST gauge suggest that other factors (e.g., Columbia River discharge) may be exerting a strong influence on the observed patterns between GB and AST. Overall, differences between the SB and GB tide gauges probably reflect mostly subtle shifts in the timing of the events as they impact the coast, reinforcing our confidence that the effects of North Pacific extratropical storms are indeed widespread, affecting large tracts of the coast at similar times.

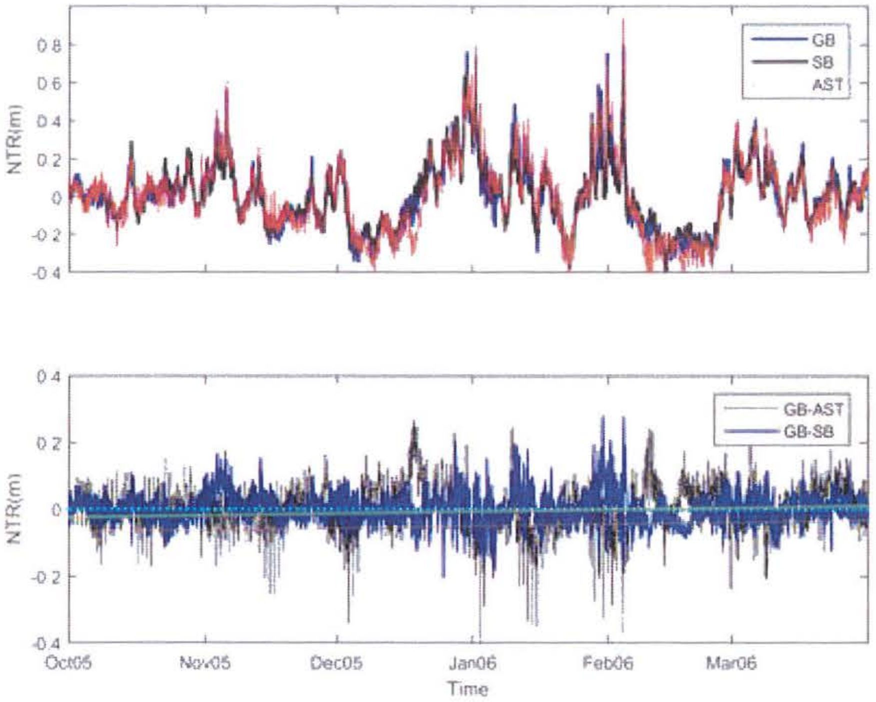


**Figure 4-6.** **Comparison of non-tidal residuals (NTRs, top), and their differences (bottom) between the South Beach (SB), Garibaldi (GB), and Astoria (AST) tide gauges for the 2005-06 winter.**

After NTRs for each of the tide gauges had been identified, individual storm surge events were identified following the procedures of Zhang and others (2001) and Allan and others (2011). **Figure 4-7** (left) presents a log number plot of all surge events for SB, GB, and AST gauges; here we include similar analyses performed on the TP tide gauge. The plot indicates that for the most part the four gauges are showing relatively similar patterns in terms of the storm surge magnitudes. In general, the mean storm surges increase northward (0.45 m [1.5 ft] at SB to 0.66 m [2.2 ft] at TP), while the highest surges have occurred at TP (1.62 m [5.3 ft]) and SB (1.42 m [4.7 ft]); despite its significantly longer record, the highest surge observed at AST reached 1.1 m (3.6 ft). **Figure 4-7** (right) presents the empirical cumulative distribution function (CDF) calculated for the four gauges, further highlighting the progressive shift in the surge magnitudes to the north. Again, the TP gauge stands out as an exception, further confirming why this site should be excluded as the time series of water levels for the Tillamook coast.

Taken together, these analyses confirm that the two open coast tide gauges located at South Beach in Newport on the central Oregon coast and at Garibaldi in Tillamook Bay provide, overall, the best measure of the open-coast still water levels, important in FEMA total water level and overtopping analyses. The main distinction between these two stations is the length of available measurements, with the Newport site having the longest record (~45 years) and Garibaldi having the shortest. Furthermore, from our analyses, we believe that the measured tides at Astoria (located 23 km upriver from the coast) are so significantly influenced by Columbia River flows that this gauge should not be used in FEMA flood analyses for the Tillamook County open coast.

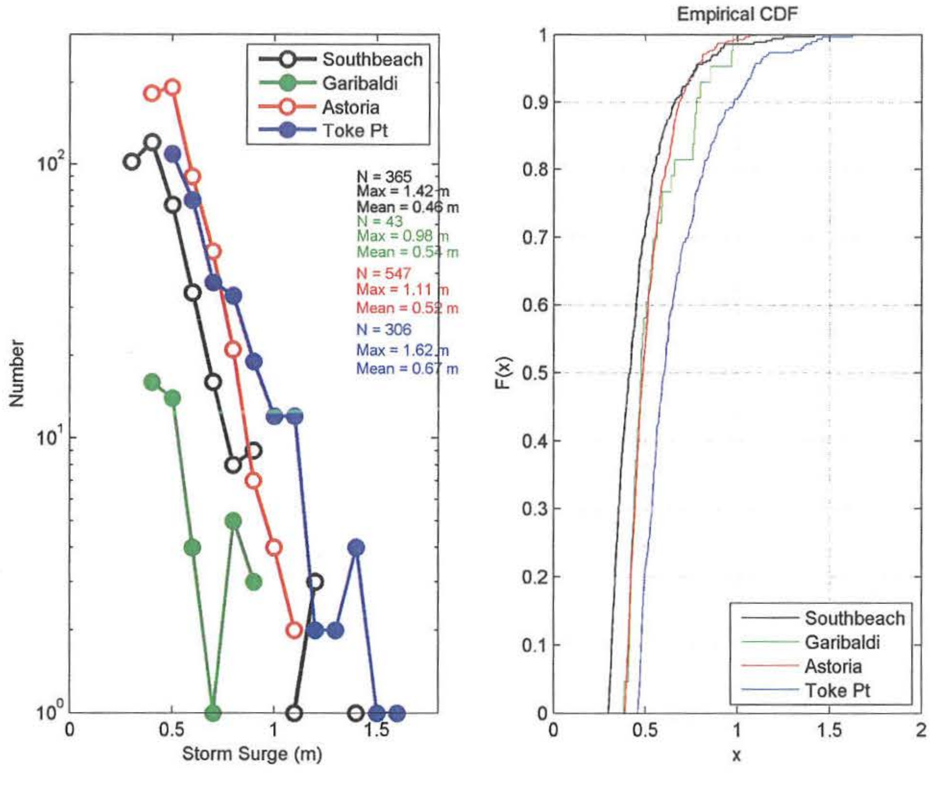


**Figure 4-7.** **(Left) Histogram of surge magnitudes determined for selected tide gauge stations. (Right) Cumulative distribution plot of storms surge magnitudes.**

## 4.5 Tillamook County Tides

For the purposes of this study, we have based our *still water level* (SWL) and *wave runup* calculations on a combined time series (1967–2011) that encompasses tides measured at the South Beach gauge (#9435380) in Yaquina Bay (1967–2005) and from the Garibaldi tide gauge (#9437540) in Tillamook Bay (2005–present). **Figure 4-8** shows the tidal elevation statistics derived from the South Beach tide gauge (the longest temporal record), with a mean range of 1.91 m (6.3 ft) and a diurnal range of 2.54 m (8.3 ft). The highest tide measured from this record reached 3.73 m (12.2 ft), recorded in December 1969 during a major storm. These values are comparable to those measured at the Garibaldi site (mean = 1.9 m, diurnal = 2.53 m), with the only real difference that this latter gauge recorded a peak water level of 3.64 m (11.9 ft) in December 2005 due to its shorter record.

As noted previously, tides on the Oregon coast tend to be enhanced during the winter months due to warmer water temperatures and the presence of northward flowing ocean currents that raise water levels along the shore. These enhanced tides persist throughout the winter rather than lasting for only a couple of days as is the case for a storm surge. This effect can be seen in the monthly averaged water levels derived from the combined time series (**Figure 4-9**), but where the averaging process has removed the water-level variations of the tides, yielding a mean water level for the entire month. Based on 45 years of data, the results in **Figure 4-9** show that on average monthly-mean water levels during the winter are nearly 25 cm (0.8 ft) higher than in the summer. Water levels are most extreme during El Niño events, due to an intensification of the processes, largely enhanced ocean sea surface temperatures offshore from the Oregon coast. This occurred particularly during the unusually strong 1982-83 and 1997-98 El Niños. As seen in **Figure 4-9**, water levels during those climate events were approximately 25–30 cm (0.8–1 ft) higher than the seasonal peak, and as much as 56 cm (1.8 ft) higher than during the preceding summer, enabling wave swash processes to reach much higher elevations on the beach during the winter months, with storm surges potentially raising the water levels even more.

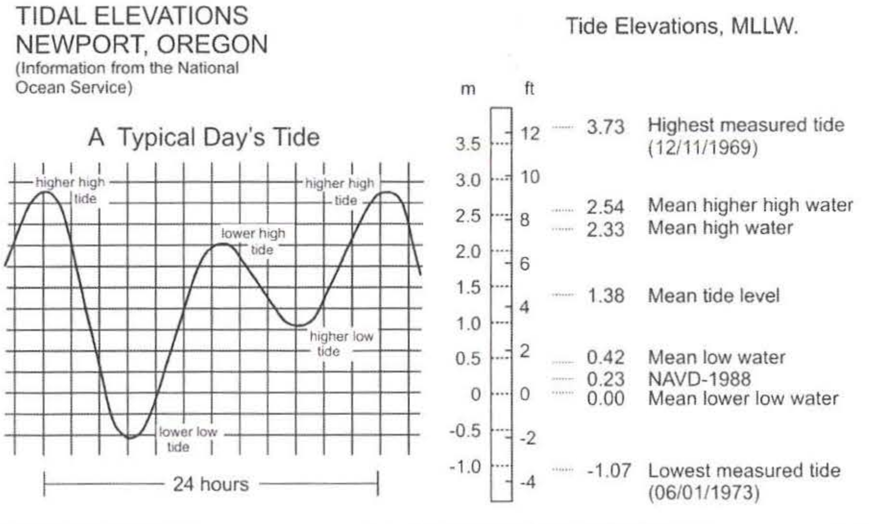


**Figure 4-8. Daily tidal elevations measured at South Beach, Newport on the central Oregon coast. Data from the NOS (http://www.co-ops.nos.noaa.gov/waterlevels.html?id=9435380). MLLW is mean lower low water.**

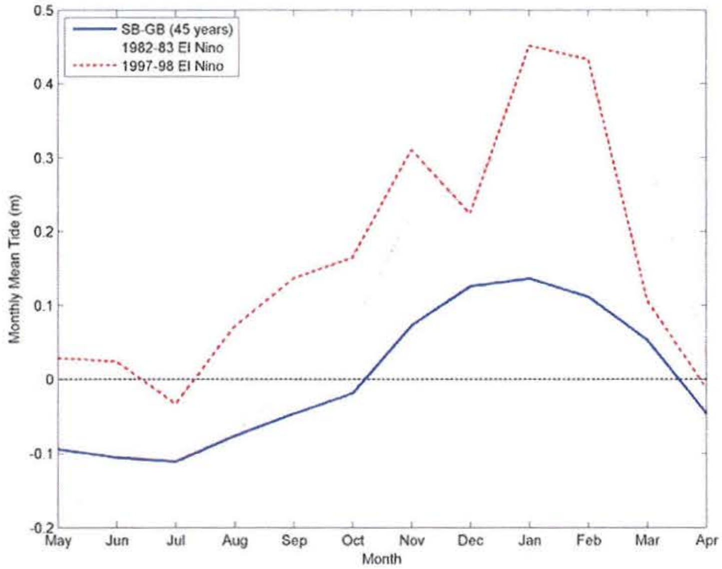


**Figure 4-9. Seasonal cycles in monthly-mean water levels based on data from the combined South Beach-Garibaldi (SB-GB) measured tides.**

Aside from seasonal to interannual effects of climate events on ocean water levels, of interest are long-term trends associated with relative sea level changes due to climate change along the Tillamook County coastline. **Figure 4-10** shows results from an analysis of the combined SB-GB time series based on a separate analysis of the summer and winter tide levels. For our purposes, "winter" is defined as the combined average tide level measured over a three-month period around the peak of the seasonal maximum in winter water levels, typically the months of December through February. Similarly, "summer" water levels reflect the combined average tide level measured over a three-month period around the seasonal minimum, typically the months of May through July when water levels also tend to be less variable (Komar and others, 2011).

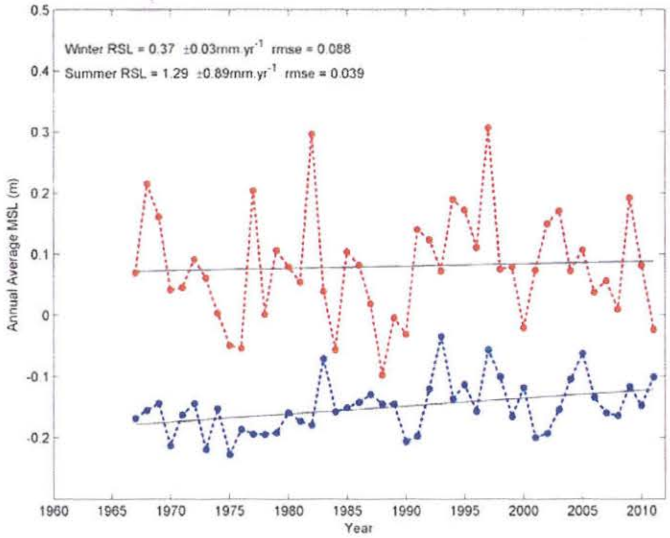


**Figure 4-10. Trends of "winter" (red) and "summer" (blue) mean sea levels measured by the SB-GB tide gauges. Results for the summer regression are statistically significant, while the estimated winter rate is not significant at the 95% confidence level.**

As observed previously in **Figure 4-9**, the winter tidal elevations are systematically displaced upward by about 25 cm (0.8 ft) above the summer elevations, with the difference between the regression lines reflecting the seasonal change in ocean water levels from summer to winter. **Figure 4-10** also emphasizes the extremes associated with major El Niños; the peaks between the 1983 and 1997 major events have systematically shifted upward over the years due to relative sea level changes along this particular section of the coast. In contrast, the summer regression line is characterized by significantly less scatter in the residuals, as it effectively excludes the influence of storms and El Niños that are dominant during the winter. Using this approach, it can be seen that the central Oregon coast is slowly being transgressed at a rate of ~1.29 ± 0.89 mm/yr, which is slightly lower than that reported by NOS (~2.18 ± 0.85 mm/yr). This difference is due to the SB tide gauge having been affected by localized subsidence, particularly in the late 1960s and early 1970s, that continued to decrease over time up until the mid 1990s (Burgette and others, 2009). Since then, repeat surveys of NGS benchmark indicate that the land now appears to be stable.

Finally, it is important to appreciate that the trends shown in **Figure 4-10** reflect relative sea level changes due to the PNW coast of Oregon and Washington being locally influenced by changes in the elevation of the land due to regional tectonics as well as by the global rise in sea level, with the net change important to both coastal erosion and flood hazards. **Figure 4-11** presents a synthesis of both tectonic land elevation changes and sea level trends derived for multiple stations along the PNW coast (Komar and others, 2011), correlated against differential surveys of first-order NGS benchmarks (e.g., Burgette and others, 2009) and GPS CORS stations. Results here indicate that, in general, the southern Oregon coast is an emergent coast with tectonic uplift of the land outpacing sea level rise. In contrast, the central to northern Oregon coast (i.e., Tillamook County) is slowly being transgressed by sea level.

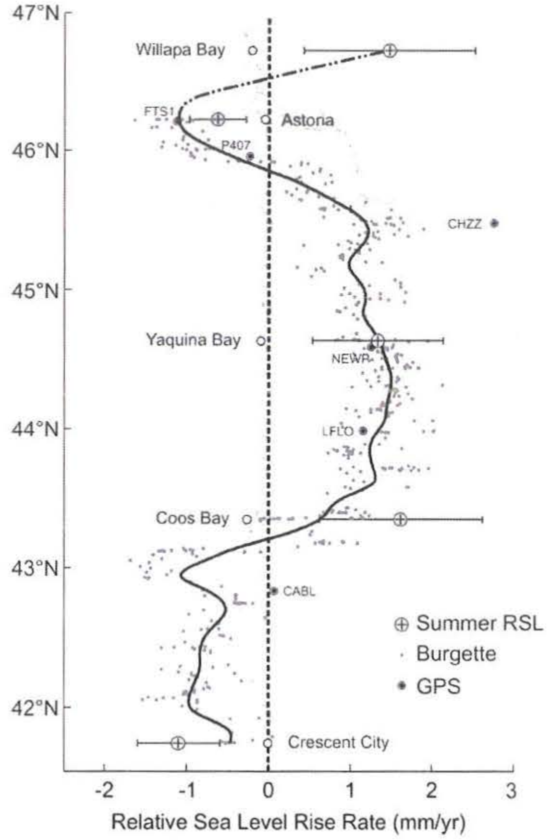


**Figure 4-11. Assessments of changes in relative sea level (RSL) based on tide-gauge records compared with NGS benchmark (Burgette) and GPS measurements of land-elevation changes, with their corresponding RSL rates obtained by adding the 2.28 mm/yr PNW eustatic rise in sea level.**

## 4.6 Still Water Level (SWL)

The still water level (SWL) is the sum of the predicted astronomical tide listed in Tide Tables plus the effects of processes such as an El Niño or storm surge that can elevate the measured tide above the predicted tide (Northwest Hydraulic Consultants, 2005). Of importance to erosion and flooding hazards are the extremes of the measured tides. In conventional analyses of extreme values, the general assumption is that the data being analyzed (e.g., the annual maxima) represent independent and identically distributed (stationary) sequences of random variables. The generalized extreme value (GEV) family of distributions is the cornerstone of extreme value theory, in which the cumulative distribution function is given as:

$$G(z, \mu, \sigma, \xi) = \exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-1/\xi}\right\} \qquad \text{(Eq. 4.3)}$$

defined on $\left\{z: 1+\frac{\xi(z-\mu)}{\sigma} > 0\right\}$,

where the parameters satisfy $-\infty < \mu < \infty$, $\sigma > 0$, $-\infty < \xi < \infty$ (Coles, 2001). The model has three parameters; $\mu$ is a location parameter, $\sigma$ is a scale parameter, and $\xi$ is a shape parameter. The EV-II (Frechet) and EV-III (Weibull) classes of extreme value distributions correspond, respectively, to the cases of $\xi > 0$ and $\xi < 0$. When $\xi = 0$, equation 4.3 collapses to the Gumbel or EV-I type extreme value distribution. By inferring the shape parameter $\xi$ (estimated here, along with the other parameters, by maximizing the log-likelihood function), the data themselves determine the most appropriate type of tail behavior and it is not necessary to make an a priori assumption about which individual extreme family to adopt, as in a classical Weibull-type extreme wave height analysis (Coles, 2001).

The GEV is often applied to annual maxima data in an approach referred to as the annual maximum method (AMM). However, one of the primary shortcomings of fitting an extreme-value distribution with annual maximum data is that useful information about the extremes is inherently discarded, particularly when data are sampled on either a daily or hourly basis (as in the case of the measured tides and deep-water significant wave heights measured by Oregon tide gauges and NDBC wave buoys). Two well-known approaches exist for characterizing extremes by using data other than simply annual (block) maxima. The first is based on the behavior of the r largest-order statistics within a block, for low r, and the second is based on exceedances above a high threshold value. For the purposes of this study, we use the peak-over-threshold (POT) approach for determining extreme SWL and wave heights.

In the peak-over-threshold (POT) method, a high threshold, $u$, is chosen in which the statistical properties of all exceedances over $u$ and the amounts by which the threshold is exceeded are analyzed. It is assumed that the number of exceedances in a given year follows a Poisson distribution with annual mean $\nu T$, where $\nu$ is the event rate and $T = 1$ year, and that the threshold excesses $y > 0$ are modeled using the Generalized Pareto Distribution (GPD) given by:

$$H(y, \sigma, \xi) = 1\text{-}\left(1+\frac{\xi y}{\sigma}\right)^{-1/\xi} \qquad \text{(Eq. 4-4)}$$

where $\xi$ is the shape parameter of the GEV distribution and $\sigma$ is a scale parameter related to GEV parameters by $\sigma = \sigma + \xi(u-\mu)$. The event rate can also be expressed in a form compatible with the GEV distribution provided that

$$\nu = \left(1+\frac{\xi(u-\mu)}{\sigma}\right)^{-1/\xi}$$

Estimates of extreme quantiles of the distributions are obtained by inverting the distributions in equation 4.4. For GPD-Poisson analyses the N-year return level, $y_N$, is given as:

$$y_N = \mu + \frac{\sigma}{\xi}\left[(N n_y \zeta_u)^{\xi} - 1\right] \qquad \text{(Eq. 4-5)}$$

where $n_y$ is the number of observations per year and $\zeta_u$ is the probability of an individual observation exceeding the threshold $u$.

**Figure 4-12** presents results of the GEV analyses for the combined SB-GB measured tides. In constructing this plot, we used a threshold of 3.06 m (10 ft). Included in the figure are the calculated 1- through 500-year SWLs. As can be seen in **Figure 4-12**, the 1% SWL calculated for the combined time series is 3.71 m (12.2 ft, relative to MLLW). When adjusted to the NAVD88 vertical datum, this value becomes 3.60 m (11.8 ft, NAVD88); note the adjustment from NAVD88 to MLLW is calculated to be 0.108 m (0.35 ft) at the GB site. The NAVD88 to MLLW adjustment at the GB site was calculated using the VDATUM tool developed by NOAA (http://vdatum.noaa.gov/). The 500-year SWL is estimated to be 3.68 m (12.1 ft) relative to the NAVD88 vertical datum. As observed previously, the highest tide measured in the combined time series reached 3.62 m (11.9 ft, relative to NAVD88).

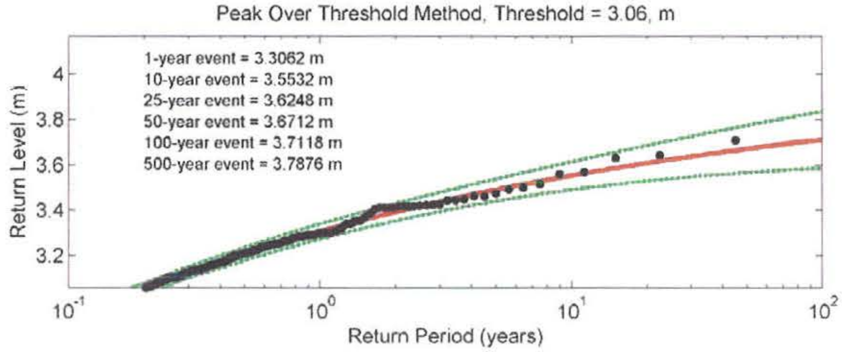


**Figure 4-12. Extreme-value analyses of the still water level (SWL) determined for the combined South Beach-Garibaldi tide gauge time series. These data are relative to the MLLW vertical datum. Black dots reflect the discrete peak tidal events and the red line is the extreme value distribution fit to those data. Green dashed line reflects the 95% confidence boundary.**

## 5.0 PACIFIC NORTHWEST WAVE CLIMATE

The wave climate offshore from the Oregon coast is one of the most extreme in the world, with winter storm waves regularly reaching heights in excess of several meters. This is because the storm systems emanating from the North Pacific travel over fetches that are typically a few thousand miles in length and are also characterized by strong winds, the two main factors that account for the development of large wave heights and long wave periods (Tillotson and Komar, 1997). These storm systems originate near Japan or off the Kamchatka Peninsula in Russia and typically travel in a southeasterly direction across the North Pacific toward the Gulf of Alaska, eventually crossing the coasts of Oregon and Washington or along the shores of British Columbia in Canada (Allan and Komar, 2002).

Wave statistics (heights and periods and, more recently, wave direction) have been measured in the Eastern North Pacific using wave buoys and sensor arrays since the mid 1970s. These data have been collected by the National Data Buoy Center (NDBC) of NOAA and by the Coastal Data Information Program (CDIP) of Scripps Institution of Oceanography (**Figure 4-1**). The buoys cover the region between the Gulf of Alaska and Southern California and are located in both deep and intermediate to shallow water over the continental shelf. The NDBC operates some 30 stations along the West Coast of North America, while CDIP has at various times carried out wave measurements at 80 stations. Presently, there are two CDIP buoys operating offshore from the mouth of the Columbia River (#46243 and #46248) and three NDBC buoys (Washington [#46005], Tillamook [#46089], and Columbia River Bar [#46029]); Note buoy #46005 is located ~540 km (335 mi) directly west of the Columbia River mouth. Wave measurements by NDBC are obtained hourly (CDIP provides measurements every 30 minutes), and are transmitted via satellite to the laboratory for analysis of the wave energy spectra, significant wave heights and peak spectral wave periods. These data can be obtained directly from the NDBC through their website[1].

An alternate source of wave data appropriate for FEMA flood modeling is hindcast wave data such as the Global Reanalysis of Ocean Waves Fine Northeast Pacific Hindcast (GROW-FINE NEPAC), purchased through Oceanweather, Inc., and Wave Information Studies (WIS)[2] hindcasts developed by the USACE (Baird, 2005). GROW is a global wave model, while GROW Fine Northeast Pacific extends the original model by incorporating a higher-resolution analysis (4 times as many data nodes), basin-specific wind adjustments based on QUIKSCAT scatterometry, enhancements due to Southern Ocean swells, and inclusion of shallow water physics (Oceanweather, Inc., 2010). These data can ultimately be applied to offshore structure design, tow-analysis, operability, and other applications where wind and wave data are required. Standard products from GROW include time series of wind and wave parameters (including sea/swell partitions), extreme criteria, operability statistics, and wave spectra (Oceanweather, Inc., 2010). The advantage of GROW as opposed to measured data is that it provides a continuous time series of wave and wind data suitable for FEMA flood modeling. In contrast, measured data obtained from wave buoys may be characterized by significant data gaps due to the instruments having come off their mooring or from instrument failure. The main disadvantage of GROW Fine Northeast Pacific data is that it is modeled basin-scale wind models and data, and the data time series is 3 hourly as opposed to hourly as provided by the buoys. For the purposes of this study, we have explored both data sets in order to define the most appropriate time series of wave data. To that end, GROW Fine Northeast Pacific data were purchased for three nodes offshore the Oregon coast. **Figure 4-1** identifies the locations of two of the GROW sites, station #18023 located offshore from southern Clatsop / northern Tillamook County and #17663 offshore from Lincoln County. Besides the hourly measured wave buoy data, we also obtained wave hindcast information on the deepwater wave climate determined through comparisons with the WIS station located adjacent to NDBC buoy 46005.

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[1] http://www.ndbc.noaa.gov/maps/Northwest.shtml

[2] http://wis.usace.army.mil/wis.shtml

Analyses of the wave climate offshore from Tillamook County were undertaken by DOGAMI staff, and as a subcontract to Dr. Peter Ruggiero, College of Earth, Ocean, and Atmospheric Sciences (CEOAS), OSU, and included numerical analyses of the 1% or 100-year extreme total water levels, which reflect the calculated wave runup superimposed on the tidal level (i.e., the still water level [SWL]) to help determine the degree of coastal flood risk along the coast of Tillamook County.

OSU performed a series of tests and analyses including wave transformations, empirical wave runup modeling, and total water level modeling. For the purposes of this study, OSU used the SWAN (Simulating Waves Nearshore) wave model to transform deepwater waves to the nearshore (typically the 20 m [65.6 ft] contour). The transformed waves were then linearly shoaled back into deep water to derive a *refracted deepwater equivalent wave parameterization* (wave height and peak period) that can be used to calculate runup levels, which combined with tides, are used to estimate the flood risk along the county's shoreline.

In our Coos County FEMA study (Allan and others, 2012b), the approach we developed involved several stages:

1. We first defined a time series of deepwater wave heights and periods for a particular location offshore of the shelf break, which we used to calculate an initial wave runup and total water level time series based on two representative beach slopes characteristic of beaches in the Coos County detailed study areas.
2. Using the above approach we defined ~135 discrete storm events for the two different slope types. We transformed the deepwater wave statistics associated with these events into the nearshore (20-m water depth) to account for wave refraction and shoaling effects. Depth-limited breaking, wind growth, quadruplets, and triad interactions were all turned off in the SWAN runs. The derived nearshore wave statistics were then converted back to their adjusted deepwater equivalent wave heights in order to perform the wave runup analyses and ultimately compute the 1% total water levels.

The main limitations associated with this approach were:

1. Only a very limited number of model runs were performed, ~135 per representative beach slope.
2. Because we used only two representative beach slopes, we may have missed a particular wave condition (wave height [$H_s$], period [$T_P$], direction [$D_d$]) and beach slope (tan $\beta$) combination that resulted in a higher total water level (TWL) at the shoreline.
3. The structural function approach used to generate the initial extreme TWLs and therefore to pick the offshore wave conditions input in SWAN is fundamentally limited. Nature gave us only one combination of waves and water levels during the 30 years we used to generate input conditions, which is not necessarily a statistically robust sample.

For the purposes of the Tillamook County study, including other detailed FEMA coastal studies underway for Oregon, we have adopted a more refined approach that reflects the following enhancements.

1. Rather than steps 1 and 2 as described for our Coos County study, modeling will be carried out based on analyses of the full range of wave and tide combinations observed over the historical period. This approach will ultimately provide a more robust measure of the 1% (and other desired return periods) total water levels.
2. We have developed a lookup table approach for analyzing thousands of possible storm combinations rather than only a few hundred as performed in Coos County. The general idea is that a "lookup table" can be developed by transforming all combinations of wave quadruplets ($H_S$, $T_P$, $D_d$, and water levels). We used SWAN to compute the transformed wave characteristics of these waves up to wave breaking.
3. Our approach still suffers from the third limitation listed above for the Coos County study.

The area over which the SWAN grid was set up is shown in **Figure 5-1**. In general, our analyses proceeded in the following order:

1. Develop a long time series of both measured (NDBC) and modeled (WIS) wave conditions (~30 years long) at approximately the shelf edge offshore of the study area;
2. Run the SWAN model with a full range of input conditions, using constant offshore boundary conditions, to compute bathymetric induced wave transformations up to wave breaking.
3. Develop "lookup tables" from the suite of SWAN simulations.
4. Transform the long time series through the "lookup tables" such that we generate alongshore varying long time series at approximately the 20-m depth contour throughout the study area.
5. Use the deepwater equivalent alongshore varying wave conditions and the appropriate measured tides from the combined Yaquina Bay-Garibaldi time series, to compute time series of TWLs for 178 beach profiles along the Tillamook County coast. These include transects established on Nehalem Spit-Manzanita (21 sites), Twin Rocks-Rockaway-Nedonna Beach (40 sites), Bayocean Spit (11 sites), Short Sand Beach (3 sites), Netarts Spit-Oceanside (29 sites), Tierra Del Mar – Sand Lake (32 sites), Nestucca spit – Pacific City (14 sites), and Neskowin (28 sites).
6. Using a Poisson-generalized Pareto distribution, compute the 1-, 10-, 25-, 50-, 100-, and 500-year TWL elevations using a peak-over-threshold (POT) approach.
7. Compare extreme TWLs with topographic elevations of various beach backing features to determine the potential extent of coastal flooding during extreme events.

The following sections describe in more detail the various procedures used in each of the aforementioned steps in this analysis.

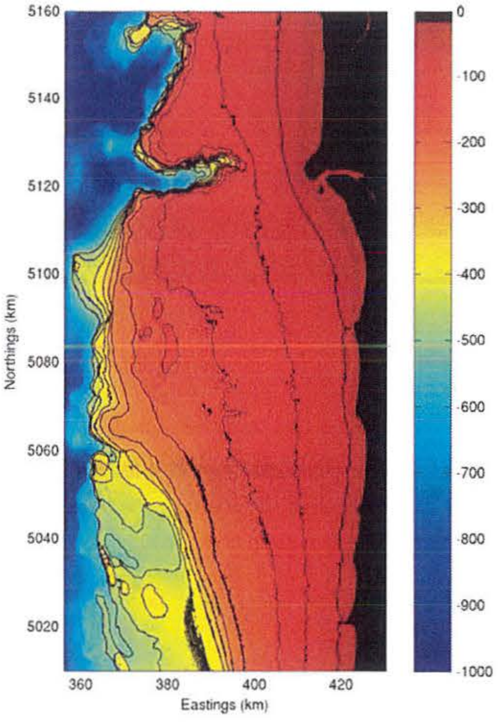

**Figure 5-1. The SWAN model domain developed for the Tillamook County coast. The model bathymetry was developed using 1/3 arc-second (~10 m) DEMs downloaded from the NOAA's NGDC. Color scale reflects depth in meters.**

## 5.1 Development of a Synthesized Wave Climate for Input into SWAN

Our primary goal was to use existing measured and hindcast wave time series to generate as long a record of the deepwater wave climate as possible for the offshore boundary of the SWAN model, approximately the edge of the continental shelf break. To this end, we downloaded all available National Data Buoy Center (NDBC, http://www.ndbc.noaa.gov/) and Coastal Data Information Program (CDIP, http://cdip.ucsd.edu/) hourly wave buoy data in the region for several wave buoys. **Figure 5-2** shows the various buoys used to derive a synthesized northern Oregon coast wave data set (data availability shown in **Figure 5-3**). In addition to the hourly measured wave buoy data, we obtained wave hindcast information on the deepwater wave climate determined through the Wave Information Studies (WIS, http://wis.usace.army.mil/) (Baird & Associates, 2005).

For the purposes of this study, we used wave hindcast data determined for station 81067 (**Figure 5-2**), which is located adjacent to NDBC buoy #46005. While NDBC #46005 has a high quality, long record of data (1975–2012), it is located in 2,981 m (9,780 ft) of water and is over 400–500 km (250–310 miles) from the shelf edge. Therefore NDBC #46089, a shelf edge, deepwater buoy, was selected as the priority buoy to be used in the SWAN analyses. A buoy (Columbia River #46029) located on the shelf was also included in this analysis, reverse shoaled to deep water to account for wave height changes in intermediate depths. Because of the variation in locations and water depths of the buoys, we needed to develop a methodology to transform these "off-shelf" and "on-shelf" waves to the "shelf-edge" offshore boundary condition of the SWAN model. This was necessary as the wave climates observed at 46005 and 46029 are significantly different than the climate observed at the Tillamook offshore buoy (**Figure 5-4**).

## Allison Hinderer

| | |
|---|---|
| **From:** | Sarah Mitchell <sm@klgpc.com> |
| **Sent:** | Tuesday, July 27, 2021 2:20 PM |
| **To:** | Sarah Absher; Allison Hinderer |
| **Cc:** | Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com |
| **Subject:** | EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 4 of 6) |
| **Attachments:** | Exh 2 - DOGAMI SP-47 Report_Part3.pdf |
| **Importance:** | High |

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Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 4 of 6.

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**From:** Sarah Mitchell
**Sent:** Tuesday, July 27, 2021 2:19 PM
**To:** sabsher@co.tillamook.or.us; Allison Hinderer <ahindere@co.tillamook.or.us>
**Cc:** Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and Lynda Cogdall (lcogdall@aol.com) <lcogdall@aol.com>; Brett Butcher (brett@passion4people.org) <brett@passion4people.org>; Dave and Frieda Farr (dfarrwestproperties@gmail.com) <dfarrwestproperties@gmail.com>; David Dowling <ddowling521@gmail.com>; David Hayes (tdavidh1@comcast.net) <tdavidh1@comcast.net>; Don and Barbara Roberts (donrobertsemail@gmail.com) <donrobertsemail@gmail.com>; Don and Barbara Roberts (robertsfm6@gmail.com) <robertsfm6@gmail.com>; evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com) <jeffklein@wvmeat.com>; Jon Creedon (jcc@pacifier.com) <jcc@pacifier.com>; kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net) <michaelmunch@comcast.net>; Mike and Chris Rogers (mjr2153@aol.com) <mjr2153@aol.com>; Mike Ellis (mikeellispdx@gmail.com) <mikeellispdx@gmail.com>; Rachael Holland (rachael@pacificopportunities.com) <rachael@pacificopportunities.com>; teriklein59@aol.com
**Subject:** RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 3 of 6)

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 3 of 6.

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**From:** Sarah Mitchell
**Sent:** Tuesday, July 27, 2021 2:17 PM

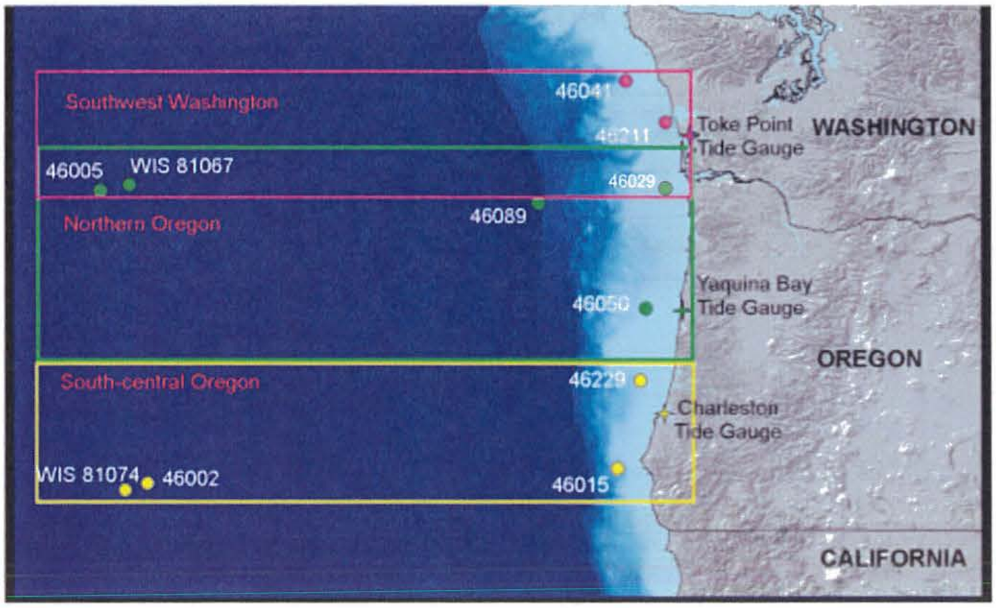

**Figure 5-2.** **Map showing the regional divisions from which synthesized wave climates have been developed.**

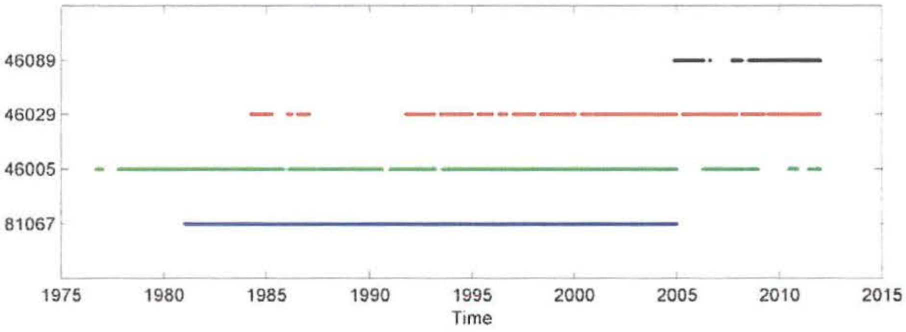

**Figure 5-3.** **Available wave data sets timeline (after Harris, 2011).**

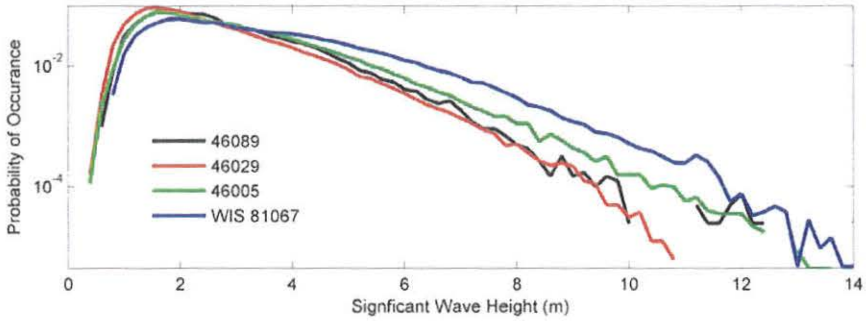

**Figure 5-4.** **Differences in the empirical probability distribution functions of the on shore and off shore buoys.**

To transform the 46005 and 46029 waves to the shelf edge, we created wave period bins (0–6, 6–8, 8–10, 10–12, 12–14, 14–16, 16–21, and 21–30 s) to evaluate if there has been a wave period dependent difference in wave heights observed at Washington 46005 and Columbia River 46029 compared with the Tillamook buoy. (Note that the NDBC wave buoys only relatively coarsely resolve long-period waves. Between 21 and 30 s only a wave period of 25 s is populated in the data set. There are no 30-s waves in the time series. Of the waves with periods between 16 s and 20 s, over 80 percent are at approximately 16 s. Only a relatively few waves in the record have recorded periods of 17, 18, and 19 s. This coarse resolution in the raw data determined our choice of period bin widths.) For our comparisons, the time stamps associated with waves measured at either 46005 or 46029 were adjusted based on the group celerity (for the appropriate wave period bin) and travel time it takes the wave energy to propagate to the wave gauge locations. For example, for waves in the period range 10–12 s the group celerity is about 8.3 m/s, and therefore it takes 13 hours for the energy to propagate from 46005 to the Tillamook buoy (**Figure 5-5**).

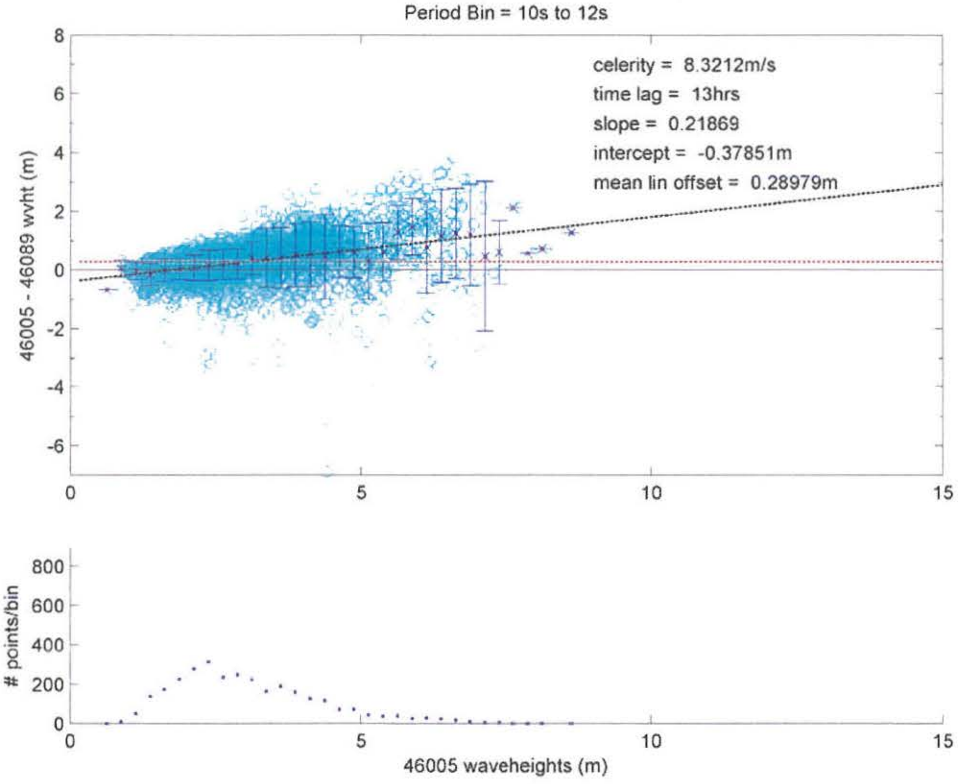

**Figure 5-5. Example development of transformation parameters between the Washington buoy (#46005) and the Tillamook (#46089) buoy for period range 10 s to 12 s. In the top panel the dashed black line is the linear regression and the dashed red line is the constant offset. Blue error bars represent the standard deviation of the wave height differences in each period bin (Harris, 2011).**

After correcting for the time of wave energy propagation, the differences in wave heights between the two buoys, for each wave period bin, were examined in two ways as illustrated in **Figure 5-5**:

1. A best fit linear regression through the wave height differences was computed for each wave period bin; and
2. A constant offset was computed for the wave height differences for each period bin.

Upon examination of the empirical probability density functions (PDF) of the buoys' raw time series (using only the years where overlap between the buoys being compared occurred) and after applying both transformation methods (**Figure 5-6**), it was determined that the constant offset method did a superior job of matching the PDFs, particularly for the high wave heights. Therefore, a constant offset adjustment dependent on the wave period was applied to the wave heights from the Washington 46005 and Columbia River 46029 buoys. Because the WIS hindcast data used in this study were also located well beyond the boundary of the SWAN model (basically at the location of 46005), the same series of steps comparing WIS wave heights to the Tillamook buoy was carried out, with a new set of constant offsets having been calculated and applied.

After applying the wave height offsets to the necessary buoys, gaps in the time series of Tillamook 46089 were filled in respectively with the Columbia River and Washington buoys. Where there were still gaps following this procedure, we filled in the time series with the corrected WIS data. Because wave transformations (particularly refraction) computed by SWAN are significantly dependent on wave direction, when this information was missing in the buoy records it was replaced with WIS data for the same date in the time series (but the wave height and period remained buoy observations where applicable).

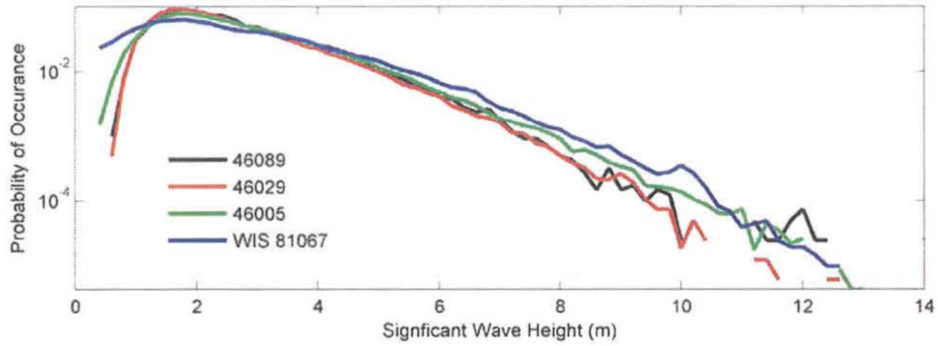

**Figure 5-6.** **Adjusted probability density functions (corrected using the constant offset approach) for buoy 46005 (green line), buoy 46029 (red line), and WIS station 81067 (blue line) as compared to the raw probability density function for buoy 46089 (black line).**

The final synthesized wave time series developed for Tillamook County extends from June 1980 through December 31, 2011, and consists of approximately ~31 years of data (measurements including at least wave height and periods) (**Figure 5-7**). Forty-two percent of the synthesized wave climate is from NDBC 46050, 36% from NDBC 4605, 15% from NDBC 46089, and ~7% from WIS station 81067. As can be seen from **Figure 5-7A**, the wave climate offshore from the northern Oregon coast is episodically characterized by large wave events (> 8 m [26 ft]), with some storms having generated deepwater extreme waves on the order of 14.5 m (48 ft). The average wave height offshore from Tillamook County is 2.6 m (8.5 ft), while the average peak spectral wave period is 10.9 s, although periods of 20–25 s are not uncommon (**Figure 5-7B**).

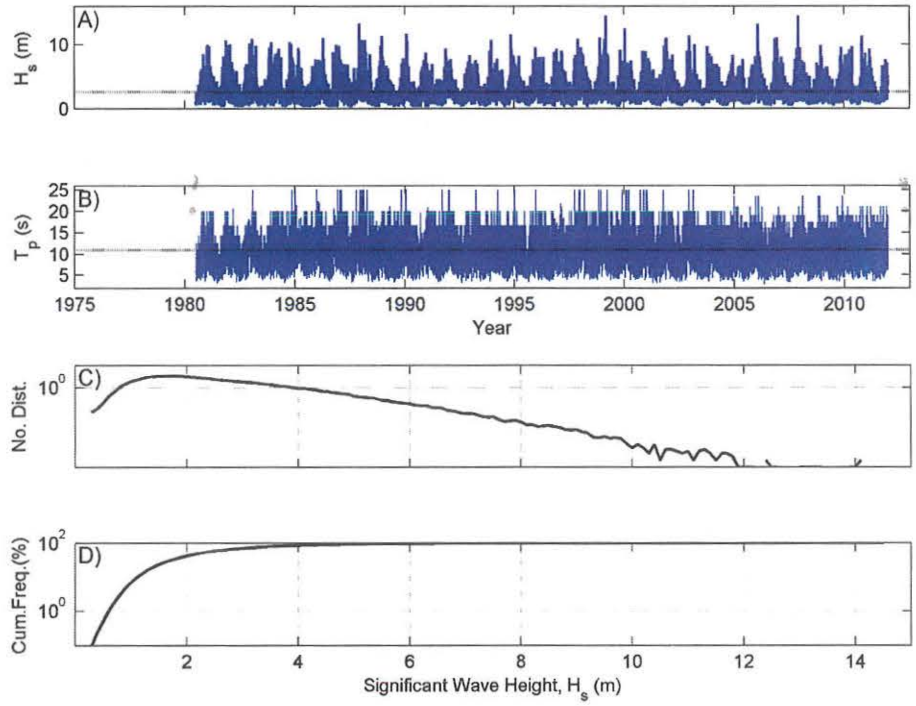

**Figure 5-7. Synthesized wave climate developed for Tillamook County. A) Significant wave height with mean wave height denoted (dashed line), B) Peak spectral wave period with mean period denoted (dashed line), C) Probability distribution of wave heights plotted on a semi-log scale, and D) Significant wave height cumulative frequency curve plotted on a semi-log scale.**

The PNW wave climate is characterized by a distinct seasonal cycle that can be seen in **Figure 5-8** by the variability in wave heights and peak periods between summer and winter. (The groupings evident in the peak periods (**Figure 5-7B**) are directly from the data and are a product of the data processing methods used by the NDBC to establish the wave frequencies and hence periods. It is for this reason that we chose coarse wave period bins for long-period waves [i.e., > 16 s].) Monthly mean significant wave heights are typically highest in December and January (**Figure 5-8**), although large wave events (>12 m [39.4 ft]) have occurred in all of the winter months except October. The highest significant wave height observed in the wave climate record is 14.5 m (48 ft). In general, the smallest waves occur during late spring and in summer, with wave heights typically averaging ~1.5 m during the peak of the summer (July/August). These findings are consistent with other studies that have examined the PNW wave climate (Tillotson and Komar, 1997; Allan and Komar, 2006; Ruggiero and others, 2010b). **Figure 5-7C** shows a probability density function determined for the complete time series, while **Figure 5-7D** is a cumulative frequency curve. The latter indicates that for 50% of the time waves are typically less than 2.2 m (7.2 ft), and less than 4.4 m (14.4 ft) for 90% of the time. Wave heights exceed 6.9 m (22.6 ft) for 1% of the time. However, although rare in occurrence it is these large wave events that typically produce the most significant erosion and flooding along the Oregon coast.

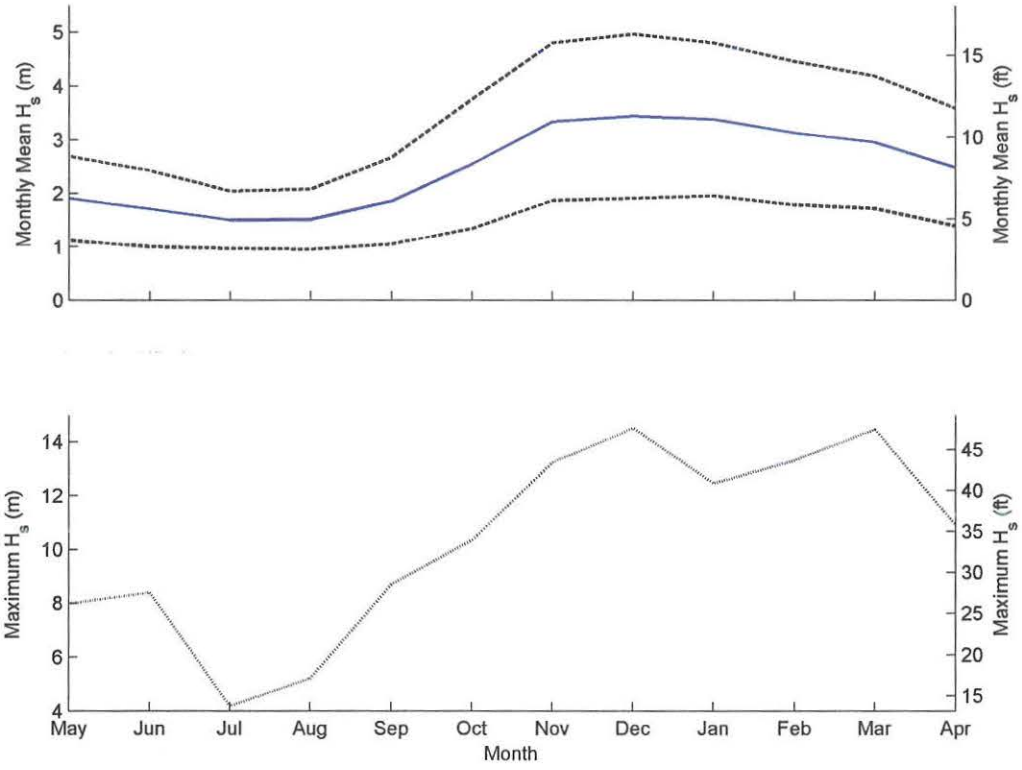

**Figure 5-8. Seasonal variability in the deepwater wave climate offshore from the northern Oregon coast. (Top) The monthly average wave height (blue line) and standard deviation (dashed line); (Bottom) The maximum monthly significant wave height.**

Finally, **Figure 5-9** provides a wave rose of the significant wave height versus direction developed for the northern Oregon coast. In general, the summer is characterized by waves arriving from the northwest, while winter waves typically arrive from the west or southwest (Komar, 1997). This pattern is shown in **Figure 5-9**, which is based on separate analyses of the summer and winter directional data developed from the synthesized time series. As can be seen in **Figure 5-9**, summer months are characterized by waves arriving from mainly the west-northwest (~48%) to northwesterly quadrant (~42%), with few waves out of the southwest. The bulk of these reflect waves with amplitudes that are predominantly less than 3 m (9.8 ft). In contrast, the winter months are dominated by much larger wave heights out of the west (~23%) and to a lesser extent the northwest (~5.8%), while waves from the southwest account for ~21% of the waves.

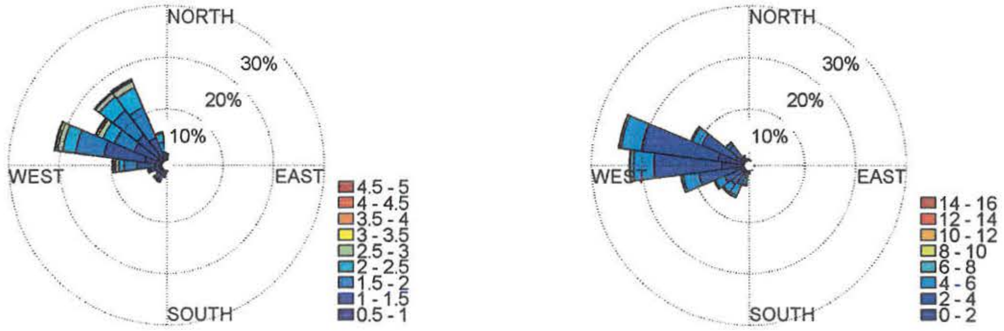

Figure 5-9. (Left) Predominant wave directions for the summer months (June-August), and (Right) winter (December-February). Colored scales indicate the significant wave height in meters.

## 5.2 Comparison of GROW versus Measured Waves

This section presents a more detailed analysis of GROW Fine Northeast Pacific wave hindcast data compared with measured waves obtained from selected wave buoys offshore from the Oregon coast. The objective here is to better define the degree of congruence between these two contrasting data sets in order to assess their relative strengths and weaknesses. The approach used here is similar to the tide analyses presented in Section 4, using empirical probability density functions (PDFs) to assess the shapes of the distributions. For the purposes of this analysis, PDF plots were derived for the GROW station (#18023) and for NDBC wave buoys 46089, located 66 km (41 mi) northwest of 18023 (**Figure 4-1**), and 46005 (not shown on map), located 540 km (335 mi) west of the Columbia River mouth.

The first plot (**Figure 5-10**) presents a series of significant wave height empirical PDFs for all measured data from NDBC buoys 46005 and 46089 as well as the GROW hindcast data from site 18023. Data from the stations span the following time frames: NDBC 46005 from 1976 through 2010; NDBC 46089 from 2004 through 2010; GROW 18023 from 1980 through 2009. Based on these PDFs, it is immediately apparent that the GROW data contain a larger number of smaller wave heights (in the 2-3 m range) than those measured by the buoys.

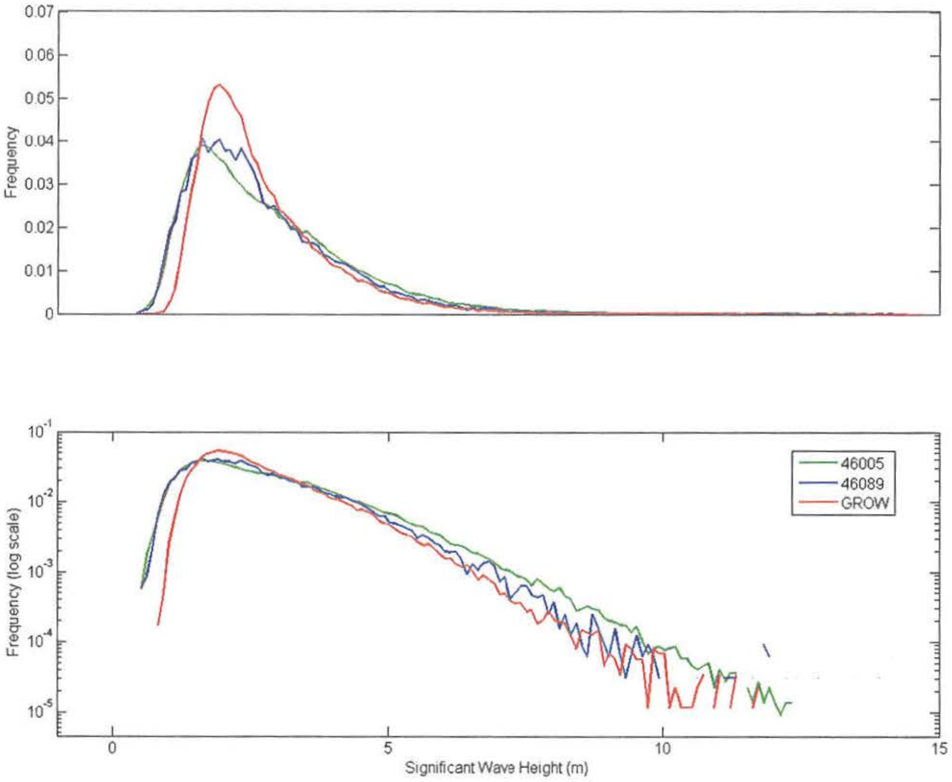

**Figure 5-10. Probability density function (PDF) plots of significant wave heights plotted on a normal (top) and log (bottom) scale. Plots include all existing data from these stations.**

Additionally, examination of the log-scale plot (bottom of **Figure 5-10**) indicates that the GROW hindcast at 18023 tends to underestimate the more extreme wave heights (waves >7 m), which are the most important for inundation and erosion vulnerability studies. **Table 5-1** lists general statistics of the various data sets where the maximum wave height modeled by GROW is shown to be nearly 3 m lower than that measured by the 46089 buoy. In contrast, GROW indicates on average slightly higher peak periods when compared with the NDBC stations. While differences between NDBC 46005 and NDBC 46089 may simply reflect buoy locations relative to the tracks of the storms, differences between 46089 and GROW 18023 are almost certainly entirely due to the ability of the numerical model to hindcast the waves. Because NDBC station 46089 spans a much shorter measurement period compared with 46005 and the GROW site, the results from the full PDFs may be construed to be misleading. To better assess this potential bias, we again performed analyses of the truncated time series, which revealed nearly identical results to those presented in **Figure 5-10**. Summary statistics for the truncated time series are included in **Table 5-1**. **Figure 5-11** shows a PDF of the peak periods for 46005, 46089, and GROW for the time period 2004–2009. This last plot clearly indicates that GROW is tending to overestimate the higher peak periods when compared with the measured data.

**Table 5-1. General statistics of the NDBC buoy and GROW data sets based on the complete time series of data and on truncated time series. Note: *H* denotes the significant wave height and *T* is the wave period.**

| | 46005 | 46089 | GROW |
|---|---|---|---|
| **Data availability** | 1976–present | 2004–present | 1980–2009 |
| Mean *H* | 2.8 m | 2.7 m | 2.6 m |
| Max *H* | 13.6 m | 14.5 m | 11.7 m |
| Min *H* | 0.2 m | 0.4 m | 0.72 m |
| *H* standard dev. | 1.4 m | 1.3 m | 1.1 m |
| Mean *T* | 10.8 s | 11.1 s | 12.6 s |
| **Data availability** | 2004–2009 | 2004–2009 | 2004–2009 |
| Mean *H* | 2.8 m | 2.6 m | 2.6 m |
| Max *H* | 12.7 m | 14.5 m | 11.7 m |
| Min *H* | 0.5 m | 0.4 m | 0.9 m |
| *H* standard dev. | 1.4 m | 1.3 m | 1.1 |
| Mean *T* | 10.6 s | 11.1 s | 12.7 s |

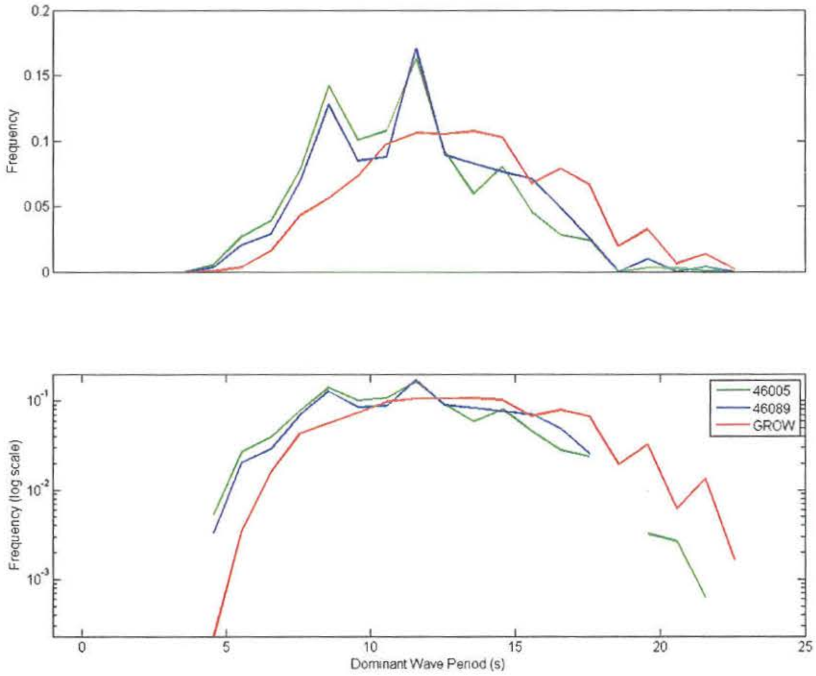

**Figure 5-11. Probability density function (PDF) plots of peak wave periods from 2004 through 2009 on a normal (top) and log (bottom) plot.**

After examination of PDFs of the various data sets, additional analyses were carried out for selected individual storms in order to better assess how well GROW is performing. The approach adopted was to select the five largest storms measured by the NDBC 46089. The storm events were selected by using a 3-day filter to ensure the selection of independent storm events. Once the peak of the storm was identified, the data (±2 days) were plotted with the GROW data. **Figure 5-12** presents results from two of the five selected storms. In general, our results indicate that while the timing of the events seems to be accurately determined by the GROW model, the magnitude is often lower than that measured by the wave gauges. This result may be due to the GROW approach of only estimating model results every 3 hours as opposed to NDBC's hourly buoy measurements. As a result, sampling at 3 hourly intervals has the potential to miss the peak of the storms. In fairness to GROW, the 3 hourly sampling probably reflects the fact that modeling waves on an hourly basis is dependent on having temporally and spatially suitable meteorological information, which remains a challenge for large-scale regional models.

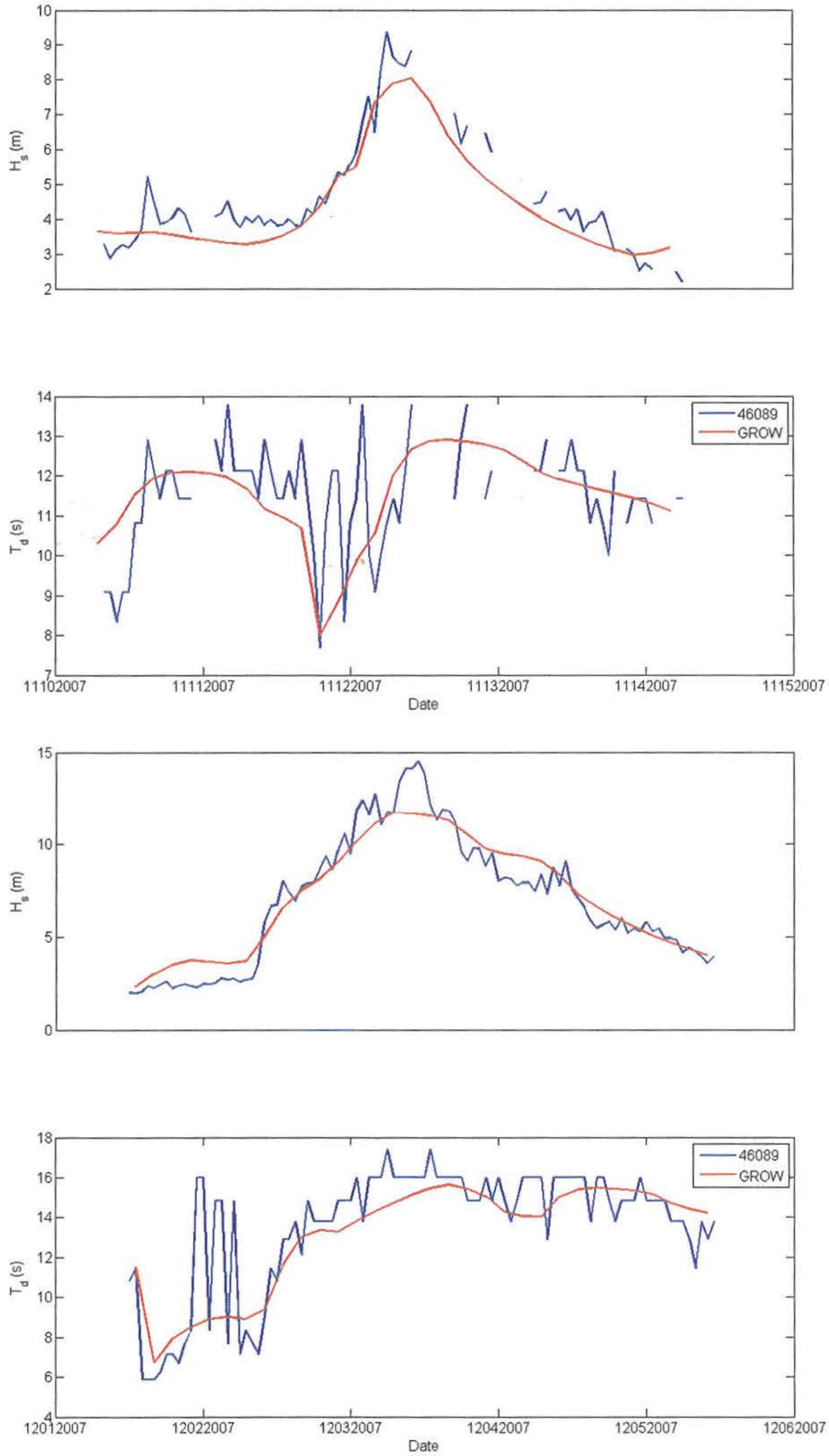

**Figure 5-12. Two examples of storms where measured and modeled waves are compared. Top) Storm on November 12, 2007, and Bottom) Major storm event on December 3, 2007.**

Finally, we also compared 2% exceedance extreme runup values estimated using the Stockdon and others (2006) approach and waves from the buoys and the GROW station. These results are presented in **Figure 5-13** and were calculated using a representative beach slope (tan $\beta$) of 0.04, which is typical for Oregon beaches. Only data from 2004 through 2009 were included in these calculations to provide a standard time frame for the comparison. Results indicate that, just as with the significant wave height PDFs, the extreme runup levels (>2.5 m [8.2 ft]) are underestimated by the GROW model, while the highest calculated runup differs by about 0.4 m (1.3 ft). Although the difference in the calculated runup between GROW and our measured time series is not as large as expected, the shape of the PDF plot would potentially reduce the number of storms available for defining the 100-year wave runup and total water level, as well as in overtopping, inundation, and erosion analyses as required for FEMA detailed coastal studies. From these findings we have concluded that all subsequent modeling of waves should be based, as much as possible, on the measured wave time series as opposed to using GROW hindcast data.

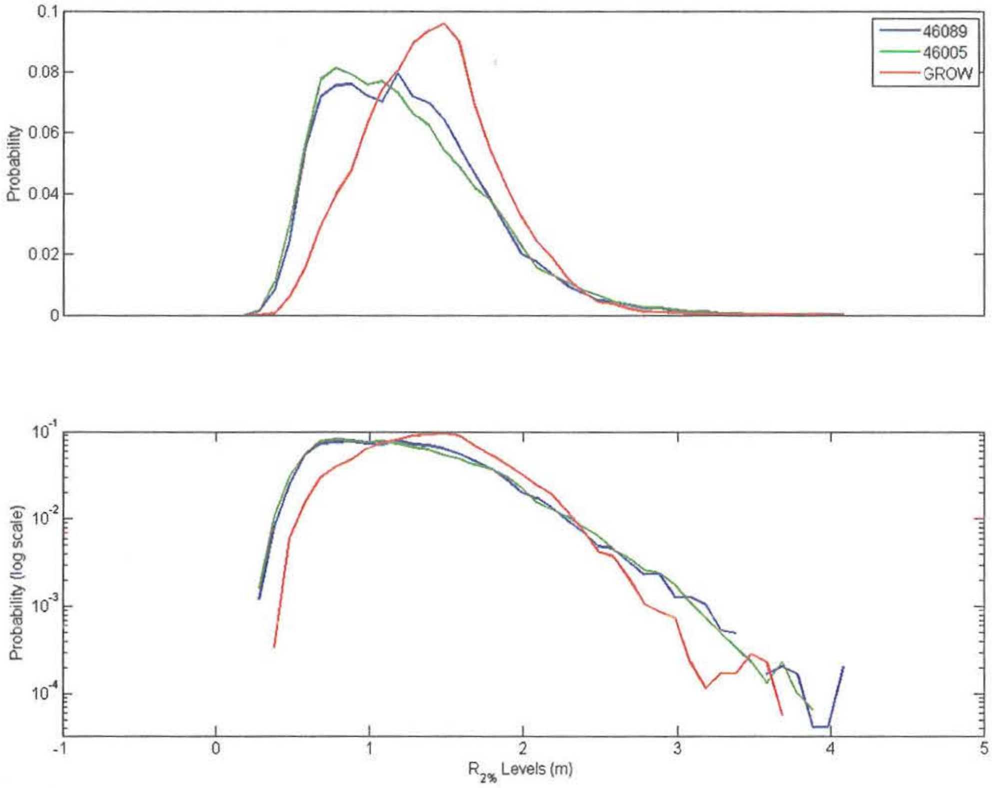

**Figure 5-13. Probability density function (PDF) plots of 2 percent extreme runup elevations ($R_{2\%}$) for NDBC 46005, 46089, and GROW hindcast results. An average beach slope of 0.04 was used for runup calculations. The bottom plot is the same as the top, but with the y-axis having been plotted using with a logarithmic scale in order to emphasize the higher wave runup characteristics.**

## 5.3 SWAN Model Development and Parameter Settings

We used the historical bathymetry assembled by the National Geological Data Center (NGDC) (described in Section 3.4) and created a model grid that covers a large portion of the northern Oregon coast (**Figure 5-1**).

SWAN (Simulating WAves Nearshore) version 40.81, a third-generation wave model developed at the Technical University of Delft in the Netherlands (Booij and others, 1999; Ris and others, 1999), was used in this study. The model solves the spectral action balance equation using finite differences for a spectral or parametric input (as in our case) specified along the boundaries. For the Tillamook County study, the cross-shore and alongshore resolution of the model grid used is 100*100 m. The total grid area is 72 km by 139 km in length, which yields 716*1,390 computational nodes. The SWAN runs were executed in stationary mode and included physics that account for shoaling, refraction, and breaking, while model settings varying from the default values are discussed in more detail below.

The north, south, and west boundaries of the model were specified using grid coordinates and forced using a parameterized JONSWAP spectrum. The functions for spectral peakedness parameters γ and *nn* in the JONSWAP directional spectra are given as:

$$\gamma = \begin{cases} 3.3\ if\ Tp < 11s \\ 0.5Tp - 1.5\ if\ Tp \geq 11s \end{cases}$$
$$nn = \begin{cases} 4\ if\ Tp < 11s \\ 2.5Tp - 20\ if\ Tp \geq 11s \end{cases} \tag{5.1}$$

Thus, the directional distribution is generated by multiplying the standard JONSWAP frequency spectrum by $cos^{nn}(\theta - \theta_{peak})$ (Smith and others, 2001). Wind wave spectra are broad (low γ and *nn* values) while swell typically have narrow distributions (high γ and *nn* values). The values used in the SWAN wave modeling were based on the input peak periods which ranged $4.055 \leq \gamma \leq 11.03$ and $7.775 \leq nn \leq 42.65$. To ensure that the wave directional spread is sufficiently resolved by the model, we specified directional bins giving a 4-degree directional resolution. The spectrum was discretized in frequency space with 29 bins from 0.032 to 1 Hz. Wind was not included in the SWAN simulations and therefore no energy growth due to wind or quadruplet wave-wave interactions occur in the simulations. Triad interactions, diffraction, and wave setup also were not activated in the model. We used the Janssen frictional dissipation option, which has a default friction coefficient of 0.067 $m^2/s^3$. No model calibration was performed in this study, although several numerical experiments were implemented to test various assumptions in the wave modeling (e.g., not to use winds).

### *5.3.1 Wind effects*

The decision not to model the effect of winds on wave growth over the continental shelf in our original Coos County study (Allan and others, 2012) was based on two observations:

- To develop our combined wave time series described previously, we performed a "statistical" wave transformation between buoy 46002 and the buoys at the edge of the continental shelf and found that, in general, the wave heights during storm events decreased even with hundreds of kilometers of additional fetch. Without understanding the details of this phenomenon (e.g., white capping versus wind wave growth) and with no data for calibration we felt that attempting to model wind growth would add to the uncertainty of our input wave conditions.
- We also have previous experience with SWAN wave modeling in the region (U.S. Pacific Northwest) in which sensitivity runs including wind were performed with only minor impact on results (Ruggiero and others, 2010a).

To test the validity of the assumptions made in our Coos County study, several wave modeling experiments were performed in order to specifically examine the role of additional wind wave development over the shelf. The basic question that was addressed is: How much do wind fields result in wave growth between the location of the GROW stations that were purchased (an off-shelf location roughly equivalent to the offshore extent of the Tillamook (46089) buoy shown in **Figure 4-1**) and the inner shelf. The latter was defined as the 100 m (300 ft) isobath. To address this question, hindcast waves were modeled for the months of January and February (i.e., peak of the winter season) and for two representative years (2006 and 2010). The wave modeling was accomplished by running a regional Eastern North Pacific (ENP) model and a 3 arc-min grid for the Oregon coast, with the outer boundary coinciding with the Tillamook buoy station (**Figure 5-14**). The model runs were forced by analyzed Global Forecast System winds with a temporal resolution of 6 hours and a spatial resolution of 1 arc-degree. A similar run was undertaken without winds over the same 3 arc-min grid, just propagating the boundary conditions. Hindcast wave data were obtained from selected points across the shelf at contour depths of 500, 400, 300, 200, and 100 m along a cross-shore transects from the offshore GROW station (A and B in **Figure 5-14**).

Results from the model runs (with and without winds) are presented in **Figure 5-15** and **Figure 5-16**. Modeled and measured waves for two NDBC buoys (46089 and 46029) are included for comparative purposes (**Figure 5-17** and **Figure 5-18**). In general, our experiments indicated that although the addition of wind sometimes changed the timing of the large wave events, producing at times a relatively large percentage error for part of the "wave hydrograph," the peaks of the wave events showed very little difference between cases where wind was included or excluded (**Figure 5-15** and **Figure 5-16**). Furthermore, in the majority of cases, the differences in the derived wave heights between model runs including (excluding) wind (no wind) were on the whole minor. This finding was also observed in the derived peak wave periods, which appear to be virtually identical in all the plots. Of greater concern in these model tests are the occasional large differences between the modeled runs (irrespective of whether wind/no wind is applied) and the actual measurements derived from NDBC wave buoys (**Figure 5-17** and **Figure 5-18**), as well as the GROW data derived for station 18023. These latter findings will be explored in more detail later in this section.

These experiments support our decision to not include wind growth in our model runs, and therefore quadruplet wave-wave interactions were also not incorporated in the simulations. Further, wave setup is not included in the simulations because we extract the transformed wave parameters at the 20-m depth contour and use the Stockdon and others (2006) empirical model to compute wave runup (which incorporates setup) along the coast.

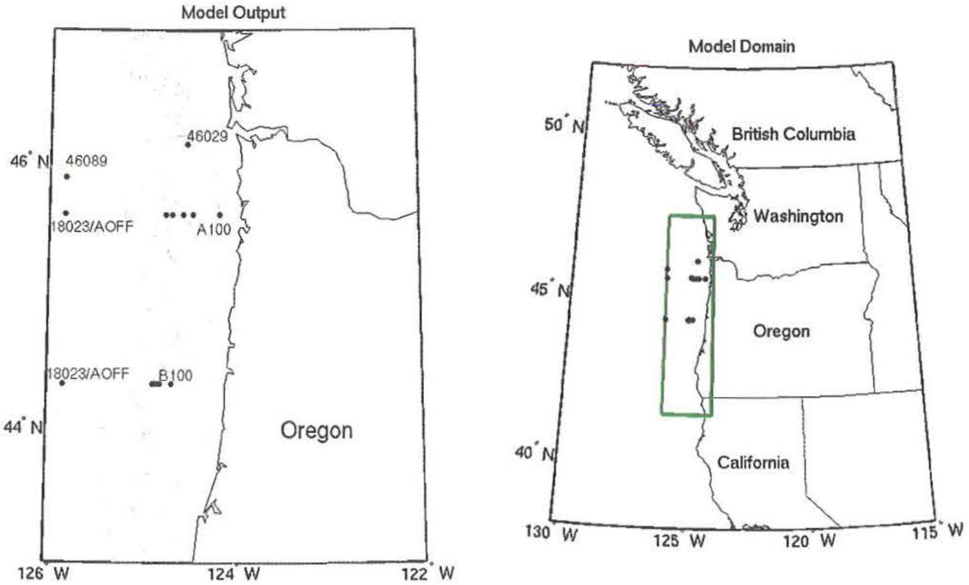

**Figure 5-14. Left) Map showing the locations of the northern Oregon coast buoys, and transect lines (A and B), and Right) model domain.**

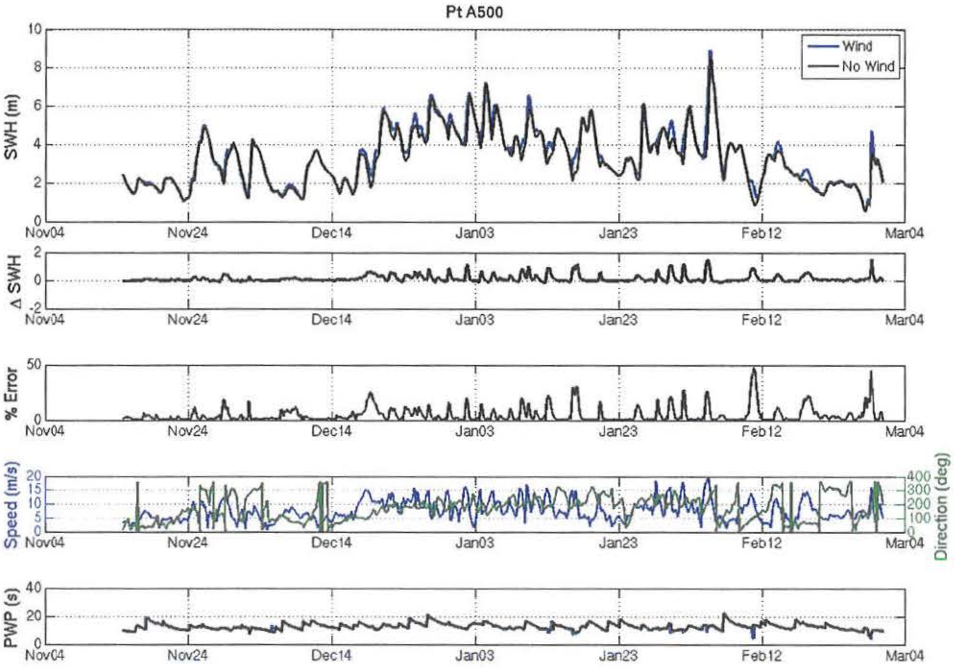

Figure 5-15. Model-model comparison at 500-m depth on transect A for the 2006 simulation.

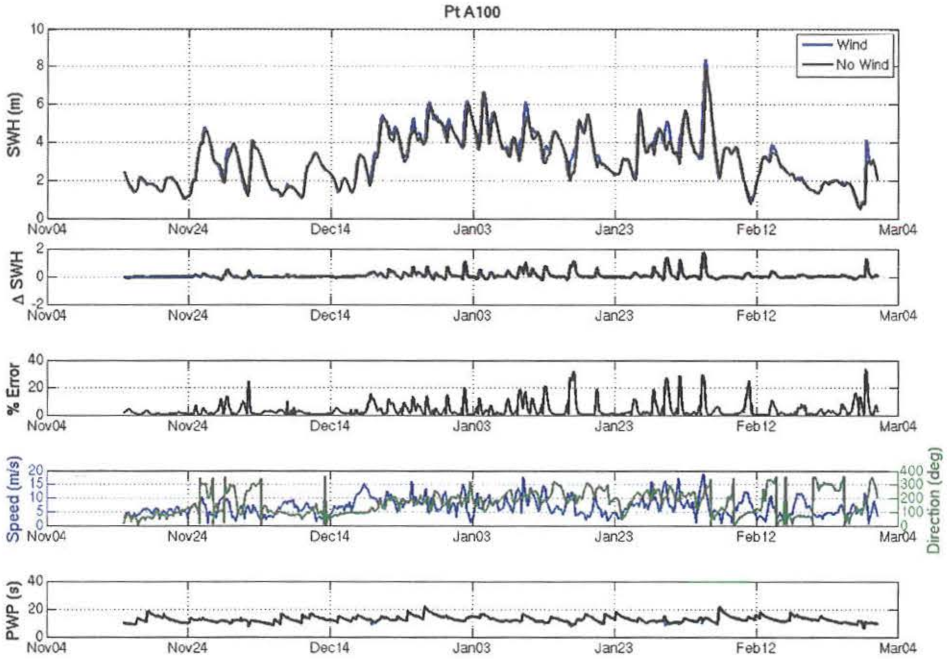

Figure 5-16. Model-model comparison at 100-m depth on transect A for the 2006 simulation.

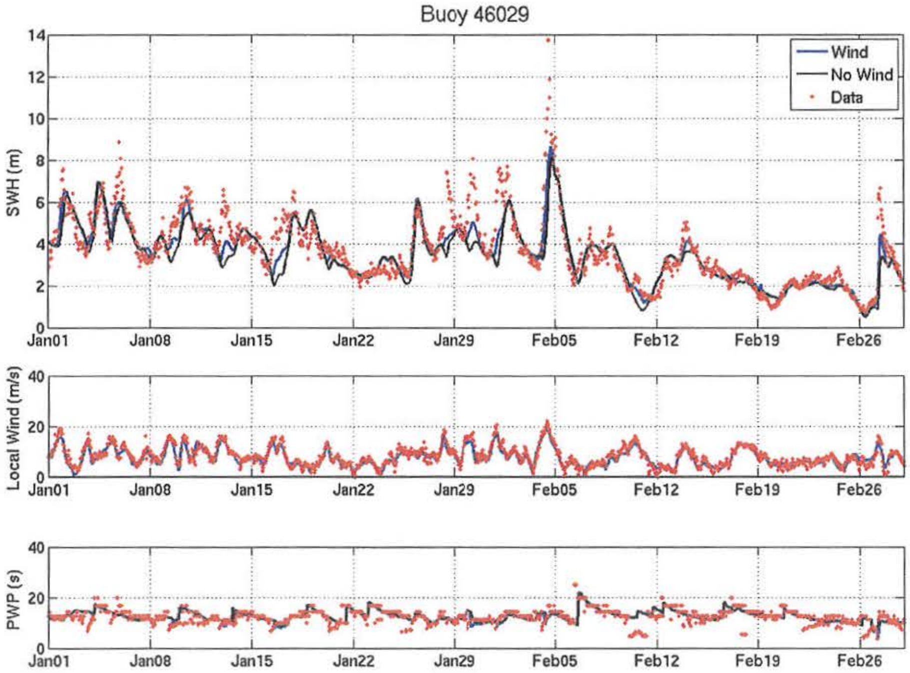

Figure 5-17. Model data comparison at NDBC buoy #46029 for the 2006 simulations.

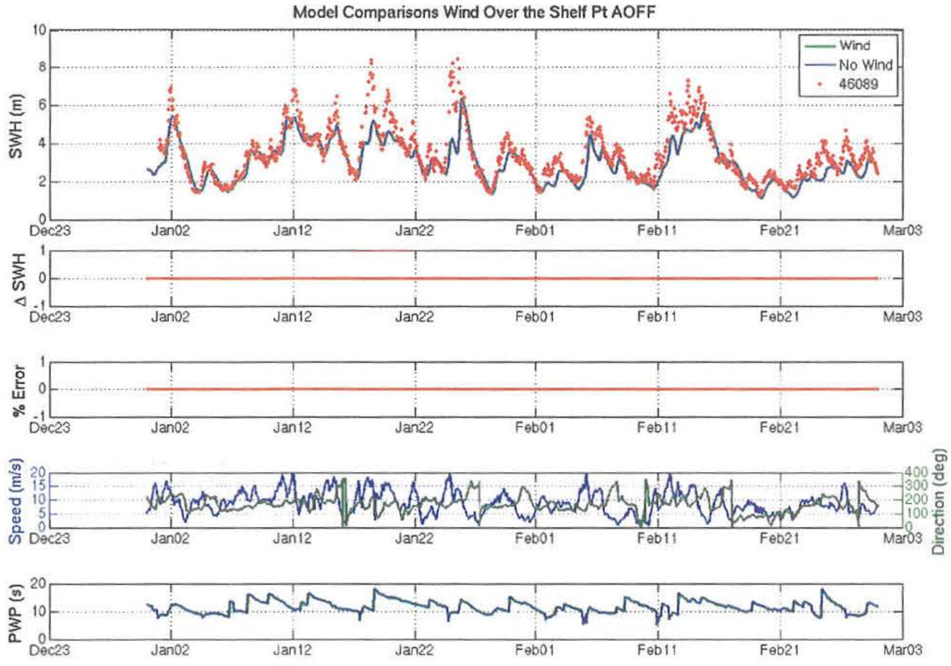

Figure 5-18. Model data comparison at Station Aoff (GROW station location) versus NDBC buoy #46089 for the 2010 simulations.

### *5.3.2 Frictional and Whitecapping Dissipation of the Wave Energies*

Additional testing was undertaken to explore the effect of not including friction and whitecapping. **Figure 5-19** and **Figure 5-20** provide two test case conditions associated with a significant wave height of 10 m and peak period of 20 s, with the waves approaching from a direction of 285 degrees (NW), while the second case is for a significant wave height of 14 m, peak period of 14 s, with the waves approaching from a direction of 270 degrees (W). **Figure 5-19** indicates that for this particular condition, the modeled results are relatively similar until immediately prior to wave breaking, where significant differences arise. However, as the significant wave height increases (**Figure 5-20**) the effect of excluding bottom friction and whitecapping becomes considerably larger. The exclusion of these processes results in an overestimation of wave heights prior to breaking. Therefore, we have chosen to include frictional dissipation and dissipation due to whitecapping in our modeling.

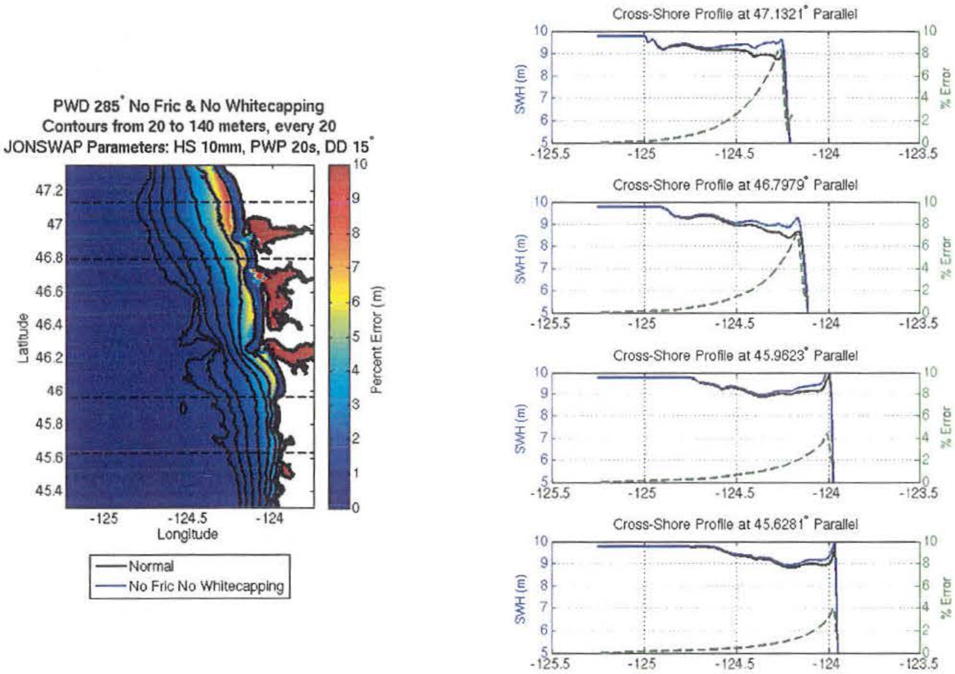

**Figure 5-19.** **The impact of ignoring bottom frictional dissipation and dissipation due to whitecapping for a 10-m significant wave height with a peak period of 20 s approaching from a direction of 285 degrees.**

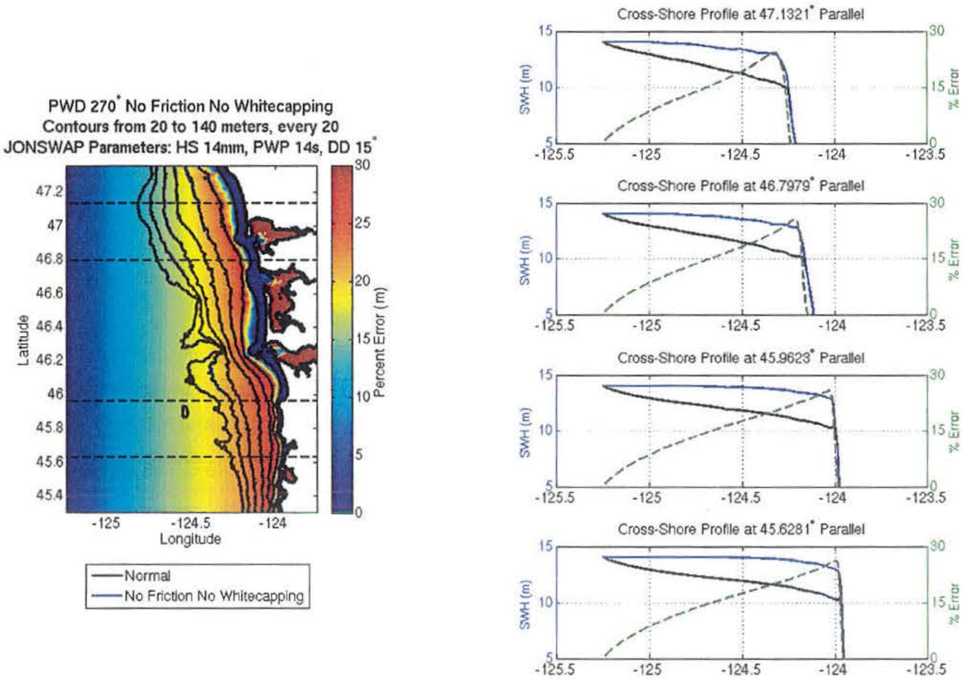

**Figure 5-20. The impact of ignoring bottom frictional dissipation and dissipation due to whitecapping for a 14-m significant wave height with a peak period of 14 s approaching from a direction of 270 degrees.**

### *5.3.3 Lookup table development*

Having demonstrated that winds have little impact in terms of additional wave development across the continental shelf of Oregon, our next goal was to develop an efficient methodology that could be used to minimize the total number of SWAN runs needed to perform the actual wave modeling and transformations, while ensuring that we resolve the influence of varying parameters on the wave transformations. To do this, we discretized the significant wave height ($H_s$), peak period ($T_p$), wave direction ($D_p$), and water level (*WL*) time series.

For the direction bins ($D_p$), the bin widths were made approximately proportional to the probability distribution function of the GROW time series (and the synthesized wave climate time series). In application of this approach in our Clatsop County study, 11 directional bins were created that have approximately an equal probability of occurrence (**Figure 5-21**). As defined, the bin edges are: $D_p$ = [170, 225, 240, 251, 260, 268, 277, 288, 304, 331, 370] and were subsequently refined in SWAN to $D_p$ = [170, 225, 240, 250, 260, 270, 280, 290, 305, 330, 370], resulting in 11 direction cases for our SWAN runs. At the bin edges, linear interpolation is used to derive the wave parameters. Using initial sensitivity runs undertaken as part of our Clatsop County study, we have determined that these bin widths are more than adequate. **Figure 5-22** shows the result of interpolating over a 20-degree bin spacing.

For the purposes of the Tillamook County work, we further refined our original approach to include an additional two directional bins. This was accomplished by refining the spread of the bins to better reflect the observed conditions offshore Tillamook and Lincoln Counties. The final bin edges are defined as: $D_p$ = [175, 205, 225, 240, 250, 260, 270, 280, 290, 300, 315, 335, 365].

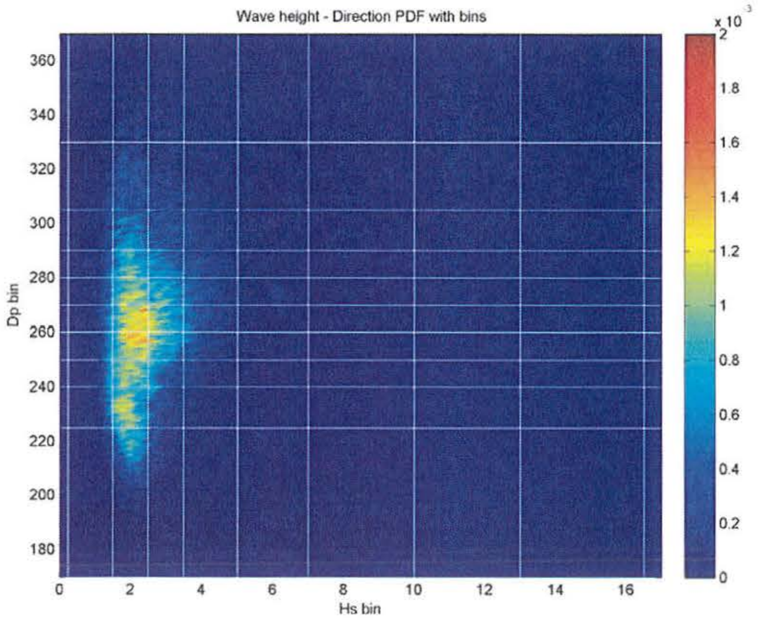

**Figure 5-21. Joint probability of wave height and dominant direction derived from the GROW time series. Overlaid in white are the wave height and direction bins for use in the wave modeling on the Clatsop coast.**

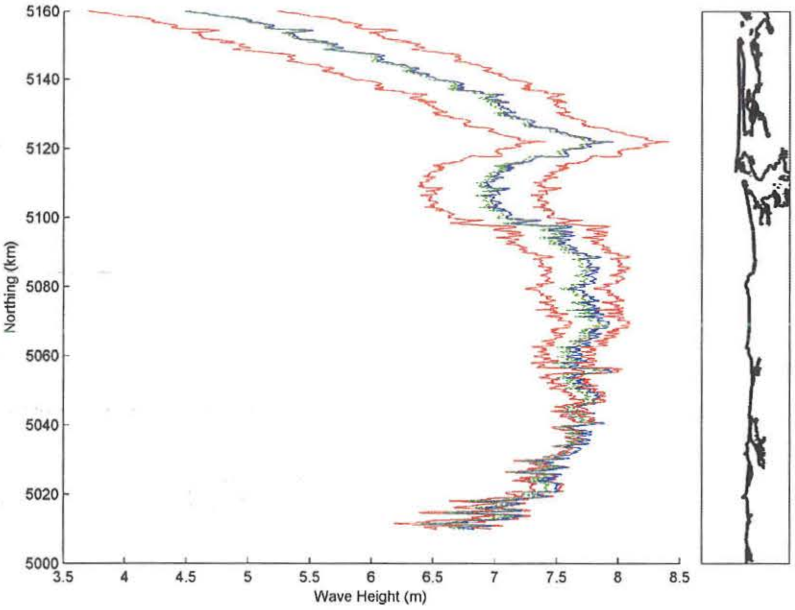

**Figure 5-22. SWAN wave modeling and calculated alongshore wave variability using the look-up table approach. The left red line represents the alongshore variable wave height at the 20-m depth contour for an incident angle of 240 degrees ($H_s = 10$, $T_p = 15$ s) and the right red line is for an angle of 260 degrees. The blue line is the wave height for an angle of 250 degrees as modeled in SWAN, while the green line represents the linearly interpolated wave heights using the look-up table. Note that this is a preliminary SWAN model run, meant for testing the interpolation scheme, and the lateral boundary conditions are not dealt with in the same manner as in our production SWAN runs.**

For the significant wave heights bins, we identified the following deepwater significant wave heights for inclusion in SWAN: $H_s$ = [0.25, 1.5, 2.5, 3.5, 5, 7, 10, 13, 16.5], which gives us nine cases. From our sensitivity tests, we found that a bin width of 3 m for large waves is sufficient for resolving the linearly interpolated wave conditions (**Figure 5-23**). In the case of the deepwater peak periods, our analyses identified the following period bins for inclusion in SWAN: $T_p$ = [2, 4, 6, 9, 11, 13, 15, 17, 20, 23, 26], which provides a total of 11 additional cases. From our sensitivity tests, we found that the linear interpolation approach for wave period is not quite as good as for direction and wave height. Because wave period affects breaking, shoaling, and whitecapping, there is significant variability in the wave transformations as a function of wave period. For our sensitivity run of $H_s$ = 10 m, and $D_p$ = 260 degrees, **Figure 5-24** illustrates the impact of linear interpolation. However, for the most part in our parameter space we will have interpolation errors only around 10%. In this particular example the maximum error is only approximately 4 percent.

**Figure 5-25** presents the joint probability of wave height and peak period from the GROW time series. The white dots represent bin centers, from a much smaller mesh, in which this combination of $H_s$ and $T_p$ does not exist in the GROW time series. The red line represents the theoretical wave steepness limit below which waves are nonphysical. We can use this information to reduce the overall matrix of model runs.

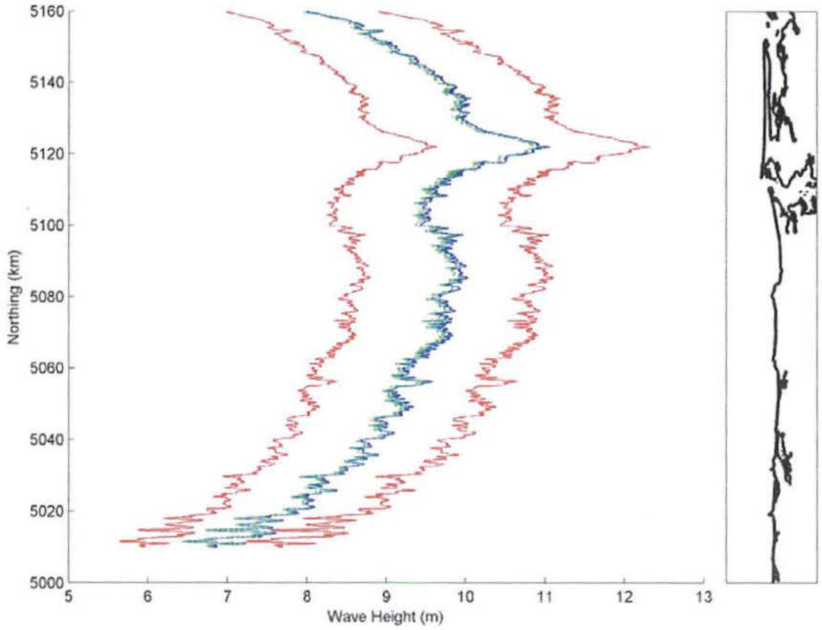

Figure 5-23. SWAN wave modeling and calculated alongshore wave variability using the look-up table approach for an 11-m and 15-m wave. In this example the red lines are the alongshore varying wave height for an 11-m and 15-m incident wave height in 20 m. The blue line is the modeled transformed 13-m wave height, while the green represents a linear interpolation between the 11- and 15-m results.

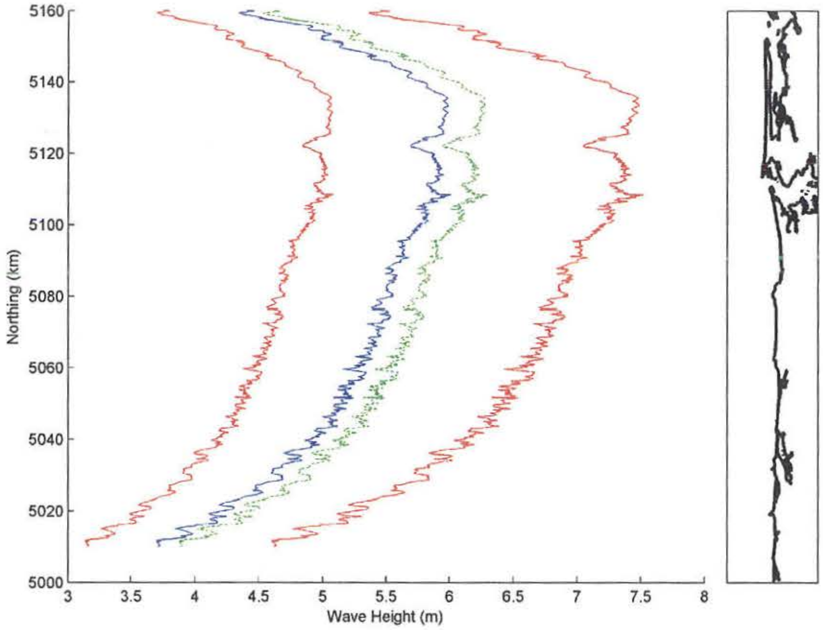

Figure 5-24. SWAN wave modeling and calculated alongshore wave variability using the look-up table approach for a 10-m wave. In this example the red lines are the alongshore varying wave height for a 10-m wave arriving from 260 degrees for 20 s and 24 s. The blue line is the modeled wave height for 22 s, and the green line represents a linear interpolation.

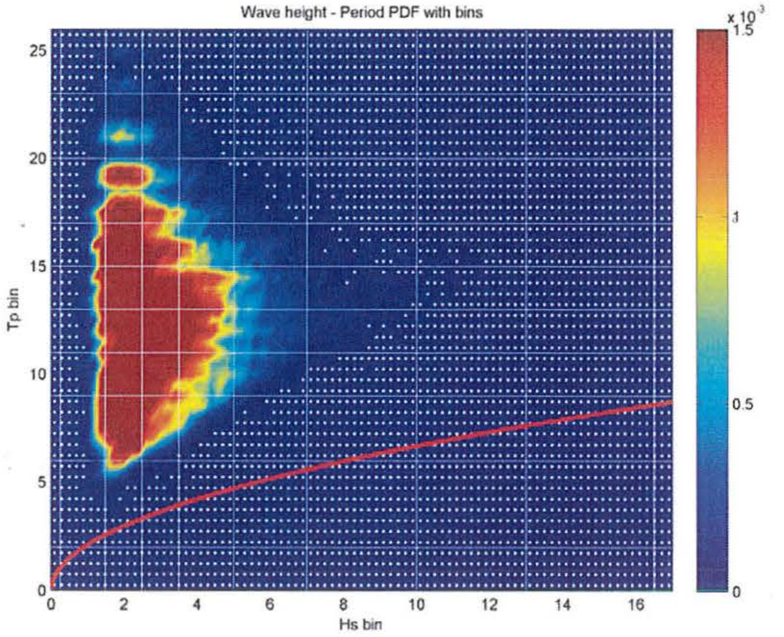

**Figure 5-25. Joint probability of wave height and peak period from the GROW time series. The white dots represent bin centers, from a much smaller mesh, in which this combination of Hs and Tp does not exist in the GROW time series. The red line represents the theoretical wave steepness limit below which waves are nonphysical.**

**Figure 5-26** is the joint probability of peak period and dominant wave height shown here for completeness. Finally, we illustrate our bin choice on the individual parameter PDFs in **Figure 5-27** (buoy data).

In summary, the lookup tables were generated using all wave parameter cases and two contrasting water levels. Our sensitivity tests indicated that varying water levels have a negligible impact on the model and linearly transformed waves. The following matrix of SWAN runs is considered for lookup table development for transforming waves offshore from Tillamook County:

$D_p =$ [175, 205, 225, 240, 250, 260, 270, 280, 290, 300, 315, 335, 365] — 13 cases
$H_s =$ [0.25, 1.5, 2.5, 3.5, 5, 7, 10, 13, 16.5] — 9 cases
$T_p =$ [2, 4, 6, 9, 11, 13, 15, 17, 20, 23, 26] — 11 cases
$WL =$ [-1.5, 4.5] — 2 cases

In total, this equates to 2,574 model cases that can be used for linearly interpolating the waves from a time series of data. However, **Figure 5-25** indicates that several $H_s$–$T_p$ combinations are physically not realistic. Multiplying these bins by the $D_p$ and $WL$ bins means that we can eliminate 390 bins for a new total of only 2,184 model runs.

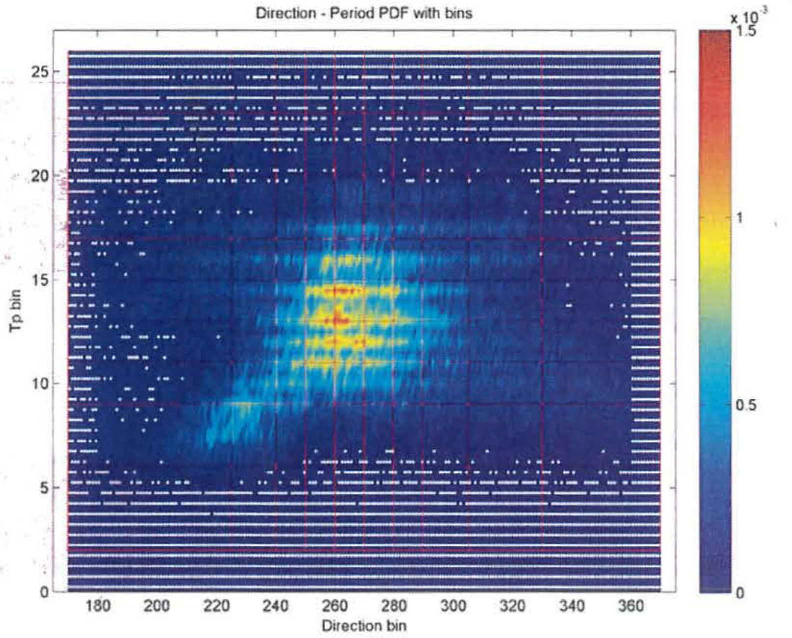

**Figure 5-26.** Joint probability of dominant direction and peak period from the GROW time series. The white dots represent bin centers, from a much smaller mesh, in which this combination of $D_p$ and $T_p$ does not exist in the GROW time series. The red lines depict the boundaries of the binning.

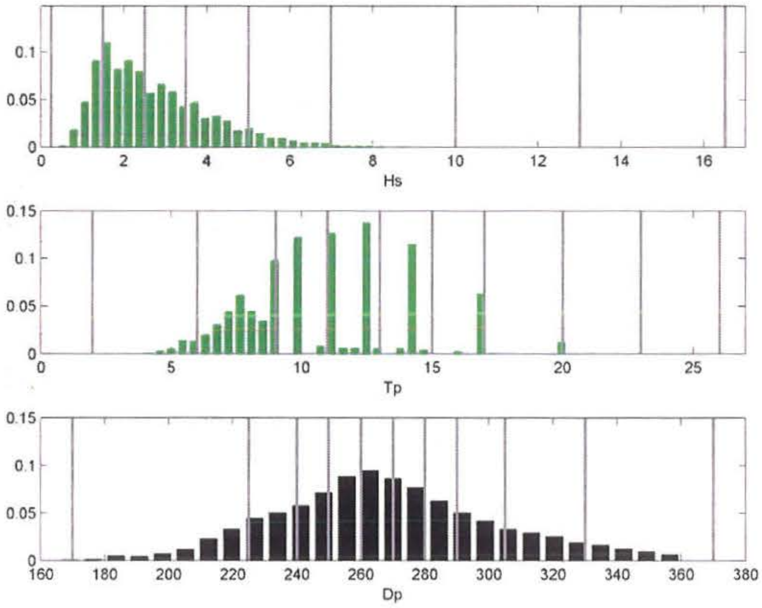

**Figure 5-27.** Individual parameter probability density function plots and bin edges using the combined buoy wave time series.

## 5.4 Summary of SWAN Results

Significant alongshore variability is apparent in many of the conditions examined with SWAN (**Figure 5-28**). Differences on the order of 3 m in significant wave height along the 20-m isobaths are not uncommon in Tillamook County. To calculate the wave runup along the County's shoreline, we subsequently extracted the wave characteristics along the 20-m contour, or the seawardmost location where the wave breaking parameter equaled 0.4, throughout the model domain (**Figure 5-28**, right panel). Because all of the parametric runup models used in this study rely on information on the deepwater equivalent wave height and peak periods as inputs, we then computed the linear wave theory shoaling coefficient and back shoaled our transformed waves to deep water. These transformed deepwater equivalent waves were then used to calculate the wave runup and generate the TWL conditions used in the subsequent extreme value analysis.

To confirm that our approach of interpolating wave transformations using lookup tables yields acceptable results, we ran several additional SWAN runs that were not part of our original matrix. These additional runs extended across a range of conditions, including extreme events capable of forcing high water levels at the coast. We then compared the results from using the lookup tables to these additional direct SWAN computations at the 20-m contour location. **Figure 5-29**, **Figure 5-30**, and **Figure 5-31** show a sample of these results for wave heights, peak periods, and directions, respectively, for a SWAN run driven with an offshore boundary condition of $H_s$ = 11.5, $T_p$ = 18.5, $D_p$ = 320, and a water level of 4.5 m NAVD88. In all cases, the percentage error between the lookup table and direct computation is low, averaging well less than 5 percent. In only a few locations, near model boundaries or inlets, are the errors significant. None of the transects analyzed in detail for extreme flooding later in this report are near those problem locations.

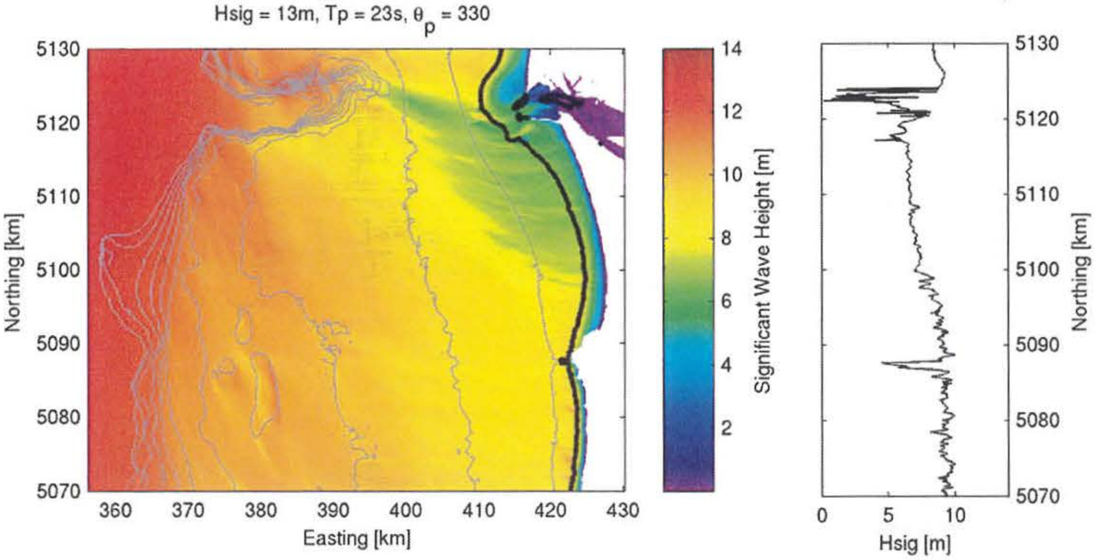

**Figure 5-28.** Example SWAN simulation, for an offshore significant wave height 13 m, peak wave period 23 s, and peak wave direction of 330°. Left) Significant wave height in the modeling domain is shown in colors. Dissipation processes result in reduced wave height. Contour lines are drawn from 50 to 500 m every 50 m in grey and every 20 m in black. Right) Modeled significant wave height extracted at 20-m water depth.

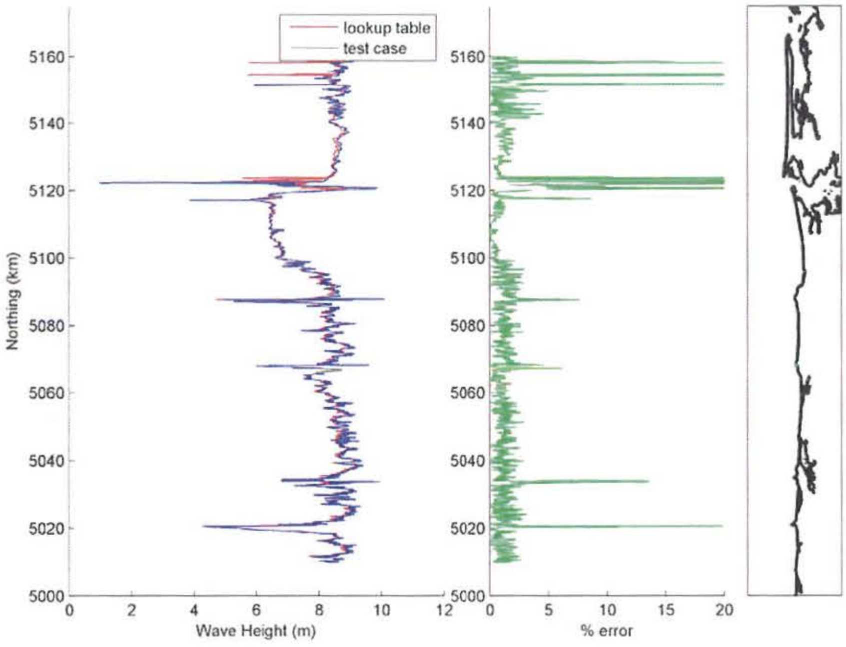

**Figure 5-29.** Comparison of alongshore varying wave height at the 20-m contour extracted from the lookup tables (red line) and from a direct SWAN computation (blue line) with an offshore boundary condition characterized as $H_s$ = 11.5, $T_p$ = 18.5, $D_p$ = 320, and a water level of 4.5 m NAVD88.

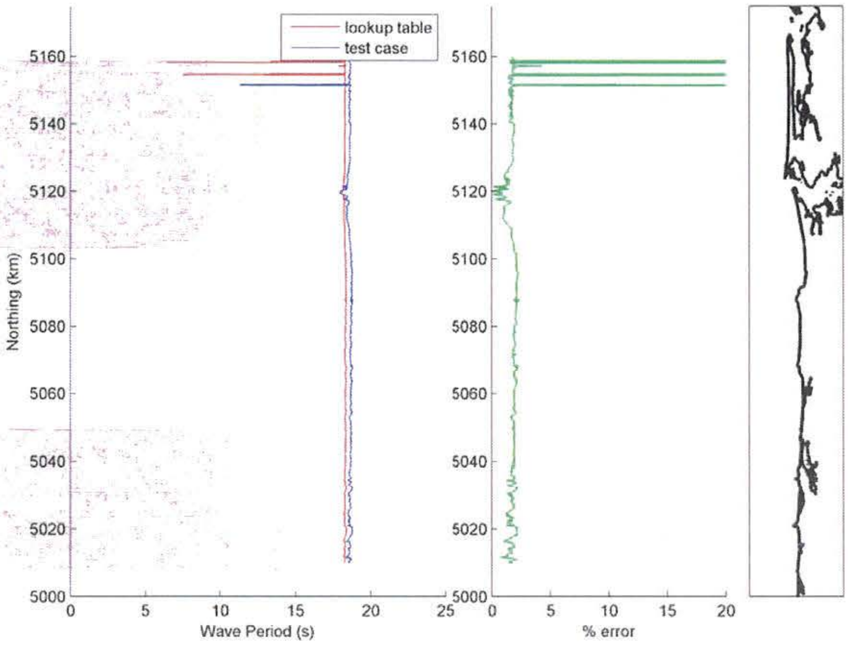

**Figure 5-30.** Comparison of alongshore varying wave period at the 20-m contour extracted from the lookup tables (red line) and from a direct SWAN computation (blue line) with an offshore boundary condition characterized as $H_s$ = 11.5, $T_p$ = 18.5, $D_p$ = 320, and a water level of 4.5 m NAVD88.

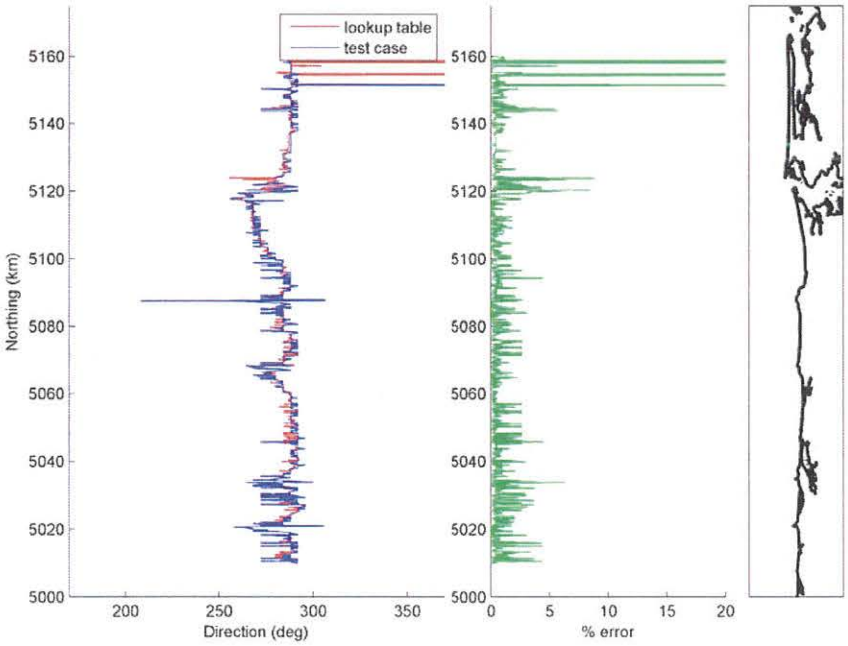

**Figure 5-31.** Comparison of alongshore varying wave direction at the 20-m contour extracted from the lookup tables (red line) and from a direct SWAN computation (blue line) with an offshore boundary condition characterized as $H_s$ = 11.5, $T_p$ = 18.5, $D_p$ = 320, and a water level of 4.5 m NAVD88.

# 6.0 WAVE RUNUP AND OVERTOPPING

Wave runup is the culmination of the wave breaking process whereby the swash of the wave above the still water level is able to run up the beach face, where it may encounter a dune, structure, or bluff, potentially resulting in the erosion or in overtopping and flooding of adjacent land (**Figure 6-1**). Runup, *R*, or wave setup plus swash, is generally defined as the time-varying location of the intersection between the ocean and the beach and, as summarized, is a function of several key parameters. These include the deepwater wave height ($H_o$ or $H_s$), peak spectral wave period ($T_p$) and the wave length ($L_o$) (specifically the wave steepness, $H_o/L_o$), and through a surf similarity parameter called the Iribarren number,

$$\xi_o = \frac{\beta}{\sqrt{H_o/L_o}},$$

which accounts for the slope ($\beta$) of a beach or an engineering structure, as well as the steepness of the wave.

The total runup, *R*, produced by waves includes three main components:

- wave setup, $\overline{\eta}$;
- a dynamic component to the still water level, $\widehat{\eta}$; and
- incident wave swash, $S_{inc}$

$$R = \overline{\eta} + \widehat{\eta} + S_{inc} \qquad (6.1)$$

Along the Pacific Northwest Coast of Oregon and Washington, the dynamic component of still water level, $\widehat{\eta}$, has been demonstrated to be a major component of the total wave runup due to relatively high contributions from infragravity energy (Ruggiero and others, 2004). This process occurs due to a transfer of energy from the incident wind-generated waves to the longer-period infragravity wave energy, the division being placed at ~20-s periods. On the dissipative beaches of the Oregon coast, it is the infragravity energy that increases swash runup levels during major storms that is ultimately responsible for erosion and overwash events. The combination of these processes produces "sneaker waves," yielding the most extreme swash runup levels.

A variety of models have been proposed for calculating wave runup on beaches (Ruggiero and others, 2001; Hedges and Mase, 2004; Northwest Hydraulic Consultants, 2005; Stockdon and others, 2006). Here we explore two approaches available for runup calculations along Tillamook County, Oregon. These included the runup model developed by Stockdon and others (2006) and the direct integration method (DIM) described in NHC (2005).

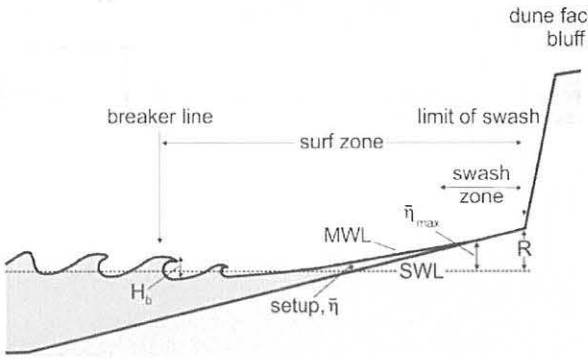

**Figure 6-1. Conceptual model showing the components of wave runup associated with incident waves (modified from Hedges and Mase, 2004).**

## 6.1 Runup Models for Beaches

### *6.1.1 Stockdon Runup Model*

For sandy beaches, Stockdon and others (2006) developed an empirical model based on analyses of 10 experimental runup data sets obtained from a wide variety of beach and wave conditions, including data from Oregon (Ruggiero and others, 2004), and by separately parameterizing the individual runup processes: setup and swash. Stockdon and others (2006) proposed the following general relationship for the elevation of the 2% exceedance elevation of swash maxima, $R_2$, for any data run:

$$R_2 = 1.1[\overline{\eta} + \frac{S}{2}] \qquad (6.2)$$

where:

$$S = \sqrt{(S_{inc})^2 + (\widehat{\eta})^2} \qquad (6.3)$$

and:

$$\overline{\eta}, S_{inc}, \widehat{\eta} = f(H_o, T_o, \beta_f)$$

where $\beta_f$ is the slope of the beach face, and $S$ reflects both the dynamic, $\widehat{\eta}$, and incident swash, $S_{inc}$, components. The 1.1 coefficient value was determined because the swash level assumes a slightly non-Gaussian distribution. The final parameterized runup equation is:

$$R_{2\%} = 1.1\left(0.35 \tan\beta \, (H_o L_o)^{\frac{1}{2}} + \frac{[H_o L_o(0.563 \tan\beta^2 + 0.004)]^{\frac{1}{2}}}{2}\right) \qquad (6.4)$$

which may be applied to natural sandy beaches over a wide range of morphodynamic conditions. In developing equation 6.4, Stockdon and others (2006) defined the slope of the beach as the average slope over a region ±2$\sigma$ around the wave setup, $\overline{\eta}$, where $\sigma$ is the standard deviation of the continuous water level record, $\eta(t)$. Simply put, the setup reflects the height of the mean-water level (MWL) excursion above the SWL, such that the slope is determined to span the region around this MWL. For Tillamook County, the slope of the beach was determined by fitting a linear regression through those data points spanning the region located between 2 and 4 m.

Combining equation 6.4 with the measured water level at tide gauges produces the total water level (TWL) at the shore, important for determining the erosion or flood risk potential. Given that equation 6.4 has been derived from quantitative runup measurements spanning a range of beach slopes (beach slopes ranged from 0.01 to 0.11 and Iribarren numbers [$\xi$] ranged from 0.1 [fully dissipative conditions] to ~2.2 [reflective conditions], Table 1 of Stockdon and others [2006]), the model is valid for the range of slopes and conditions observed along the Tillamook County coastline and elsewhere on the Oregon coast.

### *6.1.2 Direct integration method—beaches*

The FEMA coastal flood mapping guidelines (NHC, 2005) for the U.S. West Coast presents an alternative method for calculating runup. According to NHC (2005), the direct integration method (DIM) approach allows for the wave and bathymetric characteristics to be taken into consideration; specifically, the spectral shape of the waves and the actual bathymetry can be represented. Here we review the parameterized set of runup equations that may be used to calculate runup on beaches. The equations are based on a parameterized JONSWAP spectra and uniform beach slopes.

Similar to equation 6.1, the runup of waves using DIM can be defined according to its three components: the wave setup, $\overline{\eta}$, a dynamic component, $\widehat{\eta}$, and the incident band swash, $S_{inc}$. Wave setup can be calculated using:

$$\overline{\eta} = 4.0\ F_H F_T F_{Gamma} F_{slope} \quad (6.5)$$

while the root mean square (rms) of the dynamic component, $\widehat{\eta}_{rms}$, may be estimated using:

$$\widehat{\eta}_{rms} = 2.7\ G_H G_T G_{Gamma} G_{slope} \quad (6.6)$$

where the units of $\overline{\eta}$ and $\widehat{\eta}_{rms}$ are in *feet* and the factors ($F$) are for the wave height ($F_H$ and $G_H$), wave period ($F_T$ and $G_T$), JONSWAP spectrum narrowness ($F_{Gamma}$ and $G_{Gamma}$), and the nearshore slope ($F_{slope}$ and $G_{slope}$). These factors are summarized as a series of simple equations in Table D.4.5-1 (NHC, 2005). For the purposes of defining an average slope, NHC recommended that the nearshore slope be based on the region between the runup limit and twice the wave breaking depth, $h_b$, where:

$$h_b = H_b/k \quad (6.7)$$

and

$$H_b = 0.39 g^{0.2}\left(T_p H_o^2\right)^{0.4} \quad (6.8)$$

where $H_b$ is the breaker height calculated using equation 6.8 (Komar, 1998b), $g$ is acceleration due to gravity (9.81 m/s), and for the purposes here $k$ (breaker depth index) can be taken to be 0.78. Thus, one important distinction between the DIM and Stockdon methods for calculating runup is the method used to define the beach slope; the former accounts for a larger portion of the nearshore slope, while the latter is based on the slope calculated around the mid beach-face.

To derive the statistics of the oscillating wave setup and the incident swash components, the recommended approach is to base the calculations on the standard deviations ($\sigma$) of each component. The standard deviation of the incident wave oscillation ($\sigma_2$) on natural beaches may be calculated from:

$$\sigma_2 = 0.3\xi_o H_o \quad (6.9)$$

Because the standard deviation of the wave setup fluctuations ($\sigma_1$) is proportional to equation 6.6, the total oscillating component of the dynamic portion of the wave runup can be derived from:

$$\widehat{\eta_T} = 2.0\sqrt{\sigma_1^2 + \sigma_2^2} \quad (6.10)$$

Combining the results of equations 6.10 and 6.5 yields the 2% wave runup, and when combined with the tidal component results in the TWL.

### *6.1.3 Comparison between the Stockdon and DIM runup calculations*

Fundamentally, the wave runup model proposed by Stockdon and others (2006) and the DIM method described in NHC (2005) are similar, because both models account for the three components of runup described in equation 6.1. Here we examine the runup results derived from both models based on a range of conditions characteristic of the Clatsop shore (**Figure 6-2** and **Figure 6-3**). We focus on our results from Clatsop, because this is where we first tested both approaches, before settling on one approach for calculating all subsequent runup for the Oregon coast.

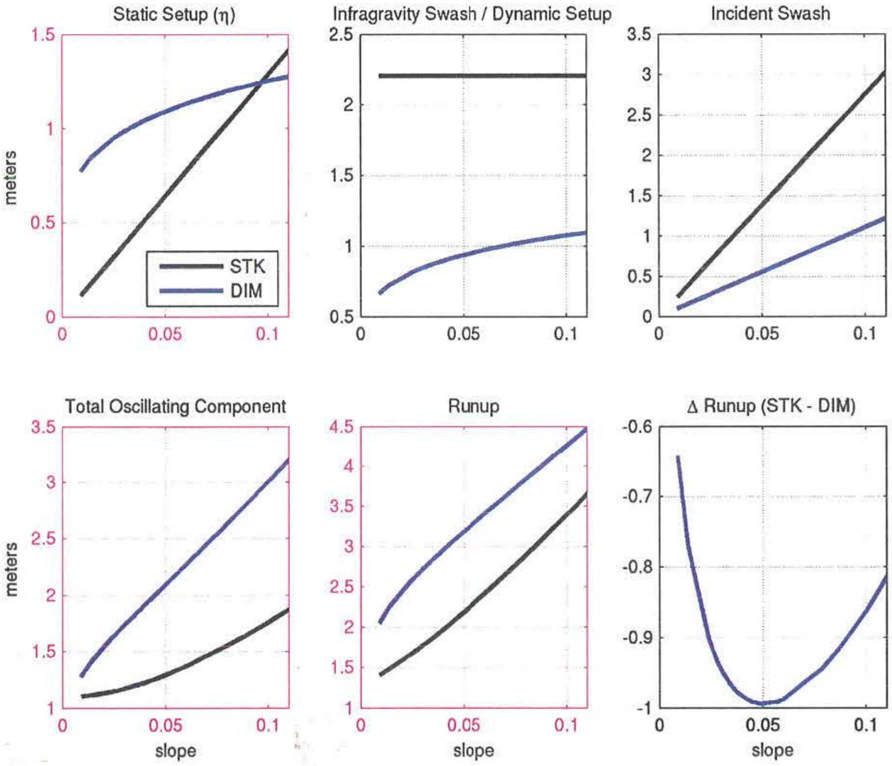

**Figure 6-2. Calculated setup, swash and runup using the Stockdon and DIM runup equations. In this example, slope values are defined similarly for both methods, at a mid-beach elevation range of 2–4 m (6.6–13 ft). A 6-m (19.7 ft) significant wave height, 12-s peak wave period, and 270° wave direction were used to drive the models. Due to the semi-empirical nature of the equations, only the magnitudes of the subplots outlined in magenta are directly comparable (the two panels showing swash results are not directly comparable). The total oscillating component compares the results from equation 6.3 (S/2) with equation 6.10.**

**Figure 6-2** provides a comparison of the various calculated parameters (setup, infragravity swash, incident swash, total oscillating component, and runup) determined using the Stockdon and DIM approaches. In this example, we use the same slope defined for the mid-beach region in order to provide a direct comparison between DIM and Stockdon. Upper estimates have been truncated to $\tan \beta = 0.11$, which reflects the slope limit on which Stockdon has been tested. In contrast, it is unclear the range of slope conditions on which DIM may be applied as there is no quantitative field testing of this particular formulation. As can be seen in **Figure 6-2**, although there are notable differences in the various parameterizations, the derived runup (bottom, middle plot) is similar. Nevertheless, as can be seen from the $\Delta R$ plot (bottom right), the DIM approach tends to estimate a slightly higher runup when compared to Stockdon, which in this example reaches a maximum of ~1 m (3.3 ft) for a beach slope of 0.04 to 0.05. Thus, overall, we can conclude that the two approaches are performing in a similar fashion when tested using the same slope.

**Figure 6-3** presents a similar suite of comparisons under the same hydrodynamic conditions. Therefore the Stockdon and others (2006) results are identical to **Figure 6-2** in all panels. However, in this example we now account for the appropriate nearshore slope in the DIM runup calculations as defined above in Section 6.1.2. This was originally done by computing the DIM runup components for this hydrodynamic condition using the full nearshore slope at 85 transects spread along the Clatsop County coastline (Allan and others, 2014). The DIM values are, however, plotted against the foreshore beach slopes defined for all 85 transects in order to make the comparisons with Stockdon meaningful. As can be seen in **Figure 6-3**, application of the nearshore slope significantly changes the magnitudes of all the runup components and, in particular, reduces the calculated runup when compared to Stockdon for most foreshore slopes. In general, at lower slopes ($\tan \beta < 0.05$) runup calculated by DIM is slightly higher than Stockdon, which reverses at steeper slopes ($\tan \beta > 0.05$). This pattern is consistent with analyses performed by Allan and others (2012) in Coos County.

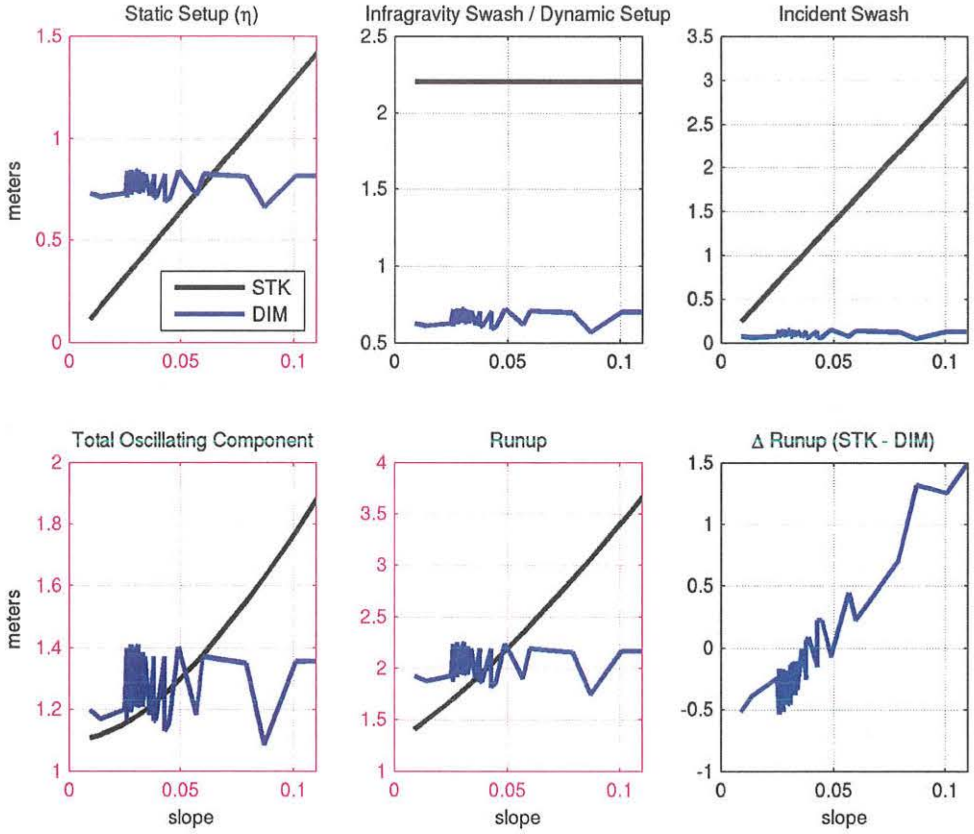

**Figure 6-3. Total water level calculations using the Stockdon (foreshore slope) and DIM runup equations (nearshore slope). A 6-m (19.7-ft) significant wave height, 12-s peak wave period, and 270° wave direction were used to drive the models. Due to the semi-empirical nature of these equations only the magnitudes of the subplots outlined in magenta are directly comparable. The results for DIM are sorted in ascending order as a function of foreshore beach slope.**

Most interesting in the comparisons shown in **Figure 6-3**, is that the DIM runup components actually do not vary as a function of the foreshore slope. The total runup **Figure 6-3**, bottom center) produced by DIM is relatively constant, oscillating between 1.7 and 2.3 m (5.6 and 7.5 ft). The oscillations are due primarily to the variability in the nearshore slopes, which are a function of wave height (equations 6.7 and 6.8). Because waves in the PNW are relatively large and upper shoreface slopes are relatively shallow, the DIM runup values are controlled by the nearshore slope with little influence from the upper beach. This lack of dependence on the foreshore is in contrast to field measurements made in Oregon (Ruggiero and others, 2004) in which runup is clearly a function of the foreshore slope. Because the Stockdon model has been extensively validated against measured runup data, including measurements on the Oregon coast (e.g., Ruggiero and others, 2001; Ruggiero and others, 2004) together with qualitative observations of runup during storms by DOGAMI staff at multiple sites along the coast, 1% extreme values of TWLs calculated for sandy beaches along the Tillamook County coast will be based primarily on the Stockdon and others (2006) model.

## 6.2 "Barrier" Runup Calculations

### *6.2.1 Introduction*

According to NHC (2005) an alternate approach is recommended for use in calculating runup on steep barriers. By definition, *barriers include "steep dune features and coastal armoring structures such as revetments"* (NHC, 2005, p. D.45-10), although little guidance is offered in terms of the range of slopes to which this alternate approach would apply. Throughout this document we use the generic term *barrier* to define the range of morphological and engineering conditions where barrier runup calculations may apply. In general, runup on barriers depends not only on the height and steepness of the incident waves defined through the Iribarren number or breaker parameter ($\xi_{m-1,0}$) but also on the geometry (e.g., the slope of the barrier and/or if a berm is present), design characteristics of the structure, and its permeability.

The recommended approach for calculating runup on barriers is to use the TAW (Technical Advisory Committee for Water Retaining Structures) method, which provides a mechanism for calculating the runup, adjusted for various reduction factors that include the surface roughness, the influence of a berm (if present), and effects associated with the angle of wave approach (van der Meer, 2002; Northwest Hydraulic Consultants, 2005; Pullen and others, 2007). According to NHC (2005) the TAW method is useful as it includes a wide range of conditions for calculating the wave runup (e.g., both smooth and rough slopes) and because it agrees well with both small- and large-scale experiments.

**Figure 6-4** is a conceptual model of the various components required to determine the extent of runup on barriers. Of importance is first determining the 2% dynamic water level ($DWL_{2\%}$) at the barrier, which includes the combined effects of the measured still water level (SWL), the wave setup ($\overline{\eta}$) and the dynamic portion ($\hat{\eta}$) of the runup (**Figure 6-4**), which is then used to establish the spectral significant wave height ($H_{mo}$) at the toe of the "barrier" (NHC, 2005).

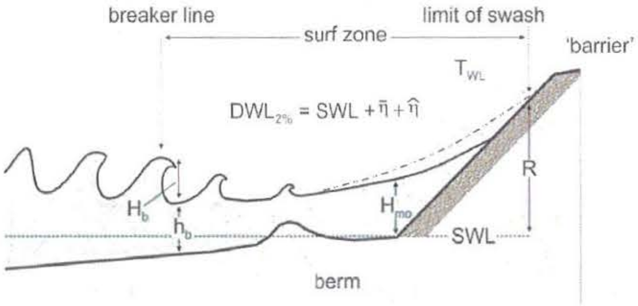

**Figure 6-4. Wave runup on a beach backed by a structure or bluff (modified from NHC, 2005).**

The general formula for calculating the 2% wave runup height on barriers is given in a non-dimensional form by equation 6.11:

$$\frac{R_{2\%}}{H_{mo}} = c_1 . \gamma_b . \gamma_f . \gamma_\beta . \xi_{m-1,0} \qquad (6.11)$$

with a maximum of:

$$\frac{R_{2\%}}{H_{mo}} = \gamma_f . \gamma_\beta \left( c_2 - \frac{c_3}{\sqrt{\xi_{m-1,0}}} \right)$$

where:

$R_{2\%}$ = wave runup height exceeded by 2% of the incoming waves

$H_{mo}$ = spectral significant wave height at the structure toe

$c_1$, $c_2$, and $c_3$ = empirical coefficients with:

$\gamma_b$ = influence factor for a berm (if present),

$\gamma_f$ = influence factor for roughness element of slope,

$\gamma_\beta$ = influence factor for oblique wave attack,

$\xi_{m-1,0}$ = breaker parameter

$$\left( \tan \beta / \left( \frac{H_{mo}}{L_{m-1,0}} \right)^{0.5} \right),$$

$\tan \beta$ = slope of the "barrier,"

$L_{m-1,0}$ = the deepwater wave length $\left( gT_{m-1,0}^2 / 2\pi \right)$, and

$T_{m-1,0}$ can be calculated from $T_p/1.1$, where $T_p$ is the peak spectral wave period.

Substituting the empirical coefficients derived from wave tank experiments and incorporating a 5% upper exceedance limit into the general equations of 6.11 (van der Meer, 2002; Pullen and others, 2007), runup on barriers may be calculated by using:

$$R_{2\%} = H_{mo}\left(1.75 . \gamma_b . \gamma_f . \gamma_\beta . \xi_{m-1,0}\right), \quad \text{where } 0 < \gamma_b . \xi_{m-1,0} < 1.8 \qquad (6.12)$$

with a maximum of:

$$R_{2\%} = H_{mo}\left( 1.0 . \gamma_f . \gamma_\beta \left( 4.3 - \frac{1.6}{\sqrt{\xi_{m-1,0}}} \right) \right), \mathit{where}\ \gamma_b . \xi_{m-1,0} \geq 1.8$$

There are, however, notable differences between equation 6.12 originally described by van der Meer (2002) and Pullen and others (2007) from that presented in equation D.4.5-19 in the FEMA West Coast methodology (NHC, 2005). For example, equation D.4.5-19 in the NHC report contains a higher coefficient value (1.77), along with one additional reduction factor (porosity) for calculating runup when the breaker parameter is less than 1.8. Similarly, for conditions where the breaker parameter exceeds 1.8 and the maximum runup equation is used, equation D.4.5-19 in the NHC report contains two extra reduction factors (berm and porosity reduction factors) that are not included in the original solution, which potentially could have a very significant effect on the calculated runup. Based on these differences, we have used the original solution presented as equation 6.12 in van der Meer (2002) and Pullen and others (2007).

### *6.2.2 Specific procedure for calculating "barrier" runup*

For those cases where the TAW method is used for determining runup on barriers (i.e., beaches backed by structures, cobble berms, and/or bluffs), we have followed the general approach laid out in section D.4.5.1.5.2 in NHC (2005), with the exception that we use Stockdon to define the $DWL_{2\%}$ (instead of DIM) at the structure toe, and TAW to calculate the incident swash on the barrier (i.e., equation 6-12). Because waves are depth limited at the barrier toe, $H_{mo}$ may be estimated from $DWL_{2\%}$ using a breaker index of 0.78 (i.e., $H_{mo} = DWL_{2\%} * 0.78$). In performing these various derivations, $DWL_{2\%}$ was first determined using equation 6.13:

$$DWL_{2\%} = SWL + 1.1 * \left(\overline{\eta} + \frac{\widehat{\eta}}{2}\right) - D_{low} \qquad (6.13)$$

where:

SWL = measured tide

$\overline{\eta} = 0.35 * \tan\beta\sqrt{H_s * L}$ *Eqn. 10 in Stockdon and others (2006)*

$\widehat{\eta} = 0.06 * \sqrt{H_s * L}$ *Eqn. 12 in Stockdon and others (2006)*

$D_{low}$ = the toe of the structure or bluff
$\tan\beta$ = the beach slope defined for the region between 2 and 4 m.

Having calculated $DWL_{2\%}$ and $H_{mo}$, the TAW runup calculation can be implemented. Equation 6.12 requires information on the slope of the barrier, used in the breaker parameter ($\xi_{m-1,0}$) calculation, which can be somewhat challenging to define. This is especially the case if the morphology of the barrier exhibits a composite morphology characterized by different slopes, such that errors in estimating the slope will translate to either significant underestimation or overestimation of the runup. According to van der Meer (2002) and Pullen and others (2007), because the runup process is influenced by the change in slope from the breaking point to the maximum wave runup, the characteristic slope should be specified for this same region. On the Oregon coast, the most common composite slope example is the case where a broad, dissipative sand beach fronts a structure or bluff that is perched relatively high on the back of the beach (structure toe > ~4-5 m). In this example, the wave runup is first influenced by the sandy beach slope and finally by the slope of the structure itself. To address this type of situation, we define a "local barrier slope" as the portion of the barrier that ranges from the calculated storm TWL (calculated initially using equation 6.4) down to a lower limit defined by the wave setup plus the SWL [i.e., $(1.1 * \overline{\eta}) + SWL$]). In a few cases, the TWL was found to exceed the barrier crest; in those cases we used the structure crest as the upper limit for defining the local slope. This process is repeated for every storm condition. Having determined the barrier slope, the TAW runup is calculated using equation 6.12 and reduced based on the appropriate site specific reduction factors.

Under certain conditions, we identified events that generated extreme runup that made little physical sense. For these (rare) cases, we calculated the TAW runup using an iterative approach based on procedures outlined in the Eurotop (2007) manual. Because the maximum wave runup is the desired outcome and is unknown when initially defining the slope, the process is iterative requiring two steps. First, the breaking limit is defined as $1.5H_{mo}$ *below* the SWL, while $1.5H_{mo}$ *above* the SWL defines the upper limit of the first slope estimate (**Figure 6-5**). Having determined the first slope estimate, the TAW runup is calculated using equation 6.12 and reduced based on the appropriate reduction factors. A second slope estimate is then performed based on the initial runup calculation, while a third iteration is not necessary based on our tests because this method converges quickly. The breaking limit is again defined as $1.5H_{mo}$ *below* the SWL, while $R_{2\%}$ *above* the SWL defines the upper limit, and the final barrier runup estimate is again calculated using equation 6.12 and reduced based on the appropriate reduction factors.

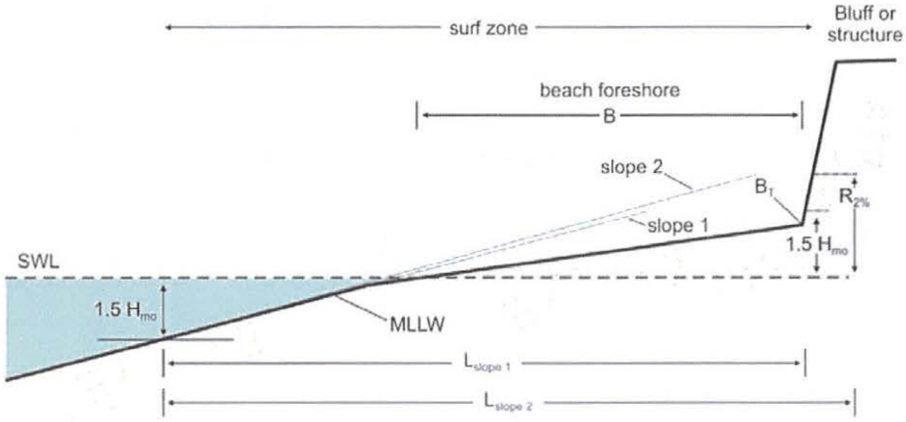

**Figure 6-5.** **Determination of an average slope based on an iterative approach. The first estimate is initially based on $1.5H_{mo}$ ±SWL, while the second estimate is based on $1.5H_{mo}$ below the SWL and the calculated $R_{2\%}$ above the SWL that is based on the first slope estimate.**

Finally, it is important to note that the runup estimates based on the "barrier" runup calculations is sensitive to the slope. Similar to our study in Coos and Clatsop counties, we identified several sites (primarily beaches backed by bluffs) along the Tillamook coast where the final TWLs calculated using TAW was unreasonably low. These few cases are entirely due to there being a very wide dissipative surf zone at these transect locations that results in very low slopes being defined. For these sites where the calculated $TWL_S$ seemed unreasonably low (relative to the morphology of the beach and observations of storm wave runup along this shore and elsewhere), we have defaulted to the TWLs calculated using the Stockdon and others model.

### 6.2.3 "Barrier" runup reduction factors

**Table 6-1** below presents information pertaining to the suite of parameters used to define wave runup (R) and ultimately the 1% TWLs along the Tillamook County coast. In the case of bluff roughness along the Tillamook shore, we used a value of 0.6 for those situations where a bluff face was highly vegetated. These bluffs are typically located at or near their stable angle of repose and are covered with Salal plants (*Gaultheria shallon*), forming a deep, nearly impenetrable thicket. The decision to use 0.6 was based on discussions with Dr. W. G. McDougal (Coastal Engineer, OSU, and Technical Coordinator of the North Pacific FEMA West Coast Guidelines, pers. comm., April 2010). At the Tillamook transects 26–28, 43–44, 46, 67–74, 94–96, and 104 (**Table 6-1**), the reduction factor was set to 1 due to the fact that these beaches were backed by a near-vertical bluff face that was essentially akin to a seawall situation. For those beaches backed by a significant riprap structure, we used a reduction factor of 0.55. In other cases, this was increased to 0.6 to 0.8, depending on whether the beach was backed by gravels/cobbles, a vegetated bluff face, or poor quality riprap. Wave direction $(\gamma_\beta)$ reduction factors were determined based on the shoreline orientation at every transect site and the actual wave directions measured during each storm condition. The reduction factor was calculated using equation D.4.5-22 of NHC (2005, p. D.4.5-13). Finally, because none of the transects where structures are present contained a protective berm, no berm reduction factor was adopted for Tillamook County.

**Table 6-1. Parameters used to define runup ($R$) and total water levels (TWLs) on beaches backed by dunes, structures, and bluffs.**

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | Beach Slope (tan β) | Wave Dir. ($\gamma_\theta$) | Roughness ($\gamma_r$) | Approach | Description |
|---|---|---|---|---|---|---|---|---|---|
| Salmon River | LINC 308 | 1 | 6.251 | 5.058 | 0.084 | 272.2 | 1.0 | 3 | dune-backed cliff |
| Cascade Head | LINC 309 | 2 | 48.172 | 1.609 | 0.027 | 268.8 | 0.95 | 1 | plunging cliff |
| | LINC 310 | 3 | 43.56 | 1.207 | 0.028 | 274.1 | 0.95 | 1 | plunging cliff |
| | LINC 311 | 4 | 24.427 | 0.358 | 0.022 | 270.3 | 0.8 | 1 | boulder beach backed by bluffs |
| | LINC 312 | 5 | 93.24 | 2.125 | 0.026 | 271.8 | 0.95 | 1 | plunging cliff |
| | LINC 313 | 6 | 139.1 | 0 | 0.023 | 273.7 | 0.95 | 1 | plunging cliff |
| Neskowin | TILL 1 | 7 | 47.278 | 0.764 | 0.025 | 294.5 | 0.55 | 1 | sandy beach backed by riprap and high cliffs |
| | TILL 2 | 8 | 8.684 | 3.914 | 0.045 | 294 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 3 | 9 | 8.452 | 3.914 | 0.042 | 287.1 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 4 | 10 | 5.184 | 3.448 | 0.018 | 283.3 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 5 | 11 | 8.312 | 2.712 | 0.049 | 267.3 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 6 | 12 | 8.447 | 3.563 | 0.073 | 275.6 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 7 | 13 | 8.169 | 1.904 | 0.062 | 284.3 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 8 | 14 | 8.539 | 2.533 | 0.062 | 286.8 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 9 | 15 | 7.075 | 5.888 | 0.06 | 286.7 | 1.0 | 3 | dune-backed |
| | TILL 10 | 16 | 8.897 | 6.235 | 0.054 | 285.1 | 1.0 | 3 | dune-backed |
| | TILL 11 | 17 | 6.679 | 5.604 | 0.041 | 282.9 | 1.0 | 3 | dune-backed |
| | TILL 12 | 18 | 8.374 | 5.521 | 0.044 | 281 | 1.0 | 3 | dune-backed |
| | TILL 13 | 19 | 7.126 | 5.709 | 0.049 | 273.3 | 1.0 | 3 | dune-backed |
| | TILL 14 | 20 | 8.118 | 5.086 | 0.099 | 282.3 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 15 | 21 | 7.587 | 4.642 | 0.069 | 272.4 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 16 | 22 | 6.767 | 6.014 | 0.052 | 277 | 1.0 | 3 | dune-backed |
| | TILL 17 | 23 | 9.986 | 4.326 | 0.039 | 283.7 | 1.0 | 3 | dune-backed |
| | TILL 18 | 24 | 8.387 | 5.512 | 0.074 | 284.4 | 1.0 | 3 | dune-backed |
| | TILL 19 | 25 | 6.014 | 6.014 | 0.059 | 285.4 | 1.0 | 3 | dune-backed |
| | TILL 20 | 26 | 7.648 | 7.066 | 0.098 | 284.5 | 1.0 | 3 | dune-backed |
| | TILL 21 | 27 | 12.562 | 5.582 | 0.049 | 287.1 | 1.0 | 3 | dune-backed |
| | TILL 22 | 28 | 6.241 | 4.489 | 0.034 | 283.2 | 1.0 | 3 | dune-backed |
| | TILL 23 | 29 | 14.334 | 6.819 | 0.088 | 280.2 | 1.0 | 3 | dune-backed |
| | TILL 24 | 30 | 7.792 | 7.185 | 0.06 | 278 | 1.0 | 3 | dune-backed |
| | TILL 25 | 31 | 7.642 | 5.627 | 0.061 | 278.3 | 1.0 | 3 | dune-backed |
| | **TILL 26** | **32** | **32.562** | **3.877** | **0.059** | **278.6** | **1.0** | **2** | **sandy beach backed by high cliffs** |
| | **TILL 27** | **33** | **28.194** | **4.519** | **0.088** | **281.5** | **1.0** | **2** | **sandy beach backed by high cliffs** |
| | **TILL 28** | **34** | **39.31** | **6.292** | **0.084** | **281.1** | **1.0** | **2** | **sandy beach backed by dunes and high cliffs** |
| Nestucca spit/ Pacific City | TILL 29 | 35 | 10.245 | 4.903 | 0.043 | 273.2 | 1.0 | 3 | dune-backed |
| | TILL 30 | 36 | 14.485 | 5.083 | 0.048 | 273.8 | 1.0 | 3 | dune-backed |
| | TILL 31 | 37 | 15.49 | 5.933 | 0.061 | 276.6 | 1.0 | 3 | dune-backed |
| | TILL 32 | 38 | 14.358 | 5.413 | 0.093 | 277 | 1.0 | 3 | dune-backed |
| | TILL 33 | 39 | 13.16 | 5.338 | 0.072 | 270.9 | 1.0 | 3 | dune-backed |
| | TILL 34 | 40 | 15.877 | 6.611 | 0.086 | 271.1 | 1.0 | 3 | dune-backed |
| | TILL 35 | 41 | 15.147 | 5.312 | 0.05 | 270 | 1.0 | 3 | dune-backed |
| | TILL 36 | 42 | 17.709 | 5.908 | 0.051 | 268.7 | 1.0 | 3 | dune-backed |
| | TILL 37 | 43 | 12.932 | 4.389 | 0.051 | 266.5 | 0.55 | 1 | sand beach backed by riprap? |
| | TILL 38 | 44 | 11.283 | 4.69 | 0.053 | 264 | 0.55 | 1 | sand beach backed by riprap? |
| | TILL 39 | 45 | 18.954 | 5.407 | 0.041 | 262.2 | 1.0 | 3 | dune-backed |
| | TILL 40 | 46 | 11.314 | 5.539 | 0.057 | 261.1 | 0.55 | 3 | sand beach backed by riprap? |
| | TILL 41 | 47 | 11.06 | 4.785 | 0.039 | 262.9 | 0.55 | 3 | sand beach backed by riprap? |
| | TILL 42 | 48 | 13.304 | 4.681 | 0.043 | 262.8 | 0.6 | 1 | sand beach backed by riprap and high bluffs |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | Beach Slope (tan β) | Wave Dir. ($Y_{\theta}$) | Rough-ness ($Y_r$) | Approach | Description |
|---|---|---|---|---|---|---|---|---|---|
| **Sand Lake/ Tierra Del Mar** | **TILL 43** | **49** | **23.369** | **5.582** | **0.046** | **281.8** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | **TILL 44** | **50** | **16.741** | **6.162** | **0.075** | **281.3** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | TILL 45 | 51 | 6.868 | 4.232 | 0.042 | 280.2 | 0.6 | 1 | sandy beach backed by cobbles - grades into bluff |
| | **TILL 46** | **52** | **18.071** | **4.865** | **0.055** | **280.8** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | TILL 47 | 53 | 18.396 | 4.063 | 0.045 | 279.7 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 48 | 54 | 7.412 | 6.555 | 0.048 | 279.8 | 1.0 | 3 | dune-backed |
| | TILL 49 | 55 | 8.24 | 6.197 | 0.044 | 279.7 | 1.0 | 3 | dune-backed |
| | TILL 50 | 56 | 6.931 | 5.891 | 0.041 | 290.1 | 1.0 | 3 | dune-backed |
| | TILL 51 | 57 | 6.317 | 4.554 | 0.05 | 278.7 | 0.8 | 1 | sand beach backed by riprap |
| | TILL 52 | 58 | 7.721 | 4.543 | 0.055 | 278.8 | 0.8 | 1 | sand beach backed by riprap |
| | TILL 53 | 59 | 8.141 | 5.026 | 0.056 | 280.3 | 0.6 | 1 | sand beach backed by riprap |
| | TILL 54 | 60 | 7.462 | 5.055 | 0.058 | 269.7 | 0.6 | 1 | sand beach backed by riprap |
| | TILL 55 | 61 | 8.094 | 5.159 | 0.045 | 283.1 | 1.0 | 3 | dune-backed |
| | TILL 56 | 62 | 8.357 | 4.652 | 0.046 | 278.7 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 57 | 63 | 11.383 | 4.823 | 0.04 | 284.8 | 0.55 | 3 | sand beach backed by riprap |
| | TILL 58 | 64 | 10.224 | 6.18 | 0.042 | 278.7 | 1.0 | 3 | dune-backed |
| | TILL 59 | 65 | 12.153 | 5.72 | 0.052 | 278.4 | 1.0 | 3 | dune-backed |
| | TILL 60 | 66 | 9.595 | 5.355 | 0.041 | 278.4 | 1.0 | 3 | dune-backed |
| | TILL 61 | 67 | 9.37 | 6.193 | 0.048 | 279.3 | 1.0 | 3 | dune-backed |
| | TILL 62 | 68 | 6.573 | 6.26 | 0.052 | 279.1 | 1.0 | 3 | dune-backed |
| | TILL 63 | 69 | 3.38 | 3.324 | 0.009 | 273.1 | 1.0 | 3 | dune-backed |
| | TILL 64 | 70 | 18.524 | 6.915 | 0.111 | 270.7 | 1.0 | 3 | dune-backed |
| | TILL 65 | 71 | 18.296 | 5.556 | 0.053 | 270.7 | 1.0 | 3 | dune-backed |
| | TILL 66 | 72 | 15.211 | 5.34 | 0.049 | 271.5 | 1.0 | 3 | dune-backed |
| | **TILL 67** | **73** | **19.042** | **8.385** | **0.069** | **272.4** | **1.0** | **3** | **sandy beach backed by high cliffs** |
| | **TILL 68** | **74** | **24.72** | **6.441** | **0.044** | **270.6** | **1.0** | **3** | **sandy beach backed by high cliffs** |
| | **TILL 69** | **75** | **29.519** | **5.96** | **0.051** | **268.7** | **1.0** | **3** | **sandy beach backed by high cliffs** |
| | **TILL 70** | **76** | **30.293** | **4.588** | **0.045** | **266.9** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | **TILL 71** | **77** | **37.153** | **4.979** | **0.055** | **263.4** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | **TILL 72** | **78** | **30.575** | **4.844** | **0.037** | **257.8** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | **TILL 73** | **79** | **28.571** | **6.625** | **0.048** | **256.8** | **1.0** | **3** | **sandy beach backed by high cliffs** |
| | **TILL 74** | **80** | **20.692** | **5.762** | **0.038** | **253.8** | **1.0** | **3** | **sandy beach backed by high cliffs** |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | Beach Slope (tan β) | Wave Dir. ($\gamma_\beta$) | Rough-ness ($\gamma_r$) | Approach | Description |
|---|---|---|---|---|---|---|---|---|---|
| **Netarts Spit/ Oceanside** | TILL 75 | 81 | 6.775 | 2.43 | 0.029 | 276.8 | 0.6 | 1 | sandy beach backed by low/high cliffs |
| | TILL 76 | 82 | 7.6 | 2.937 | 0.037 | 279.7 | 0.6 | 1 | sandy beach backed by cobbles/boulders and low cliff |
| | TILL 77 | 83 | 8.447 | 3.235 | 0.047 | 285.7 | 0.6 | 1 | sandy beach backed by dynamic revetment/artificial dune |
| | TILL 78 | 84 | 7.298 | 3.706 | 0.051 | 281.8 | 0.6 | 1 | sandy beach backed by dynamic revetment/artificial dune |
| | TILL 79 | 85 | 10.798 | 3.976 | 0.043 | 284.6 | 0.6 | 1 | dune-backed (+cobbles) |
| | TILL 80 | 86 | 9.131 | 5.381 | 0.082 | 285.4 | 1.0 | 3 | dune-backed (+cobbles) |
| | TILL 81 | 87 | 7.159 | 4.661 | 0.067 | 285.8 | 1.0 | 3 | dune-backed (+cobbles) |
| | TILL 82 | 88 | 11.562 | 5.04 | 0.056 | 283.3 | 1.0 | 3 | dune-backed |
| | TILL 83 | 89 | 12.413 | 5.492 | 0.056 | 281.9 | 1.0 | 3 | dune-backed |
| | TILL 84 | 90 | 7.322 | 6.012 | 0.046 | 271.7 | 1.0 | 3 | dune-backed |
| | TILL 85 | 91 | 11.621 | 5.37 | 0.044 | 275.8 | 1.0 | 3 | dune-backed |
| | TILL 86 | 92 | 11.763 | 6.361 | 0.047 | 276 | 1.0 | 3 | dune-backed |
| | TILL 87 | 93 | 19.722 | 4.114 | 0.043 | 281.1 | 1.0 | 3 | dune-backed |
| | TILL 88 | 94 | 6.567 | 5.72 | 0.057 | 271.2 | 1.0 | 3 | dune-backed |
| | TILL 89 | 95 | 10.543 | 5.754 | 0.048 | 274 | 1.0 | 3 | dune-backed |
| | TILL 90 | 96 | 12.156 | 4.768 | 0.046 | 278.7 | 1.0 | 3 | dune-backed |
| | TILL 91 | 97 | 9.61 | 6.516 | 0.052 | 272.5 | 1.0 | 3 | dune-backed |
| | TILL 92 | 98 | 8.324 | 6.36 | 0.05 | 284.5 | 1.0 | 3 | dune-backed |
| | TILL 93 | 99 | 4.971 | 4.855 | 0.069 | 202.6 | 0.6 | 3 | Cobble beach backed by low wall (estuary mouth) |
| | **TILL 94** | **100** | **14.619** | **5.554** | **0.074** | **223.7** | **1.0** | **2** | **sandy beach backed by high cliffs** |
| | **TILL 95** | **101** | **29.639** | **4.999** | **0.032** | **235.6** | **1.0** | **1** | **sandy beach backed by high cliffs** |
| | **TILL 96** | **102** | **39.082** | **4.536** | **0.055** | **236.2** | **1.0** | **2** | **sandy beach backed by high cliffs** |
| | TILL 97 | 103 | 55.206 | 4.631 | 0.065 | 241.7 | 1.0 | 3 | sandy beach backed by dune and high cliffs |
| | TILL 98 | 104 | 60.658 | 5.832 | 0.073 | 250.3 | 1.0 | 3 | sandy beach backed by dune and high cliffs |
| | TILL 99 | 105 | 33.925 | 4.907 | 0.044 | 254.1 | 0.6 | 3 | sandy beach backed by high cliffs |
| | TILL 100 | 106 | 36.465 | 4.585 | 0.041 | 252.2 | 0.6 | 1 | sandy beach backed by high cliffs |
| | TILL 101 | 107 | 13.733 | 5.191 | 0.045 | 248.4 | 0.7 | 3 | sandy beach backed by poor riprap and low cliffs |
| | TILL 102 | 108 | 18.353 | 5.953 | 0.05 | 250 | 0.6 | 3 | sandy beach backed by moderately high cliffs |
| | TILL 103 | 109 | 8.241 | 4.068 | 0.057 | 250.4 | 0.7 | 1 | sandy beach backed by moderately high cliffs |
| **Short Sand Beach** | **TILL 104** | **110** | **33.582** | **3.026** | **0.056** | **277.7** | **1.0** | **1** | **sandy beach backed by gravels and high cliffs** |
| | TILL 105 | 111 | 26.461 | 3.932 | 0.075 | 277.9 | 0.8 | 1 | sandy beach backed by gravels and high cliffs |
| | TILL 106 | 112 | 47.152 | 5.674 | 0.109 | 275.7 | 0.8 | 1 | sandy beach backed by gravels and high cliffs |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | Beach Slope (tan β) | Wave Dir. ($\gamma_\theta$) | Roughness ($\gamma_r$) | Approach | Description |
|---|---|---|---|---|---|---|---|---|---|
| Bayocean Spit | TILL 107 | 113 | 8.705 | 3.527 | 0.072 | 292 | 0.6 | 1 | sandy beach backed by cobble/boulder and low cliffs |
| | TILL 108 | 114 | 7.74 | 2.981 | 0.05 | 286.2 | 0.6 | 1 | sandy beach backed by cobble/boulder and low cliffs |
| | TILL 109 | 115 | 6.34 | 3 | 0.036 | 284.8 | 0.8 | 1 | sandy beach backed by cobble/boulder berm |
| | TILL 110 | 116 | 6.081 | 2.495 | 0.026 | 280 | 0.8 | 1 | sandy beach backed by cobble/boulder berm |
| | TILL 111 | 117 | 6.863 | 3.33 | 0.04 | 283.7 | 0.8 | 1 | sandy beach backed by cobble/boulder berm |
| | TILL 112 | 118 | 9.667 | 6.824 | 0.041 | 279.7 | 1.0 | 3 | dune-backed |
| | TILL 113 | 119 | 11.095 | 6.67 | 0.043 | 274.8 | 1.0 | 3 | dune-backed |
| | TILL 114 | 120 | 9.781 | 6.804 | 0.04 | 276.6 | 1.0 | 3 | dune-backed |
| | TILL 115 | 121 | 8.97 | 4.932 | 0.043 | 268.4 | 1.0 | 3 | dune-backed |
| | TILL 116 | 122 | 10.49 | 5.889 | 0.04 | 265.4 | 1.0 | 3 | dune-backed |
| | TILL 117 | 123 | 10.053 | 6.537 | 0.043 | 268.1 | 1.0 | 3 | dune-backed |
| Rockaway | TILL 118 | 124 | 5.932 | 5.932 | 0.048 | 290.2 | 1.0 | 3 | dune-backed |
| | TILL 119 | 125 | 6.332 | 4.905 | 0.043 | 285.6 | 1.0 | 3 | dune-backed |
| | TILL 120 | 126 | 6.72 | 5.37 | 0.049 | 280.7 | 1.0 | 3 | dune-backed |
| | TILL 121 | 127 | 6.749 | 5.178 | 0.058 | 282.2 | 1.0 | 3 | dune-backed |
| | TILL 122 | 128 | 6.518 | 5.388 | 0.047 | 284.7 | 1.0 | 3 | dune-backed |
| | TILL 123 | 129 | 7.242 | 3.13 | 0.029 | 286.4 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 124 | 130 | 6.905 | 5.82 | 0.05 | 285.9 | 1.0 | 3 | dune-backed |
| | TILL 125 | 131 | 5.489 | 5.489 | 0.046 | 285.1 | 1.0 | 3 | dune-backed |
| | TILL 126 | 132 | 5.858 | 4.586 | 0.02 | 286.4 | 1.0 | 3 | dune-backed |
| | TILL 127 | 133 | 7.148 | 5.709 | 0.037 | 279.2 | 1.0 | 3 | dune-backed |
| | TILL 128 | 134 | 7.976 | 5.327 | 0.038 | 279.6 | 1.0 | 3 | dune-backed |
| | TILL 129 | 135 | 7.237 | 5.136 | 0.048 | 272.7 | 1.0 | 3 | dune-backed |
| | TILL 130 | 136 | 7.344 | 5.839 | 0.046 | 274.4 | 1.0 | 3 | dune-backed |
| | TILL 131 | 137 | 7.032 | 4.682 | 0.037 | 274.8 | 1.0 | 3 | dune-backed |
| | TILL 132 | 138 | 5.486 | 3.77 | 0.038 | 290.9 | 0.8 | 3 | sand beach backed by riprap |
| | TILL 133 | 139 | 7.133 | 5.593 | 0.038 | 276.7 | 1.0 | 3 | dune-backed |
| | TILL 134 | 140 | 10.147 | 5.68 | 0.043 | 277.1 | 1.0 | 3 | dune-backed |
| | TILL 135 | 141 | 8.387 | 7.085 | 0.052 | 276.2 | 1.0 | 3 | dune-backed |
| | TILL 136 | 142 | 7.062 | 5.92 | 0.032 | 278.5 | 1.0 | 3 | sand beach backed by low bluff |
| | TILL 137 | 143 | 6.827 | 4 | 0.034 | 279.7 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 138 | 144 | 6.359 | 3.045 | 0.013 | 274.8 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 139 | 145 | 8.67 | 5.263 | 0.034 | 268.9 | 1.0 | 3 | dune-backed |
| | TILL 140 | 146 | 8.923 | 3.759 | 0.051 | 273.9 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 141 | 147 | 7.643 | 3.759 | 0.044 | 272.4 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 142 | 148 | 8.305 | 3.759 | 0.057 | 277.7 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 143 | 149 | 8.196 | 4.068 | 0.051 | 276 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 144 | 150 | 8.305 | 3.312 | 0.051 | 277.6 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 145 | 151 | 8.092 | 4.309 | 0.054 | 279.9 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 146 | 152 | 8.176 | 4.029 | 0.047 | 270.8 | 0.64 | 1 | sand beach backed by riprap |
| | TILL 147 | 153 | 7.927 | 7.16 | 0.056 | 280.1 | 1.0 | 3 | dune-backed |
| | TILL 148 | 154 | 8.101 | 5.982 | 0.052 | 281.5 | 1.0 | 3 | dune-backed |
| | TILL 149 | 155 | 8.029 | 5.997 | 0.05 | 282 | 1.0 | 3 | dune-backed |
| | TILL 150 | 156 | 8.315 | 6.325 | 0.045 | 283.3 | 1.0 | 3 | dune-backed |
| | TILL 151 | 157 | 6.974 | 4.176 | 0.022 | 282.2 | 0.55 | 1 | sand beach backed by riprap |
| | TILL 152 | 158 | 8.688 | 6.358 | 0.068 | 280.3 | 1.0 | 3 | dune-backed |
| | TILL 153 | 159 | 8.773 | 4.786 | 0.037 | 279.4 | 1.0 | 3 | dune-backed |
| | TILL 154 | 160 | 8.966 | 6.457 | 0.051 | 278.8 | 1.0 | 3 | dune-backed |
| | TILL 155 | 161 | 8.448 | 6.267 | 0.042 | 278.2 | 1.0 | 3 | dune-backed |
| | TILL 156 | 162 | 8.409 | 6.061 | 0.04 | 277.6 | 1.0 | 3 | dune-backed |
| | TILL 157 | 163 | 6.833 | 5.548 | 0.031 | 277 | 1.0 | 3 | dune-backed |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | Beach Slope (tan β) | Wave Dir. ($\Upsilon_\theta$) | Rough-ness ($\Upsilon_r$) | Approach | Description |
|---|---|---|---|---|---|---|---|---|---|
| **Nehalem Spit/ Manzanita** | TILL 158 | 164 | 7.752 | 6.112 | 0.049 | 279.2 | 1.0 | 3 | dune-backed |
| | TILL 159 | 165 | 12.218 | 6.616 | 0.053 | 279.7 | 1.0 | 3 | dune-backed |
| | TILL 160 | 166 | 8.676 | 6.254 | 0.063 | 276.6 | 1.0 | 3 | dune-backed |
| | TILL 161 | 167 | 7.828 | 5.901 | 0.056 | 273.6 | 1.0 | 3 | dune-backed |
| | TILL 162 | 168 | 15.433 | 5.338 | 0.042 | 268.4 | 1.0 | 3 | dune-backed |
| | TILL 163 | 169 | 13.023 | 5.823 | 0.043 | 263.4 | 1.0 | 3 | dune-backed |
| | TILL 164 | 170 | 14.069 | 5.912 | 0.055 | 265.7 | 1.0 | 3 | dune-backed |
| | TILL 165 | 170 | 15.75 | 5.514 | 0.051 | 268.4 | 1.0 | 3 | dune-backed |
| | TILL 166 | 172 | 12.088 | 4.356 | 0.034 | 266.4 | 1.0 | 3 | dune-backed |
| | TILL 167 | 173 | 12.772 | 5.616 | 0.039 | 266.2 | 1.0 | 3 | dune-backed |
| | TILL 168 | 174 | 13.313 | 6.617 | 0.038 | 264.6 | 1.0 | 3 | dune-backed |
| | TILL 169 | 175 | 10.635 | 7.807 | 0.075 | 267.9 | 1.0 | 3 | dune-backed |
| | TILL 170 | 176 | 9.226 | 4.313 | 0.022 | 268.1 | 0.7 | 1 | sand beach backed by riprap |
| | TILL 171 | 177 | 8.847 | 5.064 | 0.026 | 271.3 | 1.0 | 3 | dune-backed |
| | TILL 172 | 178 | 9.502 | 6.107 | 0.03 | 267.6 | 1.0 | 3 | dune-backed with road |
| | TILL 173 | 179 | 11.496 | 5.245 | 0.028 | 265 | 1.0 | 3 | dune-backed with road |
| | TILL 174 | 180 | 9.609 | 5.516 | 0.027 | 261.3 | 1.0 | 3 | dune-backed with road |
| | TILL 175 | 181 | 11.367 | 4.73 | 0.029 | 263 | 1.0 | 3 | dune-backed |
| | TILL 176 | 182 | 9.012 | 5.504 | 0.048 | 258.9 | 0.7 | 3 | sand beach backed by extensive cobble berm |
| | TILL 177 | 183 | 6.996 | 5.077 | 0.049 | 257.8 | 0.55 | 3 | sand beach backed by extensive cobble berm and bluff |
| | TILL 178 | 184 | 7.921 | 7.894 | 0.169 | 227.4 | 0.55 | 1 | sand beach backed by extensive cobble berm and bluff |
| **Falcon Cove** | CP 1 | 185 | 15.935 | 7.027 | 0.167 | 278 | 0.8 | 1 | sand, cobble berm backed by high bluff |

Notes:

$D_{HIGH}$ denotes the crest of the dune, bluff, or structure;

$D_{LOW}$ denotes the toe of the dune (i.e., $E_j$), bluff, or structure;

Beach slope reflects the calculated slope spanning the region between 2- and 4-m elevation;

Wave direction denotes the shoreline orientation used to calculate the wave reduction ($\Upsilon_\theta$) factor used in TAW runup calculations;

Roughness ($\Upsilon_r$) defines the backshore roughness used in TAW runup calculations. Bold values indicate sites where the local slope goes to 1 due to the presence of a vertical bluff; and

Approach defines the final runup approach used to calculate the wave runup, where STK = Stockdon, Snsh/TAW = nearshore slope and TAW, and LocSlp/TAW = the local barrier slope and TAW.

## 6.3 Tillamook County Wave Runup and Total Water Level Calculations

The complete hourly combined time series is run through the lookup tables to derive alongshore varying transformed wave time series. Using the transformed wave conditions, and the measured alongshore varying beach and barrier slopes, initial TWL time series based on the Stockdon approach are developed at all transect locations. From these time series we identify the ~150 highest independent TWLs at each transect over the length of the record. Wave runup is then computed for each of these storm input conditions (about 5 events per year) at every profile site shown in **Figure 3-1**, **Figure 3-2**, and **Figure 3-3** using a combination of the Stockdon and others (2006) runup equation for dune-backed beaches (equation 6.4) and TAW (equation 6-12) for wave runup on a barrier. The specific approaches used in our calculations are defined above in **Table 6-1.** For both models, the calculated runup is combined with the SWL (measured tides) to develop the TWL conditions used to generate the 10, 50, and 100-year return level event as well as the 500-year return event. The input wave conditions from the SWAN modeling used in the various calculations were determined for each transect location by extending the shore-perpendicular transects from the backshore to where they intersected the 20-m contour, or the seaward most location of $H_{mo}$/depth = 0.4, whichever was farther offshore (but almost always shallower than 30 m). This ensured that only minor dissipation due to wave breaking influenced the model results. These intersections are where wave statistics from the SWAN output were extracted.

Having calculated the storm-induced TWLs, we used the generalized extreme value (GEV) family of distributions (specifically the peak over threshold (POT) approach) to estimate the 100-year and 500-year Total Water Levels for each of the beach profile sites. Specific information about the extreme value techniques used to estimate these TWLs is described in Section 4.6. **Figure 6-6** gives an example of the extreme value (GPD-Poisson) model for the TILL 6 profile site in which the 100-year event is calculated to be 11.6 m (38 ft) and the 500-year event is estimated to be 12.6 m (41 ft). The results for all of the profiles can be found in **Table 6-2.**

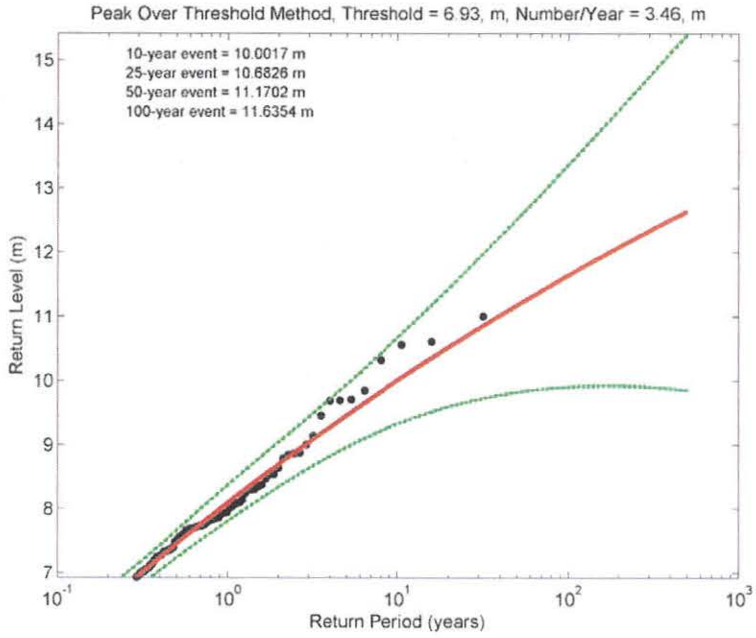

**Figure 6-6. Example peak over threshold (POT) extreme value theory results for the Tillamook 6 transect site (with 95% confidence levels) located in the Neskowin littoral cell. Note that the y-axis vertical datum is relative to the NAVD88 vertical datum. Black dots reflect the discrete peak total water level events and the red line is the extreme value distribution fit to those data. Green dashed line reflects the 95% confidence boundary.**

**Table 6-2. 100-year (1%) and 500-year (0.2%) total water levels calculated for the Tillamook County transect sites.**

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | 100-year (m) | 500-year (m) | Description |
|---|---|---|---|---|---|---|---|
| Salmon River | LINC 308 | 1 | 6.251 | 5.058 | 9.29 | 10.62 | dune-backed cliff |
| Cascade Head | LINC 309 | 2 | 48.172 | 1.609 | 14.13 | 14.28 | plunging cliff |
| | LINC 310 | 3 | 43.56 | 1.207 | 13.83 | 14.01 | plunging cliff |
| | LINC 311 | 4 | 24.427 | 0.358 | 12.91 | 13.46 | boulder beach backed by bluffs |
| | LINC 312 | 5 | 93.24 | 2.125 | 12.4 | 12.68 | plunging cliff |
| | LINC 313 | 6 | 139.103 | 0 | 17.29 | 17.49 | plunging cliff |
| Neskowin | TILL 1 | 7 | 47.278 | 0.764 | 9.97 | 10.04 | sandy beach backed by riprap and high cliffs |
| | TILL 2 | 8 | 8.684 | 3.914 | 8.32 | 8.91 | sand beach backed by riprap |
| | TILL 3 | 9 | 8.452 | 3.914 | 8.05 | 9.23 | sand beach backed by riprap |
| | TILL 4 | 10 | 5.184 | 3.448 | 7.84 | 9.18 | sand beach backed by riprap |
| | TILL 5 | 11 | 8.312 | 2.712 | 10.98 | 11.53 | sand beach backed by riprap |
| | TILL 6 | 12 | 8.447 | 3.563 | 11.64 | 12.64 | sand beach backed by riprap |
| | TILL 7 | 13 | 8.169 | 1.904 | 12.57 | 13.09 | sand beach backed by riprap |
| | TILL 8 | 14 | 8.539 | 2.533 | 11.56 | 12.24 | sand beach backed by riprap |
| | TILL 9 | 15 | 7.075 | 5.888 | 7.77 | 8.02 | dune-backed |
| | TILL 10 | 16 | 8.897 | 6.235 | 7.79 | 8.27 | dune-backed |
| | TILL 11 | 17 | 6.679 | 5.604 | 7.11 | 7.51 | dune-backed |
| | TILL 12 | 18 | 8.374 | 5.521 | 7.22 | 7.60 | dune-backed |
| | TILL 13 | 19 | 7.126 | 5.709 | 7.34 | 7.62 | dune-backed |
| | TILL 14 | 20 | 8.118 | 5.086 | 11.24 | 12.59 | sand beach backed by riprap |
| | TILL 15 | 21 | 7.587 | 4.642 | 9.13 | 9.41 | sand beach backed by riprap |
| | TILL 16 | 22 | 6.767 | 6.014 | 7.47 | 7.73 | dune-backed |
| | TILL 17 | 23 | 9.986 | 4.326 | 6.94 | 7.25 | dune-backed |
| | TILL 18 | 24 | 8.387 | 5.512 | 8.66 | 9.25 | dune-backed |
| | TILL 19 | 25 | 6.014 | 6.014 | 7.98 | 8.48 | dune-backed |
| | TILL 20 | 26 | 7.648 | 7.066 | 10.08 | 10.68 | dune-backed |
| | TILL 21 | 27 | 12.562 | 5.582 | 7.46 | 7.84 | dune-backed |
| | TILL 22 | 28 | 6.241 | 4.489 | 6.77 | 7.07 | dune-backed |
| | TILL 23 | 29 | 14.334 | 6.819 | 10.11 | 10.95 | dune-backed |
| | TILL 24 | 30 | 7.792 | 7.185 | 7.95 | 8.16 | dune-backed |
| | TILL 25 | 31 | 7.642 | 5.627 | 8.29 | 8.77 | dune-backed |
| | TILL 26 | 32 | 32.562 | 3.877 | 9.35 | 10.11 | sandy beach backed by high cliffs |
| | TILL 27 | 33 | 28.194 | 4.519 | 9.63 | 10.07 | sandy beach backed by high cliffs |
| | TILL 28 | 34 | 39.310 | 6.292 | 8.76 | 9.08 | sandy beach backed by dunes and high cliffs |
| Nestucca spit/ Pacific City | TILL 29 | 35 | 10.245 | 4.903 | 7.15 | 7.49 | dune-backed |
| | TILL 30 | 36 | 14.485 | 5.083 | 7.31 | 7.66 | dune-backed |
| | TILL 31 | 37 | 15.490 | 5.933 | 7.96 | 8.37 | dune-backed |
| | TILL 32 | 38 | 14.358 | 5.413 | 9.76 | 10.32 | dune-backed |
| | TILL 33 | 39 | 13.160 | 5.338 | 8.74 | 9.28 | dune-backed |
| | TILL 34 | 40 | 15.877 | 6.611 | 9.45 | 10.03 | dune-backed |
| | TILL 35 | 41 | 15.147 | 5.312 | 7.42 | 7.84 | dune-backed |
| | TILL 36 | 42 | 17.709 | 5.908 | 7.58 | 8.01 | dune-backed |
| | TILL 37 | 43 | 12.932 | 4.389 | 8.27 | 8.51 | sand beach backed by riprap? |
| | TILL 38 | 44 | 11.283 | 4.690 | 7.68 | 8.12 | sand beach backed by riprap? |
| | TILL 39 | 45 | 18.954 | 5.407 | 7.12 | 7.50 | dune-backed |
| | TILL 40 | 46 | 11.314 | 5.539 | 8.06 | 8.66 | sand beach backed by riprap? |
| | TILL 41 | 47 | 11.060 | 4.785 | 7.12 | 7.55 | sand beach backed by riprap? |
| | TILL 42 | 48 | 13.304 | 4.681 | 7.81 | 8.67 | sand beach backed by riprap and high bluffs |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | 100-year (m) | 500-year (m) | Description |
|---|---|---|---|---|---|---|---|
| Sand Lake/ Tierra Del Mar | TILL 43 | 49 | 23.369 | 5.582 | 7.30 | 7.67 | sandy beach backed by high cliffs |
| | TILL 44 | 50 | 16.741 | 6.162 | 8.57 | 9.02 | sandy beach backed by high cliffs |
| | TILL 45 | 51 | 6.868 | 4.232 | 10.93 | 12.05 | sandy beach backed by cobbles - grades into bluff |
| | TILL 46 | 52 | 18.071 | 4.865 | 10.43 | 11.18 | sandy beach backed by high cliffs |
| | TILL 47 | 53 | 18.396 | 4.063 | 9.01 | 10.64 | sand beach backed by riprap |
| | TILL 48 | 54 | 7.412 | 6.555 | 7.36 | 7.71 | dune-backed |
| | TILL 49 | 55 | 8.240 | 6.197 | 7.19 | 7.58 | dune-backed |
| | TILL 50 | 56 | 6.931 | 5.891 | 7.13 | 7.46 | dune-backed |
| | TILL 51 | 57 | 6.317 | 4.554 | 9.83 | 11.96 | sand beach backed by riprap |
| | TILL 52 | 58 | 7.721 | 4.543 | 10.03 | 11.37 | sand beach backed by riprap |
| | TILL 53 | 59 | 8.141 | 5.026 | 7.59 | 7.96 | sand beach backed by riprap |
| | TILL 54 | 60 | 7.462 | 5.055 | 8.03 | 8.52 | sand beach backed by riprap |
| | TILL 55 | 61 | 8.094 | 5.159 | 7.33 | 7.85 | dune-backed |
| | TILL 56 | 62 | 8.357 | 4.652 | 7.29 | 7.68 | sand beach backed by riprap |
| | TILL 57 | 63 | 11.383 | 4.823 | 7.00 | 7.36 | sand beach backed by riprap |
| | TILL 58 | 64 | 10.224 | 6.180 | 7.11 | 7.51 | dune-backed |
| | TILL 59 | 65 | 12.153 | 5.720 | 7.51 | 7.80 | dune-backed |
| | TILL 60 | 66 | 9.595 | 5.355 | 7.22 | 7.63 | dune-backed |
| | TILL 61 | 67 | 9.370 | 6.193 | 7.37 | 7.73 | dune-backed |
| | TILL 62 | 68 | 6.573 | 6.260 | 7.64 | 8.09 | dune-backed |
| | TILL 63 | 69 | 3.380 | 3.324 | 5.79 | 6.04 | dune-backed |
| | TILL 64 | 70 | 18.524 | 6.915 | 10.87 | 11.59 | dune-backed |
| | TILL 65 | 71 | 18.296 | 5.556 | 7.86 | 8.40 | dune-backed |
| | TILL 66 | 72 | 15.211 | 5.340 | 7.66 | 8.14 | dune-backed |
| | TILL 67 | 73 | 19.042 | 8.385 | 8.70 | 9.33 | sandy beach backed by high cliffs |
| | TILL 68 | 74 | 24.720 | 6.441 | 7.08 | 7.40 | sandy beach backed by high cliffs |
| | TILL 69 | 75 | 29.519 | 5.960 | 7.65 | 8.12 | sandy beach backed by high cliffs |
| | TILL 70 | 76 | 30.293 | 4.588 | 9.71 | 10.22 | sandy beach backed by high cliffs |
| | TILL 71 | 77 | 37.153 | 4.979 | 10.25 | 10.89 | sandy beach backed by high cliffs |
| | TILL 72 | 78 | 30.575 | 4.844 | 7.30 | 7.95 | sandy beach backed by high cliffs |
| | TILL 73 | 79 | 28.571 | 6.625 | 7.57 | 8.13 | sandy beach backed by high cliffs |
| | TILL 74 | 80 | 20.692 | 5.762 | 6.82 | 7.17 | sandy beach backed by high cliffs |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | 100-year (m) | 500-year (m) | Description |
|---|---|---|---|---|---|---|---|
| **Netarts Spit/ Oceanside** | TILL 75 | 81 | 6.775 | 2.430 | 9.63 | 9.99 | sandy beach backed by low/high cliffs |
| | TILL 76 | 82 | 7.600 | 2.937 | 10.40 | 11.58 | sandy beach backed by cobbles/boulders and low cliff |
| | TILL 77 | 83 | 8.447 | 3.235 | 10.38 | 11.11 | sandy beach backed by dynamic revetment/artificial dune |
| | TILL 78 | 84 | 7.298 | 3.706 | 10.06 | 10.97 | sandy beach backed by dynamic revetment/artificial dune |
| | TILL 79 | 85 | 10.798 | 3.976 | 9.84 | 11.42 | dune-backed (+cobbles) |
| | TILL 80 | 86 | 9.131 | 5.381 | 9.15 | 9.59 | dune-backed (+cobbles) |
| | TILL 81 | 87 | 7.159 | 4.661 | 8.58 | 9.13 | dune-backed (+cobbles) |
| | TILL 82 | 88 | 11.562 | 5.040 | 7.87 | 8.34 | dune-backed |
| | TILL 83 | 89 | 12.413 | 5.492 | 7.55 | 7.86 | dune-backed |
| | TILL 84 | 90 | 7.322 | 6.012 | 7.34 | 7.77 | dune-backed |
| | TILL 85 | 91 | 11.621 | 5.370 | 7.43 | 7.88 | dune-backed |
| | TILL 86 | 92 | 11.763 | 6.361 | 7.40 | 7.83 | dune-backed |
| | TILL 87 | 93 | 19.722 | 4.114 | 7.36 | 7.85 | dune-backed |
| | TILL 88 | 94 | 6.567 | 5.720 | 8.17 | 8.84 | dune-backed |
| | TILL 89 | 95 | 10.543 | 5.754 | 7.58 | 8.04 | dune-backed |
| | TILL 90 | 96 | 12.156 | 4.768 | 7.33 | 7.63 | dune-backed |
| | TILL 91 | 97 | 9.610 | 6.516 | 7.76 | 8.26 | dune-backed |
| | TILL 92 | 98 | 8.324 | 6.360 | 7.70 | 8.20 | dune-backed |
| | TILL 93 | 99 | 4.971 | 4.855 | 8.52 | 9.12 | Cobble beach backed by low wall (estuary mouth) |
| | TILL 94 | 100 | 14.619 | 5.554 | 8.89 | 9.79 | sandy beach backed by high cliffs |
| | TILL 95 | 101 | 29.639 | 4.999 | 7.30 | 8.08 | sandy beach backed by high cliffs |
| | TILL 96 | 102 | 39.082 | 4.536 | 8.29 | 9.13 | sandy beach backed by high cliffs |
| | TILL 97 | 103 | 55.206 | 4.631 | 8.30 | 8.80 | sandy beach backed by dune and high cliffs |
| | TILL 98 | 104 | 60.658 | 5.832 | 8.71 | 9.15 | sandy beach backed by dune and high cliffs |
| | TILL 99 | 105 | 33.925 | 4.907 | 7.21 | 7.56 | sandy beach backed by high cliffs |
| | TILL 100 | 106 | 36.465 | 4.585 | 7.08 | 7.44 | sandy beach backed by high cliffs |
| | TILL 101 | 107 | 13.733 | 5.191 | 7.05 | 7.36 | sandy beach backed by poor riprap and low cliffs |
| | TILL 102 | 108 | 18.353 | 5.953 | 7.57 | 8.01 | sandy beach backed by moderately high cliffs |
| | TILL 103 | 109 | 8.241 | 4.068 | 9.77 | 10.24 | sandy beach backed by moderately high cliffs |
| **Short Sand Beach** | TILL 104 | 110 | 33.582 | 3.026 | 11.00 | 11.60 | sandy beach backed by gravels and high cliffs |
| | TILL 105 | 111 | 26.461 | 3.932 | 11.99 | 12.89 | sandy beach backed by gravels and high cliffs |
| | TILL 106 | 112 | 47.152 | 5.674 | 14.39 | 18.27 | sandy beach backed by gravels and high cliffs |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | 100-year (m) | 500-year (m) | Description |
|---|---|---|---|---|---|---|---|
| **Bayocean Spit** | TILL 107 | 113 | 8.705 | 3.527 | 11.43 | 12.49 | sandy beach backed by cobble/boulder and low cliffs |
| | TILL 108 | 114 | 7.740 | 2.981 | 10.15 | 10.57 | sandy beach backed by cobble/boulder and low cliffs |
| | TILL 109 | 115 | 6.340 | 3.000 | 10.39 | 10.83 | sandy beach backed by cobble/boulder berm |
| | TILL 110 | 116 | 6.081 | 2.495 | 10.44 | 10.69 | sandy beach backed by cobble/boulder berm |
| | TILL 111 | 117 | 6.863 | 3.330 | 10.84 | 11.71 | sandy beach backed by cobble/boulder berm |
| | TILL 112 | 118 | 9.667 | 6.824 | 7.34 | 7.76 | dune-backed |
| | TILL 113 | 119 | 11.095 | 6.670 | 7.50 | 7.99 | dune-backed |
| | TILL 114 | 120 | 9.781 | 6.804 | 7.12 | 7.50 | dune-backed |
| | TILL 115 | 121 | 8.970 | 4.932 | 7.22 | 7.59 | dune-backed |
| | TILL 116 | 122 | 10.490 | 5.889 | 6.74 | 6.97 | dune-backed |
| | TILL 117 | 123 | 10.053 | 6.537 | 7.36 | 7.89 | dune-backed |
| **Rockaway** | TILL 118 | 124 | 5.932 | 5.932 | 7.52 | 7.99 | dune-backed |
| | TILL 119 | 125 | 6.332 | 4.905 | 6.93 | 7.19 | dune-backed |
| | TILL 120 | 126 | 6.720 | 5.370 | 7.23 | 7.60 | dune-backed |
| | TILL 121 | 127 | 6.749 | 5.178 | 7.79 | 8.18 | dune-backed |
| | TILL 122 | 128 | 6.518 | 5.388 | 7.29 | 7.74 | dune-backed |
| | TILL 123 | 129 | 7.242 | 3.130 | 8.32 | 8.52 | sand beach backed by riprap |
| | TILL 124 | 130 | 6.905 | 5.820 | 7.13 | 7.44 | dune-backed |
| | TILL 125 | 131 | 5.489 | 5.489 | 6.94 | 7.20 | dune-backed |
| | TILL 126 | 132 | 5.858 | 4.586 | 6.06 | 6.28 | dune-backed |
| | TILL 127 | 133 | 7.148 | 5.709 | 6.79 | 7.07 | dune-backed |
| | TILL 128 | 134 | 7.976 | 5.327 | 7.05 | 7.42 | dune-backed |
| | TILL 129 | 135 | 7.237 | 5.136 | 7.07 | 7.63 | dune-backed |
| | TILL 130 | 136 | 7.344 | 5.839 | 7.30 | 7.78 | dune-backed |
| | TILL 131 | 137 | 7.032 | 4.682 | 7.10 | 7.60 | dune-backed |
| | TILL 132 | 138 | 5.486 | 3.770 | 7.34 | 7.81 | sand beach backed by riprap |
| | TILL 133 | 139 | 7.133 | 5.593 | 7.26 | 7.70 | dune-backed |
| | TILL 134 | 140 | 10.147 | 5.680 | 7.25 | 7.61 | dune-backed |
| | TILL 135 | 141 | 8.387 | 7.085 | 7.60 | 7.89 | dune-backed |
| | TILL 136 | 142 | 7.062 | 5.920 | 6.85 | 7.20 | sand beach backed by low bluff |
| | TILL 137 | 143 | 6.827 | 4.000 | 7.44 | 8.20 | sand beach backed by riprap |
| | TILL 138 | 144 | 6.359 | 3.045 | 7.82 | 8.27 | sand beach backed by riprap |
| | TILL 139 | 145 | 8.670 | 5.263 | 6.93 | 7.25 | dune-backed |
| | TILL 140 | 146 | 8.923 | 3.759 | 9.71 | 10.57 | sand beach backed by riprap |
| | TILL 141 | 147 | 7.643 | 3.759 | 10.71 | 13.99 | sand beach backed by riprap |
| | TILL 142 | 148 | 8.305 | 3.759 | 10.34 | 11.71 | sand beach backed by riprap |
| | TILL 143 | 149 | 8.196 | 4.068 | 9.55 | 10.34 | sand beach backed by riprap |
| | TILL 144 | 150 | 8.305 | 3.312 | 10.35 | 10.88 | sand beach backed by riprap |
| | TILL 145 | 151 | 8.092 | 4.309 | 8.80 | 9.77 | sand beach backed by riprap |
| | TILL 146 | 152 | 8.176 | 4.029 | 8.93 | 9.79 | sand beach backed by riprap |
| | TILL 147 | 153 | 7.927 | 7.160 | 7.73 | 8.15 | dune-backed |
| | TILL 148 | 154 | 8.101 | 5.982 | 7.80 | 8.27 | dune-backed |
| | TILL 149 | 155 | 8.029 | 5.997 | 7.44 | 7.88 | dune-backed |
| | TILL 150 | 156 | 8.315 | 6.325 | 7.08 | 7.37 | dune-backed |
| | TILL 151 | 157 | 6.974 | 4.176 | 6.17 | 6.41 | sand beach backed by riprap |
| | TILL 152 | 158 | 8.688 | 6.358 | 8.24 | 8.76 | dune-backed |
| | TILL 153 | 159 | 8.773 | 4.786 | 6.71 | 7.03 | dune-backed |
| | TILL 154 | 160 | 8.966 | 6.457 | 7.74 | 8.35 | dune-backed |
| | TILL 155 | 161 | 8.448 | 6.267 | 7.21 | 7.69 | dune-backed |
| | TILL 156 | 162 | 8.409 | 6.061 | 6.98 | 7.39 | dune-backed |
| | TILL 157 | 163 | 6.833 | 5.548 | 6.39 | 6.67 | dune-backed |

| Reach | Transect | DFIRM Transect | $D_{HIGH}$ (m) | $D_{LOW}$ (m) | 100-year (m) | 500-year (m) | Description |
|---|---|---|---|---|---|---|---|
| **Nehalem Spit/ Manzanita** | TILL 158 | 164 | 7.752 | 6.112 | 7.62 | 8.13 | dune-backed |
| | TILL 159 | 165 | 12.218 | 6.616 | 7.83 | 8.33 | dune-backed |
| | TILL 160 | 166 | 8.676 | 6.254 | 8.62 | 9.40 | dune-backed |
| | TILL 161 | 167 | 7.828 | 5.901 | 8.13 | 8.73 | dune-backed |
| | TILL 162 | 168 | 15.433 | 5.338 | 7.01 | 7.36 | dune-backed |
| | TILL 163 | 169 | 13.023 | 5.823 | 6.89 | 7.17 | dune-backed |
| | TILL 164 | 170 | 14.069 | 5.912 | 7.66 | 8.19 | dune-backed |
| | TILL 165 | 170 | 15.750 | 5.514 | 7.57 | 8.05 | dune-backed |
| | TILL 166 | 172 | 12.088 | 4.356 | 6.89 | 7.27 | dune-backed |
| | TILL 167 | 173 | 12.772 | 5.616 | 7.05 | 7.49 | dune-backed |
| | TILL 168 | 174 | 13.313 | 6.617 | 6.94 | 7.33 | dune-backed |
| | TILL 169 | 175 | 10.635 | 7.807 | 8.93 | 9.58 | dune-backed |
| | TILL 170 | 176 | 9.226 | 4.313 | 6.35 | 6.67 | sand beach backed by riprap |
| | TILL 171 | 177 | 8.847 | 5.064 | 6.48 | 6.81 | dune-backed |
| | TILL 172 | 178 | 9.502 | 6.107 | 6.51 | 6.78 | dune-backed with road |
| | TILL 173 | 179 | 11.496 | 5.245 | 6.61 | 6.94 | dune-backed with road |
| | TILL 174 | 180 | 9.609 | 5.516 | 6.54 | 6.86 | dune-backed with road |
| | TILL 175 | 181 | 11.367 | 4.730 | 6.65 | 7.04 | dune-backed |
| | TILL 176 | 182 | 9.012 | 5.504 | 7.81 | 8.51 | sand beach backed by extensive cobble berm |
| | TILL 177 | 183 | 6.996 | 5.077 | 7.60 | 8.03 | sand beach backed by extensive cobble berm and bluff |
| | TILL 178 | 184 | 7.921 | 7.894 | 14.26 | 15.29 | sand beach backed by extensive cobble berm and bluff |
| **Falcon Cove** | CP 1 | 185 | 15.935 | 7.027 | 9.93 | 10.33 | sand, cobble berm backed by high bluff |

Notes:

100-year and 500-year total water level (TWL) values relative to NAVD88 vertical datum.

$D_{HIGH}$ is the crest of the dune, bluff, or barrier determined for the eroded profile. *Red text denotes that the crest is overtopped.*

## 6.4 Overtopping Calculations

Overtopping of natural features such as foredunes, spits, and coastal engineering structures and barriers occurs when the wave runup superimposed on the tide exceeds the crest of the foredune or structure (**Figure 6-7**). Hazards associated with wave overtopping can be linked to a number of simple direct flow parameters including (Pullen and others, 2007):

- mean overtopping discharge, $q$;
- overtopping velocities over the crest and farther landward, $V$;
- landward extent of green water and splash overtopping $y_{G,\ outer}$; and
- overtopping flow depth, $h$ at a distance $y$ landward of the foredune crest or "barrier."

NHC (2005) notes that there are three physical types of wave overtopping:

1. *Green water or bore overtopping* occurs when waves break onto or over the foredune or barrier and the overtopping volume is relatively continuous;
2. *Splash overtopping* occurs when the waves break seaward of the foredune or barrier, or where the foredune or barrier is high relative to the wave height and overtopping consists of a stream of droplets. Splash overtopping can be a function of its momentum due to the runup swashing up the barrier and/or may be enhanced due to onshore direct winds; and,
3. *Spray overtopping* is generated by the effects of wind blowing droplets and spray that are derived from the wave crests.

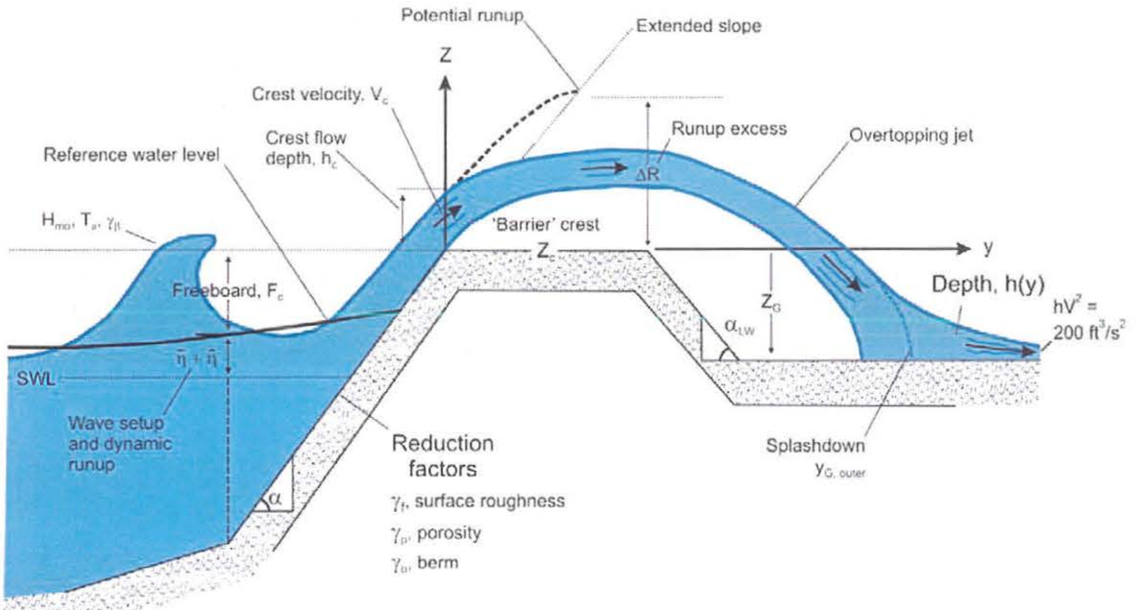

**Figure 6-7. Nomenclature of overtopping parameters available for mapping base flood elevations (BFEs) and flood hazard zones (after NHC, 2005).**

Mapping these respective flood inundation zones requires an estimate of the velocity, *V*, the overtopping discharge, *q*, of the water that is carried over the crest, the inland extent of green water and splash overtopping, and the envelope of the water surface that is defined by the water depth, *h*, landward of the barrier crest. According to NHC (2005) these hazard zones are ultimately defined from following two derivations:

- Base flood elevations (BFEs) are determined based on the water surface envelope landward of the barrier crest; and
- Hazard zones are determined based on the landward extent of green water and splash overtopping, and on the depth and flow velocity in any sheet flow areas beyond that, defined as $hV^2 = 5.7\ m^3/s^2$ *or* $200\ ft^3/s^2$.

A distinction can be made between whether green water (or bore) or splash overtopping predominates at a particular location that is dependent on the ratio of the calculated wave runup height relative to the barrier crest elevation, $R/Z_c$. When $1 < R/Z_c < 2$, splash overtopping dominates; when $R/Z_c > 2$, bore propagation occurs. In both cases, *R* and $Z_c$ are relative to the 2% dynamic water level ($DWL_{2\%}$) at the barrier (Figure D.4.5-12 in NHC [2005, p. D.4.5-22]).

### 6.4.1 Mean overtopping rate at the "barrier" crest

Wave overtopping of dunes and barrier is a function of both hydraulic and barrier structure parameters whereby:

$$q = f(H_{mo}, T_p, \beta, F_c, DWL_{2\%}, geometry) \qquad (6.14)$$

where *q* is the overtopping discharge (expressed as cubic meters per second per meter, m³/s/m [ft³/s/ft]), $H_{mo}$ is the significant wave height at the toe of the structure, $T_p$ is the peak period, $\beta$ is the angle of wave attack, $F_c$ is the freeboard, and $DWL_{2\%}$ is 2% dynamic water level at the toe of the structure (**Figure 6-7**).

Prior to calculating the mean overtopping rate at the barrier crest it is necessary to distinguish between four contrasting types of wave breaking situations that may impact a particular barrier or dune overtopping situation. There four conditions include *non-breaking* or *breaking* on a normally sloped barrier (where $0.067 < \tan\alpha < 0.67$), and *reflecting* or *impacting* on steeply sloping or vertical barriers (where $\tan\alpha \geq 0.67$). Of these, the breaking wave situation is the dominant condition in Tillamook County, where the waves have already broken across the surf zone and are reforming as bores prior to swashing up the beach face or barrier.

For beaches and normally sloping barriers (where $0.067 < \tan\alpha < 0.67$), a distinction can be made between situations where waves break directly on the barrier versus those conditions where the waves have not yet broken. These conditions can be determined using the surf similarity parameter (Iribarren number) defined here in terms of the beach or structure slope ($\tan\alpha$), and the wave steepness ($S_{op} = H_{mo}/L_o$):

$$\xi_{op} = \frac{\tan\alpha}{\sqrt{\frac{H_{mo}}{L_o}}} = \frac{\tan\alpha}{\sqrt{S_{op}}} \qquad (6.15)$$

Breaking on normally sloping surfaces generally occurs where the surf similarity number, $\xi_{op} \leq 1.8$, while non-breaking conditions occur when $\xi_{op} > 1.8$. As noted above, for the Tillamook County coastline the identified Iribarren numbers almost always fell below the 1.8 criteria, indicating that the incident waves are always broken prior to reaching the beach or the barrier face.

At the beach or barrier crest, the relative freeboard ($F_c/H_{mo}$), **Figure 6-7,** is a particularly important because changing these two parameters controls the volume of water that flows over the barrier crest. For example, increasing the wave height or period increases the overtopping discharge, as does reducing the beach or barrier crest height or raising the water level.

A variety of prediction methods are available for calculating the overtopping discharge and are almost entirely based on laboratory experiments using a range of structure slopes (slopes between 1:1 and 1:8, with occasional tests at slopes around 1:15 or lower). Factors that will serve to reduce the potential overtopping discharge include the barrier *surface roughness* ($\gamma_f$), the presence of a *berm* ($\gamma_b$), *wave approach directions* ($\gamma_\beta$), and the *porosity* of the barrier ($\gamma_p$) (**Figure 6-7**). In terms of porosity, increasing this variable effectively reduces the wave runup and overtopping discharge because more of the water is able to be taken up by the voids between the clasts and particles. As noted in NHC (2005), the effect of the *porosity* factor makes it convenient to distinguish between impermeable and permeable structures. Methods for determining the various reduction factors are described in Table D.4.5-3 in NHC (2005, p. D.4.5-13), with one difference whereby the approach recommended for determining the wave approach ($\gamma_\beta$) reduction factor for wave overtopping calculations is based on the following equation:

$$\gamma_\beta = \begin{Bmatrix} 1 - 0.0033|\beta|, (0 \leq |\beta| \leq 80°) \\ 1 - 0.0033|80|, (|\beta| \geq 80°) \end{Bmatrix} \qquad (6.16)$$

Table D.4.5-3 in NHC (2005, p. D.4.5-13) identifies four general categories of overtopping applications: overtopping on a normally sloping barrier (e.g., riprap structure), steep sloping or vertical barrier (e.g., seawall or bluff where some waves broken); steep sloping or vertical barrier (all waves broken); and shallow foreshore slopes subject to large Iribarren numbers.

For a normally sloping barrier, where 0.05 < tan $\alpha$ < 0.67 and the Iribarren number ($\xi_{op}$) ≤ 1.8 (breaking wave condition), the following formulation can be used to determine the mean overtopping discharge (both dimensional [$q$] and non-dimensional [$Q$] forms) at the barrier crest:

$$q = Q\sqrt{\frac{gH_{mo}\tan\alpha}{S_{op}}} \text{ where:} \qquad (6.17)$$

$$Q = 0.06e^{-4.7F'} \text{, and}$$

$$F' = \frac{F_c}{H_{mo}} \frac{\sqrt{S_{op}}}{\tan\alpha} \frac{1}{\gamma_f \gamma_b \gamma_\beta \gamma_p}$$

For non-breaking conditions (Iribarren number ($\xi_{op}$) > 1.8):

$$q = Q\sqrt{gH_{mo}^3} \text{ where:} \qquad (6.18)$$

$$Q = 0.2e^{-2.3F'} \text{, and}$$

$$F' = \frac{F_c}{H_{mo}} \frac{1}{\gamma_f \gamma_\beta}$$

For steep sloping or vertical barrier, where tan α > 0.67 and $h_* \geq 0.3$ (reflecting conditions where

$$h_* = \frac{h}{H_{mo}}\left(\frac{2\pi h}{gT_m^2}\right)$$

and $h$ is the water depth at the structure toe), the following formulation can be used:

$$q = Q\sqrt{gH_{mo}^3} \text{ where:} \qquad (6.19)$$

$$Q = 0.05e^{-2.78F_c/H_{mo}}$$

For impacting conditions ($h_* < 0.3$):

$$q = Q\sqrt{gh^3}\, h_*^2 \text{ where:} \qquad (6.20)$$

$$Q = 1.37 * 10^{-4}(F')^{-3.24} \text{, and}$$

$$F' = \frac{F_c}{H_{mo}} h_*$$

For steep sloping or vertical barrier (all waves are broken) where the structure toe < $DWL_{2\%}$ water level and where $(F_c/H_{mo})^*h_* \leq 0.03$:

$$q = Q\sqrt{gh^3}\, h_*^2 \text{ where:} \qquad (6.21)$$

$$Q = 0.27 * 10^{-4} e^{-3.24\,(F_c/H_{mo})h_*}$$

For steep sloping or vertical barrier (all waves are broken) where the structure toe > $DWL_{2\%}$ water level:

$$q = Q\sqrt{gh^3}\, h_*^2 \text{ where:} \qquad (6.22)$$

$$Q = 0.06e^{-4.7\,F_c S_{op}^{-0.17}}$$

We have implemented two additional overtopping calculations following discussions with Dr. W. G. McDougal, which may be applied to beaches subject to gently sloping ($\tan\beta < 0.4$), dissipative foreshores:

$$q = Q\sqrt{gh^3}h_*^2 \text{ where:} \tag{6.23}$$

$$Q = 0.21\sqrt{gH_{mo}^3}e^{-F\prime}\text{, and}$$

$$F' = \frac{F_c}{\gamma_f\gamma_\beta H_{mo}(0.33 + 0.022\xi_{op})}$$

and cases where there is negative freeboard. The latter occurs when the dynamic water level (DWL2%) is higher than the barrier crest, which produces a negative freeboard (i.e., $-F_c$). In this situation we apply the well-known weir type formula to define the volume of water that is overflowing the crest (Eurotop, 2007). The formulation used is:

$$q = Q_s + q_w \text{ where:} \tag{6.24}$$

$$Q_s = 0.4583(-F_C)\sqrt{-F_C g}\,,$$

$$Q_w = 0.21\sqrt{gH_{mo}^3}\text{, and}$$

$$q_w = Q_w\sqrt{gh^3}h_*^2$$

### *6.4.2 Overtopping limits and flood hazard zones landward of the "barrier" crest*

Estimates of the landward limit of the splashdown distance associated with wave overtopping and the landward limit of the hazard zone require several calculation steps. These include:

1. The following three initial parameters are first calculated:
   a. excess potential runup: $\Delta R = R\text{-}Z_c$;
   b. crest flow rate, $V_c\cos\alpha$ (where $V_c = 1.1\sqrt{g\Delta R}$ for cases where splash overtopping, and $V_c = 1.8\sqrt{g\Delta R}$ for bore overtopping); and
   c. initial flow depth, $h_c$ (where $h_c = 0.38\Delta R$).

2. The associated onshore wind component, *Wy*, is determined from available wind data. For the purposes of this study, we used $Wy = 19.6$ m/s (64.3 ft/s), which was determined from an analysis of winds (mean from a select number of storms) measured at the Cape Arago C-MAN station operated by the NDBC. In the absence of wind data, NHC (2005) recommends a wind speed of 13.4 m/s (44 ft/s).
3. The enhanced onshore water velocity component $(V_c \cos\alpha)'$ is then calculated using equation 6.25:

For vertical bluffs and seawalls;

$$(V_c \cos\alpha)' = 0.3 * W_y$$

(6.25)

All other cases: $(V_c \cos\alpha)' = V_c\cos\alpha + 0.3(W_y - V_c\cos\alpha)$

4. The effective angle, $\alpha_{\text{eff}}$, is calculated from:

$$\tan\alpha_{eff} = \frac{V_c\sin\alpha}{(V_c\cos\alpha)'}\,.$$

5. Having determined the above parameters, the outer limit of the splash region, $y_{G\ outer}$ is calculated using equation 6.26. Here we have used an algorithm developed by Dr. W. G. McDougal (Coastal Engineer, OSU and Technical Coordinator of the North Pacific FEMA West Coast Guidelines) of the form:

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$$y_{G\ outer} = \frac{(V_c \cos\ \alpha)'}{g} * V_c \sin\ \alpha - mBackshore * (V_c \cos\ \alpha)' * \qquad (6.26)$$

$$1 + \sqrt{1 - \frac{2g * bBackshore}{(V_c \sin\ \alpha - mBackshore * (V_c \cos\ \alpha)'^2)}}$$

and

$$Z_G = bBackshore + (mBackshore * y_{G\ outer}) \qquad (6.27)$$

---

where *bBackshore* is the intercept for the backshore slope adjacent to the barrier crest and mBackshore is the slope of the backshore. equation 6.26 is ultimately based on Figure D.4.5-15 in NHC (2005, p. D.4.5-30).

6. The total energy, *E*, of the splashdown is calculated from $E = \Delta R - Z_G$.
7. Finally, the initial splashdown velocity, $V_o$ (where $V_o = 1.1\sqrt{gE}$), and depth, $h_o$ (where $h_o = 0.19E$) are calculated. In the case of green water or bore overtopping, the splashdown velocity, $V_o$, can be calculated from $V_o = 1.1\sqrt{g\Delta R}$, while the flow depth is determined as $h_o = 0.38E$.

Having determined the initial splashdown velocity, $V_o$, and flow depth, $h_o$, the landward extent of the overland flow is calculated using an approach modified from that originally proposed by Cox and Machemehl (1986). The version presented by NHC (2005) effectively calculates the flow depth, *h*, with distance, *y*, from the barrier crest, such that the flow depth decays asymptotically as y-distance increases away from the barrier crest, eventually approaching zero. The NHC (2005) equation is shown as equation 6.28:

$$h(y) = \left[\sqrt{h_o} - \frac{5(y - y_o)}{A\sqrt{gT^2}}\right]^2 \qquad (6.28)$$

where $h_o$ is determined from step 7 above and for an initial approximation the nondimensional *A* parameter may be taken as unity. For sloping backshores, the *A* parameter in equation 6.28 can be modified such that $A_m = A(1 - 2 * \tan\alpha_{LW})$, and the value in parentheses is limited to the range 0.5 to 2. According to NHC (2005) if the maximum distance of splash or bore propagation calculated using equation 6.28 does not appear reasonable or match field observations, the *A* parameter can be adjusted in order to increase or decrease the landward wave propagation distance. In addition, for green water or bore propagation the *A* parameter value is taken initially to be 1.8.

For the purposes of this study we have adopted a modified version of equation 6.28 developed by Dr. W. G. McDougal of the form:

$$h(y) = \left[ h_o^{1/2} - \frac{y - y_o}{2\alpha(\alpha + 1)^{\frac{3}{2}} (1 - 2m)\, g^{0.5} T} \right]^2 \qquad (6.29)$$

where $m$ is the slope of the backshore and $\alpha$ is a constant that can be varied in order to increase or decrease the landward wave propagation distance.

Finally, the landward limit of the hazard zone defined as $hV^2 = 5.7$ m$^3$/s$^2$ (or 200 ft$^3$/s$^2$) is determined, whereby $h$ is the water depth given by the modified Cox and Machemehl (1986) method (equation 6.29) and $V = V_o$ calculated from step 7 above.

### *6.4.3 Initial testing of the landward limit of wave overtopping*

Our initial computations of the landward extent of wave overtopping using the steps outlined above yielded narrow hazard zones for our original coastal FIRM study in Coos County. To calibrate equation 6.29, we performed wave overtopping calculations and inundation for a site on the northern Oregon coast where there are field observations of wave overtopping: Cape Lookout State Park in Tillamook County (Allan and others, 2006; Allan and Komar, 2002a; Komar and others, 2003). The southern portion of Cape Lookout State Park is characterized by a wide, gently sloping, dissipative sand beach, backed by a moderately steep gravel berm and ultimately by a low foredune that has undergone significant erosion since the early 1980s (Komar and others, 2000).

On March 2-3, 1999, the crest of the cobble berm/dune at Cape Lookout State Park was overtopped during a major storm; the significant wave heights reached 14.1 m (46.3 ft), while the peak periods were 14.3 s measured by a deepwater NDBC wave buoy (Allan and Komar, 2002b). Wave overtopping of the dune and flooding extended ~70 m (230 ft) into the park (Dr. P. Komar, Emeritus Professor, College of Oceanic and Atmospheric Sciences, pers. comm., 2010), evidence for which included photos and field evidence including pockmarks at the bases of tree trunks located in the park. These pockmarks were caused by cobbles having been carried into the park from the beach by the overtopping waves, where the cobbles eventually slammed into the bases of the trees as ballistics. Because the average beach slopes at Cape Lookout State Park are analogous to those observed elsewhere along the Tillamook County coastline and because large wave events associated with extratropical storms affect significant stretches (100s to 1000 kilometers) of the coast at any single point in time, we believe these data provide a reasonable means in which to investigate a range of alpha ($\alpha$) values that may be used to determine the landward extent of wave inundation in the park.

Using beach morphology data (slope (tan $\beta$) = 0.089, barrier crest = 5.5 m [18 ft]) from Cape Lookout State Park and deepwater wave statistics from a nearby NDBC wave buoy (#46050), we experimented with a range of alpha values in order to replicate the landward extent of the inundation. As can be seen in **Figure 6-8**, in order to emulate the landward extent of flooding observed at Cape Lookout our analyses yielded an alpha of 0.58. Using alpha = 0.58, we in turn calculated the extent of the hazard zone where $h(y)$ = 200 ft$^3$/s$^2$, which was found to be ~34 m from the crest of the cobble berm/dune, consistent with damage to park facilities.

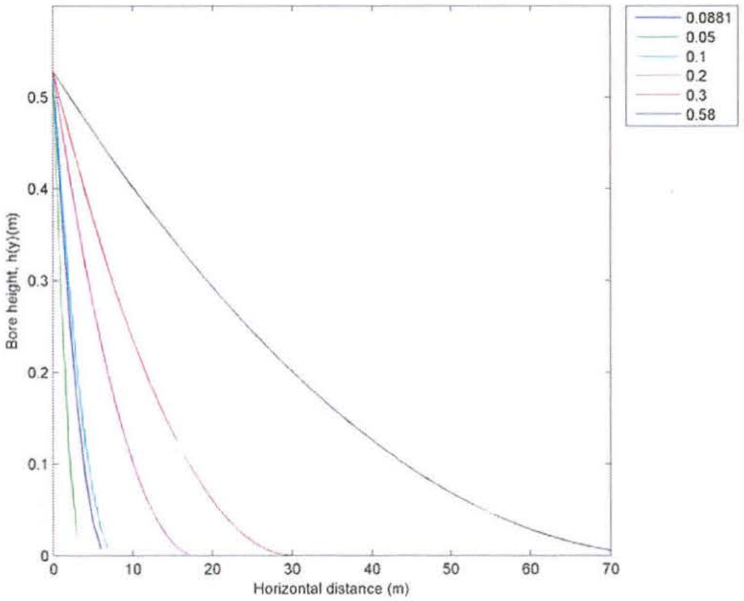

**Figure 6-8.** **Calculations of bore height decay from wave overtopping at Cape Lookout State Park at the peak of the March 2-3, 1999, storm based on a range of alpha (α) values (shown in small box).**

### *6.4.4 Wave overtopping and hazard zone limits calculated for Tillamook County*

**Table 6-3** presents the results of the calculated splashdown distances ($y_{G\,outer}$) and the landward extent of the flow ($hV^2$) where the flows approach 5.7 $m^3/s^2$ (or 200 $ft^3/s^2$). **Table 6-3** includes a more conservative splashdown distance, based on an enhanced wind velocity of 19.6 m/s (64.3 ft/s); this contrasts with the default wind speed of 13.4 m/s (44 ft/s) suggested by NHC (2005). This enhanced wind velocity was determined from an analysis of wind speeds measured by the Cape Arago C-MAN (http://www.ndbc.noaa.gov/station_page.php?station=CARO3) station located adjacent to the mouth of Coos Bay (Allan and others 2012b). Essentially, Allan and others examined the wind speeds identified at Cape Arago for a range of storm events and identified a wide range of values, with a maximum mean wind speed of 19.6 m/s (64.3 ft/s). Because the measured wind speeds reflect a 2-min average such that higher wind speeds have been measured throughout the entire record (e.g., the maximum 2-minute average wind speed is 29.3 m/s [96 ft/s], while the maximum 5-s wind gust reached 38.1 m/s [125.0 ft/s]), we believe it is justified to use the more conservative enhanced wind velocity of 19.6 m/s (64.3 ft/s). Furthermore, comparisons by Allan and others (2012b) indicated that the relative difference between the value suggested by NHC (2005) and the enhanced wind used here differs by about 30%. As can be seen from the **Table 6-3**, the calculated splash-down distances ($y_{G\,outer}$) indicate splash distances that range from as little as 0.9 m (3 ft) to a maximum of 5.9 m (19.4 ft); the mean splash distance is 2.9 m (9.6 ft), while the standard deviation is 1.6 m (5.2 ft). Thus, adopting the reduced wind velocity would cause the zones to narrow by ~1.8 m for the highest splash distance and 0.3 m for the smallest. Overall, these differences are negligible given the tremendous uncertainties in calculating splash and overtopping (NHC, 2005).

**Table 6-3.** **Splashdown and hazard zone limits calculated for Tillamook County detailed coastal sites. Values reported in the table reflect the maximum values derived from all the storm runup and overtopping calculations. Note: Dist_3, Dist_2, and Dist_1 reflect the landward extent at which the calculated bore height decreases from 0.9 m (3 ft), to 0.6 m (2 ft) and, finally, to 0.3 m (1 ft). In all cases, the hazard zones are ultimately defined relative to the location of the dune/structure crest.**

| Profiles | Transect | DFIRM Transect | Splashdown $y_{G\,outer}$ (m) | Bore Ht (m) | Dist_3 (≥0.91 m) | Dist_2 (>0.61 <0.91 m) | Dist_1 (≤0.31 m) | $hV^2 >$ $5.7 m^3/s^2$ (m) |
|---|---|---|---|---|---|---|---|---|
| **Salmon River** | LINC 308 | 1 | 1.4 | 0.57 | | | 2.66 | 36.24 |
| **Neskowin** | TILL 4 | 10 | 4.64 | 0.48 | | | 19.79 | 36.33 |
| | TILL 5 | 11 | 6.54 | 0.50 | | | 21.97 | 39.86 |
| | TILL 6 | 12 | 2.30 | 0.53 | | | 17.37 | 31.08 |
| | TILL 7 | 13 | 7.69 | 0.82 | | 14.24 | 39.89 | 64.60 |
| | TILL 8 | 14 | 4.29 | 0.54 | | | 24.21 | 43.10 |
| | TILL 9 | 15 | 1.29 | 0.15 | | | | |
| | TILL 11 | 17 | 0.33 | 0.04 | | | | |
| | TILL 13 | 19 | 1.15 | 0.05 | | | | |
| | TILL 14 | 20 | 2.73 | 0.55 | | | 26.58 | 47.15 |
| | TILL 15 | 21 | 5.62 | 0.51 | | | 22.03 | 39.86 |
| | TILL 16 | 22 | 1.59 | 0.16 | | | | |
| | TILL 18 | 24 | 3.74 | 0.29 | | | | |
| | TILL 19 | 25 | 2.55 | 0.42 | | | 14.05 | 26.84 |
| | TILL 20 | 26 | 1.77 | 0.45 | | | 17.56 | 32.79 |
| | TILL 22 | 28 | 1.30 | 0.11 | | | | |
| | TILL 24 | 30 | 0.77 | 0.04 | | | | |
| | TILL 25 | 31 | 0.69 | 0.08 | | | | |
| **Sand Lake** | TILL 45 | 51 | 1.00 | 0.68 | | 7.52 | 47.53 | 80.16 |
| | TILL 50 | 56 | 2.33 | 0.13 | | | | |
| | TILL 51 | 57 | 5.49 | 0.76 | | 10.30 | 36.60 | 60.29 |
| | TILL 52 | 58 | 4.71 | 0.51 | | | 18.23 | 32.88 |
| | TILL 54 | 60 | 2.03 | 0.16 | | | | |
| | TILL 62 | 68 | 0.37 | 0.19 | | | | |
| | TILL 63 | 69 | 0.19 | 0.44 | | | 15.82 | 29.75 |
| **Netarts** | TILL 75 | 81 | 2.24 | 0.52 | | | 30.63 | 54.94 |
| | TILL 76 | 82 | 5 | 0.6 | | | 39.42 | 68.39 |
| | TILL 77 | 83 | 10.79 | 1.33 | 27.1 | 51.41 | 83.07 | 123.33 |
| | TILL 78 | 84 | 11.97 | 1.57 | 43.8 | 69.78 | 103.84 | 150.1 |
| | TILL 80 | 86 | | | | | | |
| | TILL 81 | 87 | 1.1 | 0.24 | | | | |
| | TILL 88 | 94 | 4.53 | 0.48 | | | 20.98 | 38.47 |
| | TILL 93 | 99 | 1.27 | 0.66 | | 4.84 | 37.22 | 63.07 |
| | TILL 103 | 109 | 3.78 | 0.37 | | | 7.02 | 14.21 |
| **Bayocean Spit** | TILL 107 | 113 | 2.40 | 0.46 | | | 15.18 | 28.24 |
| | TILL 108 | 114 | 1.51 | 0.44 | | | 14.67 | 27.56 |
| | TILL 109 | 115 | 0.74 | 0.76 | | 13.67 | 48.34 | 79.62 |
| | TILL 110 | 116 | 2.21 | 0.81 | | 18.46 | 53.68 | 87.21 |
| | TILL 111 | 117 | 6.14 | 0.94 | 1.76 | 27.24 | 60.44 | 95.45 |

| Profiles | Transect | DFIRM Transect | Splashdown $y_{G\ outer}$ (m) | Bore Ht (m) | Dist_3 (≥0.91 m) | Dist_2 (>0.61 <0.91 m) | Dist_1 (≤0.31 m) | $hV^2 > 5.7 m^3/s^2$ (m) |
|---|---|---|---|---|---|---|---|---|
| **Rockaway** | TILL 118 | 124 | 1.83 | 0.33 | | | 2.95 | 6.84 |
| | TILL 119 | 125 | 1.23 | 0.12 | | | | |
| | TILL 120 | 126 | 0.81 | 0.10 | | | | |
| | TILL 121 | 127 | 1.72 | 0.21 | | | | |
| | TILL 122 | 128 | 0.86 | 0.15 | | | | |
| | TILL 123 | 129 | 9.34 | 1.06 | 8.87 | 30.77 | 59.32 | 91.65 |
| | TILL 124 | 130 | 0.22 | 0.05 | | | | |
| | TILL 125 | 131 | 1.99 | 0.31 | | | 0.56 | 2.10 |
| | TILL 126 | 132 | 0.77 | 0.04 | | | | |
| | TILL 131 | 137 | 2.03 | 0.10 | | | | |
| | TILL 132 | 138 | 0.77 | 0.34 | | | 4.69 | 10.02 |
| | TILL 137 | 143 | 0.58 | 0.02 | | | | |
| | TILL 138 | 144 | 1.55 | 0.27 | | | | |
| | TILL 140 | 146 | 1.71 | 0.15 | | | | |
| | TILL 141 | 147 | 2.84 | 0.52 | | | 24.25 | 43.49 |
| | TILL 142 | 148 | 5.79 | 0.57 | | | 26.12 | 45.86 |
| | TILL 143 | 149 | 6.12 | 0.49 | | | 18.26 | 33.29 |
| | TILL 144 | 150 | 3.93 | 0.32 | | | 1.34 | 3.48 |
| | TILL 145 | 151 | 1.58 | 0.12 | | | | |
| | TILL 146 | 152 | 0.92 | 0.14 | | | | |

Hazard zone calculations shown in **Table 6-3** indicate a similarly broad range of values that vary from negligible (i.e., effectively where the 1% TWL intersects with the backshore, plus the width of the splash zone where applicable) to as much as 73 m (240 ft) wide, with the widest zones having occurred where overtopping significantly exceeds the eroded beach crest elevations such as at Falcon Cove and at the south end of Seaside. Qualitative field observations of past storm wave overtopping events at all sites subject to overtopping calculated in this study confirm that this is indeed the case. Hence, field-based observations appear to be consistent with the calibrated results identified in **Table 6-3**. Overtopping for supplemental transects can be found in Appendix D. The depth of flooding at each mapped overtopping zone is indicated in **Table 6-4**.

**Table 6-4. The depth of flooding at the overtopping zones landward of the structure crest.**

| Profiles | Transect | DFIRM Transect | Dist_3 (≥0.91 m) | Dist_2 (>0.61 <0.91 m) | Dist_1 (≤0.31 m) | $hV^2 >$ $5.7 m^3/s^2$ (m) | Comment |
|---|---|---|---|---|---|---|---|
| Neskowin | TILL 4 | 10 | | | 0.3 | 0.3 | |
| | TILL 5 | 11 | | | 0.3 | 0.3 | |
| | TILL 6 | 12 | | | 0.3 | 0.3 | |
| | TILL 7 | 13 | | 0.61 | 0.3 | 0.3 | |
| | TILL 8 | 14 | | | 0.3 | 0.3 | |
| | TILL 14 | 20 | | | 0.3 | 0.3 | |
| | TILL 15 | 21 | | | 0.3 | 0.3 | |
| | TILL 20 | 26 | | | 0.3 | 0.3 | $hV^2$ zone added to VE zone |
| Sand Lake | TILL 45 | 51 | | 0.61 | 0.3 | 0.3 | $hV^2$ zone not mapped due to topo barrier |
| | TILL 51 | 57 | | 0.61 | 0.3 | 0.3 | |
| | TILL 52 | 58 | | | 0.3 | 0.3 | |
| Netarts | TILL 75 | 81 | | | 0.3 | 0.3 | overtopping stopped by topo barrier |
| | TILL 76 | 82 | | | 0.3 | 0.3 | |
| | TILL 77 | 83 | 0.91 | 0.61 | 0.3 | 0.3 | |
| | TILL 78 | 84 | 0.91 | 0.61 | 0.3 | 0.3 | |
| | TILL 88 | 94 | | | 0.3 | 0.3 | |
| | TILL 93 | 99 | | 0.61 | 0.3 | 0.3 | $hV^2$ zone cut short by topo barrier |
| | TILL 103 | 109 | | | 0.3 | 0.3 | |
| Bayocean Spit | TILL 107 | 113 | | | 0.3 | 0.3 | |
| | TILL 108 | 114 | | | 0.3 | 0.3 | |
| | TILL 109 | 115 | | 0.61 | 0.3 | 0.3 | |
| | TILL 110 | 116 | | 0.61 | 0.3 | 0.3 | |
| | TILL 111 | 117 | 0.91 | 0.61 | 0.3 | 0.3 | |
| Rockaway | TILL 118 | 124 | | | 0.3 | 0.3 | narrow overtopping added to VE zone |
| | TILL 123 | 129 | 0.91 | 0.61 | 0.3 | 0.3 | |
| | TILL 141 | 147 | | | 0.3 | 0.3 | |
| | TILL 142 | 148 | | | 0.3 | 0.3 | |
| | TILL 143 | 149 | | | 0.3 | 0.3 | |
| | TILL 144 | 150 | | | 0.3 | 0.3 | narrow overtopping added to VE zone |

# 7.0 COASTAL EROSION CAUSED BY INDIVIDUAL STORM EVENTS

In order to estimate beach (or bluff) erosion and the resulting profile changes that occur during a particular storm, it is important to first establish the initial profile conditions that existed prior to that storm. As outlined in Section 3.2, this initial profile morphology is represented by the most likely winter profile (MLWP), which forms the basis for determining profile changes that could eventuate as a result of a particularly severe storm(s). Having established the MLWP for a site, the profile is then modified according to the amount of erosion estimated to occur during a specified storm as a result of the increased water levels (tide + surge + ENSO) as well as from wave processes, specifically the wave runup. This section explores two approaches described in the revised FEMA guidelines, which may be used to establish the eroded profiles along the Tillamook County coastline. The second half of the section describes the specific approach adopted for Tillamook County and the results from our erosion analyses.

## 7.1 Models of Foredune Erosion

### *7.1.1 The Komar and others (1999) model*

The erosion potential of sandy beaches and foredunes along the Pacific Northwest coast of Oregon and Washington is a function of the total water level produced by the combined effect of the wave runup plus the tidal elevation ($E_T$), exceeding some critical elevation of the fronting beach, typically the elevation of the beach-dune junction ($E_J$). This basic concept is depicted in **Figure 7-1A** based on the model developed by Ruggiero and others (1996), and in the case of the erosion of a foredune backing the beach the application of a geometric model (**Figure 7-1B**) formulated by Komar and others (1999). Clearly, the more extreme the total water level elevation, the greater the resulting erosion that occurs along both dunes and bluffs.

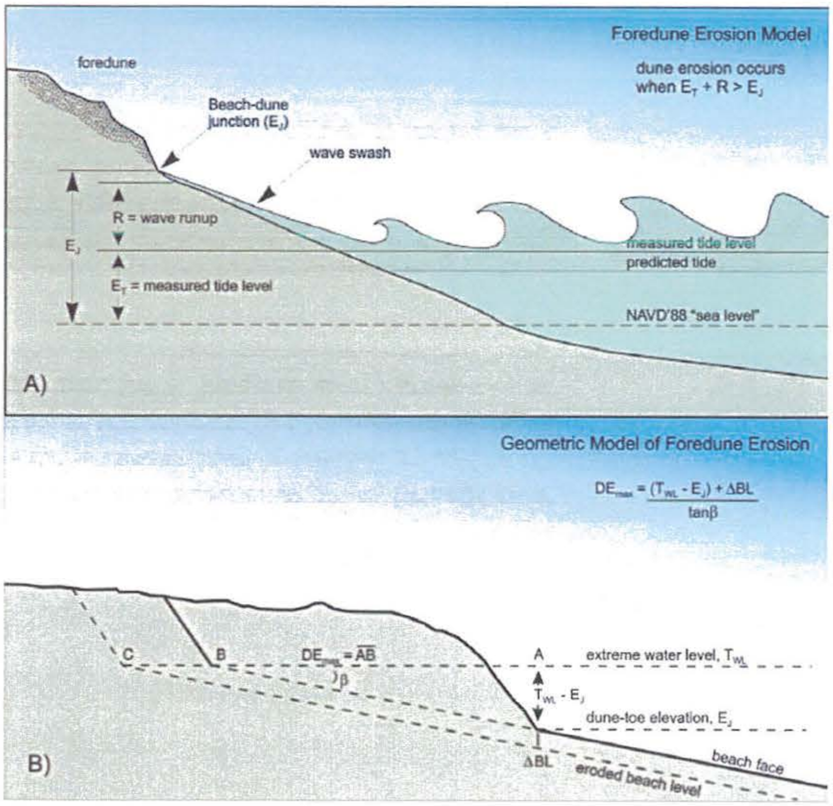

**Figure 7-1. A) The foredune erosion model. B) The geometric model used to assess the maximum potential beach erosion in response to an extreme storm (Komar and others, 1999).**

As can be seen **from Figure 7-1B**, estimating the maximum potential dune erosion ($DE_{max}$) is dependent on first determining the total water level (TWL) elevation diagrammed in **Figure 7-1A**, which includes the combined effects of extreme high tides plus storm surge plus wave runup, relative to the elevation of the beach-dune junction ($E_J$). Therefore, when the TWL > $E_J$, the foredune retreats landward by some distance, until a new beach-dune junction is established, the elevation of which approximately equals the extreme water level. Because beaches along the high-energy Oregon coast are typically wide and have a nearly uniform slope (tan $\beta$), the model assumes that this slope is maintained, and the dunes are eroded landward until the dune face reaches point B in **Figure 7-1B**. As a result, the model is geometric in that it assumes an upward and landward shift of a triangle, one side of which corresponds to the elevated water levels, and then the upward and landward translation of that triangle and beach profile to account for the total possible retreat of the dune (Komar and others, 1999).

An additional feature of the geometric model is its ability to accommodate further lowering of the beach face due to the presence of a rip current, which has been shown to be important to occurrences on the Oregon coast of localized "hot spot" erosion and property impacts (Komar, 1997). This feature of the model is represented by the beach-level change $\Delta BL$ shown in **Figure 7-1B**, which causes the dune to retreat some additional distance landward until it reaches point C. As can be seen from **Figure 7-1B**, the distance from point A to point C depicts the total retreat, $DE_{max}$, expected during a particularly severe storm event (or series of storms) that includes the localized effect enhancement by a rip current. Critical then in applying the model to evaluate the susceptibility of coastal properties to erosion, is an evaluation of the occurrence of extreme tides ($E_T$), the runup of waves, and the joint probabilities of these processes along the coast (Ruggiero and others, 2001), this having been the focus of Section 6, above.

The geometric model gives the maximum potential equilibrium cross-shore change in the shoreline position landward of the MLWP resulting from a storm. However, in reality it is unlikely that this extreme degree of response is ever fully realized, because of the assumptions that had been made in deriving the geometric model with the intent of evaluating the maximum potential dune erosion. As noted by Komar and others (1999), in the first instance the geometric model projects a mean linear beach slope. As a result, if the beach is more concave, it is probable that the amount of erosion would be less, though not by much. Perhaps of greater significance is that the geometric model assumes an instantaneous erosional response, with the dunes retreating landward as a result of direct wave attack. However, the reality of coastal change is that it is far more complex, there in fact being a lag in the erosional response behind the forcing processes. As noted by Komar and others (1999), the extreme high runup elevations typically occur for only a relatively short period of time (e.g., the period of time in which the high wave runup elevations coincide with high tides). Because tide elevation varies with time (e.g., hourly), the amount of erosion can be expected to be much less when the water levels are lower. Thus, it is probable that several storms during a winter may be required to fully realize the degree of erosion estimated by the geometric model; this did occur, for example, during the winter of 1998-99, with the last five storms the most extreme and erosive (Allan and Komar, 2002). In addition, as beaches erode, the sediment is removed offshore (or farther along the shore) into the surf zone where it accumulates in near shore sand bars. This process helps to mitigate the incoming wave energy by causing the waves to break farther offshore, dissipating some of the wave energy and forming the wide surf zones that are characteristic of the Oregon coast. In turn, this process helps to reduce the rate of beach erosion that occurs. In summary, the actual amount of beach erosion and dune recession is dependent on many factors, the most important of which include the incident wave conditions, the TWL, and the duration of the storm event(s).

### *7.1.2 The Kriebel and Dean (1993) model*

Kriebel and Dean (1993), hereafter known as K&D, developed a dune erosion model that is broadly similar to the Komar and others (1999) geometric model. At its core is the assumption that the beach is in statistical equilibrium with respect to the prevailing wave climate and mean water levels (Bruun, 1962). As water levels increase, the beach profile is shifted upward by an amount equal to the change in water level ($S$) and landward by an amount $R_\infty$ until the volume of sand eroded from the subaerial beach matches the volume deposited offshore in deeper water (**Figure 7-2**); *note that $DE_{MAX}$ and $R_\infty$ are essentially synonymous with each other.*

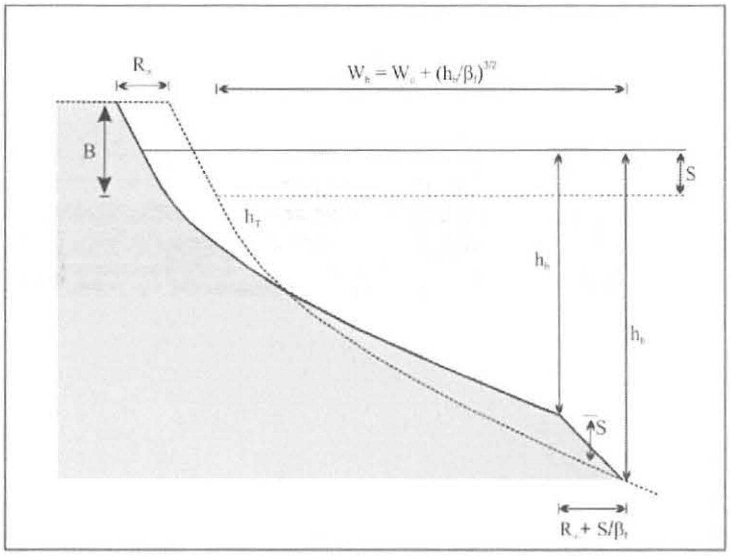

**Figure 7-2. Maximum potential erosion ($R_\infty$) due to a change in water levels (after Kriebel and Dean, 1993).**

One important distinguishing feature in the K&D model relative to Bruun (1962) is that it relies on the equilibrium beach profile theory proposed by Dean (1977) to account for the erosion following an increase in the water level. The Dean model is a simplified equilibrium form for open-coast beach profiles expressed as a power-law curve of the form:

$$h = Ax^{2/3} \text{ or equivalently as } x = \left(\frac{h}{A}\right)^{3/2} \qquad (7.1)$$

where $h$ is the water depth at a distance $x$ offshore from the still water level and $A$ is a parameter that governs the overall steepness (and slope) of the profile and is a function of the beach grain size. Thus, incorporating the assumed components of Bruun (1962) and Dean (1977), the maximum erosion potential, $R_\infty$, was determined by K&D to be a function of the increase in mean water level ($S$) caused by a storm, the breaking wave water depth ($h_b$), surf zone width ($W_b$), berm or dune height ($B$ or $D$), and the slope ($\beta_f$) of the upper foreshore beach face. The breaking wave depth ($h_b$) may be calculated from the wave breaker height (equation 6.8) multiplied by 0.78 (the breaker index).

As a result of the above concepts, K&D developed two approaches for determining the maximum erosion potential. These include:

- A beach backed by a low sand berm

$$R_\infty = \frac{S(W_b - h_b/\beta_f)}{B + h_b - S/2} \qquad (7.2)$$

- A beach backed by high sand dune

$$R_\infty = \frac{S(W_b - h_b/\beta_f)}{D + h_b - S/2} \qquad (7.3)$$

Like the Komar and others (1999) model, the Kriebel and Dean (1993) dune erosion model estimates the *maximum potential erosion* ($DE_{MAX}$) associated with a major storm and assumes that a particular storm will last sufficiently long enough to fully erode the dune. In reality, $DE_{MAX}$ is almost never fully realized because storms rarely last long enough to fully erode the dune to the extent of the model predictions. Because the duration of a storm is a major factor controlling beach and dune erosion, K&D developed an approach to account for the duration effects of storms with respect to the response time scale required to fully erode a beach profile. The time scale for the erosion of a dune to the extent $R$ given by equation (7.2) can be estimated using equation 7.4:

$$T_S = C_1 \frac{H_b^{3/2}}{g^{1/2}A^3}\left(1 + \frac{h_b}{B} + \frac{\beta_f W_b}{h_b}\right)^{-1} \qquad (7.4)$$

where $T_S$ is the time scale of response, $C_1$ is an empirical constant (320), $H_b$ is the breaker height, $h_b$ is the breaker depth, $g$ is acceleration due to gravity, $B$ is the berm elevation, $\beta_f$ is the slope of the foreshore, $W_b$ is the surf zone width, and $A$ is the beach profile parameter that defines an equilibrium profile. Using equation 7.4 yields typical response times for complete profile erosion that are on the order of 10 to 100 hours (NHC, 2005). In general, as the surf zone width increases due to larger wave heights, smaller grain sizes or gentler slopes, the response time increases. In addition, the response time will also increase as the height of the berm increases.

The beach profile response is determined by a convolution integral. According to NHC (2005), the time dependency of the storm hydrograph may be approximated by:

$$f(t) = \sin^2\left(\pi \frac{t}{T_D}\right) \; for\; 0 < t < T_D \qquad (7.5)$$

where $t$ is time from the start of the storm and $T_D$ is the storm duration. The convolution integral is:

$$DE(t) = \frac{DE_{MAX}}{T_S} \int_0^t f(\tau) e^{-(t-\tau)/T_S} \, d\tau \qquad (7.6)$$

which integrates to:

$$\begin{aligned}\frac{DE(t)}{DE_{MAX}} = 0.5\Bigg\{1 - \frac{\beta^2}{1+\beta^2}\exp\left(-\frac{t}{T_S}\right) \\ - \frac{1}{1+\beta^2}\left[\cos\left(\frac{2\pi t}{T_D}\right)\right. \\ \left. + \beta \sin\left(\frac{2\pi t}{T_D}\right)\right]\Bigg\}\end{aligned} \qquad (7.7)$$

where $\beta = 2\pi T_S/T_D$ and $DE_{MAX}$ is the maximum potential recession that would occur if the storm duration was infinite. Thus, if the storm duration, $T_D$, is long relative to the time scale of profile response, $T_S$, then a significant portion of the estimated erosion determined by the K&D or geometric model will occur. As the ratio of these two values decreases, the amount of erosion will also decrease. The time required for maximum beach and dune recession is determined by setting the derivative of equation 7.7 to zero and solving for time. This yields:

$$\begin{aligned}exp\left(-\frac{t_m}{T_D}\right) = \cos\left(\frac{2\pi t_m}{T_S}\right) \\ - \frac{T_D}{2\pi T_S}\sin\left(\frac{2\pi t_m}{T_S}\right)\end{aligned} \qquad (7.8)$$

in which $t_m$ is the time that the maximum erosion occurs with respect to the beginning of the storm. Unfortunately, this equation can only be solved by approximation or numerically. Thus the maximum recession associated with a duration limited storm can be calculated by:

$$\alpha = \frac{DE_m}{DE_{MAX}} = 0.5\left[1 - \cos\left(2\pi \frac{t_m}{T_D}\right)\right] \qquad (7.9)$$

where $\alpha$ is the duration reduction factor and $DE_m$ is the maximum recession that occurs for a given storm duration that occurs at time $t_m$. As a result, the duration limited recession is:

$$DE_m = \alpha DE_{MAX} \qquad (7.10)$$

### *7.1.3 Erosion modeling on Tillamook County beaches*

In order to determine the duration reduction factor, α, the duration of each storm event first has to be identified. The approach used here involved an analysis of the number of hours a specific TWL event was found to exceed a particular beach profile's beach-dune junction elevation, applying the Ruggiero and others (2001) analysis approach. **Figure 7-3** is an example of the approach we used, which is based on a script developed in MATLAB. In essence, the blue line is the TWL time series for a particular profile, ±3 days from the event. The script moves backward and forward in time from the identified event until the TWL falls below the critical threshold shown as the black line in **Figure 7-3**, which reflects the beach-dune junction elevation. The duration of the storm was then determined as the period where the TWL exceeds the threshold and includes the shoulders of the event (i.e., when the TWL first falls below the critical threshold). This process was undertaken for every storm and for each of the profile sites. One limitation of this approach that was encountered is that it is possible for the duration to be underestimated if the TWL dips below the threshold for an hour or more and then rises again above the threshold, as seen in the example in **Figure 7-3**.

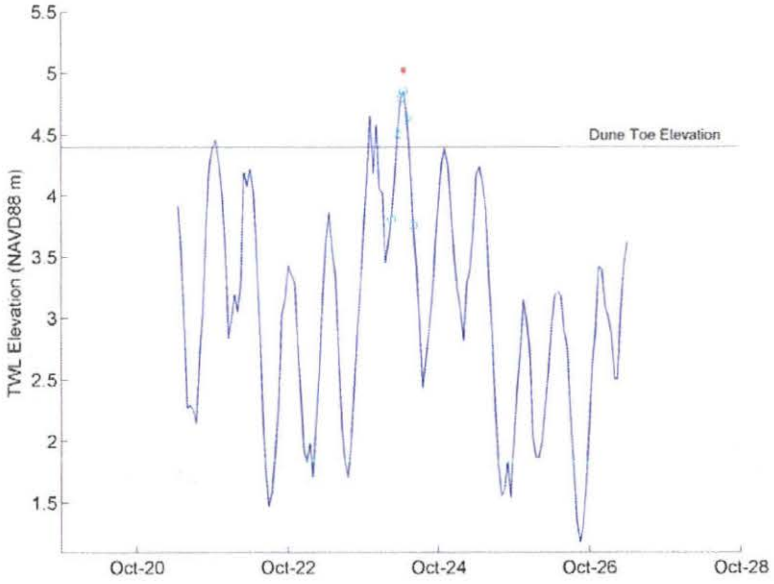

**Figure 7-3.** **Example plot of the approach used to define storm duration along the Coos County shoreline. Note: The red asterisk denotes the location of the storm peak. The light blue circles denote the hours when the event exceeded the critical beach-dune junction toe elevation (including the shoulders) that are used to define the "duration" of the event.**

As described previously, the breaker height, $H_b$, was calculated using equation 6.8 and the breaker depth, $h_b$, was calculated using a breaker index of 0.78. The berm elevation was established at 3 m (typical for PNW beaches), while the surf zone width, $W_b$, was determined for each breaker depth value by interpolating along a profile line of interest (**Figure 7-4**). Although we have grain size information available that could have been used to define the $A$ parameter for Tillamook County, the approach we took was to iteritively determine an equilibrium $A$ value based on the actual beach profile data. Here we used the profile data seaward to the 8 m (26.3 ft) water depth, and a range of $A$ values were fit to the data until a value was found that best matched the profile morphology. This approach was adopted for all the profile sites. **Figure 7-5** presents the alongshore varying dune erosion parameters (beach slope, $A$, surfzone width, and breaker depth) calculated for each transect site and averaged over every storm. These data are also summarized in **Table 7-1**.

**Figure 7-6** presents the alongshore varying time-scale for the erosion of a dune ($T_S$), storm duration ($T_D$), and duration reduction factor ($\alpha$) values determined for those transect sites characterized as "dune-backed" in Tillamook County. In all cases, we used the surf zone width, breaking depth, and water levels determined at the respective transect site (along with information pertaining to the site's beach/dune morphology) to calculate $T_S$, and $T_D$ for each storm, while the final parameter, $Tm$, was solved numerically using equation 7.8 in order to define the duration reduction factor ($\alpha$). These data have subsequently been averaged for each of the transect locations and are included in **Table 7-1** and presented in **Figure 7-5** and **Figure 7-6**.

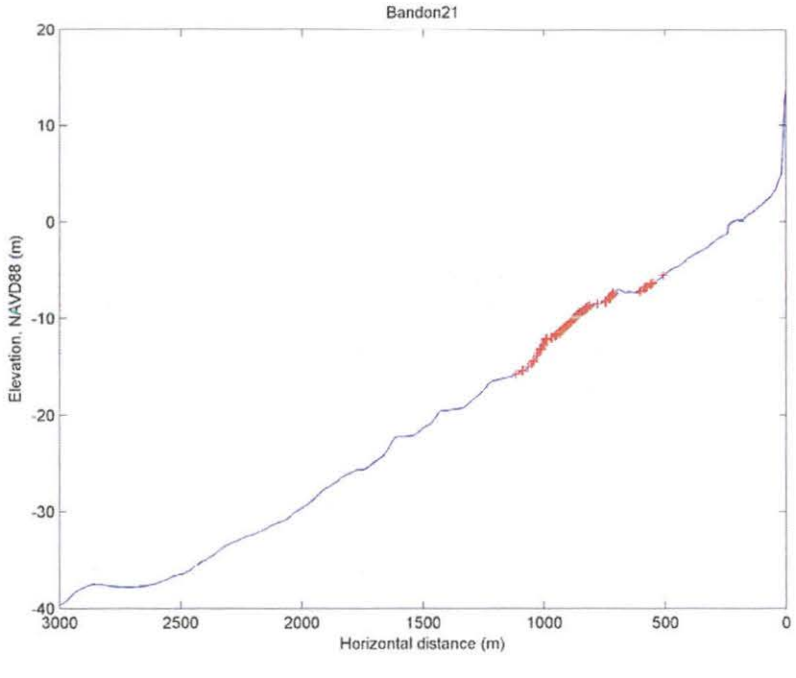

**Figure 7-4. Example transect from Coos County showing the locations of $h_b$ (red crosses), used to define the cross-shore width ($W_b$) of the surf zone.**

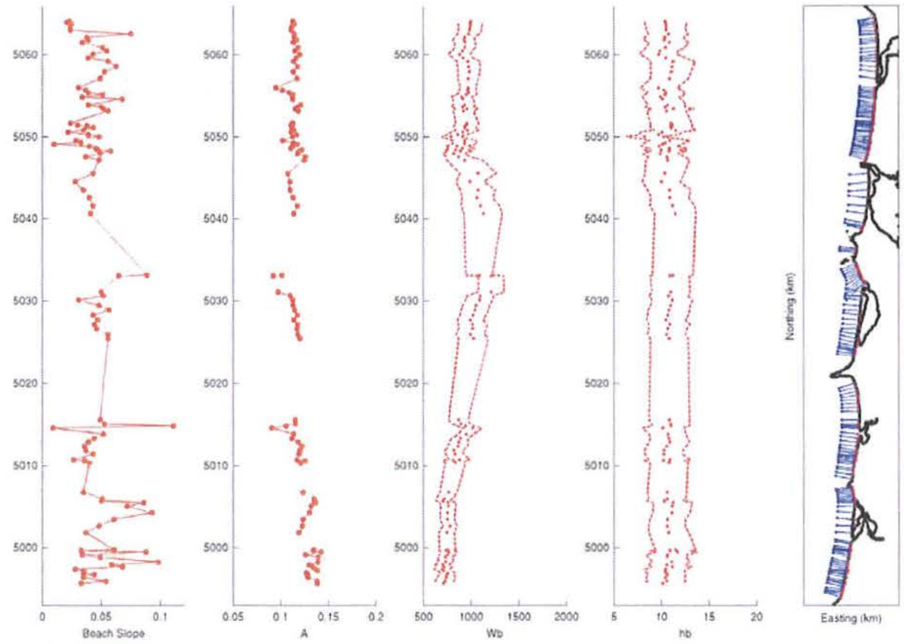

Figure 7-5. Plot showing the dune erosion parameters (tan β, $A$, $W_b$, and $h_b$) used to calculate the profile responses ($T_S$), storm durations ($T_D$), alpha, and the storm induced dune erosion. For $W_b$ and $h_b$ we show the mean value and ±1 standard deviation computed using all of the storms.

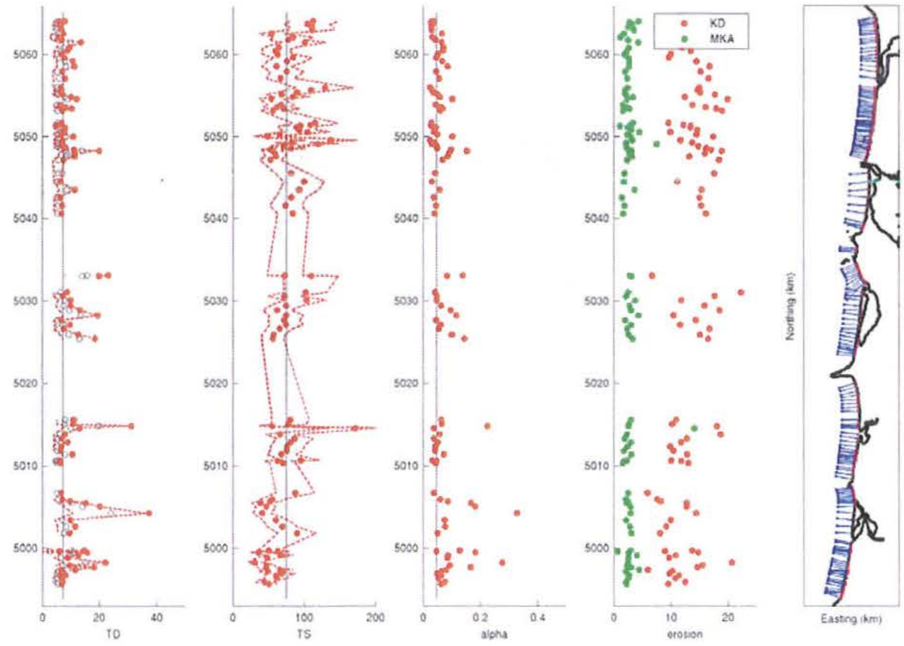

Figure 7-6. Plot showing the storm duration hours ($T_D$), the calculated time scale of profile response hours ($T_S$), alpha, and the storm induced K&D and geometric model erosion adjusted using equation 7.10 for the dune-backed profiles along the Tillamook County shore.

Having defined the duration reduction factor ($\alpha$) for each transect location, the storm-induced erosion was calculated using equation 7.10. As can be seen in **Table 7-1**, calculations of the maximum potential dune erosion ($DE_{MAX}$) using the Komar and others (1999) geometric model yielded results that are considerably smaller than those derived using the Kriebel and Dean (1993) approach. These differences are largely due to the effect of the surf zone width parameter and the low nearshore slopes used in the K&D calculations. Our initial calculations of storm-induced erosion based on the K&D approach indicated several sites with anomalously large estimates of dune erosion (>20 m [65.6 ft]), when compared with actual field observations by DOGAMI staff over the past two decades. In contrast, storm-induced erosion estimates based on the maximum potential dune erosion ($DE_{MAX}$) calculated using the geometric model produced very negligible erosion responses that made little physical sense. As a result, our final calculation of the storm-induced erosion ($DE_m$) is based on the K&D approach. To reduce the large erosion responses observed at several of the transect sites, we ultimately defined an alongshore averaged duration reduction factor ($\alpha$) of 0.047 (**Table 7-1**), which was used to calculate the storm-induced erosion ($DE_m$) at each of the dune-backed transect sites present along Tillamook County. As can be seen from **Table 7-1**, this resulted in erosion responses that range from a minimum of 5.9 m (19.4 ft) to as much as 22.3 m (73 ft), while the mean storm-induced erosion response is calculated to be 13 m (42.7 ft). These results are entirely consistent with actual field observations derived from both GPS beach surveys and from previous analyses of topographic change data measured using lidar (Allan and Harris, 2012; Allan and Stimely, 2013).

**Table 7-1.** Calculated storm-induced erosion parameters for dune-backed beaches in Tillamook County. Note: MKA denotes the geometric model and K&D is the Kriebel and Dean model.

| Profiles | Transect | DFIRM Transect | $A$ | $W_b$ | $T_D$ | $T_S$ | $\alpha$ | MKA ($DE_{MAX}$) | MKA ($DE_m$) | K&D ($DE_{MAX}$) | K&D ($DE_m$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Salmon R. | LINC 308 | 1 | 0.11 | 798.42 | 24.87 | 69.19 | 0.16 | 76.35 | 3.66 | 368.05 | 17.64 |
| Neskowin | TILL 9 | 15 | 0.14 | 712.64 | 6.68 | 50.64 | 0.06 | 48.09 | 2.25 | 203.18 | 9.5 |
| | TILL 10 | 16 | 0.14 | 722.37 | 7.17 | 44 | 0.08 | 45.48 | 2.13 | 266.33 | 12.45 |
| | TILL 11 | 17 | 0.13 | 739.27 | 6.81 | 61.46 | 0.05 | 55.37 | 2.59 | 229.76 | 10.74 |
| | TILL 12 | 18 | 0.13 | 741.74 | 8.14 | 60.99 | 0.06 | 57.5 | 2.69 | 242.34 | 11.33 |
| | TILL 13 | 19 | 0.13 | 760.19 | 6.86 | 68.65 | 0.05 | 52.02 | 2.43 | 208.52 | 9.75 |
| | TILL 16 | 22 | 0.14 | 714.18 | 6.73 | 49.48 | 0.06 | 45.52 | 2.13 | 218 | 10.19 |
| | TILL 17 | 23 | 0.14 | 695.49 | 11.52 | 66.27 | 0.08 | 95.44 | 4.46 | 128.02 | 5.98 |
| | TILL 18 | 24 | 0.13 | 716.27 | 18.21 | 46.66 | 0.17 | 63.8 | 2.98 | 312.9 | 14.62 |
| | TILL 19 | 25 | 0.13 | 701.34 | 9.62 | 46.86 | 0.09 | 49.07 | 2.29 | 331.62 | 15.5 |
| | TILL 20 | 26 | 0.14 | 734.73 | 22.22 | 30.54 | 0.28 | 53.06 | 2.48 | 441.15 | 20.62 |
| | TILL 21 | 27 | 0.14 | 731.12 | 8.86 | 48.09 | 0.09 | 53.55 | 2.5 | 206.44 | 9.65 |
| | TILL 22 | 28 | 0.13 | 753.94 | 12.55 | 66.68 | 0.09 | 87.63 | 4.1 | 231.5 | 10.82 |
| | TILL 23 | 29 | 0.14 | 768.35 | 15.66 | 36.01 | 0.18 | 55.04 | 2.57 | 316.45 | 14.79 |
| | TILL 24 | 30 | 0.13 | 738.81 | 6.04 | 63.03 | 0.05 | 14.69 | 0.69 | 191.74 | 8.96 |
| | TILL 25 | 31 | 0.13 | 751.14 | 14.6 | 50.47 | 0.13 | 62.92 | 2.94 | 293.27 | 13.71 |
| Pacific City | TILL 29 | 35 | 0.12 | 744.43 | 9.53 | 90.47 | 0.05 | 66.07 | 3.09 | 173.33 | 8.1 |
| | TILL 30 | 36 | 0.12 | 779.31 | 11.45 | 69.47 | 0.08 | 60.19 | 2.81 | 197.34 | 9.22 |
| | TILL 31 | 37 | 0.12 | 750.86 | 9.82 | 60.61 | 0.08 | 46.26 | 2.16 | 212.93 | 9.95 |
| | TILL 32 | 38 | 0.13 | 753.17 | 37.35 | 41.04 | 0.33 | 63.53 | 2.97 | 309.26 | 14.45 |
| | TILL 33 | 39 | 0.13 | 761.88 | 20.25 | 47.08 | 0.18 | 62.73 | 2.93 | 273.59 | 12.79 |
| | TILL 34 | 40 | 0.14 | 760.24 | 15.17 | 38.79 | 0.17 | 48.52 | 2.27 | 273.82 | 12.8 |
| | TILL 35 | 41 | 0.14 | 706.32 | 9.81 | 52.08 | 0.09 | 54.29 | 2.54 | 175.78 | 8.21 |
| | TILL 36 | 42 | 0.13 | 719.24 | 7.07 | 55.64 | 0.06 | 45.15 | 2.11 | 163.42 | 7.64 |
| | TILL 39 | 45 | 0.12 | 767.5 | 6.62 | 87.75 | 0.04 | 54.66 | 2.55 | 126.49 | 5.91 |
| Sand Lake | TILL 48 | 54 | 0.12 | 836.71 | 6.38 | 70.5 | 0.04 | 32.67 | 1.53 | 279.25 | 13.05 |
| | TILL 49 | 55 | 0.13 | 817.5 | 6.07 | 63.05 | 0.05 | 39.9 | 1.86 | 253.02 | 11.82 |
| | TILL 50 | 56 | 0.12 | 880.96 | 6.13 | 95.32 | 0.03 | 50.64 | 2.37 | 215.19 | 10.06 |
| | TILL 55 | 61 | 0.12 | 829.65 | 10.48 | 68.43 | 0.07 | 66.1 | 3.09 | 274.64 | 12.84 |
| | TILL 58 | 64 | 0.12 | 821.41 | 6.41 | 75.77 | 0.04 | 38.16 | 1.78 | 223.87 | 10.46 |
| | TILL 59 | 65 | 0.12 | 867.33 | 6.7 | 76.52 | 0.04 | 52.08 | 2.43 | 211.22 | 9.87 |
| | TILL 60 | 66 | 0.12 | 874.61 | 8.89 | 81.32 | 0.05 | 64.06 | 2.99 | 251.35 | 11.75 |
| | TILL 61 | 67 | 0.11 | 889.38 | 6.76 | 87.03 | 0.04 | 40.4 | 1.89 | 272.73 | 12.75 |
| | TILL 62 | 68 | 0.11 | 953.4 | 8.04 | 66.54 | 0.06 | 50.17 | 2.34 | 400.8 | 18.73 |
| | TILL 63 | 69 | 0.11 | 953.4 | 8.04 | 66.54 | 0.06 | 50.17 | 2.34 | 400.8 | 18.73 |
| | TILL 64 | 70 | 0.11 | 944.48 | 31.08 | 55.33 | 0.23 | 54.78 | 2.56 | 386.3 | 18.05 |
| | TILL 65 | 71 | 0.12 | 893.19 | 10.81 | 78.47 | 0.06 | 57.05 | 2.67 | 218.31 | 10.2 |
| | TILL 66 | 72 | 0.12 | 869.49 | 11.02 | 81.1 | 0.06 | 64.25 | 3 | 233.68 | 10.92 |
| Netarts | TILL 82 | 88 | 0.12 | 1029.92 | 18.55 | 55.93 | 0.14 | 70.86 | 3.31 | 353.98 | 16.54 |
| | TILL 83 | 89 | 0.12 | 993.78 | 12.62 | 57.29 | 0.1 | 54.84 | 2.56 | 323.33 | 15.11 |
| | TILL 84 | 90 | 0.12 | 1017.88 | 7.53 | 66.01 | 0.05 | 50.07 | 2.34 | 357.96 | 16.73 |
| | TILL 85 | 91 | 0.12 | 1021.41 | 9.84 | 75.2 | 0.06 | 65.12 | 3.04 | 247.47 | 11.57 |
| | TILL 86 | 92 | 0.11 | 994.98 | 6.78 | 71.99 | 0.05 | 42.1 | 1.97 | 307.03 | 14.35 |
| | TILL 87 | 93 | 0.12 | 1023.68 | 19.44 | 75.08 | 0.12 | 92.71 | 4.33 | 222.97 | 10.42 |
| | TILL 88 | 94 | 0.11 | 1043.23 | 13.12 | 62.3 | 0.1 | 64.85 | 3.03 | 397.13 | 18.56 |
| | TILL 89 | 95 | 0.11 | 1056.53 | 9.91 | 75.08 | 0.06 | 58.65 | 2.74 | 340.41 | 15.91 |
| | TILL 90 | 96 | 0.11 | 1089.76 | 10.05 | 103.28 | 0.05 | 80.54 | 3.76 | 253.07 | 11.83 |
| | TILL 91 | 97 | 0.11 | 1099.97 | 7.16 | 72.44 | 0.05 | 46.47 | 2.17 | 378.14 | 17.67 |
| | TILL 92 | 98 | 0.1 | 1214.09 | 8.74 | 102.14 | 0.04 | 54.7 | 2.56 | 476.14 | 22.25 |
| | TILL 97 | 103 | 0.09 | 1213.67 | 19.94 | 109.98 | 0.08 | 66.55 | 3.11 | 143.97 | 6.73 |
| | TILL 98 | 104 | 0.1 | 1088.69 | 23.13 | 73.19 | 0.14 | 59.13 | 2.76 | 143.92 | 6.73 |

| Profiles | Transect | DFIRM Transect | $A$ | $W_b$ | $T_D$ | $T_S$ | $\alpha$ | MKA ($DE_{MAX}$) | MKA ($DE_m$) | K&D ($DE_{MAX}$) | K&D ($DE_m$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bayocean** | TILL 112 | 118 | 0.11 | 1129.98 | 6.77 | 84.29 | 0.04 | 33.25 | 1.55 | 346.07 | 16.17 |
| | TILL 113 | 119 | 0.12 | 1102.1 | 6.96 | 74.17 | 0.04 | 40.27 | 1.88 | 327.78 | 15.32 |
| | TILL 114 | 120 | 0.11 | 1067.45 | 6.25 | 82.08 | 0.04 | 29.5 | 1.38 | 321.71 | 15.04 |
| | TILL 115 | 121 | 0.11 | 1076.73 | 11.41 | 93.32 | 0.06 | 78.67 | 3.68 | 329.28 | 15.39 |
| | TILL 116 | 122 | 0.11 | 990.11 | 6.25 | 99.92 | 0.03 | 36.98 | 1.73 | 237.39 | 11.09 |
| | TILL 117 | 123 | 0.11 | 1076.77 | 7 | 81.62 | 0.04 | 40.57 | 1.9 | 376.63 | 17.6 |
| **Rockaway** | TILL 118 | 124 | 0.12 | 933.68 | 7.5 | 52.59 | 0.07 | 49.99 | 2.34 | 393.64 | 18.4 |
| | TILL 119 | 125 | 0.13 | 868.41 | 11.19 | 60.25 | 0.09 | 68.29 | 3.19 | 283.03 | 13.23 |
| | TILL 120 | 126 | 0.12 | 817.94 | 11.39 | 58.5 | 0.09 | 57.74 | 2.7 | 341.79 | 15.97 |
| | TILL 121 | 127 | 0.12 | 891.38 | 19.95 | 56.18 | 0.15 | 67.22 | 3.14 | 404.81 | 18.92 |
| | TILL 122 | 128 | 0.12 | 841.92 | 11.13 | 52.38 | 0.1 | 60.72 | 2.84 | 363.07 | 16.97 |
| | TILL 124 | 130 | 0.11 | 908.63 | 8.16 | 81.79 | 0.05 | 48.71 | 2.28 | 345.46 | 16.15 |
| | TILL 125 | 131 | 0.11 | 851.29 | 7.02 | 71.19 | 0.05 | 47.96 | 2.24 | 316.45 | 14.79 |
| | TILL 126 | 132 | 0.11 | 851.29 | 7.02 | 71.19 | 0.05 | 47.96 | 2.24 | 316.45 | 14.79 |
| | TILL 127 | 133 | 0.11 | 934.31 | 6.71 | 83.48 | 0.04 | 46.17 | 2.16 | 293.92 | 13.74 |
| | TILL 128 | 134 | 0.1 | 933.36 | 7.04 | 137.41 | 0.02 | 69.61 | 3.25 | 249.27 | 11.65 |
| | TILL 129 | 135 | 0.11 | 792.57 | 10.94 | 48.9 | 0.1 | 63.12 | 2.95 | 372.44 | 17.41 |
| | TILL 130 | 136 | 0.12 | 863.23 | 6.72 | 65.56 | 0.05 | 50.22 | 2.35 | 309.97 | 14.49 |
| | TILL 131 | 137 | 0.11 | 917.13 | 7.83 | 104.66 | 0.04 | 96.74 | 4.52 | 212.33 | 9.92 |
| | TILL 133 | 139 | 0.11 | 967.17 | 7.59 | 93.12 | 0.04 | 65.91 | 3.08 | 312.76 | 14.62 |
| | TILL 134 | 140 | 0.11 | 937.96 | 8.03 | 89.33 | 0.04 | 52.74 | 2.47 | 286.76 | 13.4 |
| | TILL 135 | 141 | 0.11 | 938.06 | 5.18 | 94.63 | 0.03 | 23.48 | 1.1 | 288.86 | 13.5 |
| | TILL 139 | 145 | 0.11 | 961.29 | 6.71 | 115.22 | 0.03 | 72.28 | 3.38 | 204.31 | 9.55 |
| | TILL 147 | 153 | 0.12 | 924.87 | 7.01 | 55.98 | 0.06 | 33.36 | 1.56 | 405.44 | 18.95 |
| | TILL 148 | 154 | 0.12 | 960.23 | 10.27 | 71.21 | 0.07 | 57.41 | 2.68 | 383.87 | 17.94 |
| | TILL 149 | 155 | 0.12 | 912.02 | 7.97 | 62.23 | 0.06 | 49.47 | 2.31 | 344.69 | 16.11 |
| | TILL 150 | 156 | 0.12 | 934.25 | 6.17 | 67.82 | 0.04 | 33.35 | 1.56 | 294.76 | 13.78 |
| | TILL 152 | 158 | 0.11 | 919.41 | 12.08 | 54.08 | 0.1 | 50.89 | 2.38 | 426.31 | 19.92 |
| | TILL 153 | 159 | 0.11 | 902.13 | 10.16 | 84 | 0.06 | 72.24 | 3.38 | 265.94 | 12.43 |
| | TILL 154 | 160 | 0.11 | 951.31 | 7.08 | 68.27 | 0.05 | 45.71 | 2.14 | 379.01 | 17.71 |
| | TILL 155 | 161 | 0.11 | 975.26 | 6.57 | 89.8 | 0.04 | 41.23 | 1.93 | 324.63 | 15.17 |
| | TILL 156 | 162 | 0.1 | 967.48 | 6.68 | 109.06 | 0.03 | 43.22 | 2.02 | 313.58 | 14.66 |
| | TILL 157 | 163 | 0.09 | 972.43 | 6.46 | 129.39 | 0.02 | 52.1 | 2.44 | 320.55 | 14.98 |
| **Nehalem** | TILL 158 | 164 | 0.12 | 972.19 | 7.87 | 66.9 | 0.06 | 50.89 | 2.38 | 354.31 | 16.56 |
| | TILL 159 | 165 | 0.11 | 982.77 | 7.01 | 75.71 | 0.04 | 42.75 | 2 | 324.99 | 15.19 |
| | TILL 160 | 166 | 0.12 | 978.15 | 11.29 | 60.98 | 0.09 | 57.12 | 2.67 | 358.29 | 16.74 |
| | TILL 161 | 167 | 0.11 | 971.16 | 10.68 | 75.97 | 0.07 | 58.15 | 2.72 | 310.33 | 14.5 |
| | TILL 162 | 168 | 0.12 | 919.97 | 7.84 | 84.33 | 0.04 | 55.25 | 2.58 | 206.23 | 9.64 |
| | TILL 163 | 169 | 0.12 | 880.48 | 6.69 | 62.76 | 0.05 | 40.35 | 1.89 | 213.27 | 9.97 |
| | TILL 164 | 170 | 0.11 | 908.82 | 8.75 | 59.44 | 0.07 | 49.56 | 2.32 | 288.63 | 13.49 |
| | TILL 165 | 171 | 0.12 | 939.04 | 9.71 | 64.73 | 0.07 | 56.26 | 2.63 | 255.72 | 11.95 |
| | TILL 166 | 172 | 0.11 | 941.75 | 13.53 | 100.69 | 0.06 | 91.68 | 4.28 | 228.42 | 10.68 |
| | TILL 167 | 173 | 0.12 | 927.17 | 6.86 | 77.74 | 0.04 | 53.61 | 2.51 | 247.47 | 11.57 |
| | TILL 168 | 174 | 0.11 | 933.89 | 5.58 | 84.99 | 0.03 | 25.2 | 1.18 | 235.56 | 11.01 |
| | TILL 169 | 175 | 0.11 | 976.6 | 7.42 | 54.01 | 0.06 | 37.11 | 1.73 | 411.96 | 19.25 |
| | TILL 171 | 177 | 0.11 | 989 | 6.69 | 110.48 | 0.03 | 75.24 | 3.52 | 225.95 | 10.56 |
| | TILL 172 | 178 | 0.11 | 995.61 | 6.29 | 110.49 | 0.03 | 53.95 | 2.52 | 213.52 | 9.98 |
| | TILL 173 | 179 | 0.11 | 995.27 | 6.67 | 104.42 | 0.03 | 67.56 | 3.16 | 204.89 | 9.58 |
| | TILL 174 | 180 | 0.11 | 995.85 | 6.04 | 111.34 | 0.03 | 58.71 | 2.74 | 192.45 | 8.99 |
| | TILL 175 | 181 | 0.11 | 1002.39 | 7.96 | 111.91 | 0.03 | 92.54 | 4.32 | 195.85 | 9.15 |
| **Mean** | | | **0.12** | **905.16** | **10.11** | **75.39** | **0.047** | **58.85** | **2.75** | **277.17** | **12.96** |

Note: $A$ is the beach profile parameter that defines an equilibrium profile; $W_b$ is the surf zone width; $T_D$ is the storm duration; $T_S$ is the time scale of response; α is the duration reduction factor.

**Figure 7-7** and **Figure 7-8** provide two examples where the most eroded winter profile is eroded to reflect the storm-induced erosion values identified in **Table 7-1**. The first example is the Clatsop Plains 1 profile site where the beach is backed by a prominent foredune. In this example, the calculated duration reduced recession is ~16.9 m (55 ft). The location of the beach-dune junction is depicted in **Figure 7-7** by the brown circle, while the most eroded winter profile is shown as the black line. Because the underlying principle of the K&D and geometric models is for the slope to remain constant, the dune is eroded landward by shifting the location of the beach/dune junction landward by 16.9 m (55 ft) and upward to its new location where it forms an erosion scarp (**Figure 7-7**). Due to the high dune crest, overtopping does not occur at this location. **Figure 7-8** provides an example where dune breaching and overtopping occurs in response to the calculated 1% TWL for the Clatsop Plains 14 profile site. The calculated dune erosion for Clatsop Plains 14 is ~17.9 m (59 ft). The location of the beach-dune junction is depicted in **Figure 7-8** by the shaded black circle, while the *MLWP* is shown as the black line. As noted by NHC (2005), when dunes are subject to major overtopping events, breaching of the dune typically results in significant lowering of the dune morphology and the development of an overwash fan on the lee side of the dune. Because the present methodologies are unable to account for such responses, NHC recommends that the dune profile be adjusted by extending the *MLWP* slope to the backside of the dune. This type of adjustment is demonstrated in **Figure 7-8** where the entire foredune is assumed to be eroded and removed as a result of a major storm.

Unfortunately, there are no measured examples of the type of response depicted in **Figure 7-8** for the Tillamook County area that can be used to make comparisons against. However, monitoring of beaches by DOGAMI on the Oregon coast provides some suggestion that this approach is probably reasonable. **Figure 7-9** is an example of beach profile changes measured along a barrier beach adjacent to Garrison Lake, Port Orford, located to the south of Bandon. In this example, the barrier beach, which has a crest elevation of 8-9 m NAVD88 (26–29 ft), is known to have been overtopped during several major storms in February/March 1999 (**Figure 7-10**) (Allan and others, 2003). Analyses of the mean shoreline position at this site indicate that changes in the morphology of the beach is controlled primarily by the occurrence of these major storms as well as by El Niño climate events that result in hotspot erosion. Examination of the beach profile changes along the Garrison Lake shore indicate that during major events characterized by overtopping, the crest of the barrier beach is lowered, with some of the eroded sand having been carried landward where they form washover fans, while the bulk is removed seaward to form sand bars. Ultimately though, any dune located at the back of the profile is removed entirely, as the barrier rolls landward, consistent with the response depicted in **Figure 7-7**.

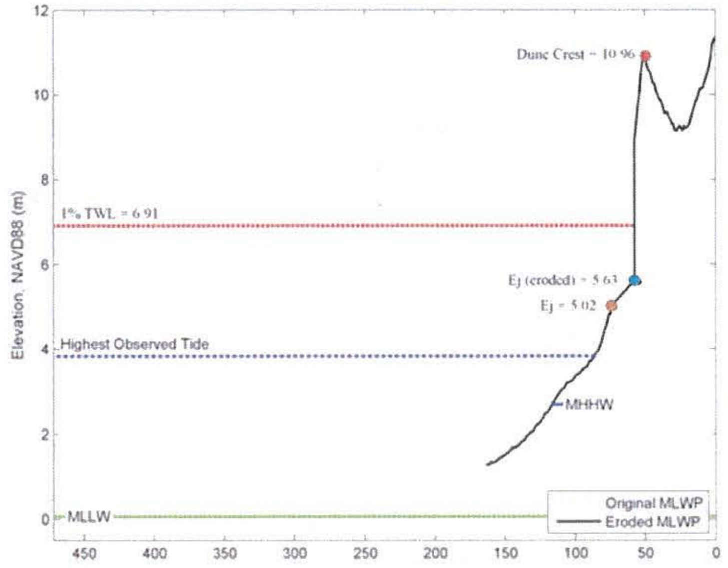

Figure 7-7. Application of the duration reduced erosion estimate to the most likely winter profile *(MLWP)* at Clatsop Plains 1. Brown (cyan) dot depicts the original (eroded) beach/dune juncture, and red dot depicts the dune crest (Dhigh).

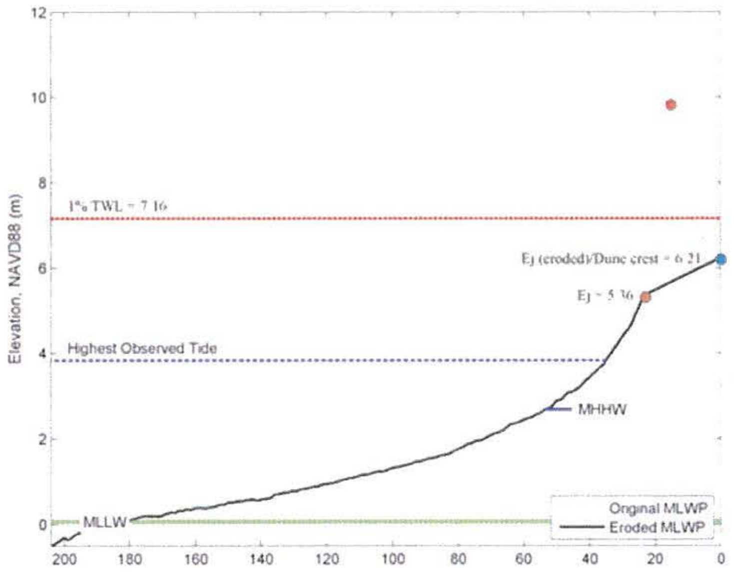

Figure 7-8. Application of the duration reduced erosion estimate to the most likely winter profile *(MLWP)* at Clatsop Plains 14 where overtopping and breaching occurs. Brown (cyan) dot depicts the original (eroded) beach/dune juncture, and red dot depicts the dune crest (Dhigh).

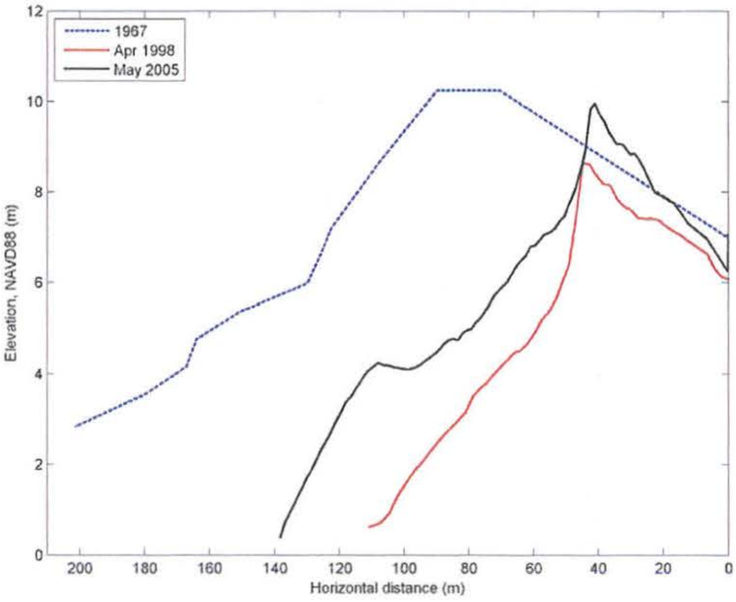

**Figure 7-9.** Example profile where a barrier beach is overtopped and eroded. This example is based on measured beach profile changes at Garrison Lake, Port Orford on the southern Oregon coast. The 1967 morphology was derived from Oregon Department of Transportation surveys of the beach on September 25, 1967, used to define the Oregon statutory vegetation line.

**Figure 7-10.** Overtopping of the barrier beach adjacent to Garrison Lake during a major storm on February 16, 1999 (photo courtesy of a resident at Port Orford).

# 8.0 FLOOD MAPPING

## 8.1 Detailed Coastal Zone VE Flood Zone Mapping

Detailed mapping of the 1% chance flood event within selected areas of Tillamook County was performed using two contrasting approaches, controlled ultimately by the geomorphology of the beach and backshore. In all cases we followed the methods described in section D.4.9 in the final draft guidelines of the Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States (NHC, 2005). Due to the complexities of each mapping approach for the 0.1% chance flood event, it was not possible to reasonably map the 0.2% chance event. The reasons for this are described in more detail in the following sections.

### *8.1.1 Bluff-backed beaches*

For bluff-backed beaches the total water level (*TWL*) values calculated in Section 6.3 were extended into the bluff. The first step involved identifying specific contours of interest, which were extracted from the 1-m resolution bare-earth lidar grid DEM (surveyed in 2009). For the bluff-backed beaches the landward extent of the coastal Zone VE is defined by the contour representing the TWL elevation calculated for each of the represented detailed surveyed transects (e.g., **Figure 8-1** and **Table 6-2**. FEMA Operating Guidance 9-13 (2013) dictates that areas near the landward extent of Zone VE, where the difference between the TWL and ground elevation is less than 3 feet, be designated as Zone AE. However, due to the steepness of the shoreline along bluff-backed beaches, such areas are too thin in Tillamook County (with one exception at the TILL 177 transect located north of Manzanita) to be visible at the prescribed map scale, and therefore Zone AE was not designated in these environments.

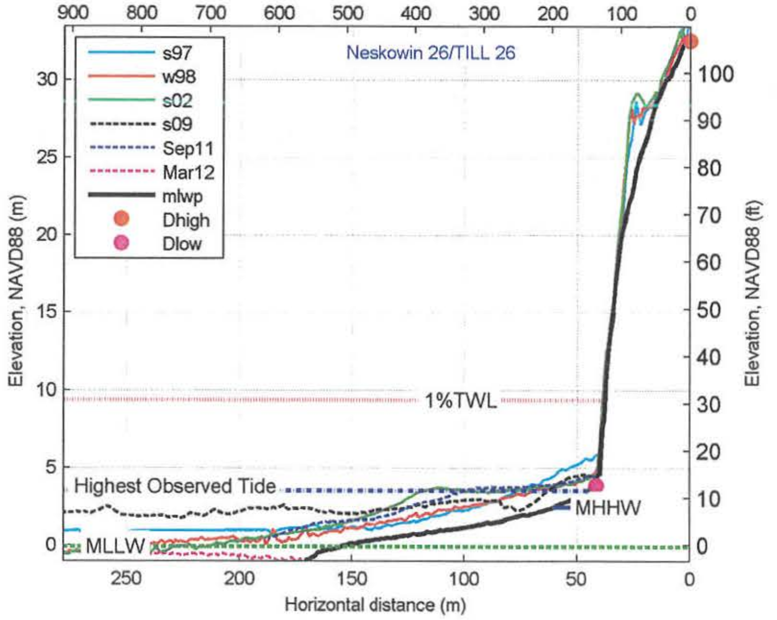

**Figure 8-1. Example of a bluff-backed beach (TILL 26) where the calculated total water level and defined velocity (VE) zone extends into the bluff.**

To define the velocity zones between transects, we used professional judgment to establish appropriate zone breaks between the various transects. For example, along-shore geomorphic barriers were identified within which the transect TWL value is valid (**Figure 8-2**). Slope and hillshade derivatives of the lidar DEM, as well as 1-m orthophotos (acquired in 2009), provided the base reference. An effort was made to orient zone breaks perpendicular to the beach at the location of the geomorphic barrier. The seaward extents for the majority of Zone VE were inherited from the preliminary DFIRM (2011). In some cases adopting the effective extent produced inconsistent zone widths (too thin), and the boundaries were subsequently extended seaward.

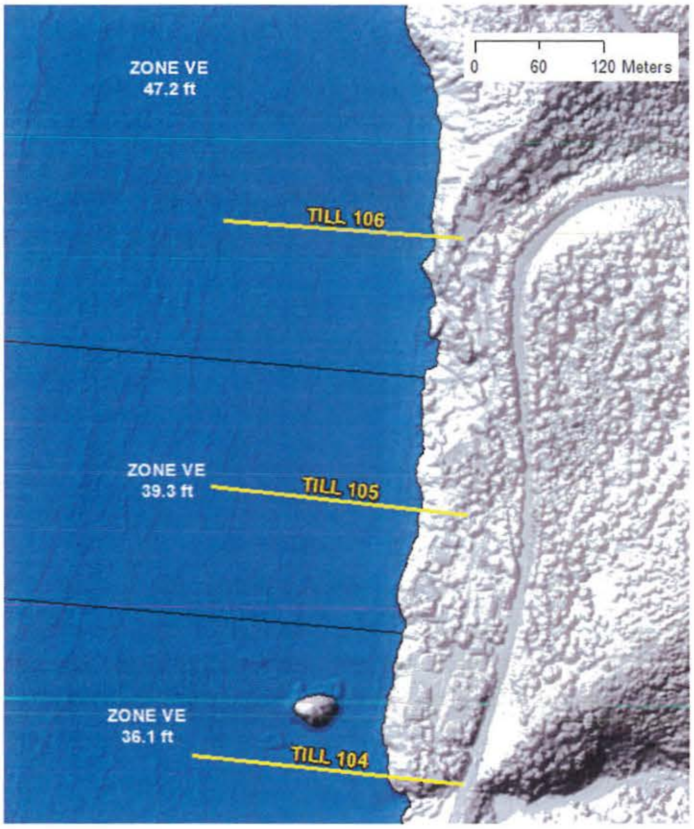

**Figure 8-2. Example of along-shore zone breaks and their relationship to geomorphic barriers and surveyed transects. Surveyed transects are symbolized as yellow lines; zone breaks are solid black lines.**

### 8.1.2 Dune-backed beaches

For dune-backed beaches, the VE flood zone was determined according to one or more criteria specified in the NHC (2005) guidelines. These are:

1. The ***wave runup zone***, which occurs where the TWL exceeds the (eroded) ground profile by ≥ 0.91 m (3 ft);
2. The ***wave overtopping splash zone*** is the area landward of the dune/bluff/structure crest where splashover occurs. The landward limit of the splash zone is mapped only in cases where the wave runup exceeds the crest elevation by ≥ 0.91 m (3 ft);
3. The ***high-velocity flow zone*** occurs landward of the overtopping splash zone, where the product of flow times the flow velocity squared ($hV^2$) is ≥ 5.7 $m^3/s^2$ (or 200 $ft^3/s^2$);
4. The ***breaking wave height zone*** occurs where wave heights ≥ 0.91 m (3 ft) could occur and is mapped when the wave crest profile is 0.64 m (2.1 ft) or more above the static water elevation; and
5. The ***primary frontal dune (PFD) zone*** as defined in Part 44 of the U.S. Code of Federal Regulations, Section 59.1; FEMA Coastal Hazard Bulletin, No. 15.

**Table 6-3** lists the overtopping calculations for those transects where overtopping occurs, including the calculated splashdown distances ($Y_{G\ outer}$), bore height associated with wave overtopping ($h_o$), and the landward extent of the high-velocity flow ($hV^2$) where the flows approach 5.7 $m^3/s^2$ (or 200 $ft^3/s^2$). As noted above, $hV^2$ reflects the farthest point landward of the dune/bluff/structure crest that experiences coastal flooding due to overtopping and is ultimately controlled by the extent of the landward flow where it approaches 5.7 $m^3/s^2$ (or 200 $ft^3/s^2$); values greater than 5.7 $m^3/s^2$ (or 200 $ft^3/s^2$) are located within the high-velocity flow (VE) zone while lower values are located within the passive overland flooding (AE) zone. Included in **Table 6-3** are the transition zones in which the calculated bore decreases in height, which have been defined accordingly:

- Dist_3 identifies the landward extent of flood zones where the bore height ($h_o$) was determined to be ≥ 0.91 m (3 ft) and were ultimately rounded up to the nearest whole foot (i.e., having an elevation of 0.91 m (3 ft) above the land surface);
- Dist_2 identifies the landward extent of flood zones where the bore height ($h_o$) was determined to be between 0.61 and 0.91 m (2 and 3 ft high) and were ultimately rounded up to the nearest whole foot above the ground surface; and
- "Dist_1" marks the seaward extent of flood zones where the bore height falls below 0.3 m (1 ft) above the ground surface; these values were again rounded up to the nearest whole foot.

Areas where flood zones exhibited bore height elevations of 0.61 m (2 ft) above the land surface were inferred as existing in the area between the two previously described regions (i.e., between "Distance from 'x' Where Bore >2 <3 ft" and "Distance from 'x' Where Bore <1").

As with bluff-backed beaches, we used professional judgment to establish appropriate zone breaks between the detailed transects. This was achieved through a combination of having detailed topographic information of the backshore and from knowledge of the local geomorphology. Some interpretation was required to produce flood zones appropriate for the printed map scale. Elevations were identified from the 1-m resolution bare-earth lidar DEM to aid in establishing zone breaks due to changes in flood depth landward of the dune crest (**Figure 8-3**). Slope and hillshade derivatives of the lidar DEM, as well as 1-m orthophotos, provided base reference.

In overtopping splash situations, the flood zone was determined by adding the splashdown distances ($Y_{G\ outer}$) to the $D_{high}$ distance. For all overtopping splash situations on the Tillamook coast, the splash distance was very short and not distinguishable at a mapping scale. Therefore, it was added to the VE zone extent (**Figure 8-4**).

For flood zones seaward of the dune crest, the calculated TWL values were used. As with bluff-backed beaches, along-shore geomorphic barriers were identified within which the transect TWL value is valid. In all cases, an effort was made to orient zone breaks perpendicular to the beach at the location of the geomorphic barrier. The seaward extent of the flood zones were inherited from the preliminary DFIRM (2011).

The PFD is defined as "a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. The landward limit of the primary frontal dune, also known as the toe or heel of the dune, occurs at a point where there is a distinct change from a relatively steep slope to a relatively mild slope. The primary frontal dune toe represents the landward extension of the Zone VE coastal high hazard velocity zone" (Part 44 of the U.S. Code of Federal Regulations, Section 59.1, as modified in FEMA Coastal Hazard Bulletin, No. 15, https://www.floodmaps.fema.gov/listserv/ch_jul02.shtml).

The approach developed by DOGAMI to define the morphology of the beach and dune system, including the location of the PFD, follows procedures developed in our Coos Bay study (Allan and others, 2012) and was based on detailed analyses of lidar data measured by the USGS/NASA/NOAA in 1997, 1998, and 2002 and by DOGAMI in 2009. However, because the lidar data flown by the USGS/NASA/NOAA is of relatively poor resolution (~1 point/m$^2$) and reflects a single return (i.e., includes vegetation where present), while the lidar data flown by DOGAMI has a higher resolution (8 points/m$^2$) and is characterized by multiple returns enabling the development of a bare-earth DEM, determination of the PFD was based entirely on analysis of the 2009 lidar data.

Lidar data flown in 1997, 1998, and 2002 were downloaded from NOAA's Coastal Service Center, (http://coast.noaa.gov/dataregistry/search/collection/info/coastallidar) and were gridded in ArcGIS using a triangulated irregular network (TIN) algorithm (Allan and Harris, 2012). Transects spaced 25 m apart were cast for the full length of the county coastline using the Digital Shoreline Analysis System (DSAS) developed by USGS (Thieler and others, 2009); this process yielded 3,628 individual transects in Tillamook County. For each transect, *x,y,z* values for the 1997, 1998, 2002, and 2009 lidar data were extracted at 1-m intervals along each transect line and saved as a text file using a customized ArcGIS script.

Processing of the lidar data was undertaken in MATLAB using a beach profile analysis script developed by DOGAMI. This script requires the user to interactively define various morphological features including the dune/bluff/structure crest/top, bluff/structure slope, landward edge of the PFD(s), beach-dune juncture elevations for various years, and the slopes of the beach foreshore (Allan and Harris, 2012). Although we evaluated all 3,628 transects, not all morphological features were applicable and therefore the PFD could be defined for only a subset of transects. **Figure 8-5** provides an example from Tillamook #1997 located near the south end of Netarts Spit. In this example, the dune crest in 2009 is located at 10.59 m (34.7 ft); prior to 2009, the dune crest was as high as 11.3 m (37 ft). As can be seen from the figure, the seaward face of the dune eroded landward by ~17 m (56 ft) between 1997 and 2009; shoreline change (erosion/accretion) was determined based on the change in position of the 6 m (19.7 ft) contour elevation, which is an excellent proxy for determining the effects of storm erosion (Allan and others, 2003). **Figure 3-12** and **Figure 3-16** depict changes in the position of the 6-m (19.6 ft) contour along the length of the Tillamook County shoreline. As can be seen from the figures, erosion is acute along much of the county shoreline, especially in the areas of Neskowin, north of Tierra Del Mar, Netarts Spit, and along much of the Rockaway cell (**Figure 3-16**). In contrast, accretion dominates the northern half of Bayocean and Nehalem Spits (**Figure 3-12** and **Figure 3-16**).

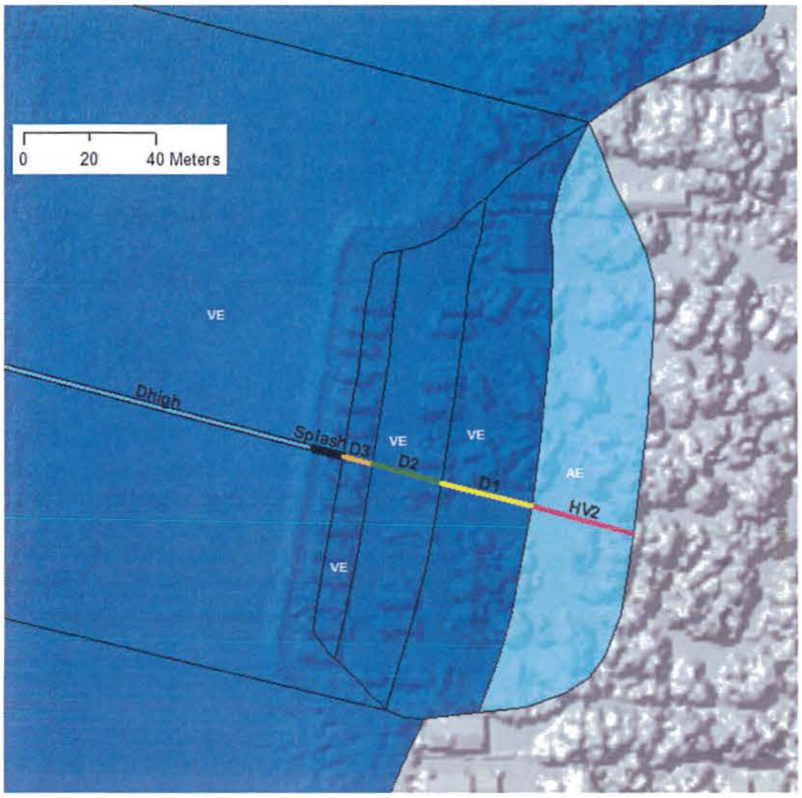

**Figure 8-3.** **Overtopping along the TILL 123 transect (near Twin Rocks), where Dhigh is the area seaward of Dhigh distance, Splash is the splashdown distance, D3 is depth > 3 ft, D2 is depth > 2 and < 3 ft, D1 is depth ≤0.31 m, HV2 is flow < 5.7 $m^3/s^2$ (or 200 $ft^3/s^2$). Zone breaks are solid black lines. Dark blue flood zones are VE zones; light blue are AE zones.**

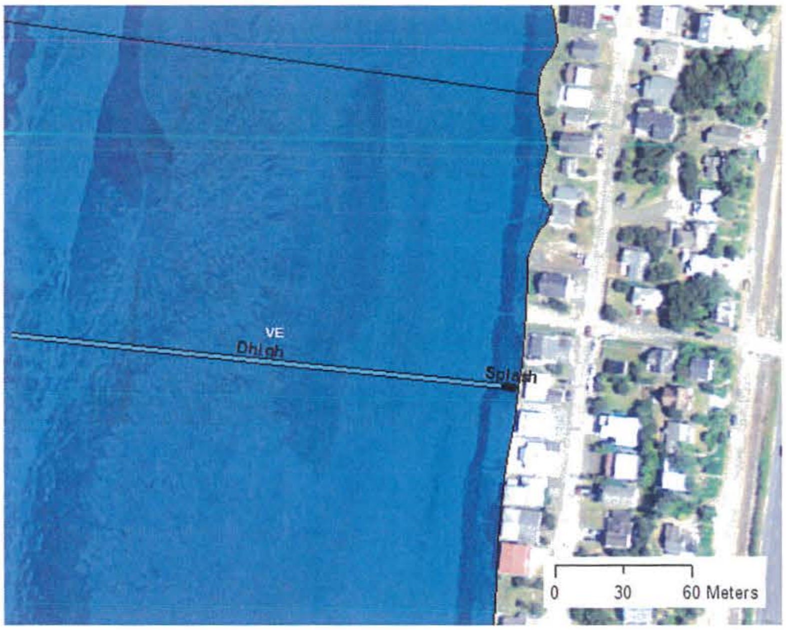

**Figure 8-4.** **TILL 144 transect at Rockaway with overtopping splash zone. The short splash zone distance (black) was added to the extent of the VE zone.**

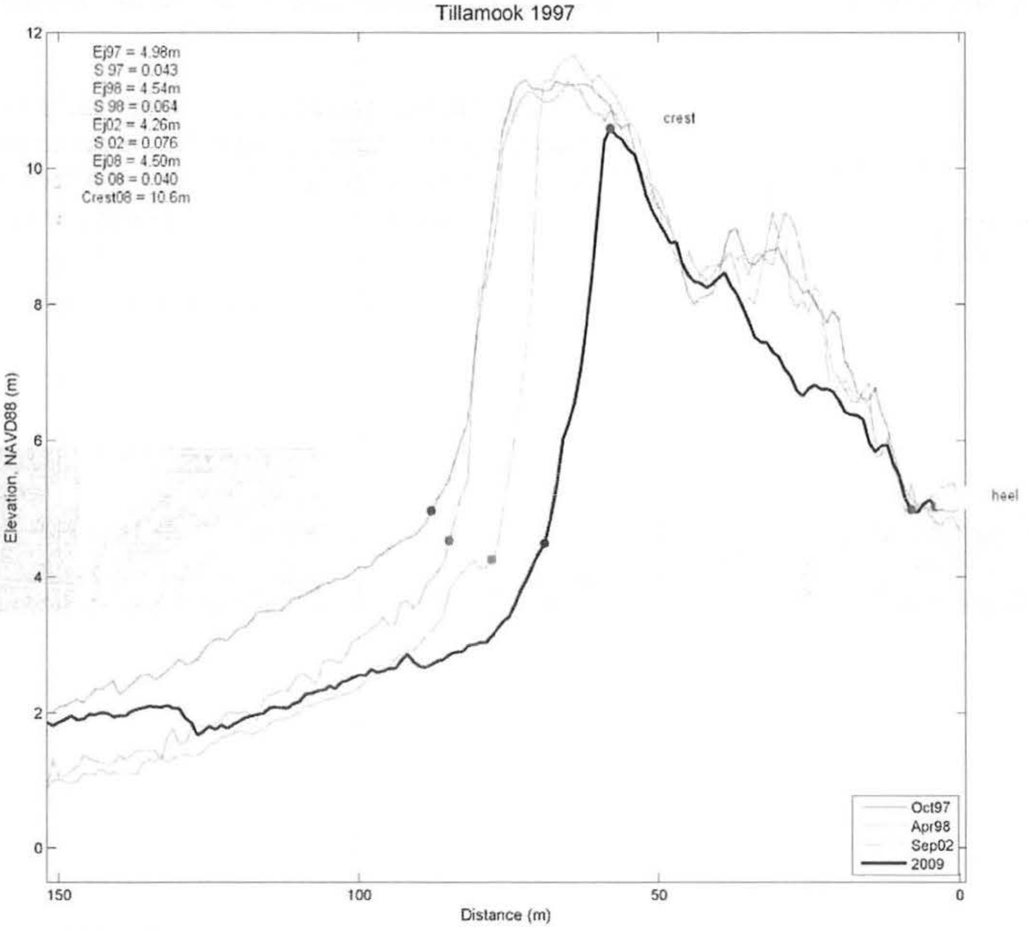

**Figure 8-5. Example beach profile (#1997) located near the south end of Netarts Spit and derived from 1997, 1998, 2002, and 2009 lidar data (Allan and Harris, 2012).**

After the lidar transect data had been interpolated to define the various morphological parameters, the actual locations of the PFDs[3] were plotted in ArcGIS and overlaid on both current and historical aerial photos of the county and on shaded relief imagery derived from the 2009 lidar. In a number of locations the PFD was found to be located either farther landward or seaward relative to adjacent PFD locations. This response is entirely a function of the degree to which the morphology of foredunes varies along a coast, and further the ambiguity of defining the PFD. Our observations of the PFD approach highlighted a number of uncertainties, including:

1. There were numerous examples of smaller dune features that have begun to develop in front of a main dune (or are the product of erosion of the dune) but have not yet attained dimensions and volumes where they would be considered an established dune; they may continue to erode and could disappear entirely. However, the PFD approach does not adequately account for such features. In this example, the smaller dunes are almost certainly subject to erosion and periodic overtopping and have morphologies that resemble the FEMA PFD definition. However, because they are subject to short-term erosion responses they are more ephemeral in nature, and thus it is debatable whether they should be defined as PFDs. Furthermore, over the life of a typical map (~10 years) these dunes could be

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[3] In many cases, multiple PFD locations were defined along a single transect.

eroded and removed entirely leaving a "gap" between the original polygon boundary and the eroding dune. For example, from repeated observations of beach profile transects on the northern Oregon coast, single storm events have been documented to remove as much as 9 to 25 m (30–82 ft) of the dune (Allan and Hart, 2007, 2008);

2. The PFD does not adequately account for a large established foredune, where the dune may have attained heights of 10 to 15 m (33–49 ft), with cross-shore widths on the order of 100 to 200 m (328–656 ft) due to prolonged aggradation and progradation of the beach. In this example, although there may be a clear landward heel located well inland away from the beach (e.g., profile #840 in **Figure 8-6**, which was derived from our Clatsop County study), the PFD is clearly not subject to "frequent" wave overtopping due to its height and erosion (because of its large volume of sand). Defining the PFD at the location of the heel is consistent within the definition provided by FEMA but would almost certainly generate a very conservative V zone.
3. Although numerous transects exhibited clear examples of single PFD locations, many others were characterized by more than one PFD. Profile #1929 (**Figure 8-7**) is an example where, multiple potential PFDs could be defined.

To account for these variations and uncertainties, the PFDs shown on the profile plots (e.g., **Figure 8-5**, **Figure 8-6**, and **Figure 8-7**) were reexamined, and adjustments were made where necessary in order to define a single PFD line. For example, in a few locations along the Clatsop Plains, the PFD extent for a particular transect was physically moved in ArcGIS so that it was more in keeping with the adjacent PFD locations to its immediate north and south. As can be seen in **Figure 8-8**, the final PFD designation was invariably some distance inland, often representing the clearest signal determined from all available data and adhering best to the FEMA definition.

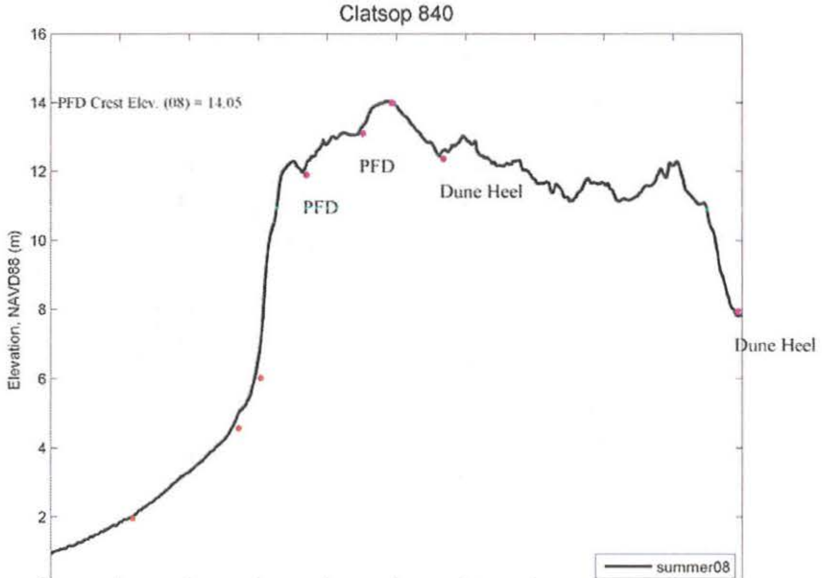

**Figure 8-6. Example profile from the Clatsop Plains where considerable aggradation and progradation of the dune has occurred. In this example, the PFD could conceivably be drawn at a variety of locations and meet the FEMA definition.**

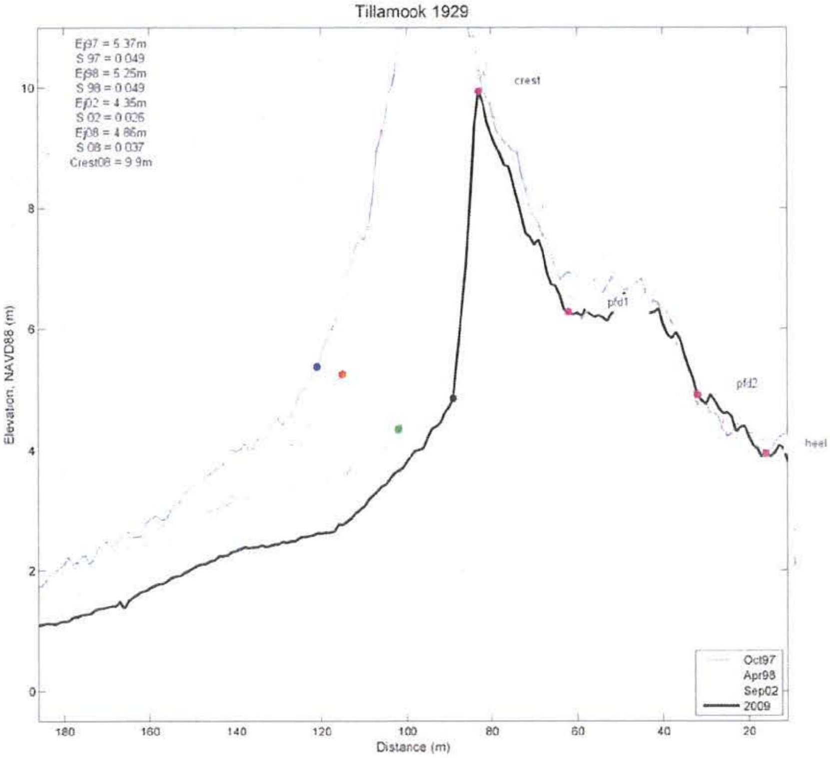

Figure 8-7. **Example profile (#1929) from Netarts Spit showing the presence of at least two PFD locations.**

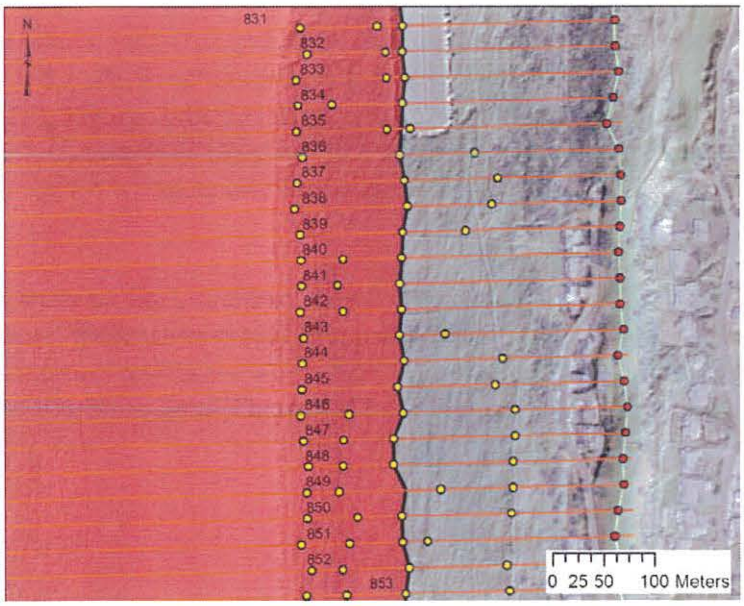

**Figure 8-8. Plot showing identified PFD locations (yellow dots) along each transect, landward most dune heel (red dots), and derived PFD line (black line). Red zone depicts the VE zone having accounted for all possible criteria. Red lines depict the locations of the lidar transects, which were spaced 25 m (82 ft) apart.**

The PFD was defined at a number of locations where significant human modification has occurred on the dune. In these areas, the natural dune system has been severely impacted and the PFD line does not represent a natural dune system. **Table 8-1** lists the transect locations where this situation occurs and also provides the VE zone extent used in place of the PFD.

**Table 8-1. Transect locations where the PFD was not used for mapping due to significant human modification of the dune.**

| Transect | DFIRM Transect | VE Zone Extent | Transect | DFIRM Transect | VE Zone Extent |
|---|---|---|---|---|---|
| TILL 2 | 8 | runup | TILL 54 | 60 | runup |
| TILL 3 | 9 | runup | TILL 55 | 61 | runup |
| TILL 4 | 10 | high velocity flow | TILL 56 | 62 | runup |
| TILL 5 | 11 | high velocity flow | TILL 57 | 63 | runup |
| TILL 6 | 12 | high velocity flow | TILL 135 | 141 | runup |
| TILL 7 | 13 | high velocity flow | TILL 136 | 142 | runup |
| TILL 8 | 14 | high velocity flow | TILL 137 | 143 | runup |
| TILL 14 | 20 | high velocity flow | TILL 138 | 144 | wave overtopping splash zone |
| TILL 15 | 21 | high velocity flow | TILL 139 | 145 | runup |
| TILL 37 | 43 | runup | TILL 140 | 146 | runup |
| TILL 38 | 44 | runup | TILL 141 | 147 | high velocity flow |
| TILL 40 | 46 | runup | TILL 142 | 148 | high velocity flow |
| TILL 41 | 47 | runup | TILL 143 | 149 | high velocity flow |
| TILL 42 | 48 | runup | TILL 144 | 150 | high velocity flow |
| TILL 51 | 57 | high velocity flow | TILL 145 | 151 | runup |
| TILL 52 | 58 | high velocity flow | TILL 146 | 152 | runup |
| TILL 53 | 59 | runup | TILL 170 | 176 | runup |

### *8.1.3 Mapping of estuarine flooding*

Tillamook County includes a number of large estuarine features. Due to their complexity, the following river mouths were redelineated using previously effective BFEs: Kiwanda and Neskowin Creeks, Nestucca Bay, Netarts Bay, Barview Jetty and the Nehalem River (**Figure 8-9**). No new studies were performed at these locations, and the adjacent open coast detailed coastal analysis could not reasonably be used for mapping these estuaries. Open water was mapped in northern part of Tillamook Bay and the southern part of Netarts Bay. These open water areas are digitized water bodies that represent unstudied portions of the bays.

Sand Lake is one estuary that had not previously been subjected to detailed coastal or riverine analyses. This particular estuary is periodically influenced by coastal backwater flooding due to extreme coastal water levels. For the purposes of establishing a new BFE in the estuary, we used the still water level (SWL) to map the coastal backwater effect of the 1% and 0.2% flood events into Sand Lake (**Figure 8-10**). Procedures for developing the SWL are described in Section 4.6. The 1% SWL value for the Tillamook County coast is 3.60 m (11.8 ft, NAVD88), and 0.2% SWL is estimated to be 3.68 m (12.1 ft, NAVD88).

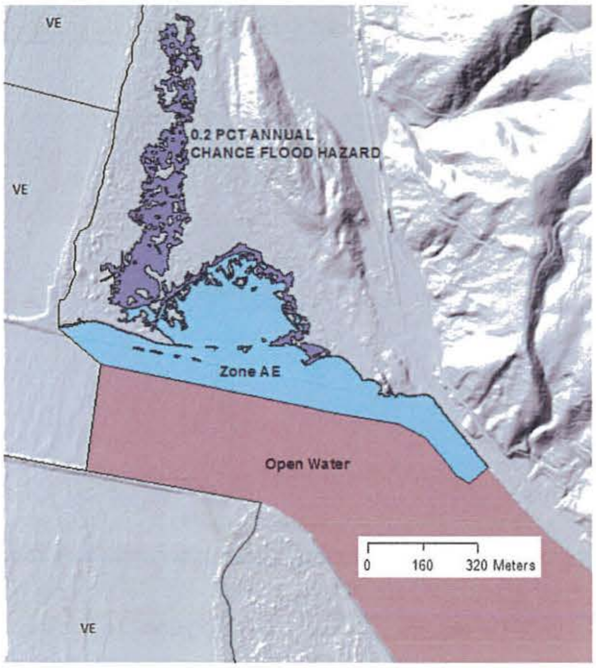

**Figure 8-9.** **Redelineation at Barview Jetty (Zone AE and 0.2 percent annual chance flood hazard) and the open water section of Tillamook Bay.**

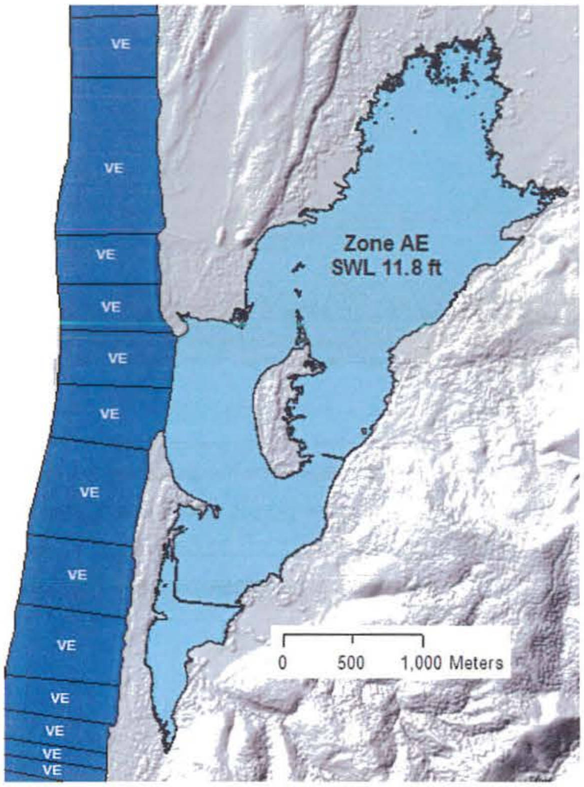

**Figure 8-10. Coastal backwater flooding mapped from still water levels (SWLs) for Sand Lake. The 0.2% chance flooding is too small to be visible at this scale.**

## 8.2 Coastal V-Zone Mapping along the Tillamook County Shoreline

### *8.2.1 Dune-backed beaches*

The FEMA guidelines provide little direct guidance for mapping approximate coastal velocity zones (Zone V) in areas where no detailed studies have occurred, other than by defining the location of the PFD, using the methodology described above. In the case of Tillamook County, we have endeavored to undertake detailed mapping in all areas backed by dunes.

### *8.2.2 V-zone mapping on coastal bluffs and headlands*

Several sections of the Tillamook County coastline are characterized by coastal bluffs and cliffs of varying heights. For these areas, the approach adopted by DOGAMI was to map the top of the active bluff (**Figure 8-11**) that is most likely subject to wave erosion, which is a readily identifiable feature that can be used to constrain the landward extent of the Zone V. **Figure 8-11** provides an example of a lidar transect established at the seaward end of Cape Lookout in Tillamook County, where the top of the active bluff face is located at ~65 m (213 ft). **Figure 8-12** depicts the derived bluff top line based on a synthesis of all available information, including the lidar transect data, analyses of lidar contours, and hillshades. This approach was used primarily for the headlands (e.g., Neahkahnie Mountain, Cape Meares, Cape Lookout, Cape Kiwanda, and Cascade Head).

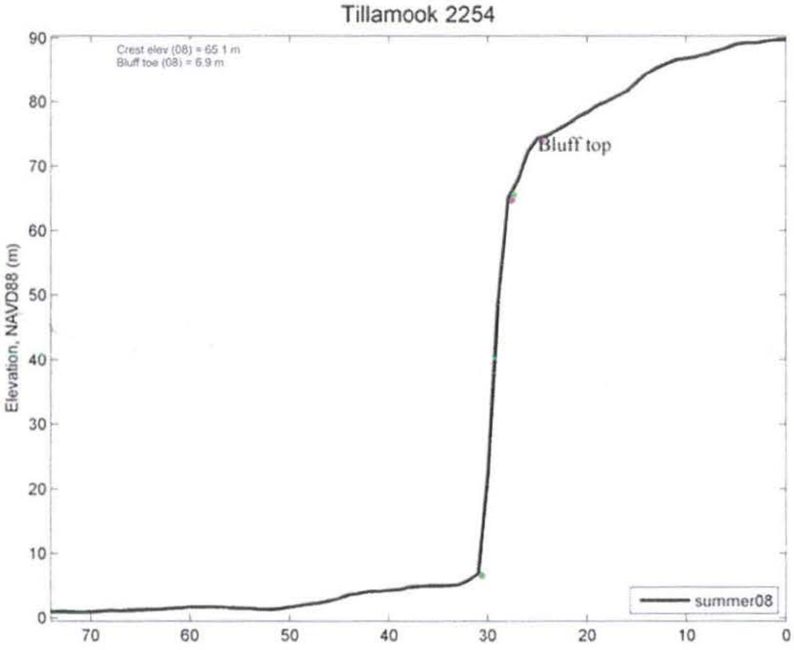

**Figure 8-11. Zone V mapping morphology designation along coastal bluffs and cliffs. Example is from the western end of Cape Lookout (Tillamook profile #2254). Magenta dots denote the locations of the bluff/cliff top, while the green dot reflects the bluff toe.**

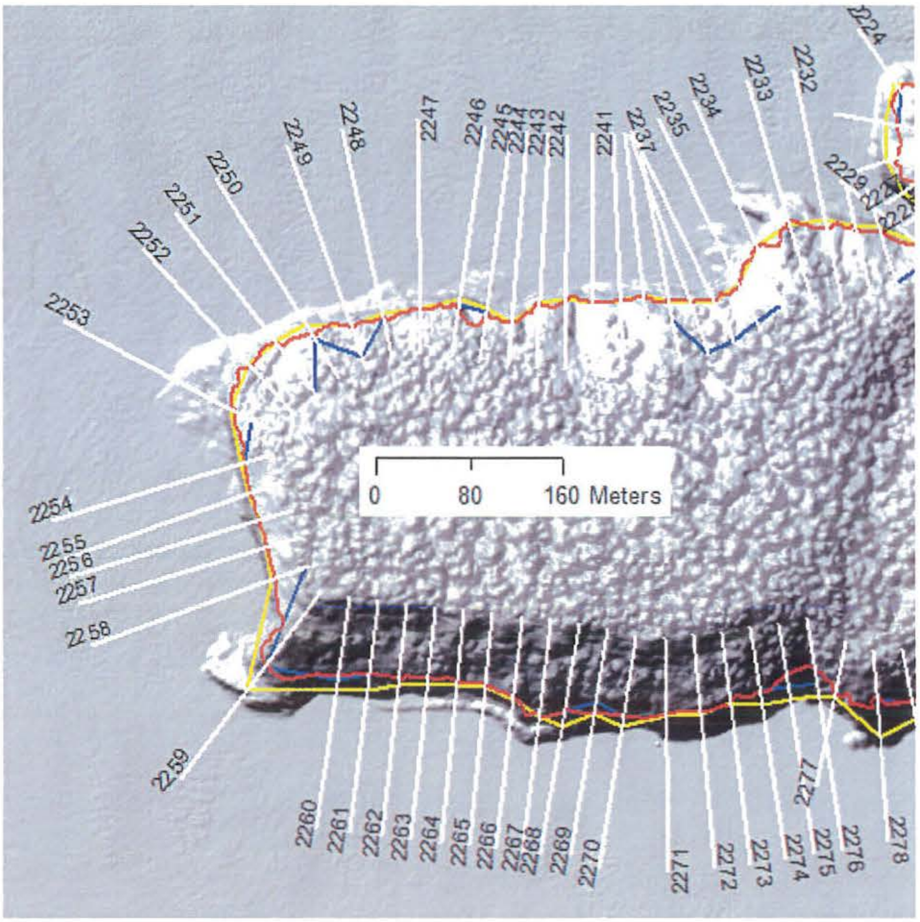

Figure 8-12. Zone V mapping example showing the locations of the individual transects (white lines), bluff top 1 (yellow line) and bluff top 2 (blue line) derived from analyses of the lidar transects, and the final derived bluff line (red line), which incorporates all available data (transects, contours, hillshade, and orthophotos).

## 9.0 ACKNOWLEDGMENTS

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# 11.0 APPENDICES

- Appendix A: Ground Survey Accuracy Assessment Protocols
- Appendix B: Tillamook County DFIRM/DOGAMI Naming Convention
- Appendix C: Tillamook County Beach and Bluff Profiles
- Appendix D: Supplemental Transect Overtopping Table

## 11.1 Appendix A: Ground Survey Accuracy Assessment Protocols

*See report by Watershed Sciences, Inc., dated December 21, 2009.*

## 11.3 Appendix B: Tillamook County DFIRM/DOGAMI Naming Conventions

| Reach | Transect Order | DFIRM Transect | DOGAMI Transect | Transect Type | Site | Lidar Transect | Description |
|---|---|---|---|---|---|---|---|
| Salmon River | 1 | 1 | LINC 308 | main | Salmon 6 | | dune-backed beach |
| Cascade Head | 2 | 2 | LINC 309 | main | Cascade 1 | | plunging cliff |
| | 3 | 3 | LINC 310 | main | Cascade 2 | | plunging cliff |
| | 4 | 4 | LINC 311 | main | Cascade 3 | | boulder beach backed by bluffs |
| | 5 | 5 | LINC 312 | main | Cascade 4 | | plunging cliff |
| | 6 | 6 | LINC 313 | main | Cascade 5 | | plunging cliff |
| Neskowin | 7 | 7 | TILL1 | main | Neskowin 1 | | sandy beach backed by riprap and high cliffs |
| | 8 | | | lidar | Neskowin 2 | 2_3524 | |
| | 9 | 8 | TILL2 | main | Neskowin 2 | | sand beach backed by riprap |
| | 10 | | | lidar | Neskowin 2 | 2_3521 | |
| | 11 | | | lidar | Neskowin 2 | 2_3517 | |
| | 12 | | | lidar | Neskowin 3 | 3_3514 | |
| | 13 | 9 | TILL3 | main | Neskowin 3 | | sand beach backed by riprap |
| | 14 | | | lidar | Neskowin 3 | 3_3508 | |
| | 15 | | | lidar | Neskowin 3 | 3_3506 | |
| | 16 | | | lidar | Neskowin 3 | 3_3504 | |
| | 17 | | | lidar | Neskowin 3 | 3_3502 | |
| | 18 | 10 | TILL4 | main | Neskowin 4 | | sand beach backed by riprap |
| | 19 | 11 | TILL5 | main | Neskowin 5 | | sand beach backed by riprap |
| | 20 | 12 | TILL6 | main | Neskowin 6 | | sand beach backed by riprap |
| | 21 | 13 | TILL7 | main | Neskowin 7 | | sand beach backed by riprap |
| | 22 | 14 | TILL8 | main | Neskowin 8 | | sand beach backed by riprap |
| | 23 | 15 | TILL9 | main | Neskowin 9 | | dune-backed |
| | 24 | 16 | TILL10 | main | Neskowin 10 | | dune-backed |
| | 25 | 17 | TILL11 | main | Neskowin 11 | | dune-backed |
| | 26 | 18 | TILL12 | main | Neskowin 12 | | dune-backed |
| | 27 | 19 | TILL13 | main | Neskowin 13 | | dune-backed |
| | 28 | 20 | TILL14 | main | Neskowin 14 | | sand beach backed by riprap |
| | 29 | 21 | TILL15 | main | Neskowin 15 | | sand beach backed by riprap |
| | 30 | 22 | TILL16 | main | Neskowin 16 | | dune-backed |
| | 31 | 23 | TILL17 | main | Neskowin 17 | | dune-backed |
| | 32 | 24 | TILL18 | main | Neskowin 18 | | dune-backed |
| | 33 | 25 | TILL19 | main | Neskowin 19 | | dune-backed |
| | 34 | 26 | TILL20 | main | Neskowin 20 | | dune-backed |
| | 35 | 27 | TILL21 | main | Neskowin 21 | | dune-backed |
| | 36 | 28 | TILL22 | main | Neskowin 22 | | dune-backed |
| | 37 | 29 | TILL23 | main | Neskowin 23 | | dune-backed |
| | 38 | 30 | TILL24 | main | Neskowin 24 | | dune-backed |
| | 39 | 31 | TILL25 | main | Neskowin 25 | | dune-backed |
| | 40 | 32 | TILL26 | main | Neskowin 26 | | sandy beach backed by high cliffs |
| | 41 | 33 | TILL27 | main | Neskowin 27 | | sandy beach backed by high cliffs |
| | 42 | 34 | TILL28 | main | Neskowin 28 | | sandy beach backed by dunes and high cliffs |

| Reach | Transect Order | DFIRM Transect | DOGAMI Transect | Transect Type | Site | Lidar Transect | Description |
|---|---|---|---|---|---|---|---|
| Nestucca Spit/Pacific City | 43 | 35 | TILL29 | main | PacificC 1 | | dune-backed |
| | 44 | 36 | TILL30 | main | PacificC 2 | | dune-backed |
| | 45 | 37 | TILL31 | main | PacificC 3 | | dune-backed |
| | 46 | 38 | TILL32 | main | PacificC 4 | | dune-backed |
| | 47 | 39 | TILL33 | main | PacificC 5 | | dune-backed |
| | 48 | 40 | TILL34 | main | PacificC 6 | | dune-backed |
| | 49 | 41 | TILL35 | main | PacificC 7 | | dune-backed |
| | 50 | 42 | TILL36 | main | PacificC 8 | | dune-backed |
| | 51 | 43 | TILL37 | main | PacificC 9 | | sand beach backed by riprap? |
| | 52 | 44 | TILL38 | main | PacificC 10 | | sand beach backed by riprap? |
| | 53 | 45 | TILL39 | main | PacificC 11 | | dune-backed |
| | 54 | 46 | TILL40 | main | PacificC 12 | | sand beach backed by riprap? |
| | 55 | 47 | TILL41 | main | PacificC 13 | | sand beach backed by riprap? |
| | 56 | 48 | TILL42 | main | PacificC 14 | | sand beach backed by riprap and high bluffs |
| Sand Lake / Tierra Del Mar | 57 | 49 | TILL43 | main | Sand Lake 1 | | sandy beach backed by high cliffs |
| | 58 | 50 | TILL44 | main | Sand Lake 2 | | sandy beach backed by high cliffs |
| | 59 | 51 | TILL45 | main | Sand Lake 3 | | sandy beach backed by cobbles - grades into bluff |
| | 60 | 52 | TILL46 | main | Sand Lake 4 | | sandy beach backed by high cliffs |
| | 61 | 53 | TILL47 | main | Sand Lake 5 | | sand beach backed by riprap |
| | 62 | 54 | TILL48 | main | Sand Lake 6 | | dune-backed |
| | 63 | 55 | TILL49 | main | Sand Lake 7 | | dune-backed |
| | 64 | 56 | TILL50 | main | Sand Lake 8 | | dune-backed |
| | 65 | 57 | TILL51 | main | Sand Lake 9 | | sand beach backed by riprap |
| | 66 | 58 | TILL52 | main | Sand Lake 10 | | sand beach backed by riprap |
| | 67 | 59 | TILL53 | main | Sand Lake 11 | | sand beach backed by riprap |
| | 68 | 60 | TILL54 | main | Sand Lake 12 | | sand beach backed by riprap |
| | 69 | 61 | TILL55 | main | Sand Lake 13 | | dune-backed |
| | 70 | 62 | TILL56 | main | Sand Lake 14 | | sand beach backed by riprap |
| | 71 | 63 | TILL57 | main | Sand Lake 15 | | sand beach backed by riprap |
| | 72 | 64 | TILL58 | main | Sand Lake 16 | | dune-backed |
| | 73 | 65 | TILL59 | main | Sand Lake 17 | | dune-backed |
| | 74 | 66 | TILL60 | main | Sand Lake 18 | | dune-backed |
| | 75 | 67 | TILL61 | main | Sand Lake 19 | | dune-backed |
| | 76 | 68 | TILL62 | main | Sand Lake 20 | | dune-backed |
| | 77 | 69 | TILL63 | main | Sand Lake 21 | | dune-backed |
| | 78 | 70 | TILL64 | main | Sand Lake 22 | | dune-backed |
| | 79 | 71 | TILL65 | main | Sand Lake 23 | | dune-backed |
| | 80 | 72 | TILL66 | main | Sand Lake 24 | | dune-backed |
| | 81 | 73 | TILL67 | main | Sand Lake 25 | | sandy beach backed by high cliffs |
| | 82 | 74 | TILL68 | main | Sand Lake 26 | | sandy beach backed by high cliffs |
| | 83 | 75 | TILL69 | main | Sand Lake 27 | | sandy beach backed by high cliffs |
| | 84 | 76 | TILL70 | main | Sand Lake 28 | | sandy beach backed by high cliffs |
| | 85 | 77 | TILL71 | main | Sand Lake 29 | | sandy beach backed by high cliffs |
| | 86 | 78 | TILL72 | main | Sand Lake 30 | | sandy beach backed by high cliffs |
| | 87 | 79 | TILL73 | main | Sand Lake 31 | | sandy beach backed by high cliffs |
| | 88 | 80 | TILL74 | main | Sand Lake 32 | | sandy beach backed by high cliffs |

| Reach | Transect Order | DFIRM Transect | DOGAMI Transect | Transect Type | Site | Lidar Transect | Description |
|---|---|---|---|---|---|---|---|
| **Netarts Spit/ Oceanside** | 89 | 81 | TILL75 | main | Netarts 1 | | sandy beach backed by low/high cliffs |
| | 90 | 82 | TILL76 | main | Netarts 2 | | sandy beach backed by cobbles/boulders and low cliff |
| | 91 | 83 | TILL77 | main | Netarts 3 | | sandy beach backed by dynamic revetment/artificial dune |
| | 92 | 84 | TILL78 | main | Netarts 4 | | sandy beach backed by dynamic revetment/artificial dune |
| | 93 | | | lidar | Netarts 5 | 79_2035 | |
| | 94 | | | lidar | Netarts 5 | 79_2033 | |
| | 95 | 85 | TILL79 | main | Netarts 5 | | dune-backed (+cobbles) |
| | 96 | 86 | TILL80 | main | Netarts 6 | | dune-backed (+cobbles) |
| | 97 | 87 | TILL81 | main | Netarts 7 | | dune-backed (+cobbles) |
| | 98 | 88 | TILL82 | main | Netarts 8 | | dune-backed |
| | 99 | 89 | TILL83 | main | Netarts 9 | | dune-backed |
| | 100 | 90 | TILL84 | main | Netarts 10 | | dune-backed |
| | 101 | 91 | TILL85 | main | Netarts 11 | | dune-backed |
| | 102 | 92 | TILL86 | main | Netarts 12 | | dune-backed |
| | 103 | 93 | TILL87 | main | Netarts 13 | | dune-backed |
| | 104 | 94 | TILL88 | main | Netarts 14 | | dune-backed |
| | 105 | 95 | TILL89 | main | Netarts 15 | | dune-backed |
| | 106 | 96 | TILL90 | main | Netarts 16 | | dune-backed |
| | 107 | 97 | TILL91 | main | Netarts 17 | | dune-backed |
| | 108 | 98 | TILL92 | main | Netarts 18 | | dune-backed |
| | 109 | 99 | TILL93 | main | Netarts 19 | | Cobble beach backed by low wall (estuary mouth) |
| | 110 | 100 | TILL94 | main | Netarts 20 | | sandy beach backed by high cliffs |
| | 111 | 101 | TILL95 | main | Netarts 21 | | sandy beach backed by high cliffs |
| | 112 | 102 | TILL96 | main | Netarts 22 | | sandy beach backed by high cliffs |
| | 113 | 103 | TILL97 | main | Netarts 23 | | sandy beach backed by dune and high cliffs |
| | 114 | 104 | TILL98 | main | Netarts 24 | | sandy beach backed by dune and high cliffs |
| | 115 | 105 | TILL99 | main | Netarts 25 | | sandy beach backed by high cliffs |
| | 116 | 106 | TILL100 | main | Netarts 26 | | sandy beach backed by high cliffs |
| | 117 | 107 | TILL101 | main | Netarts 27 | | sandy beach backed by poor riprap and low cliffs |
| | 118 | 108 | TILL102 | main | Netarts 28 | | sandy beach backed by moderately high cliffs |
| | 119 | 109 | TILL103 | main | Netarts 29 | | sandy beach backed by moderately high cliffs |
| **Short Sand Beach** | 120 | 110 | TILL104 | main | Short Sand 1 | | sandy beach backed by gravels and high cliffs |
| | 121 | 111 | TILL105 | main | Short Sand 2 | | sandy beach backed by gravels and high cliffs |
| | 122 | 112 | TILL106 | main | Short Sand 3 | | sandy beach backed by gravels and high cliffs |
| **Bayocean Spit** | 123 | 113 | TILL107 | main | Bayocean 1 | | sandy beach backed by cobble/boulder and low cliffs |
| | 124 | 114 | TILL108 | main | Bayocean 2 | | sandy beach backed by cobble/boulder and low cliffs |
| | 125 | 115 | TILL109 | main | Bayocean 3 | | sandy beach backed by cobble/boulder berm |
| | 126 | 116 | TILL110 | main | Bayocean 4 | | sandy beach backed by cobble/boulder berm |
| | 127 | 117 | TILL111 | main | Bayocean 5 | | sandy beach backed by cobble/boulder berm |
| | 128 | 118 | TILL112 | main | Bayocean 6 | | dune-backed |
| | 129 | 119 | TILL113 | main | Bayocean 7 | | dune-backed |
| | 130 | 120 | TILL114 | main | Bayocean 8 | | dune-backed |
| | 131 | 121 | TILL115 | main | Bayocean 9 | | dune-backed |
| | 132 | 122 | TILL116 | main | Bayocean 10 | | dune-backed |
| | 133 | 123 | TILL117 | main | Bayocean 11 | | dune-backed |

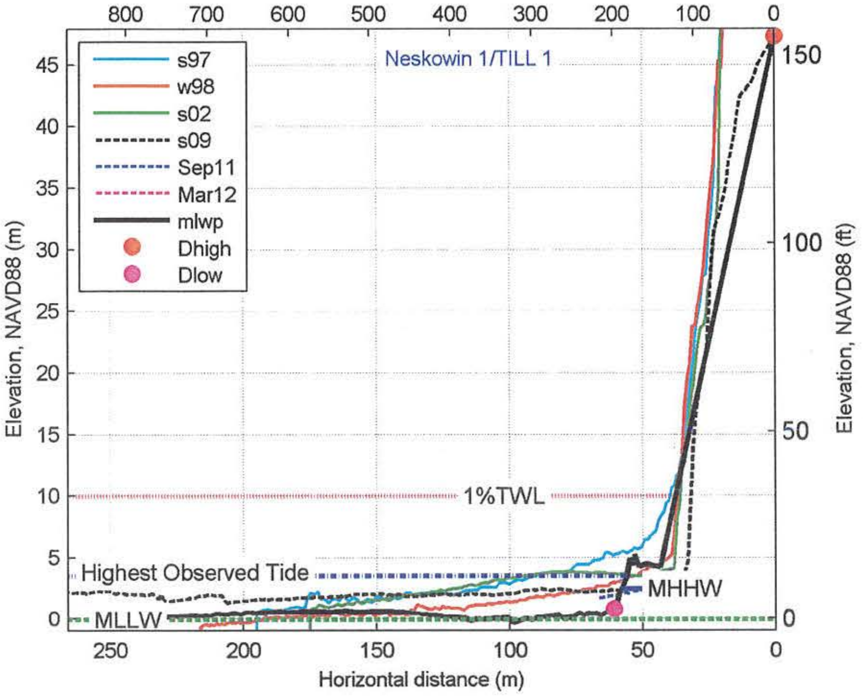
| Reach | Transect Order | DFIRM Transect | DOGAMI Transect | Transect Type | Site | Lidar Transect | Description |
|---|---|---|---|---|---|---|---|
| **Rockaway** | 134 | 124 | TILL118 | main | Rockaway 1 | | dune-backed |
| | 135 | 125 | TILL119 | main | Rockaway 2 | | dune-backed |
| | 136 | 126 | TILL120 | main | Rockaway 3 | | dune-backed |
| | 137 | 127 | TILL121 | main | Rockaway 4 | | dune-backed |
| | 138 | 128 | TILL122 | main | Rockaway 5 | | dune-backed |
| | 139 | 129 | TILL123 | main | Rockaway 6 | | sand beach backed by riprap |
| | 140 | 130 | TILL124 | main | Rockaway 7 | | dune-backed |
| | 141 | 131 | TILL125 | main | Rockaway 8 | | dune-backed |
| | 142 | 132 | TILL126 | main | Rockaway 9 | | dune-backed |
| | 143 | 133 | TILL127 | main | Rockaway 10 | | dune-backed |
| | 144 | 134 | TILL128 | main | Rockaway 11 | | dune-backed |
| | 145 | 135 | TILL129 | main | Rockaway 12 | | dune-backed |
| | 146 | 136 | TILL130 | main | Rockaway 13 | | dune-backed |
| | 147 | 137 | TILL131 | main | Rockaway 14 | | dune-backed |
| | 148 | 138 | TILL132 | main | Rockaway 15 | | sand beach backed by riprap |
| | 149 | 139 | TILL133 | main | Rockaway 16 | | dune-backed |
| | 150 | 140 | TILL134 | main | Rockaway 17 | | dune-backed |
| | 151 | | | lidar | Rockaway 18 | 135_857 | |
| | 152 | | | lidar | Rockaway 18 | 135_856 | |
| | 153 | 141 | TILL135 | main | Rockaway 18 | | dune-backed |
| | 154 | 142 | TILL136 | main | Rockaway 19 | | sand beach backed by low bluff |
| | 155 | 143 | TILL137 | main | Rockaway 20 | | sand beach backed by riprap |
| | 156 | 144 | TILL138 | main | Rockaway 21 | | sand beach backed by riprap |
| | 157 | 145 | TILL139 | main | Rockaway 22 | | dune-backed |
| | 158 | 146 | TILL140 | main | Rockaway 23 | | sand beach backed by riprap |
| | 159 | 147 | TILL141 | main | Rockaway 24 | | sand beach backed by riprap |
| | 160 | 148 | TILL142 | main | Rockaway 25 | | sand beach backed by riprap |
| | 161 | 149 | TILL143 | main | Rockaway 26 | | sand beach backed by riprap |
| | 162 | 150 | TILL144 | main | Rockaway 27 | | sand beach backed by riprap |
| | 163 | 151 | TILL145 | main | Rockaway 28 | | sand beach backed by riprap |
| | 164 | 152 | TILL146 | main | Rockaway 29 | | sand beach backed by riprap |
| | 165 | | | lidar | Rockaway 30 | 147_783 | |
| | 166 | 153 | TILL147 | main | Rockaway 30 | | dune-backed |
| | 167 | | | lidar | Rockaway 30 | 147_778 | |
| | 168 | 154 | TILL148 | main | Rockaway 31 | | dune-backed |
| | 169 | 155 | TILL149 | main | Rockaway 32 | | dune-backed |
| | 170 | 156 | TILL150 | main | Rockaway 33 | | dune-backed |
| | 171 | 157 | TILL151 | main | Rockaway 34 | | sand beach backed by riprap |
| | 172 | 158 | TILL152 | main | Rockaway 35 | | dune-backed |
| | 173 | 159 | TILL153 | main | Rockaway 36 | | dune-backed |
| | 174 | 160 | TILL154 | main | Rockaway 37 | | dune-backed |
| | 175 | 161 | TILL155 | main | Rockaway 38 | | dune-backed |
| | 176 | 162 | TILL156 | main | Rockaway 39 | | dune-backed |
| | 177 | 163 | TILL157 | main | Rockaway 40 | | dune-backed |

| Reach | Transect Order | DFIRM Transect | DOGAMI Transect | Transect Type | Site | Lidar Transect | Description |
|---|---|---|---|---|---|---|---|
| **Nehalem Spit / Manzanita** | 178 | 164 | TILL158 | main | Manzanita 1 | | dune-backed |
| | 179 | 165 | TILL159 | main | Manzanita 2 | | dune-backed |
| | 180 | 166 | TILL160 | main | Manzanita 3 | | dune-backed |
| | 181 | 167 | TILL161 | main | Manzanita 4 | | dune-backed |
| | 182 | 168 | TILL162 | main | Manzanita 5 | | dune-backed |
| | 183 | 169 | TILL163 | main | Manzanita 6 | | dune-backed |
| | 184 | 170 | TILL164 | main | Manzanita 7 | | dune-backed |
| | 185 | 171 | TILL165 | main | Manzanita 8 | | dune-backed |
| | 186 | 172 | TILL166 | main | Manzanita 9 | | dune-backed |
| | 187 | 173 | TILL167 | main | Manzanita 10 | | dune-backed |
| | 188 | 174 | TILL168 | main | Manzanita 11 | | dune-backed |
| | 189 | 175 | TILL169 | main | Manzanita 12 | | dune-backed |
| | 190 | 176 | TILL170 | main | Manzanita 13 | | sand beach backed by riprap |
| | 191 | 177 | TILL171 | main | Manzanita 14 | | dune-backed |
| | 192 | 178 | TILL172 | main | Manzanita 15 | | dune-backed with road |
| | 192 | 178 | TILL172 | main | Manzanita 15 | | dune-backed with road |
| | 193 | 179 | TILL173 | main | Manzanita 16 | | dune-backed with road |
| | 194 | 180 | TILL174 | main | Manzanita 17 | | dune-backed with road |
| | 195 | 181 | TILL175 | main | Manzanita 18 | | dune-backed |
| | 196 | 182 | TILL176 | main | Manzanita 19 | | sand beach backed by extensive cobble berm |
| | 197 | 183 | TILL177 | main | Manzanita 20 | | sand beach backed by extensive cobble berm and bluff |
| | 198 | 184 | TILL178 | main | Manzanita 21 | | sand beach backed by extensive cobble berm and bluff |
| **Falcon Cove** | 199 | 185 | CP 1 | main | CP 1 | | sand, cobble berm backed by high bluff |

## 11.4 Appendix C: Tillamook County Beach and Bluff Profiles

### *11.4.1 Neskowin*

**fm_nesk 1**



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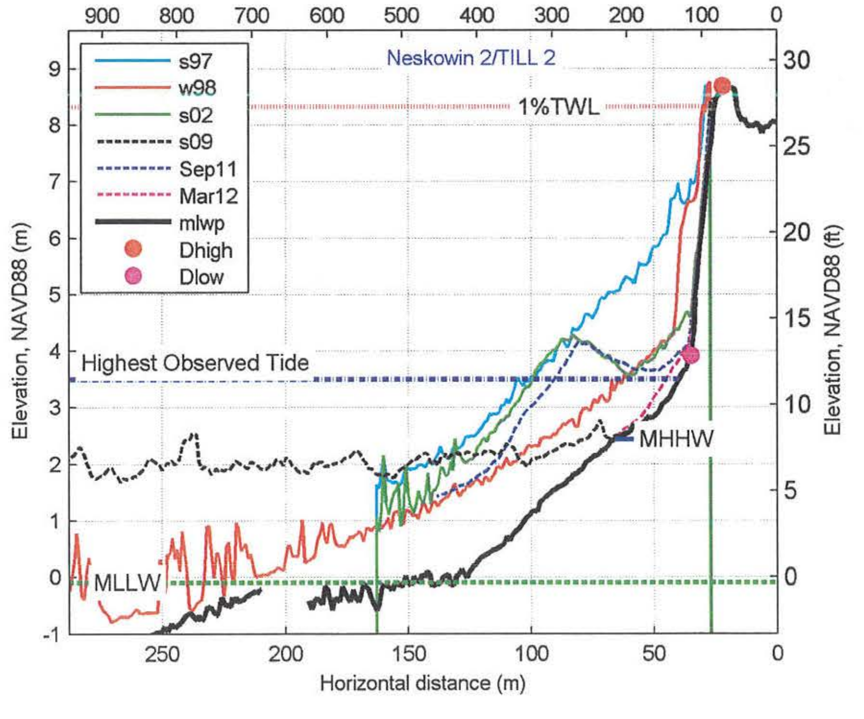

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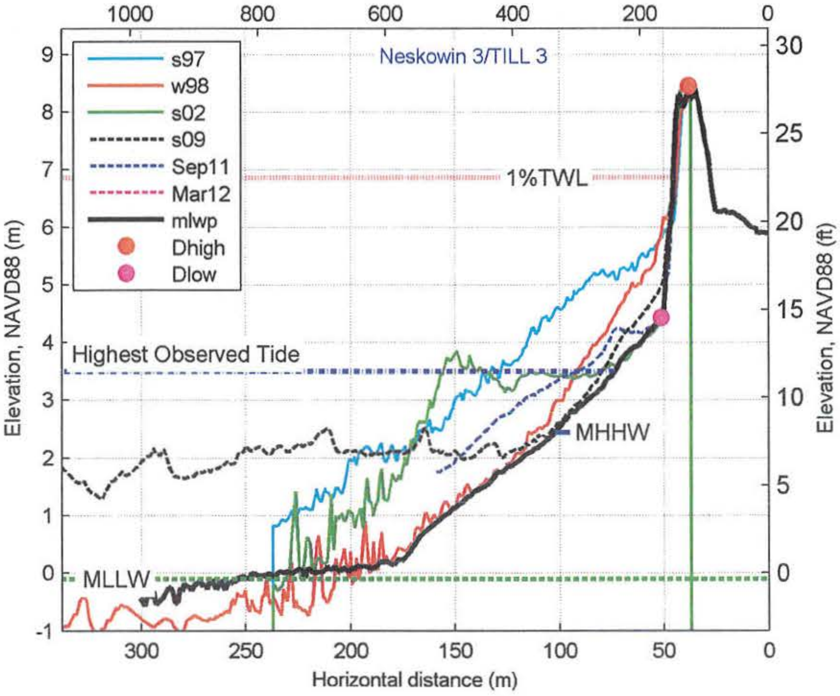

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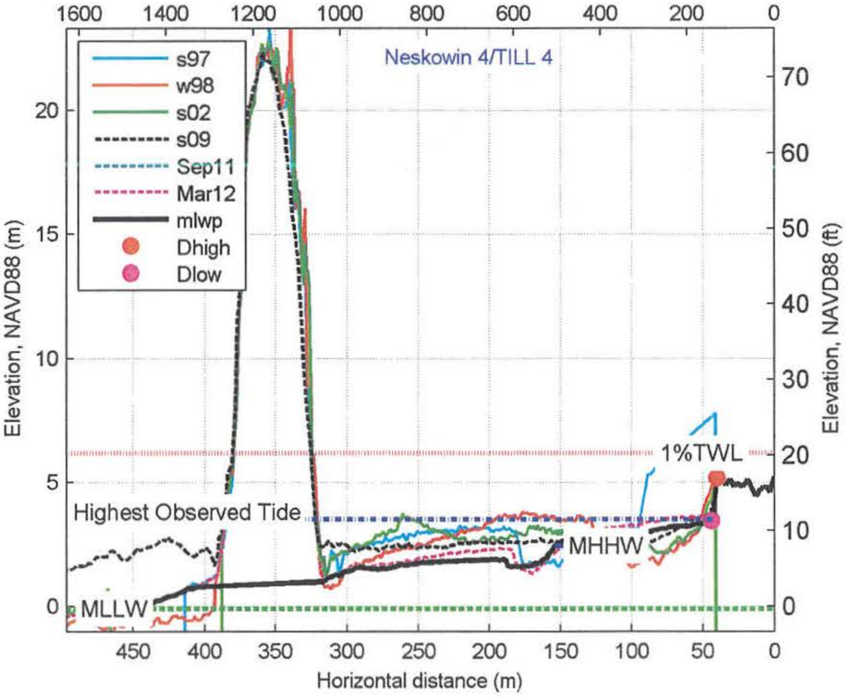

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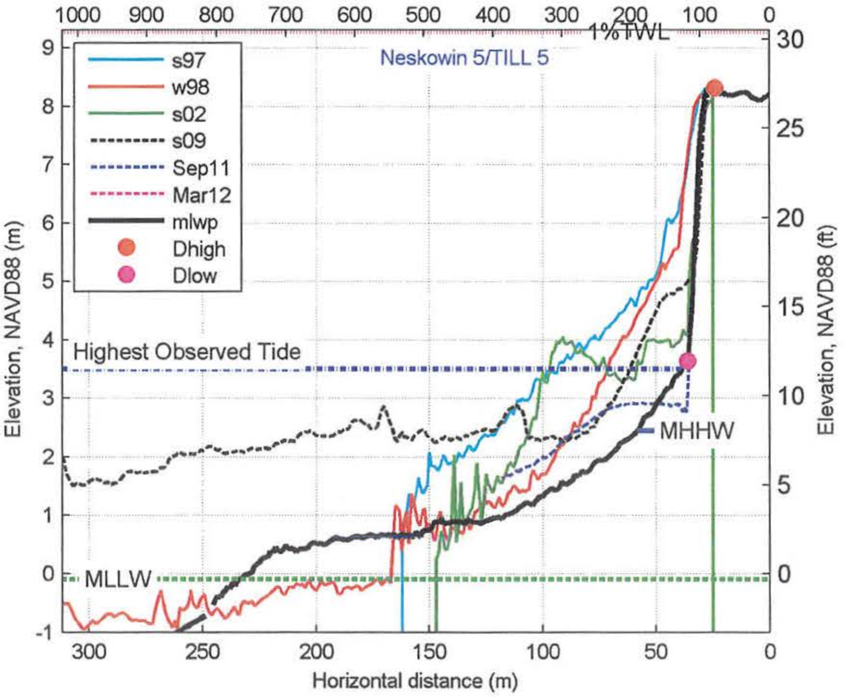

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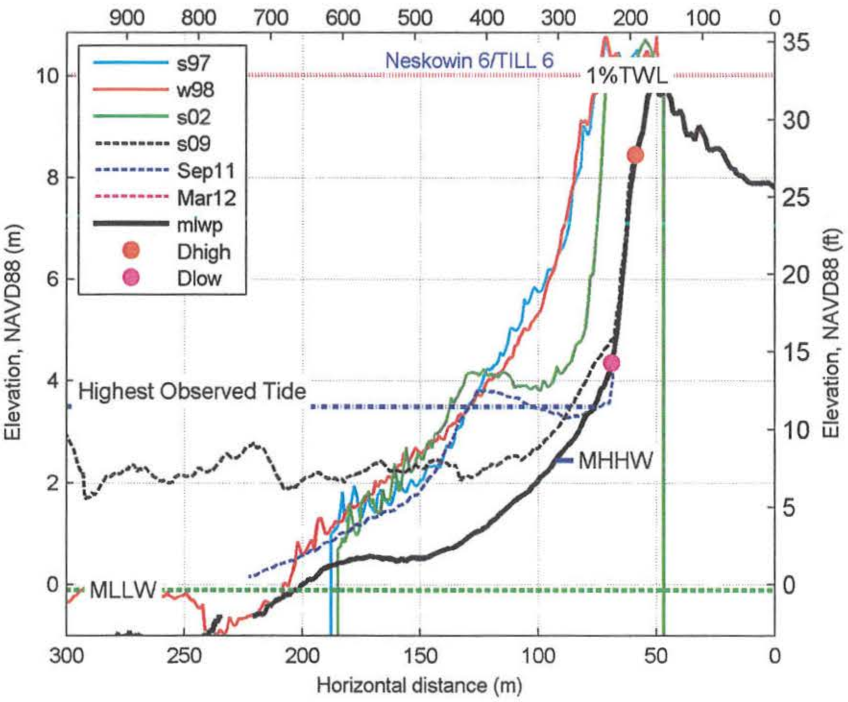

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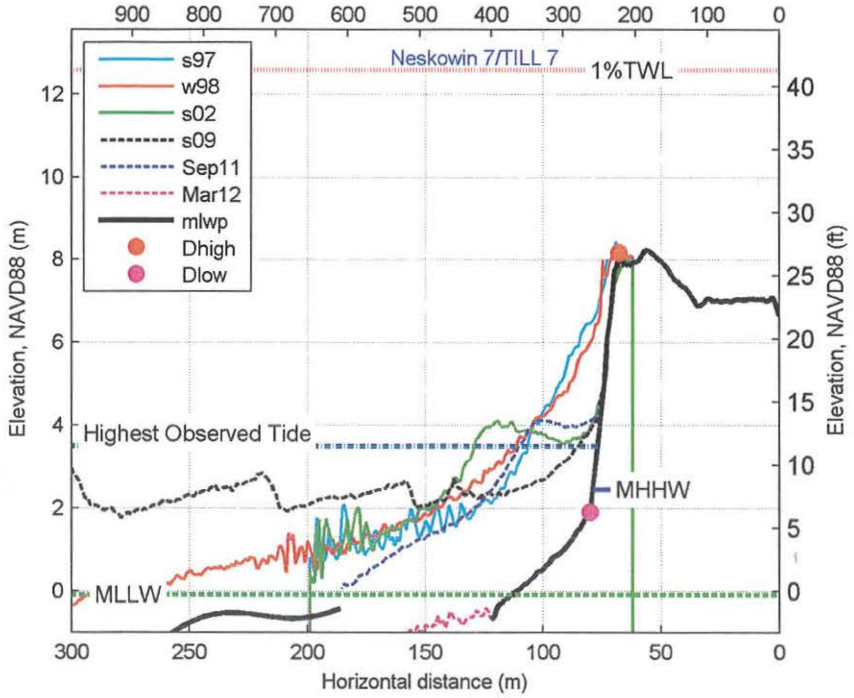

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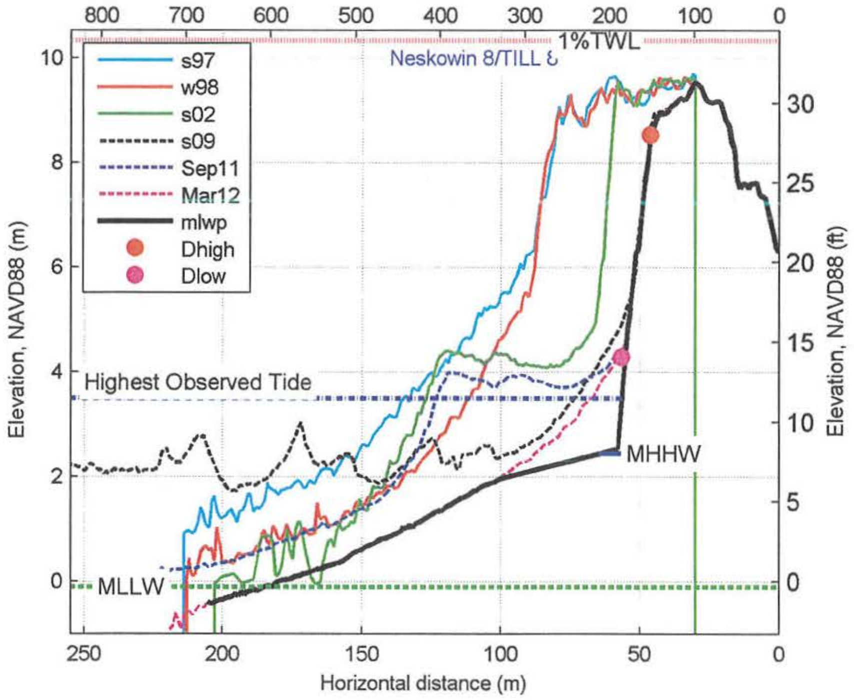

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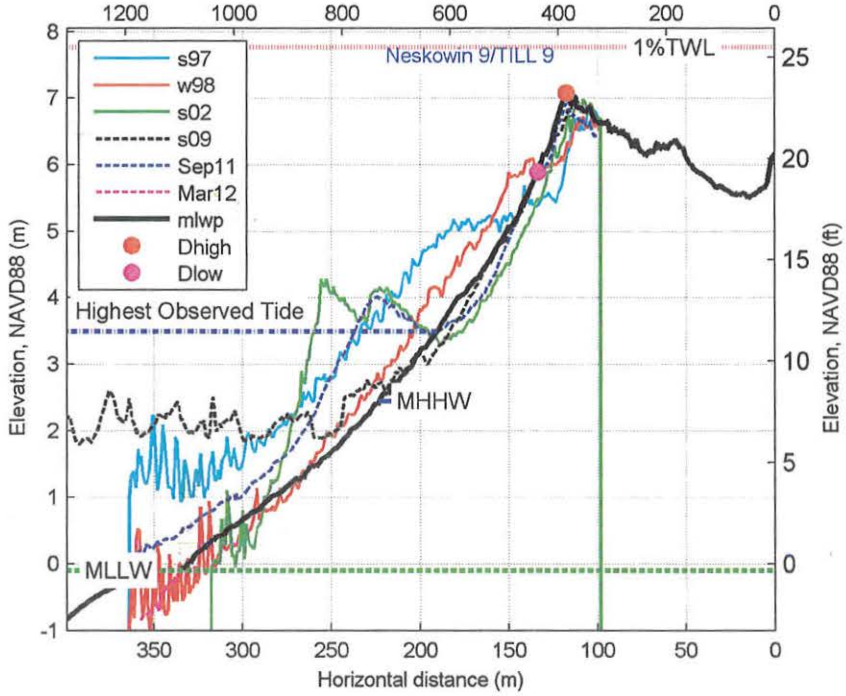

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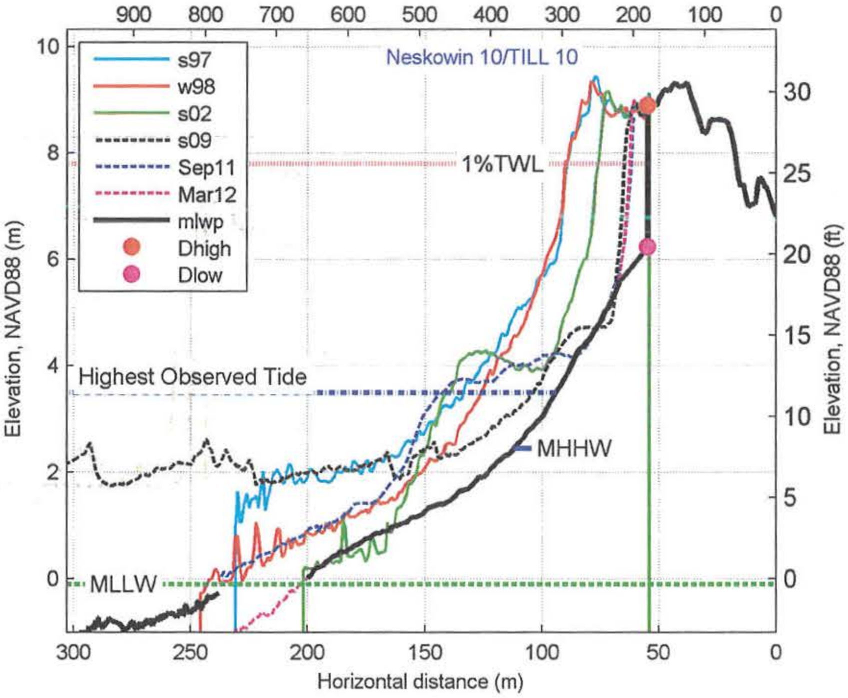

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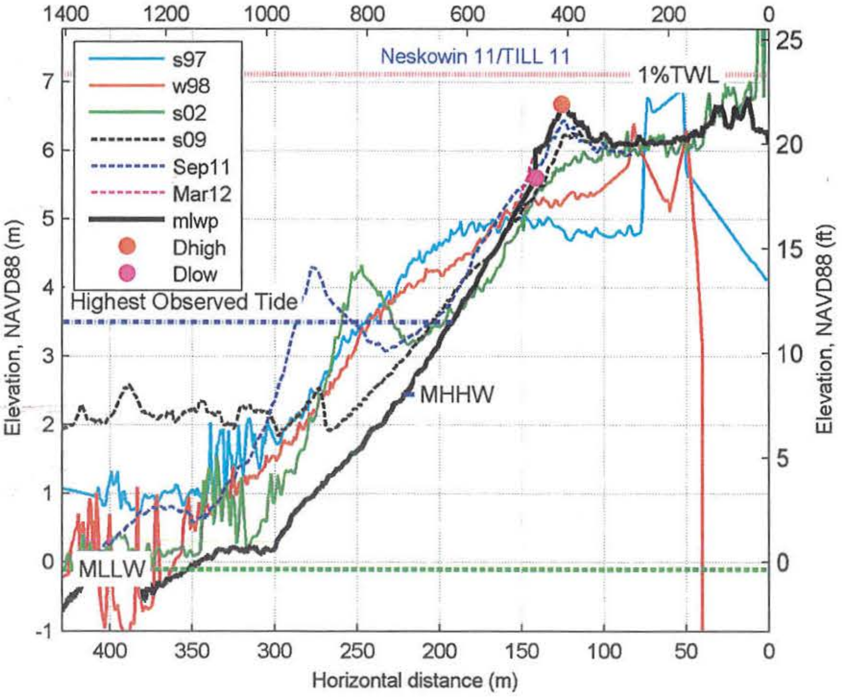

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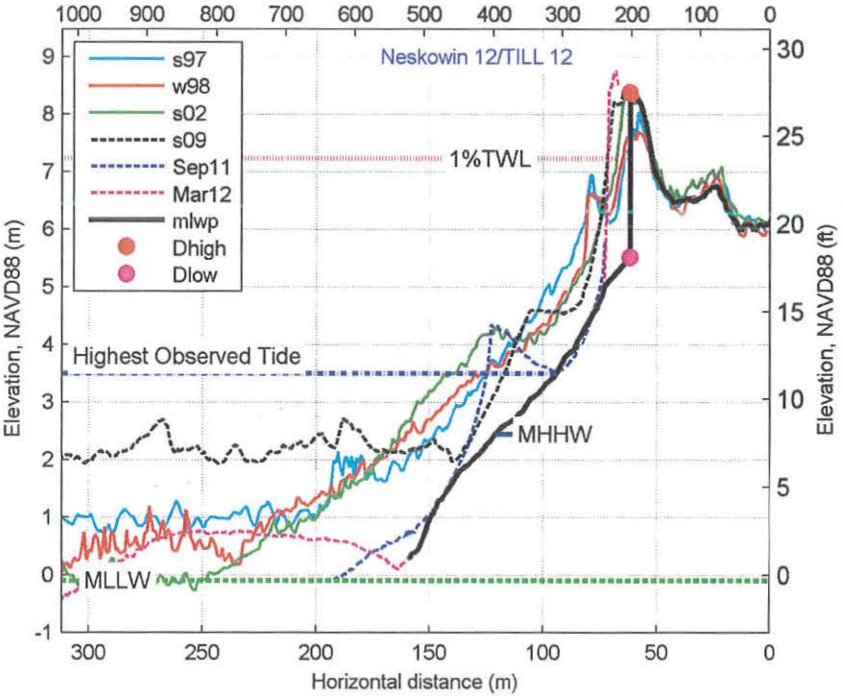

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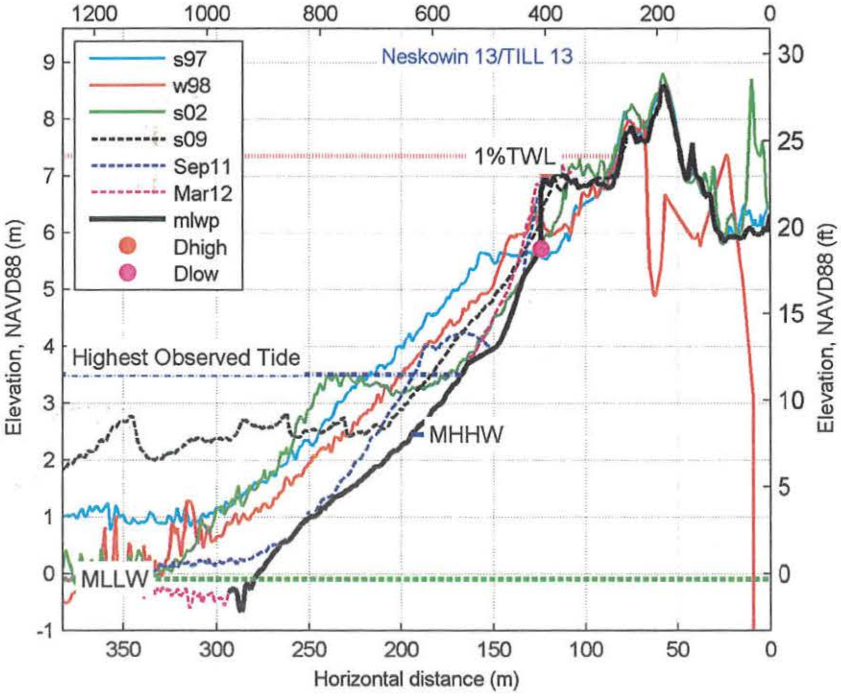

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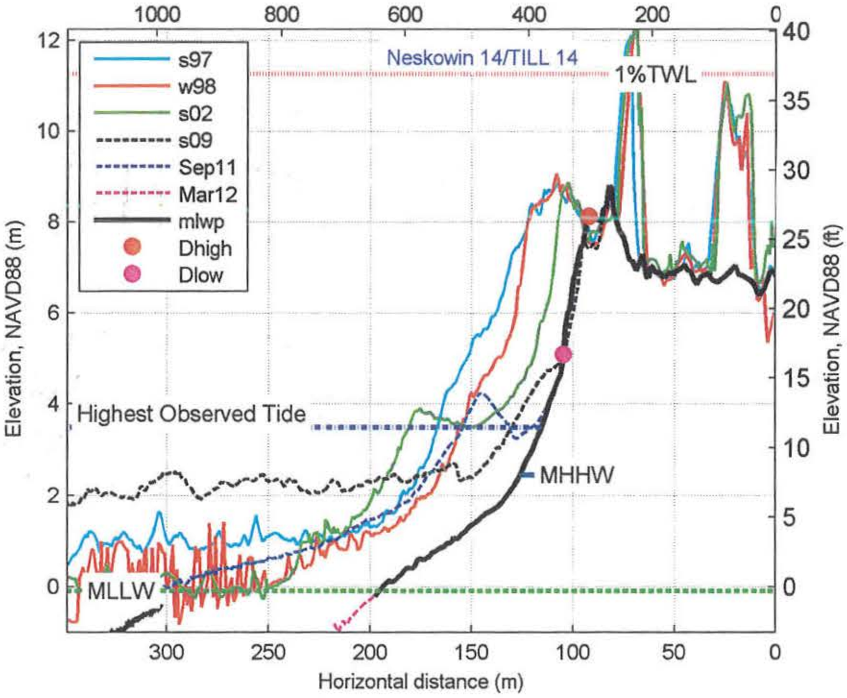

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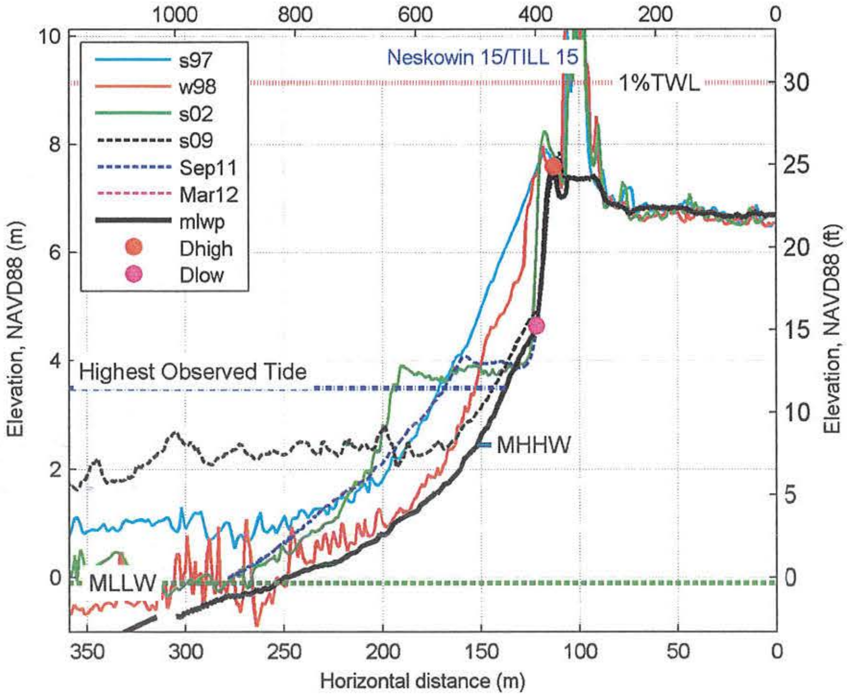

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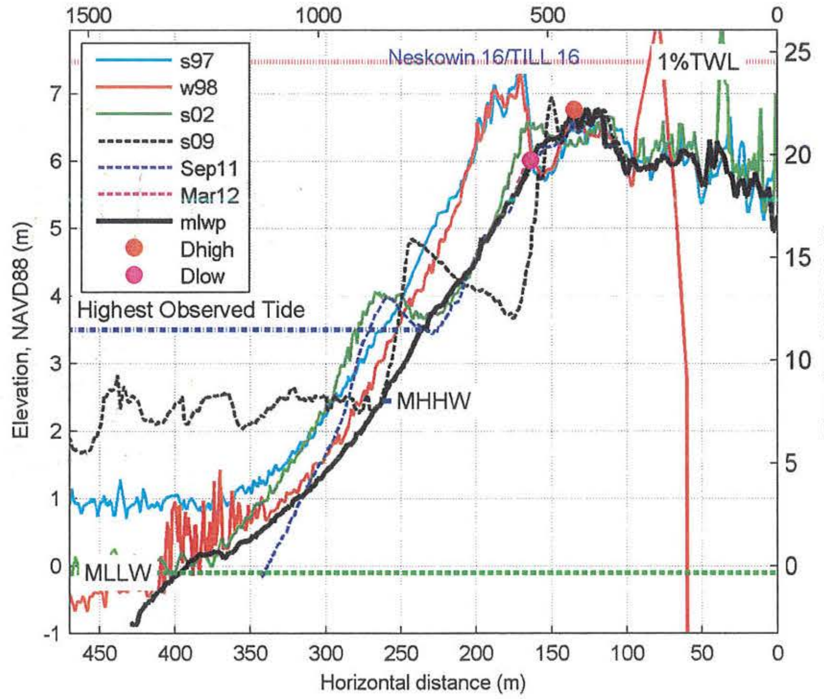

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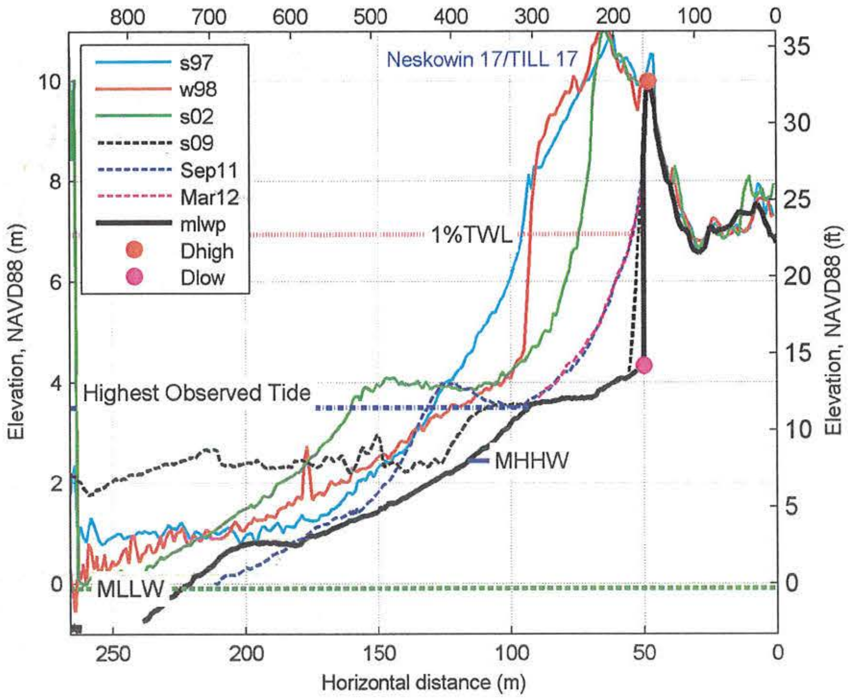

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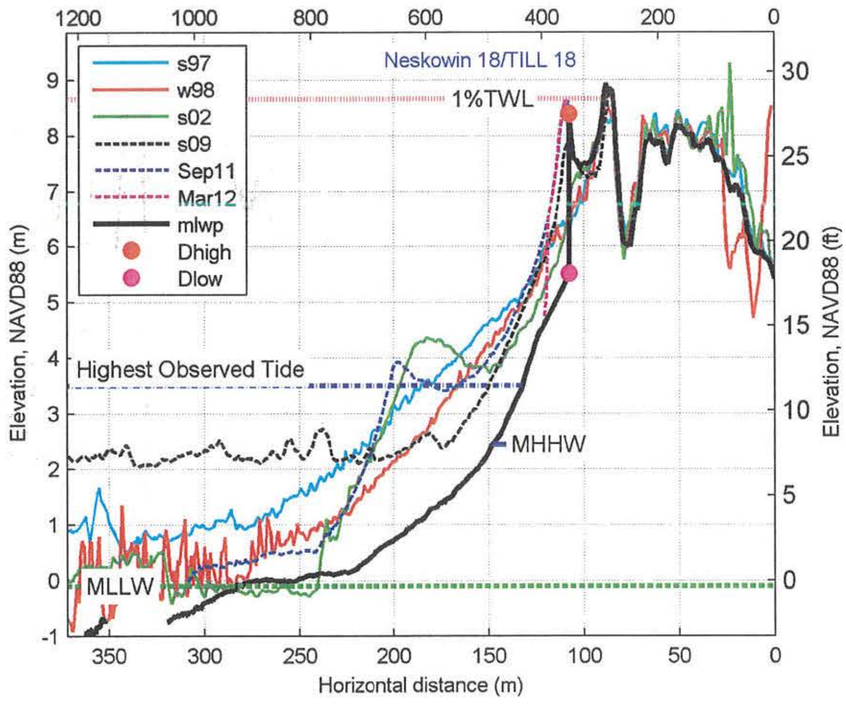

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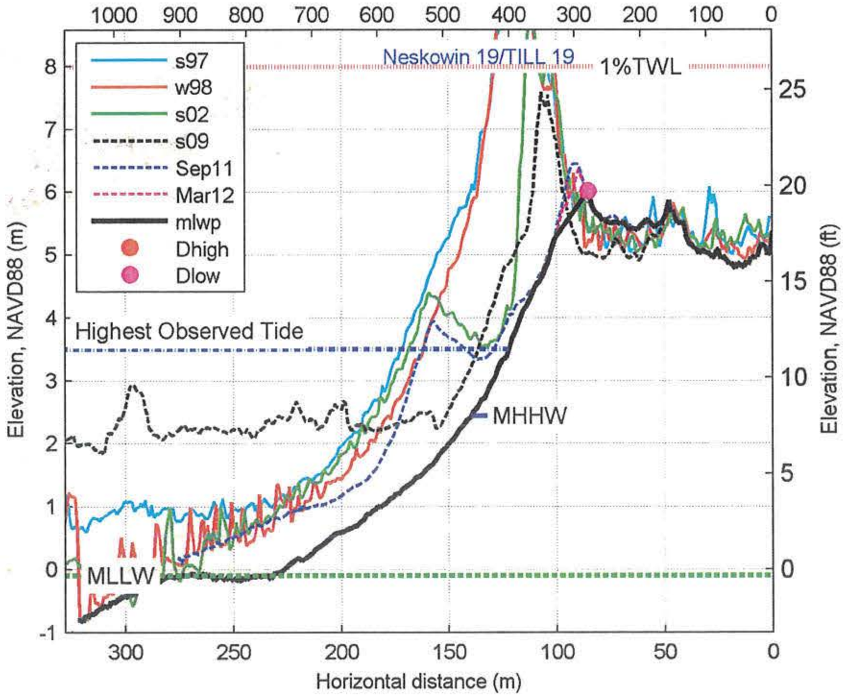

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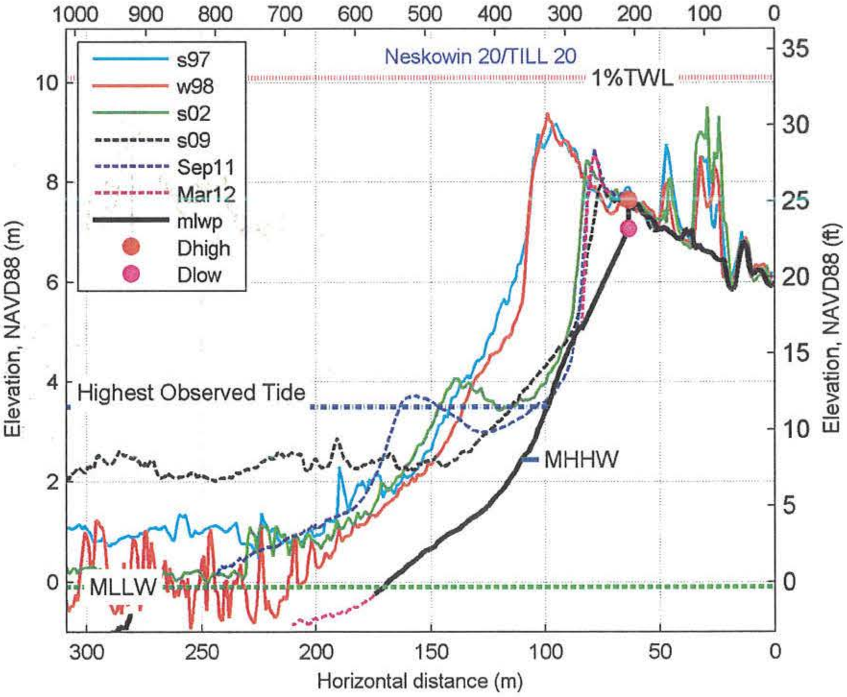

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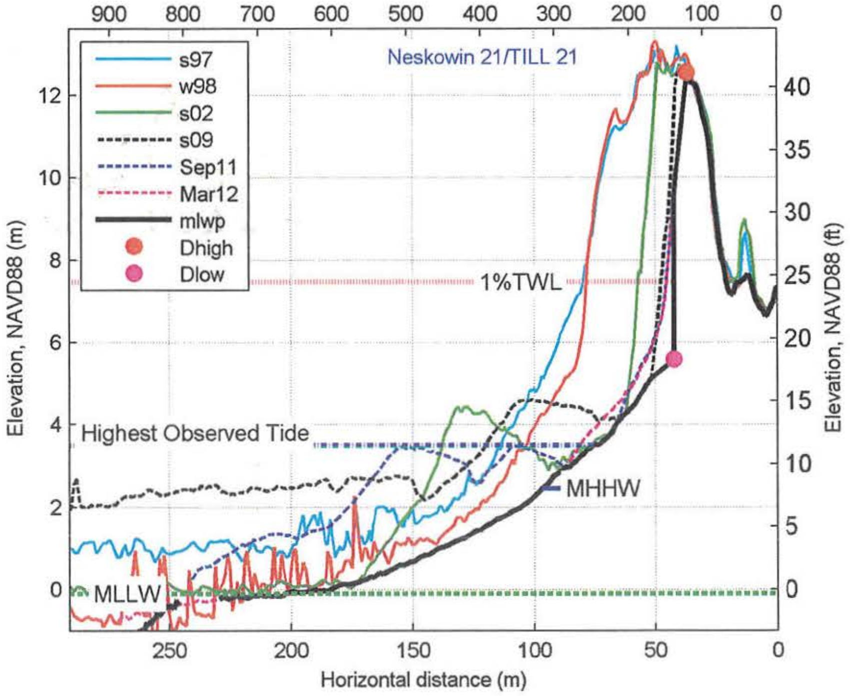

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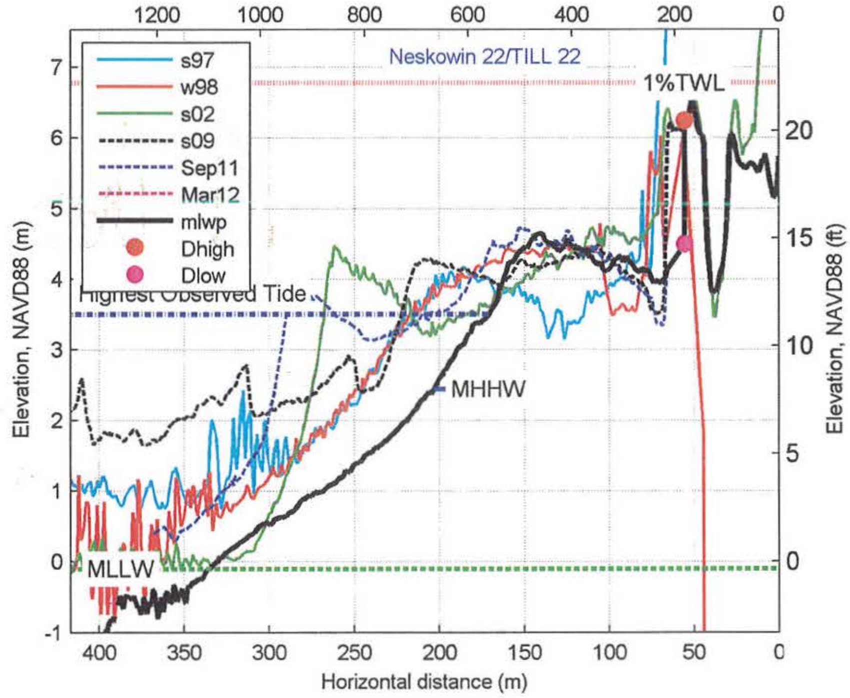

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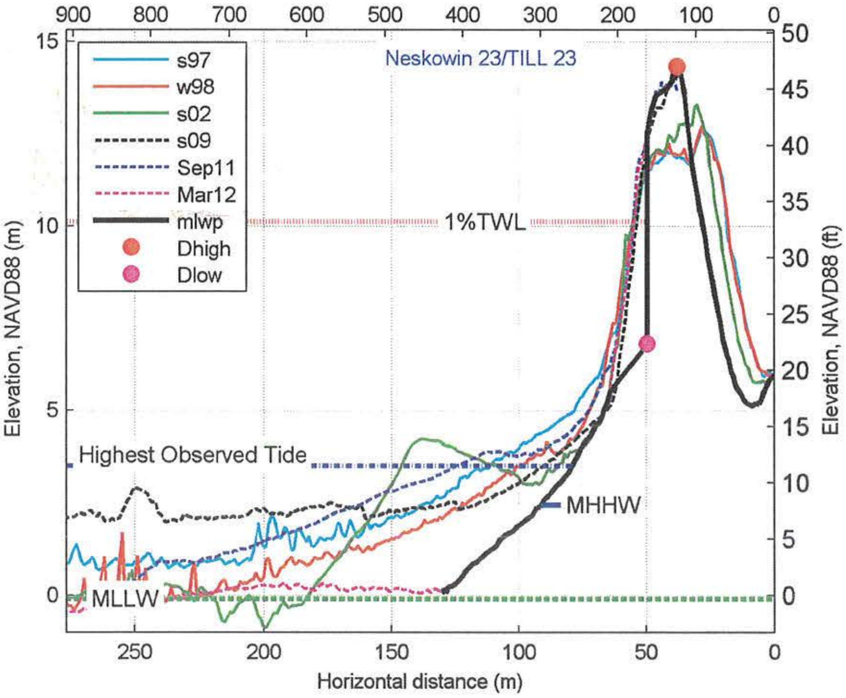

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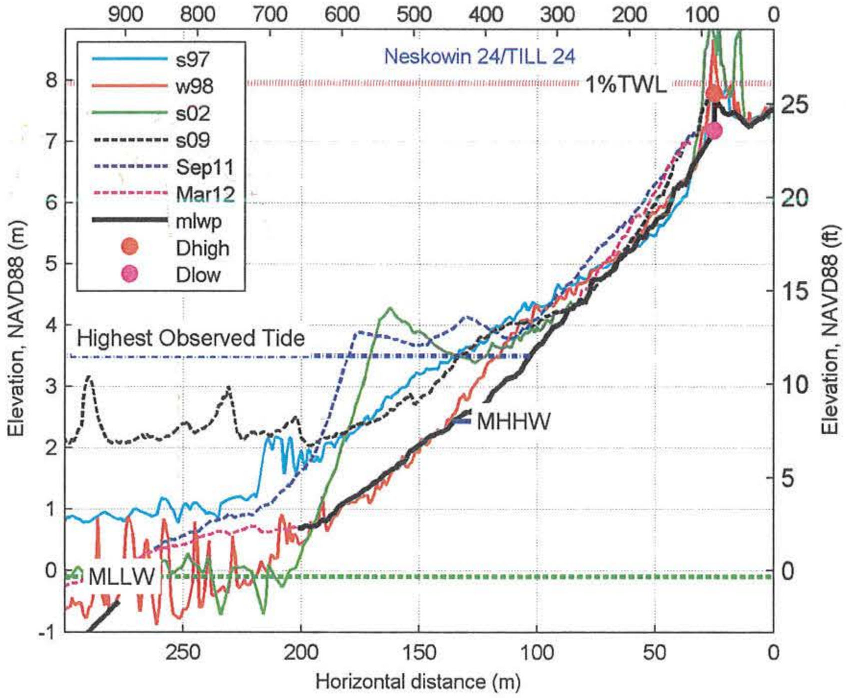

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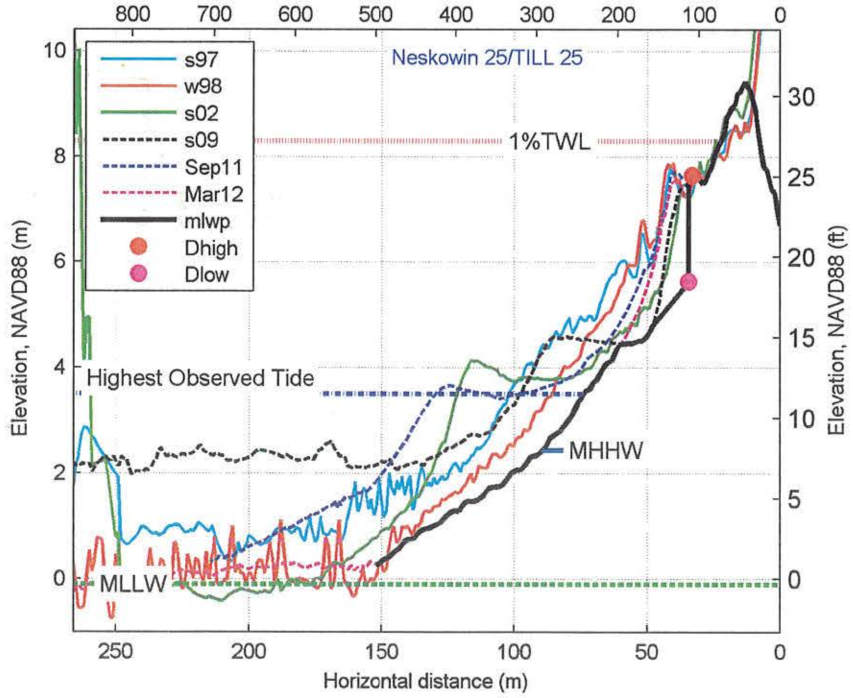

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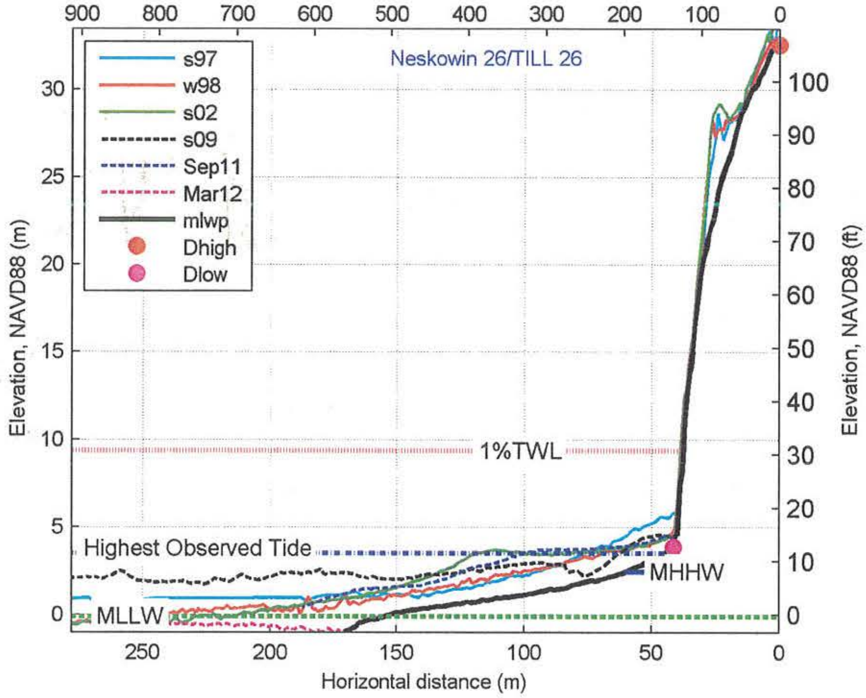

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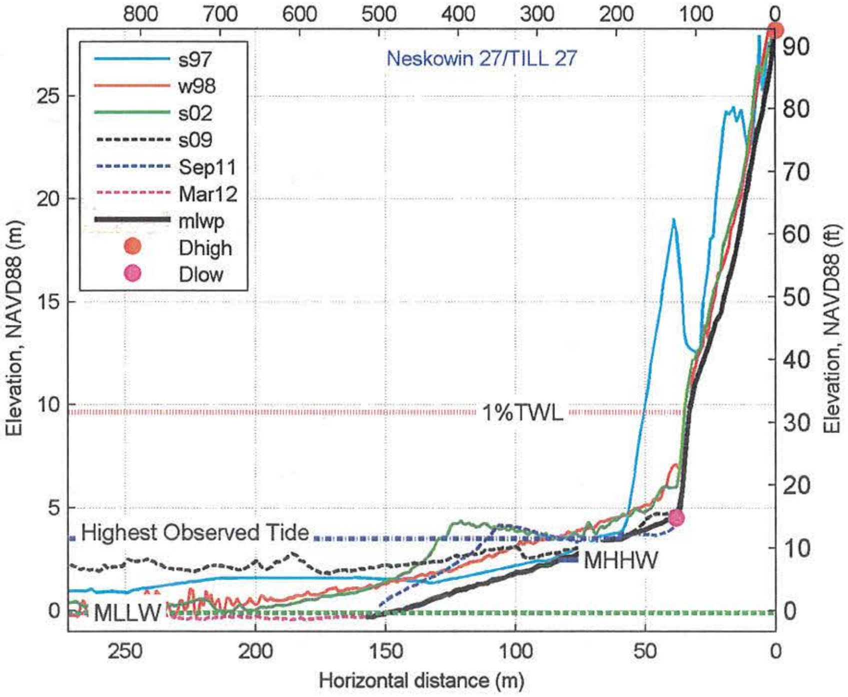

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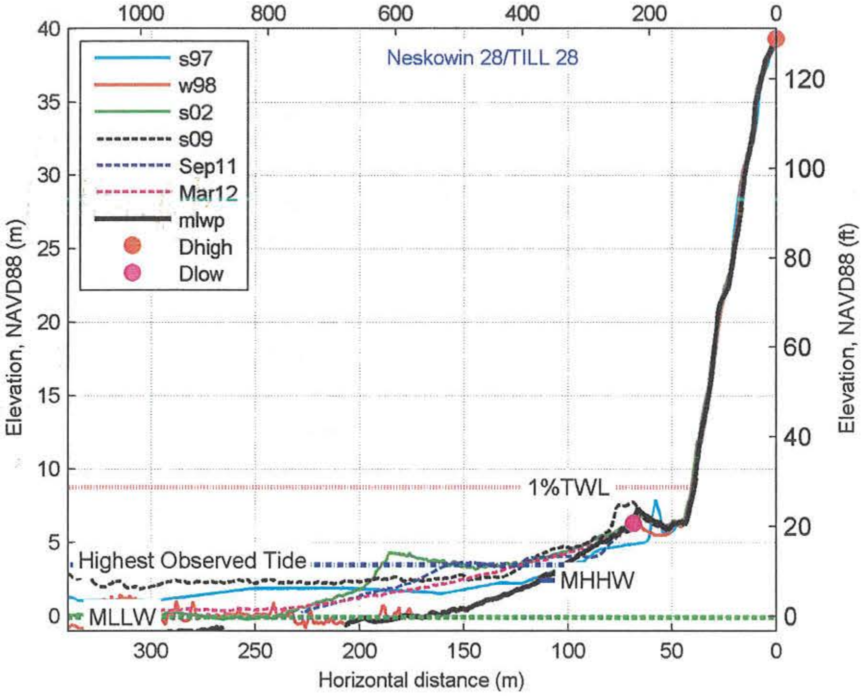

### *11.4.2 Pacific City*

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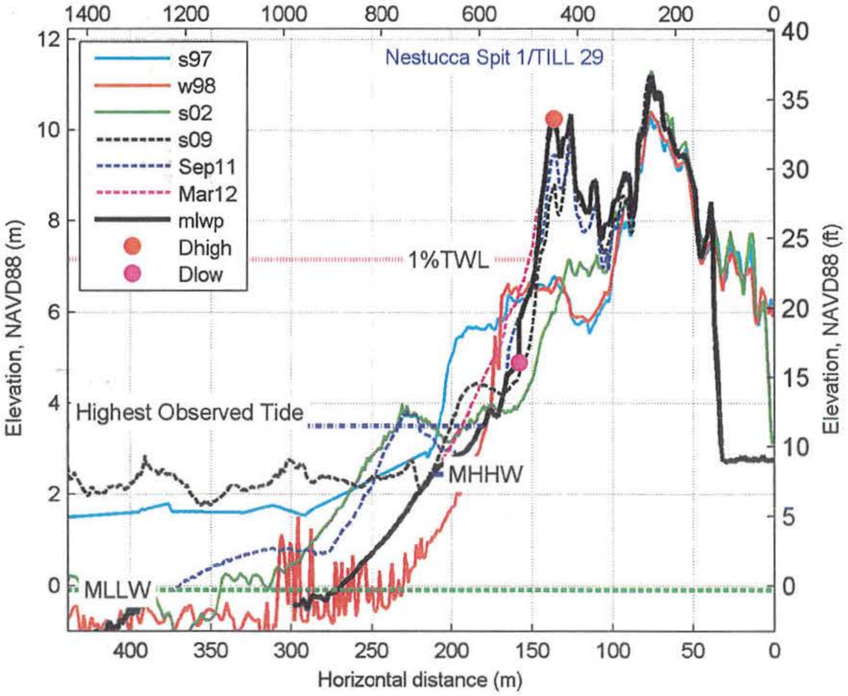

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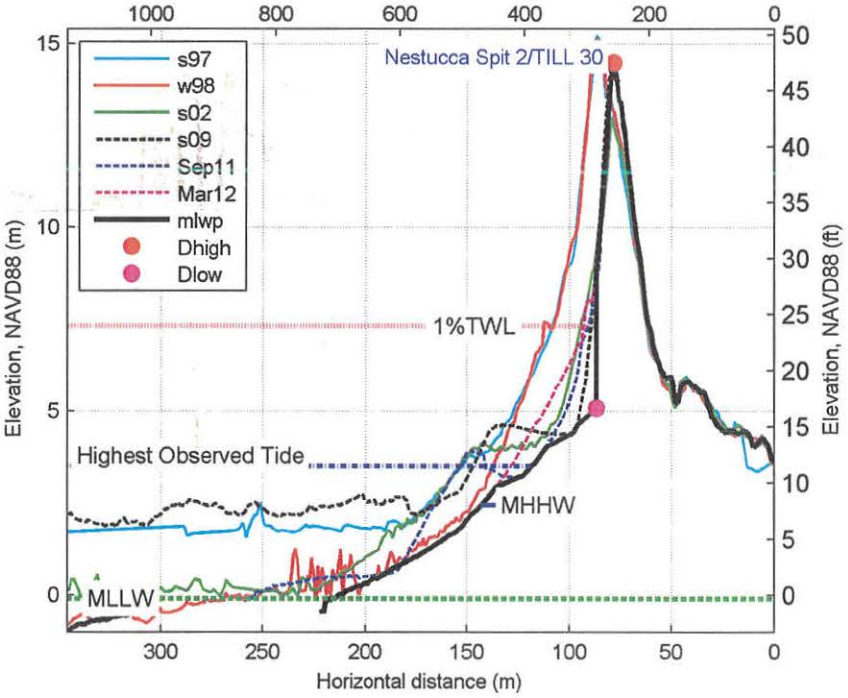

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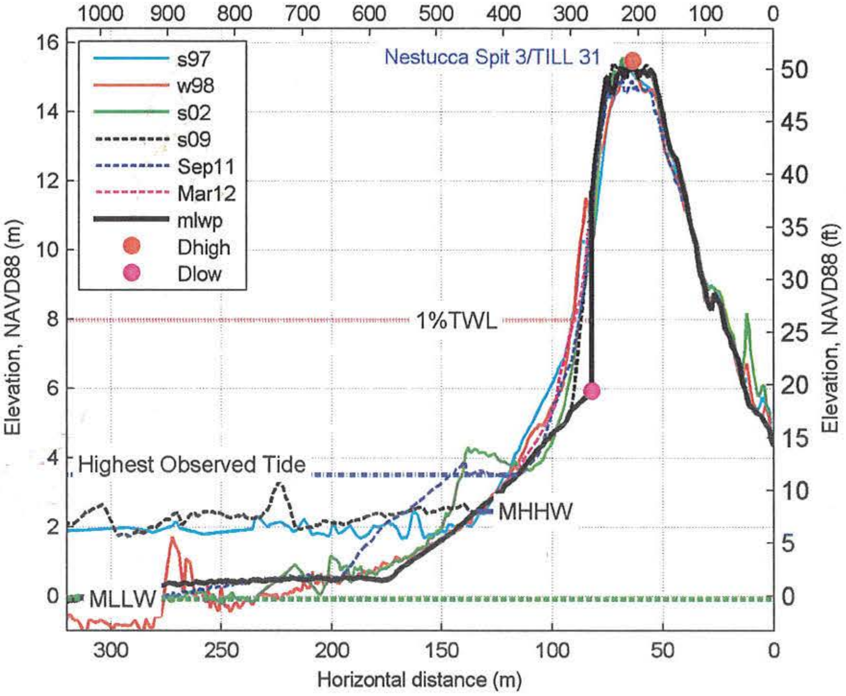
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w98
s02
s09
Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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0 5 10 15 20 25 30 35 40 45 50

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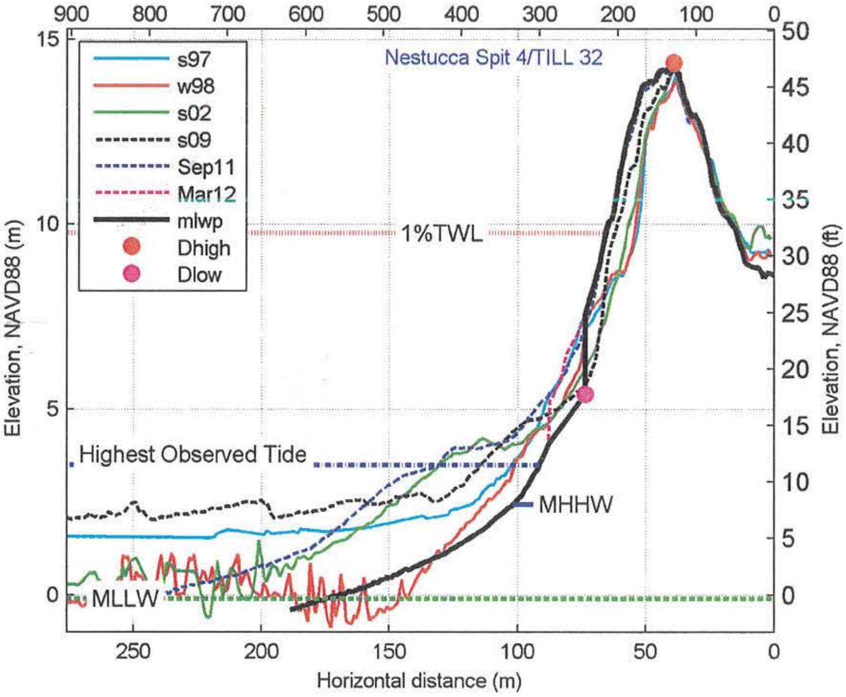
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w98
s02
s09
Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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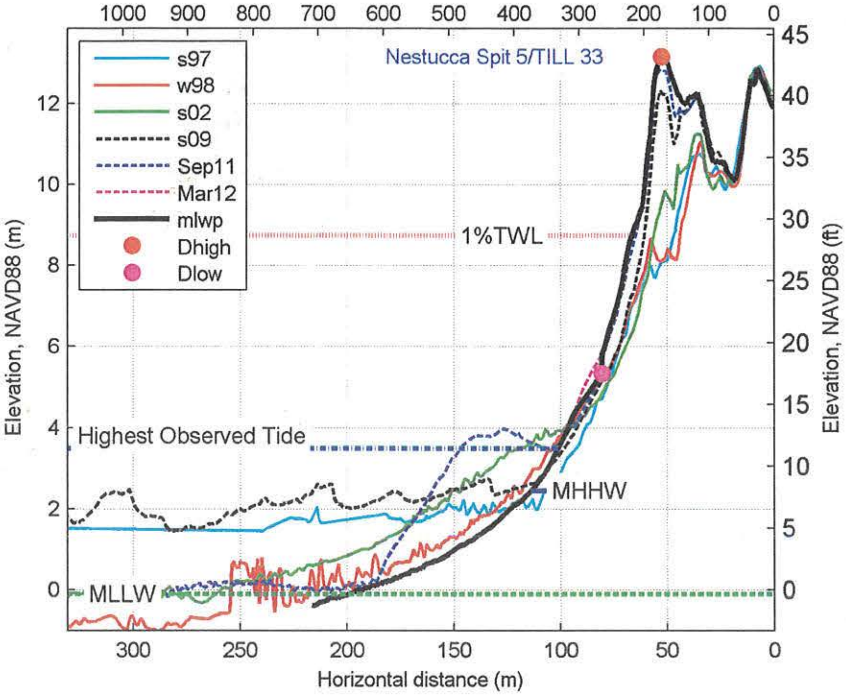
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Mar12
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1%TWL
Highest Observed Tide
MHHW
MLLW
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Elevation, NAVD88 (ft)
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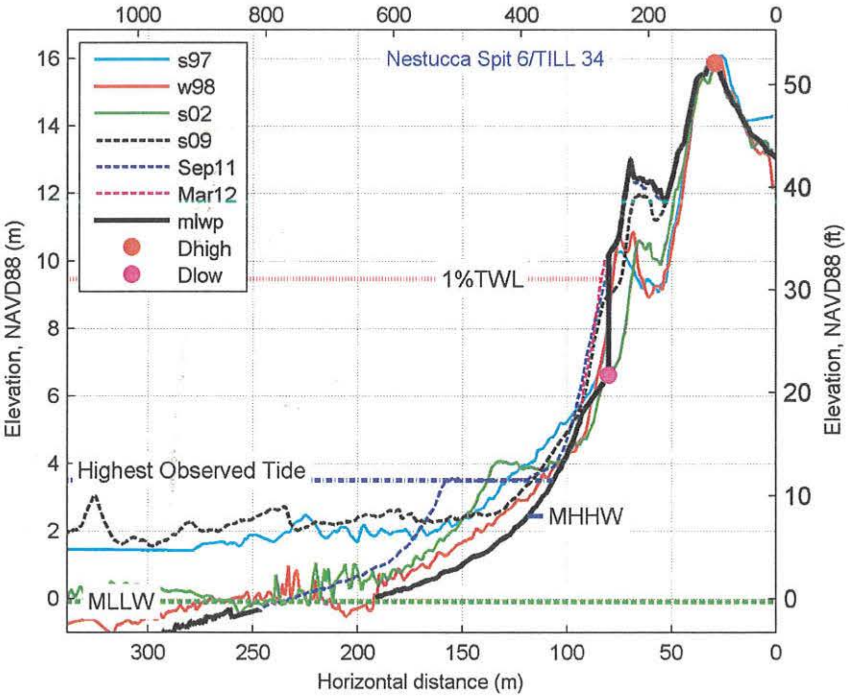
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1%TWL
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MLLW
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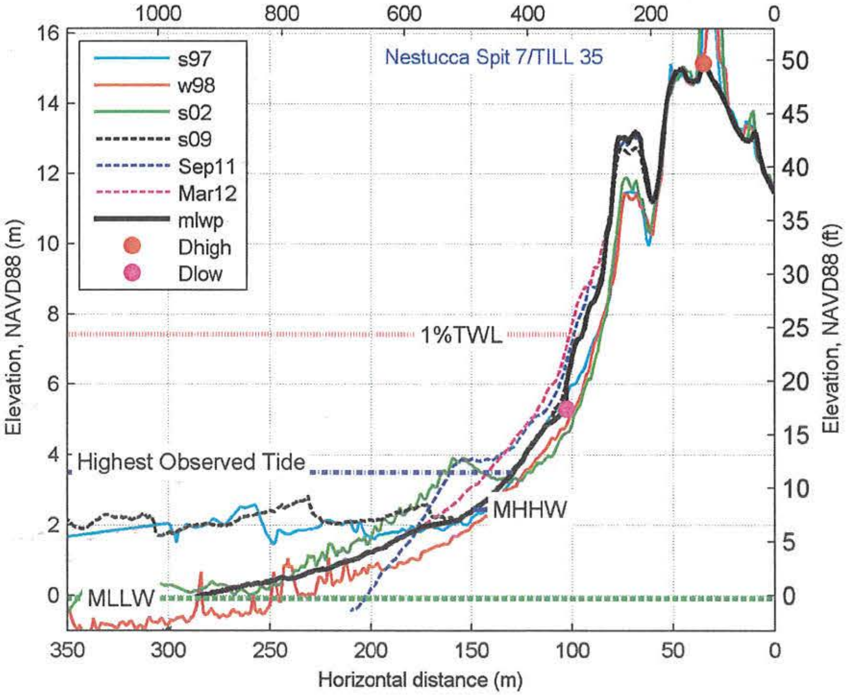
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s97
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Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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150
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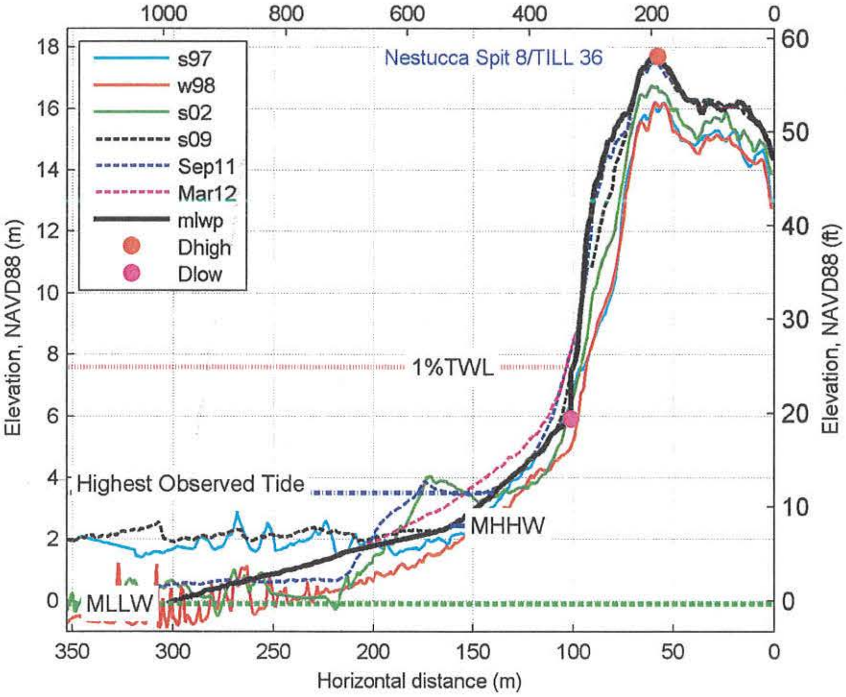
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Highest Observed Tide
MHHW
MLLW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
350
300
250
200
150
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800
600
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200
0
18
16
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10
0

## Allison Hinderer

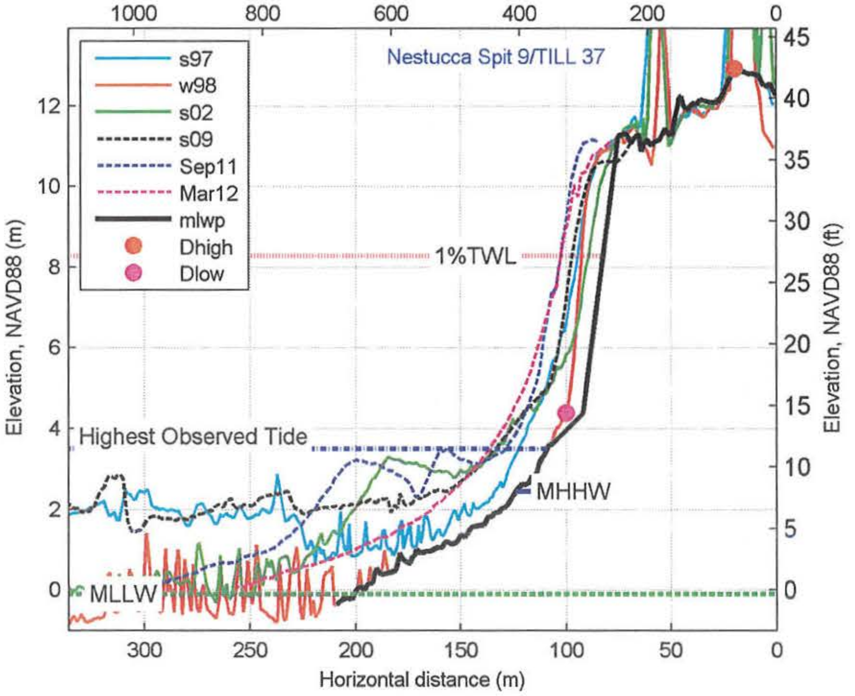
| | |
|---|---|
| **From:** | Sarah Mitchell <sm@klgpc.com> |
| **Sent:** | Tuesday, July 27, 2021 2:21 PM |
| **To:** | Sarah Absher; Allison Hinderer |
| **Cc:** | Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1@comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com |
| **Subject:** | EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 5 of 6) |
| **Attachments:** | Exh 2 - DOGAMI SP-47 Report_Part4.pdf |
| **Importance:** | High |

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 5 of 6.

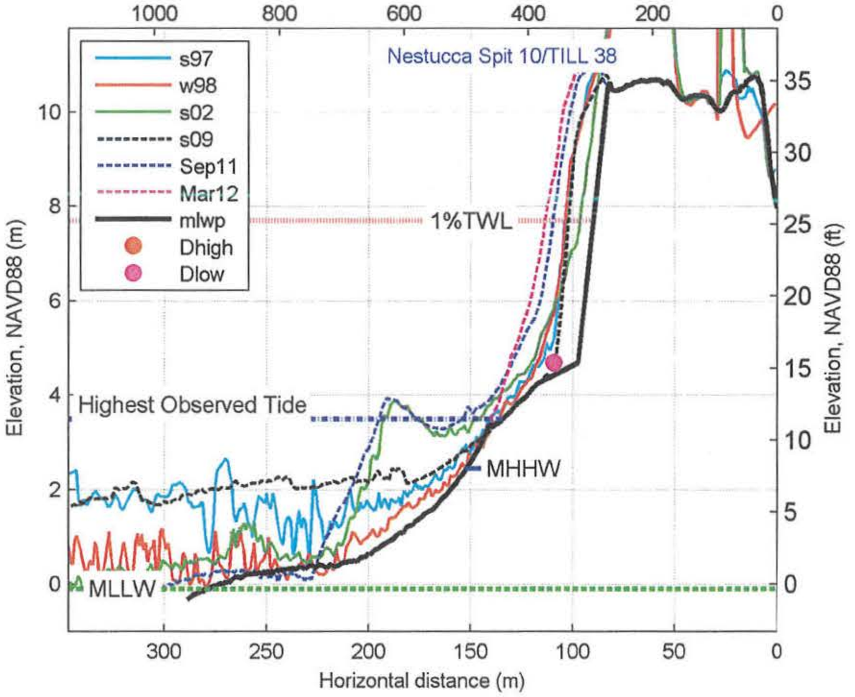
**From:** Sarah Mitchell
**Sent:** Tuesday, July 27, 2021 2:20 PM
**To:** sabsher@co.tillamook.or.us; Allison Hinderer <ahindere@co.tillamook.or.us>
**Cc:** Wendie Kellington <wk@klgpc.com>; Bill and Lynda Cogdall (jwcogdall@gmail.com) <jwcogdall@gmail.com>; Bill and Lynda Cogdall (lcogdall@aol.com) <lcogdall@aol.com>; Brett Butcher (brett@passion4people.org) <brett@passion4people.org>; Dave and Frieda Farr (dfarrwestproperties@gmail.com) <dfarrwestproperties@gmail.com>; David Dowling <ddowling521@gmail.com>; David Hayes (tdavidh1@comcast.net) <tdavidh1@comcast.net>; Don and Barbara Roberts (donrobertsemail@gmail.com) <donrobertsemail@gmail.com>; Don and Barbara Roberts (robertsfm6@gmail.com) <robertsfm6@gmail.com>; evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com) <jeffklein@wvmeat.com>; Jon Creedon (jcc@pacifier.com) <jcc@pacifier.com>; kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net) <michaelmunch@comcast.net>; Mike and Chris Rogers (mjr2153@aol.com) <mjr2153@aol.com>; Mike Ellis (mikeellispdx@gmail.com) <mikeellispdx@gmail.com>; Rachael Holland (rachael@pacificopportunities.com) <rachael@pacificopportunities.com>; teriklein59@aol.com
**Subject:** RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 4 of 6)
**Importance:** High

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 4 of 6.

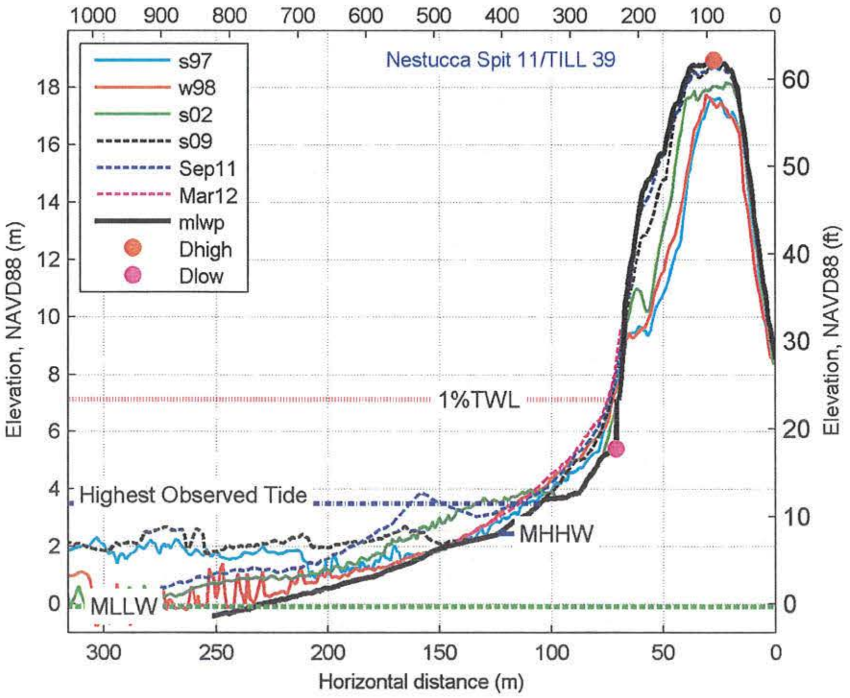
**fm_pc 9**



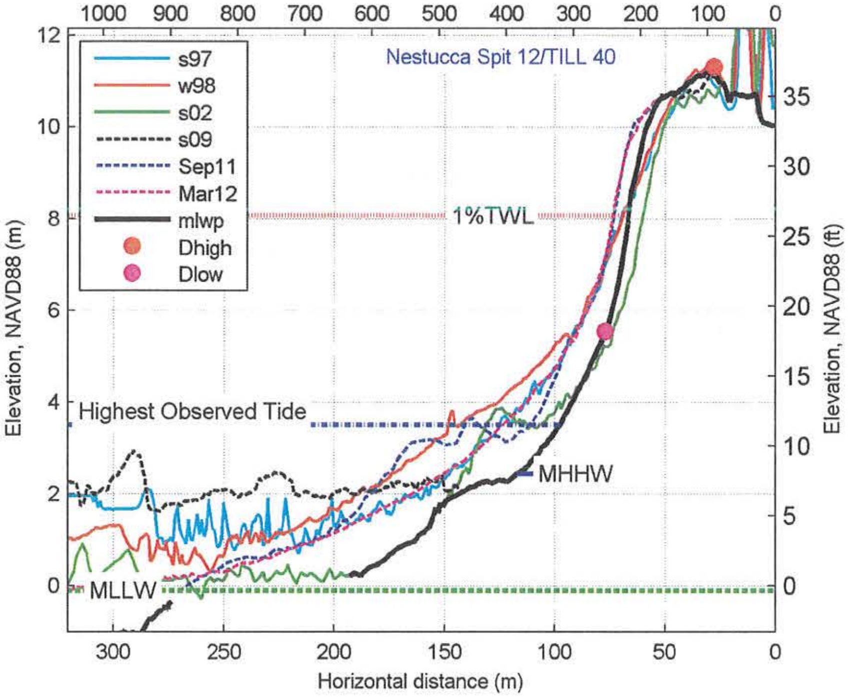
**fm_pc 10**



**fm_pc 11**



**fm_pc 12**



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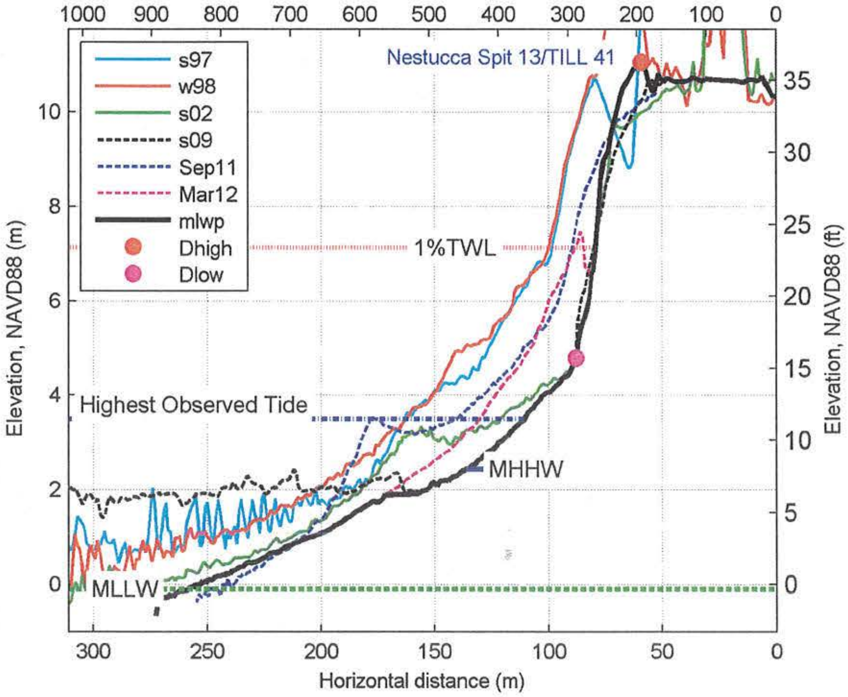
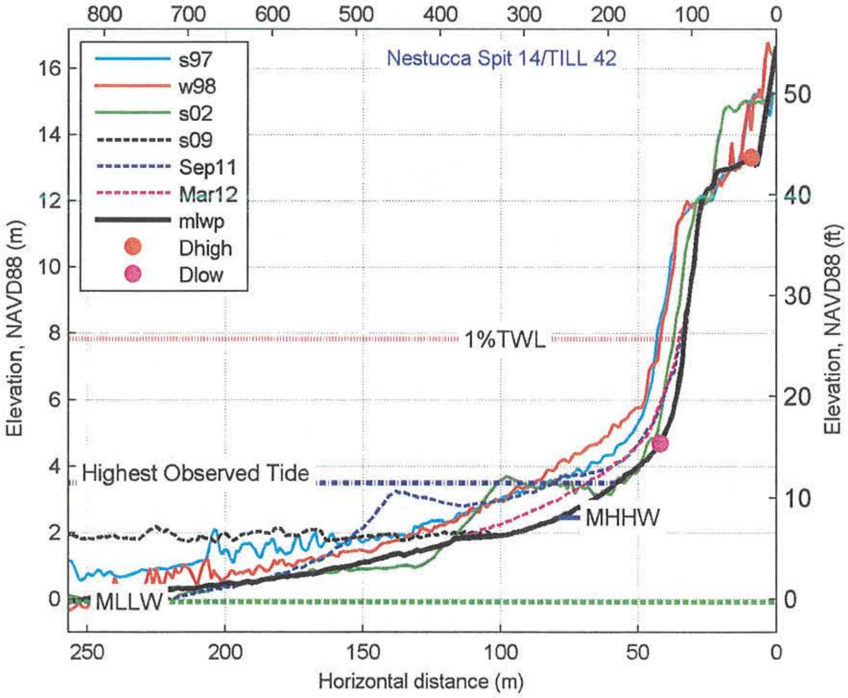
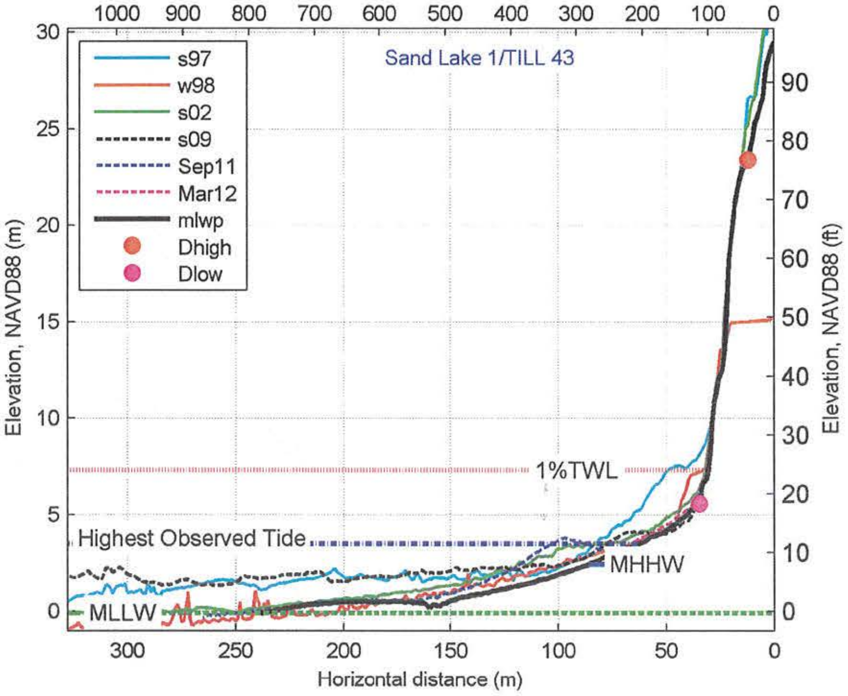


**fm_pc 14**

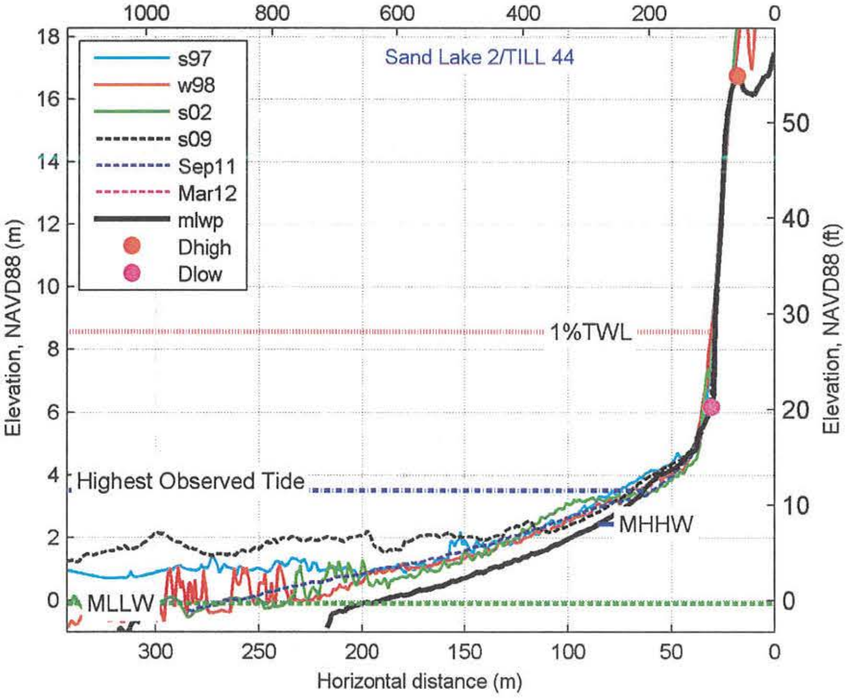


### *11.4.3 Sand Lake*

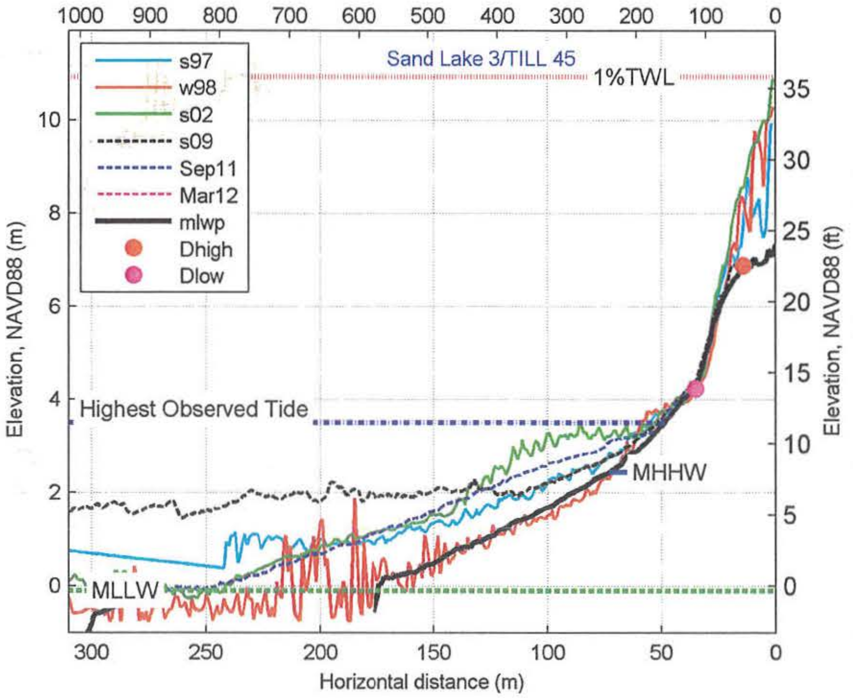
**fm_slk 1**



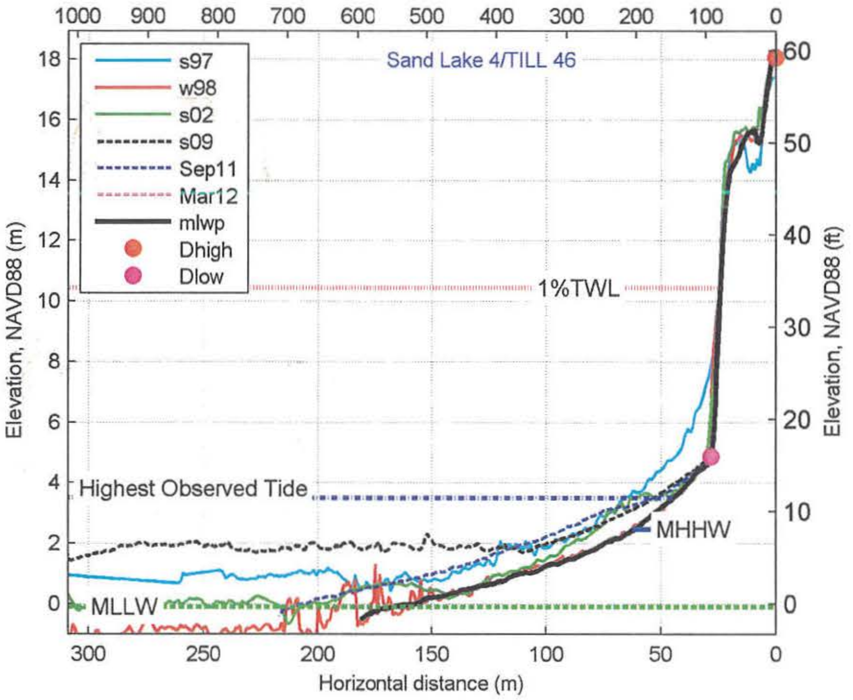
**fm_slk 2**



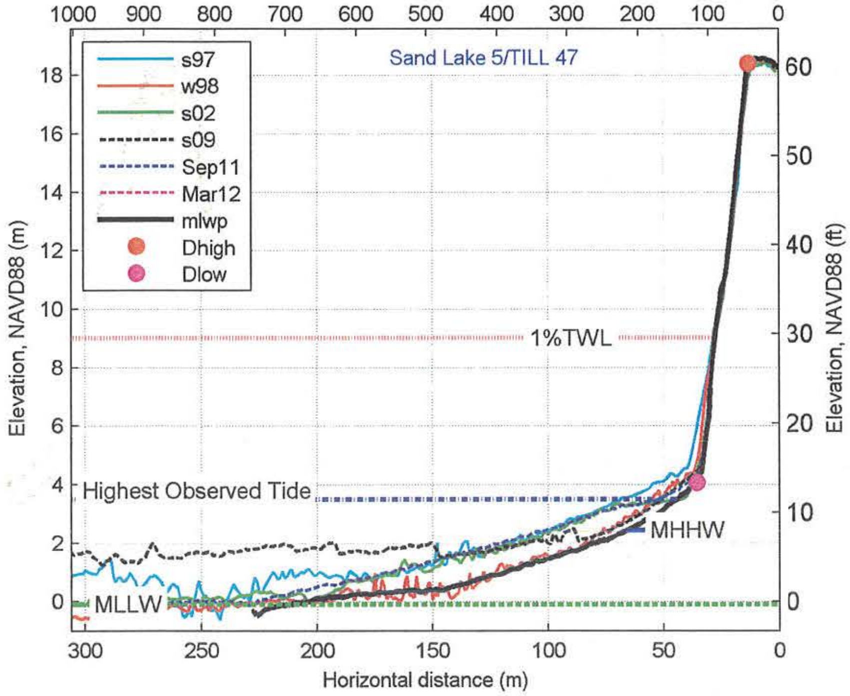
**fm_slk 3**



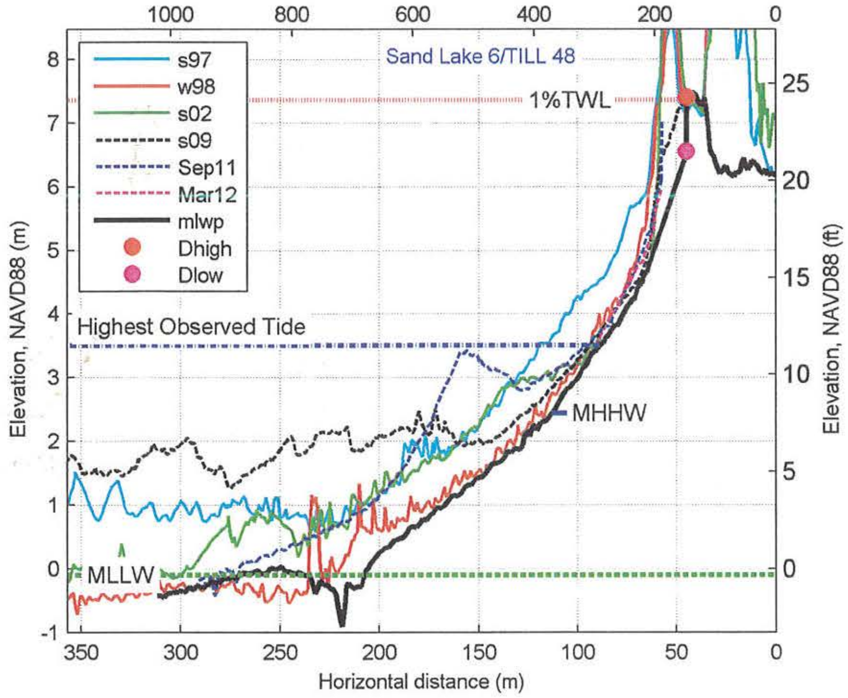
**fm_slk 4**



**fm_slk 5**



**fm_slk 6**



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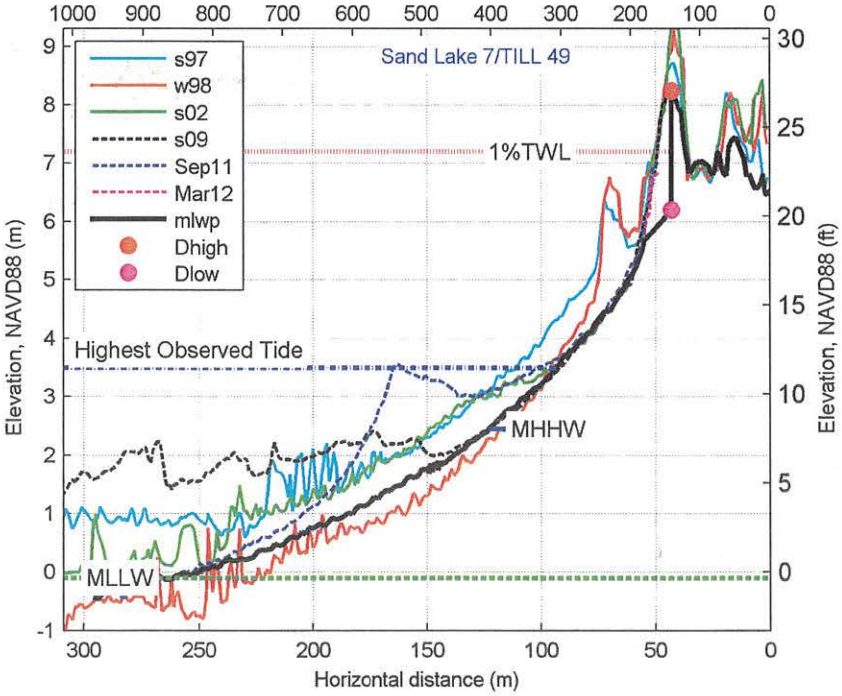
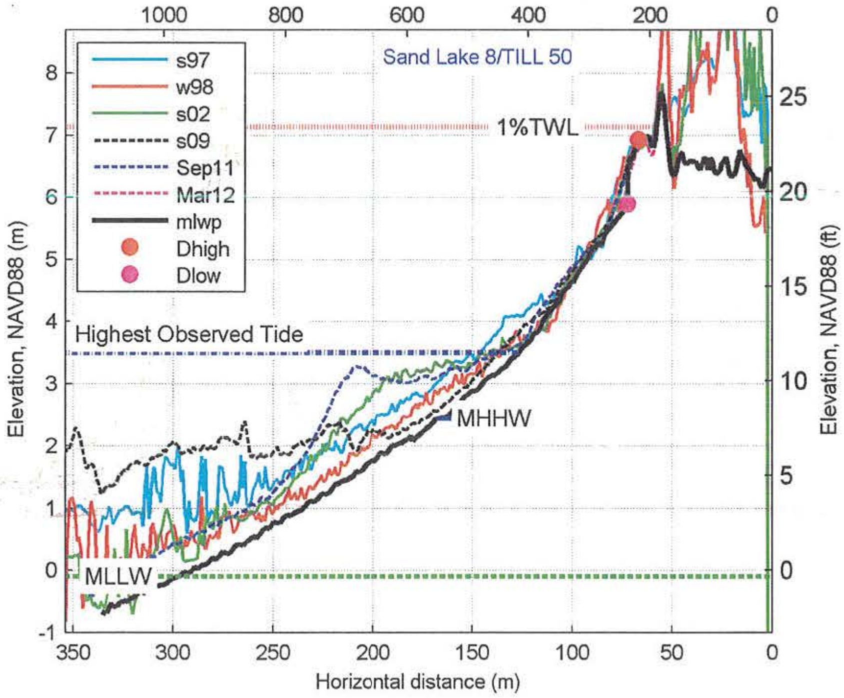
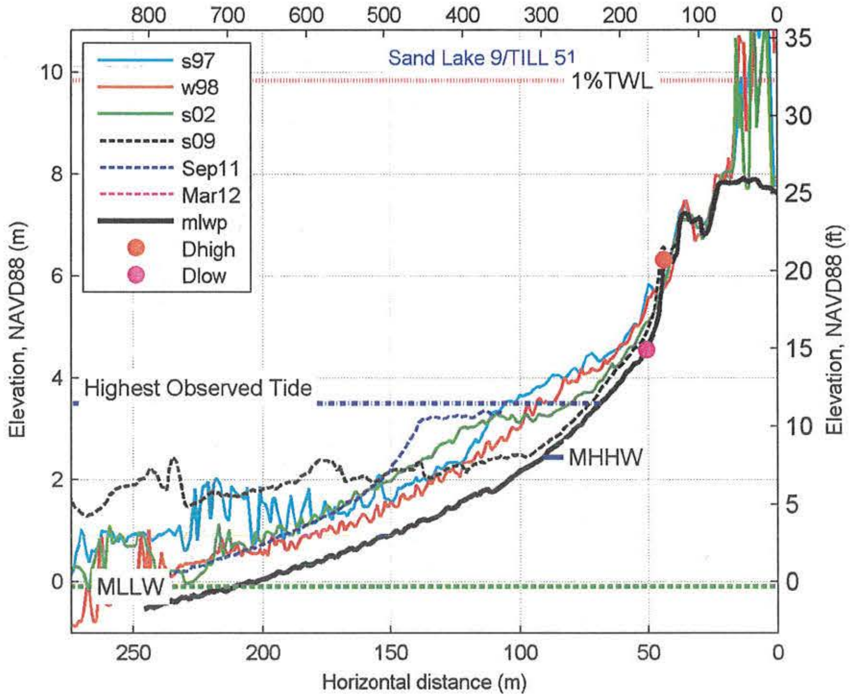


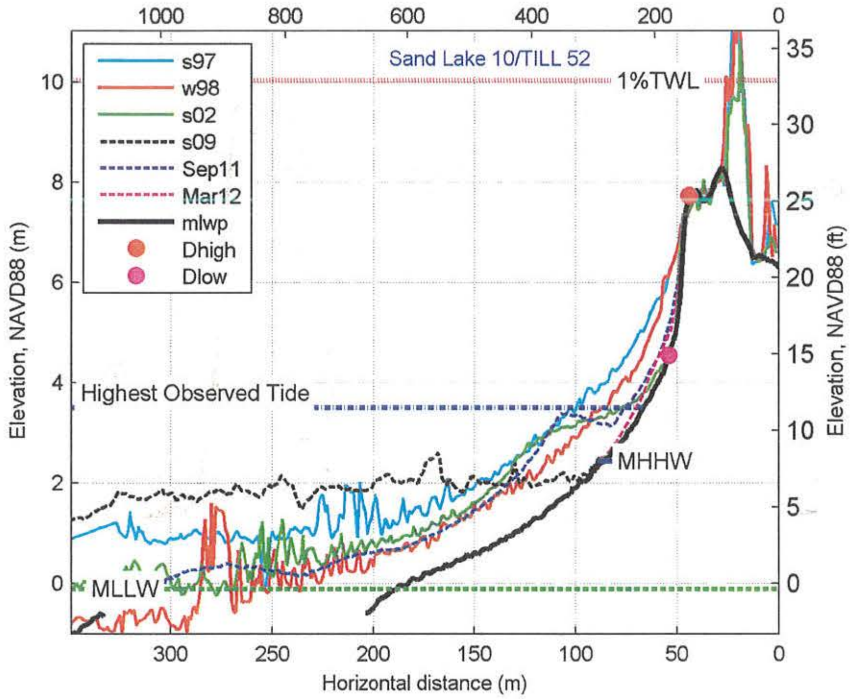
**fm_slk 8**



**fm_slk 9**



**fm_slk 10**



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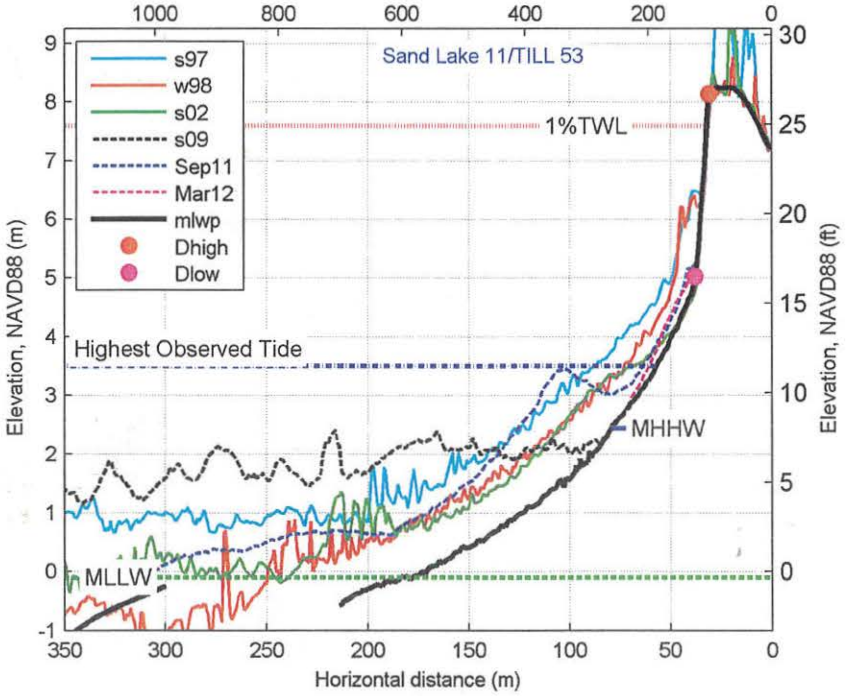
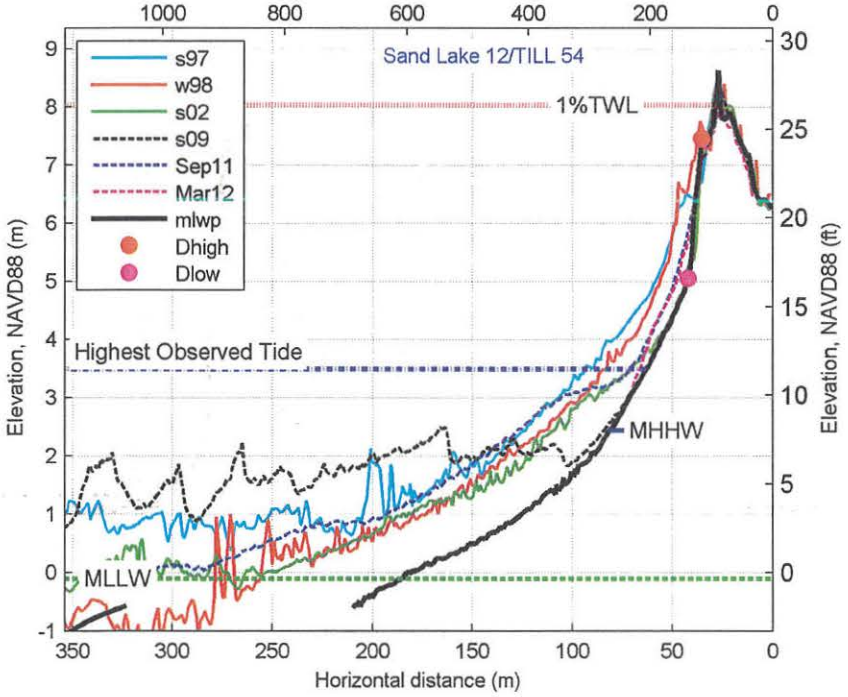
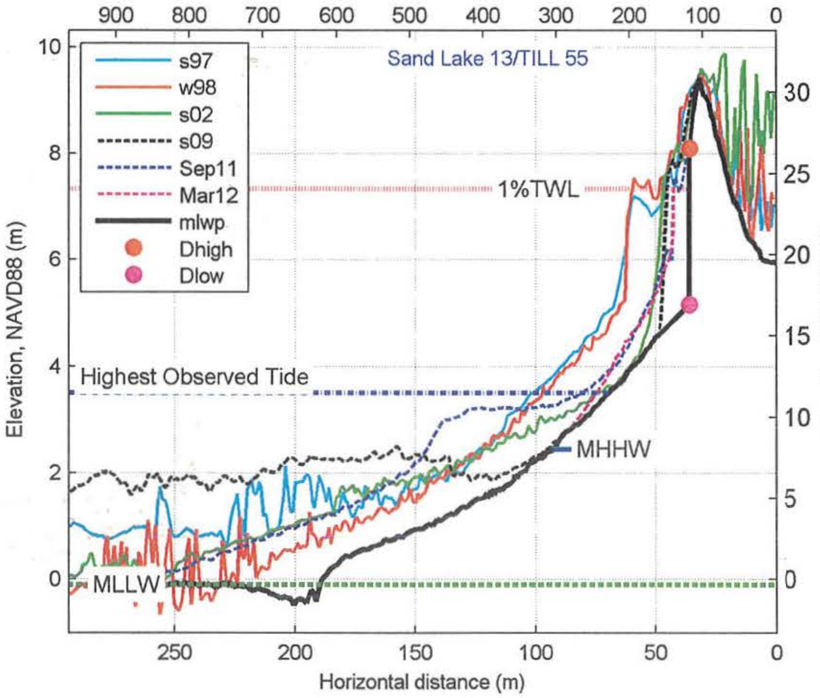


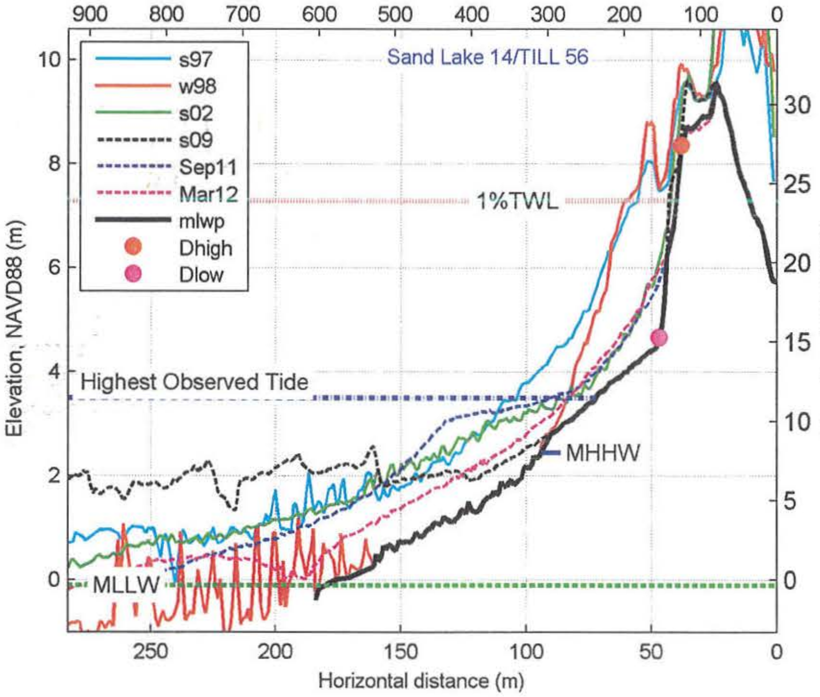
**fm_slk 12**



**fm_slk 13**



**fm_slk 14**



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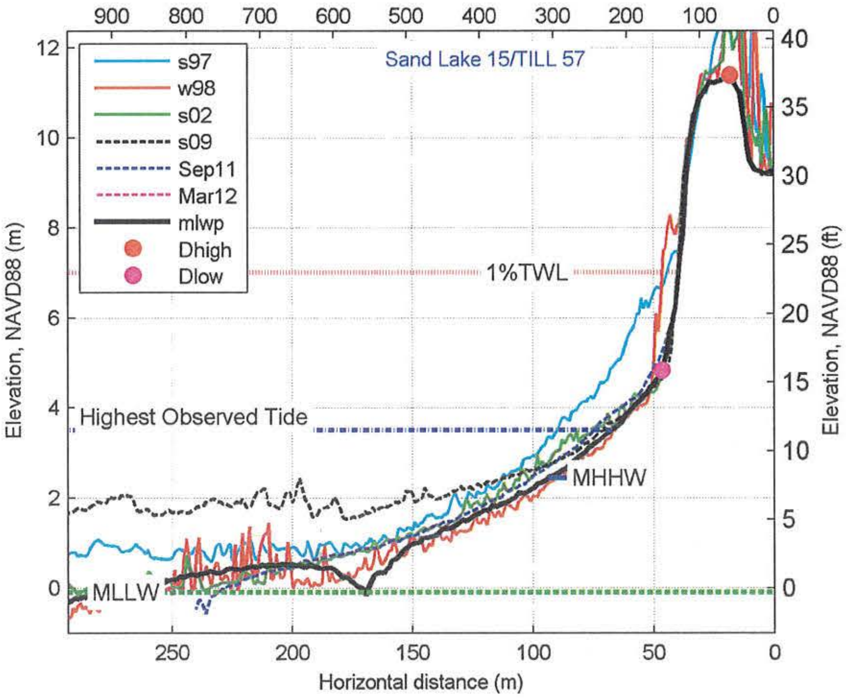
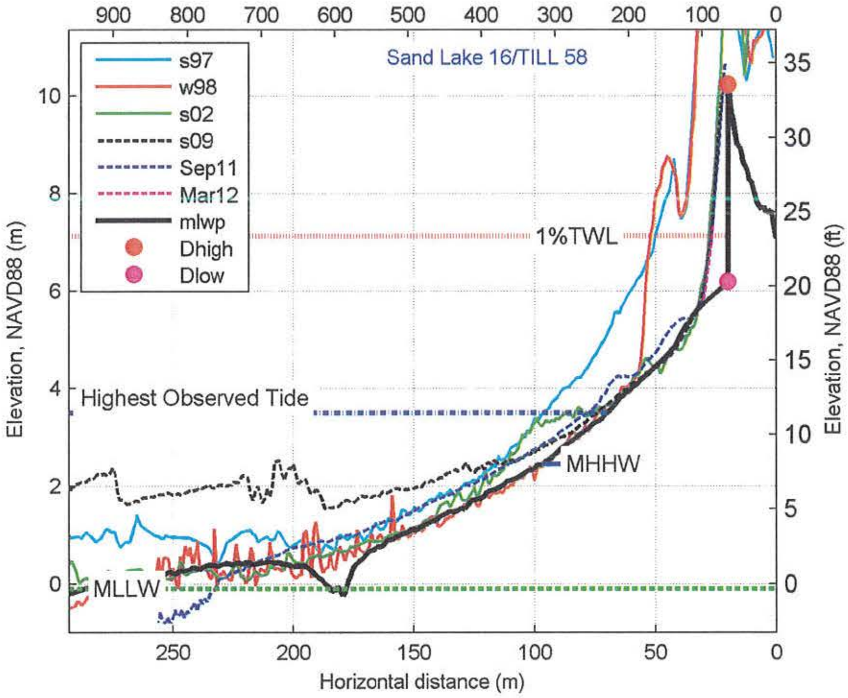
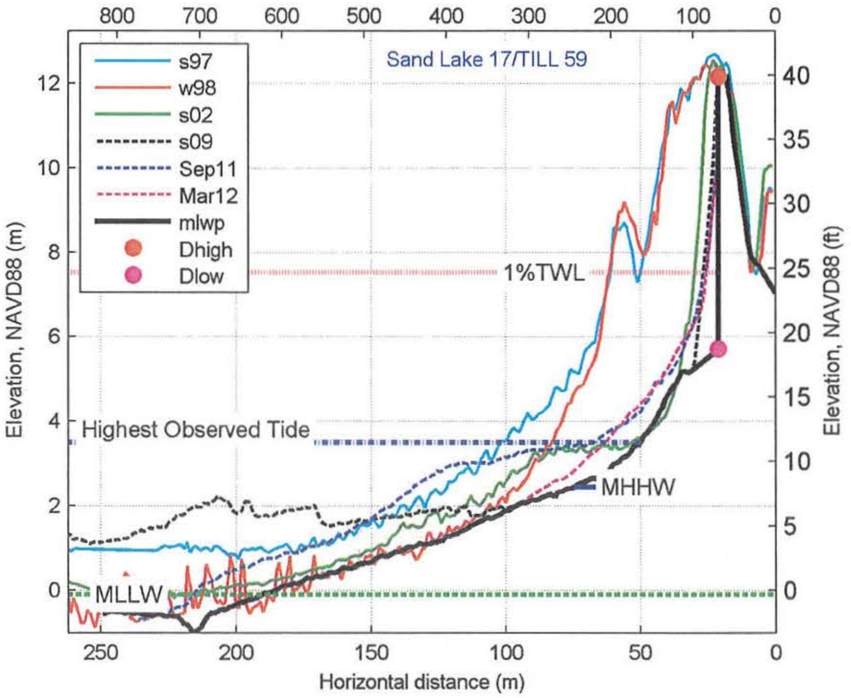


**fm_slk 16**



**fm_slk 17**



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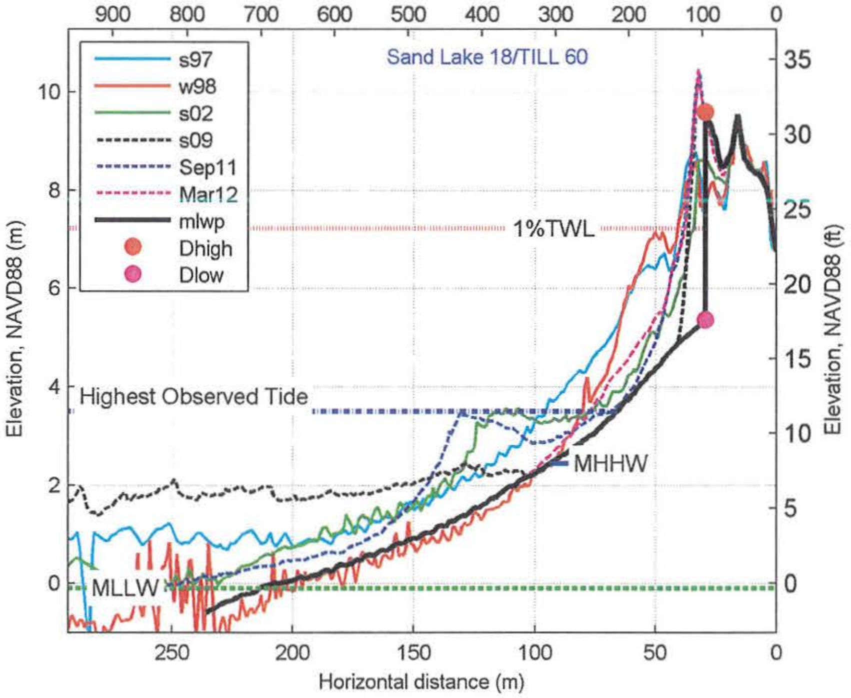
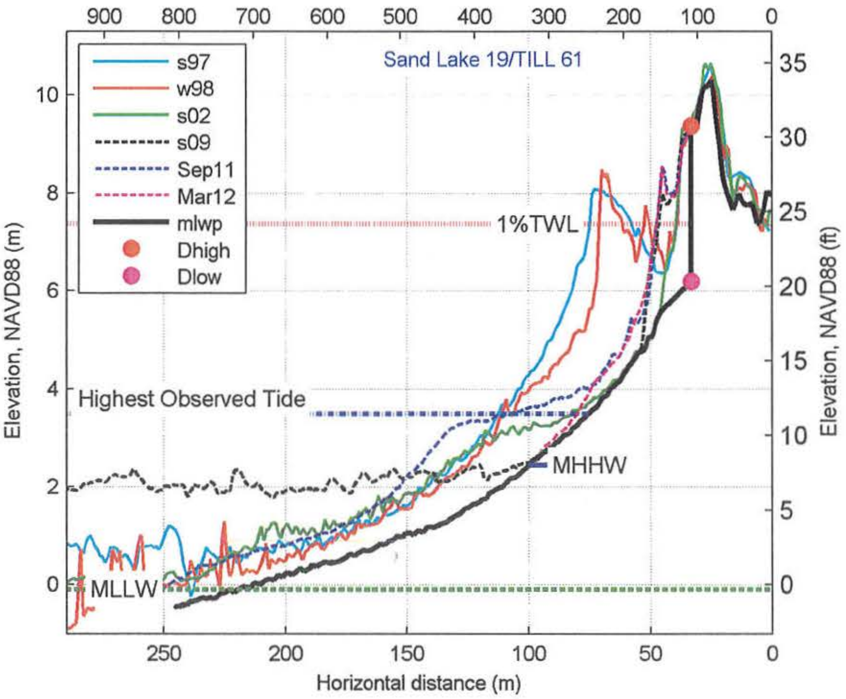
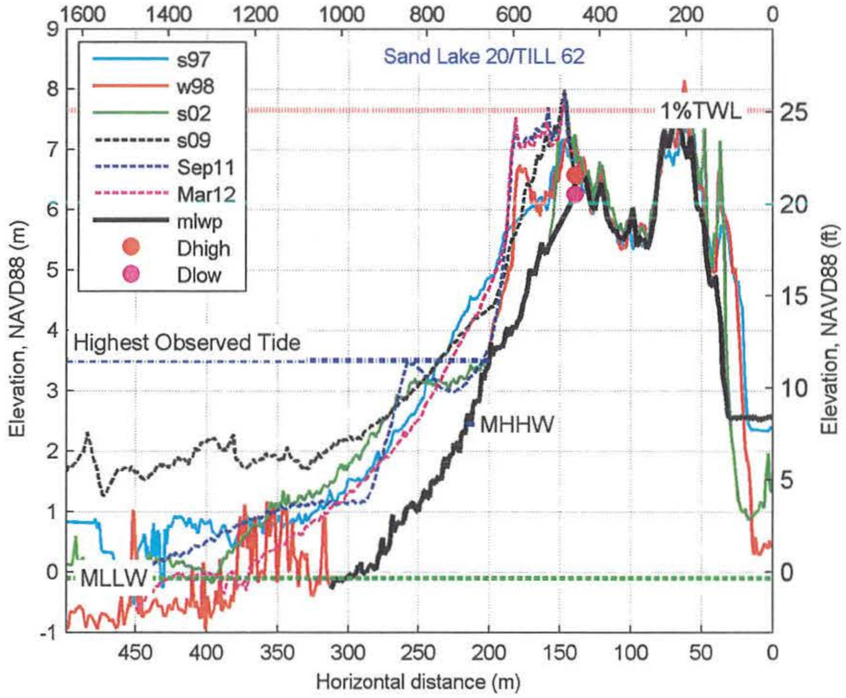


**fm_slk 19**



**fm_slk 20**



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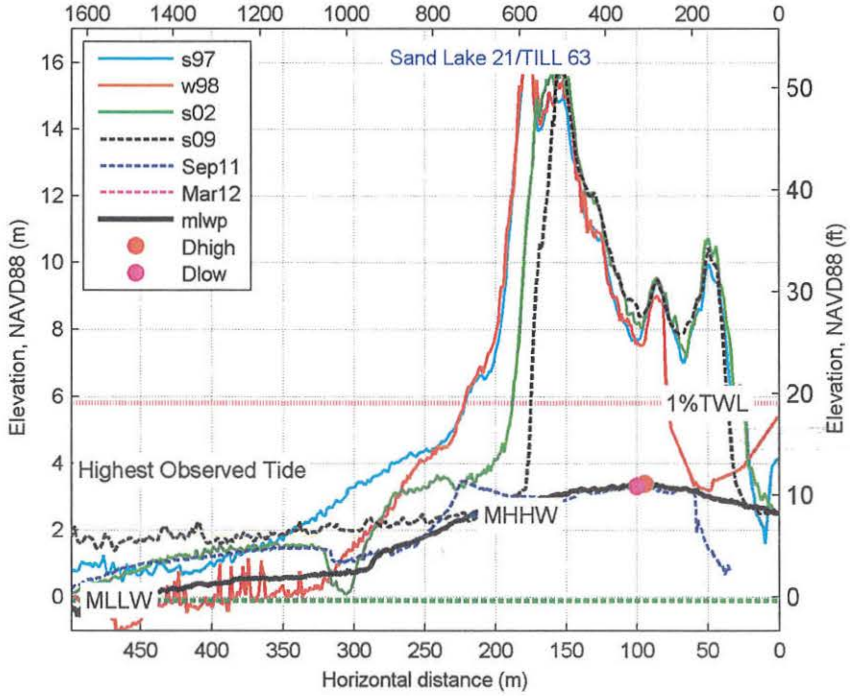
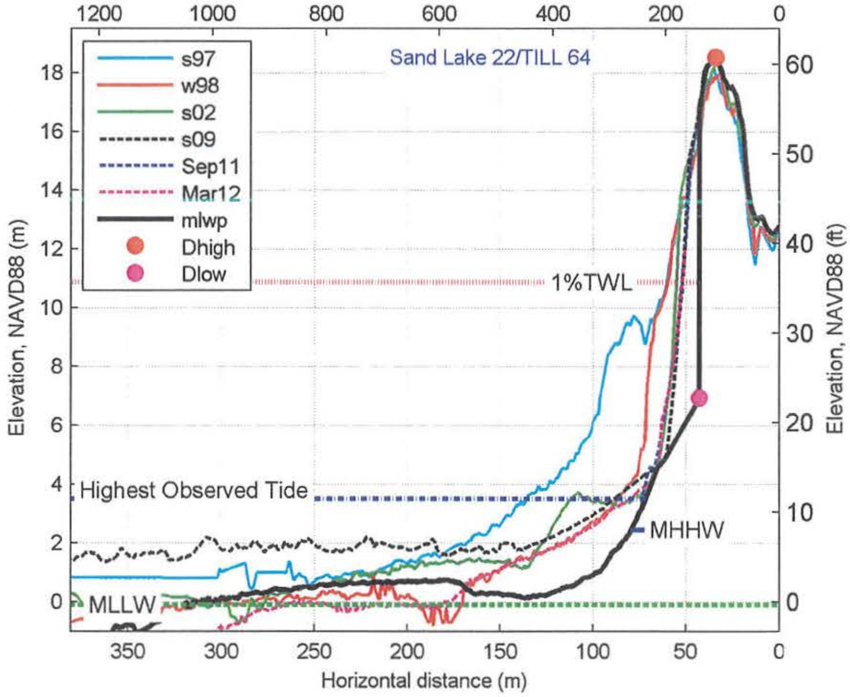


**fm_slk 22**



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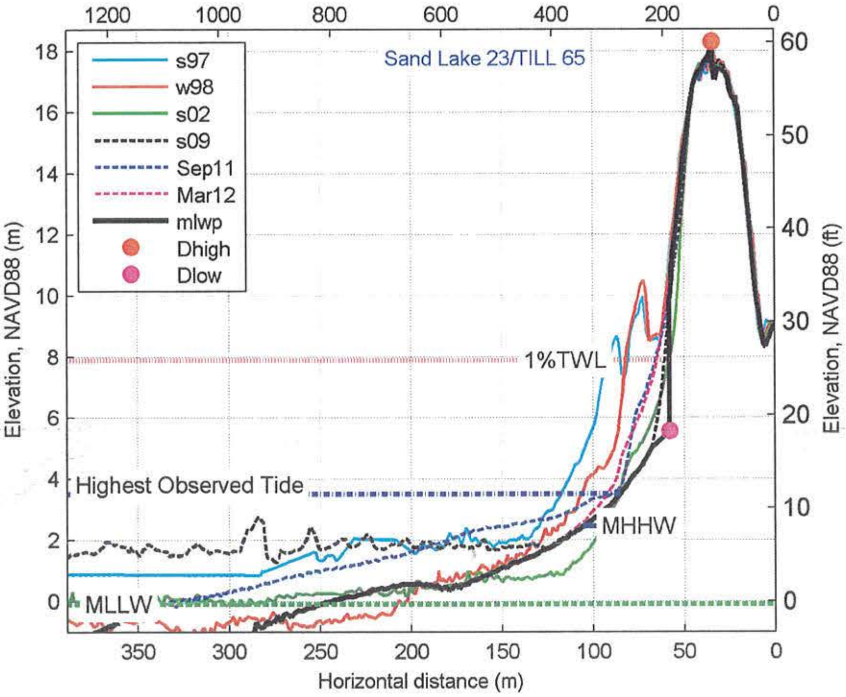
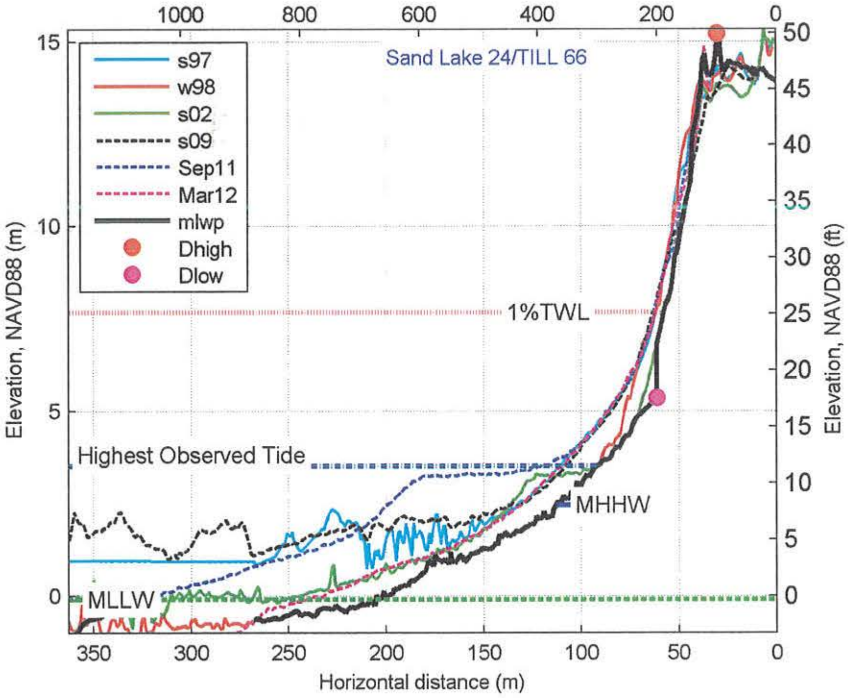


**fm_slk 24**



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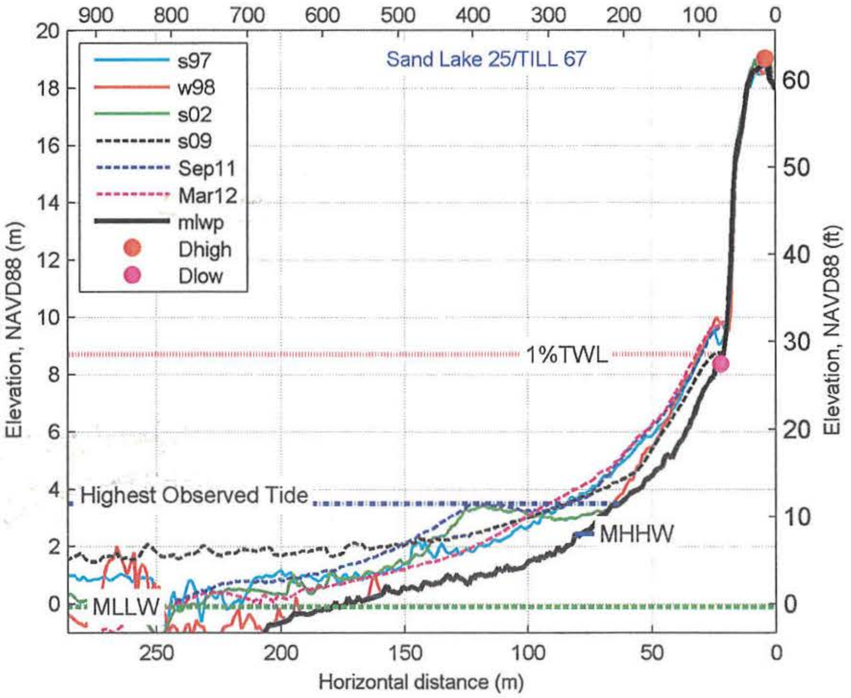
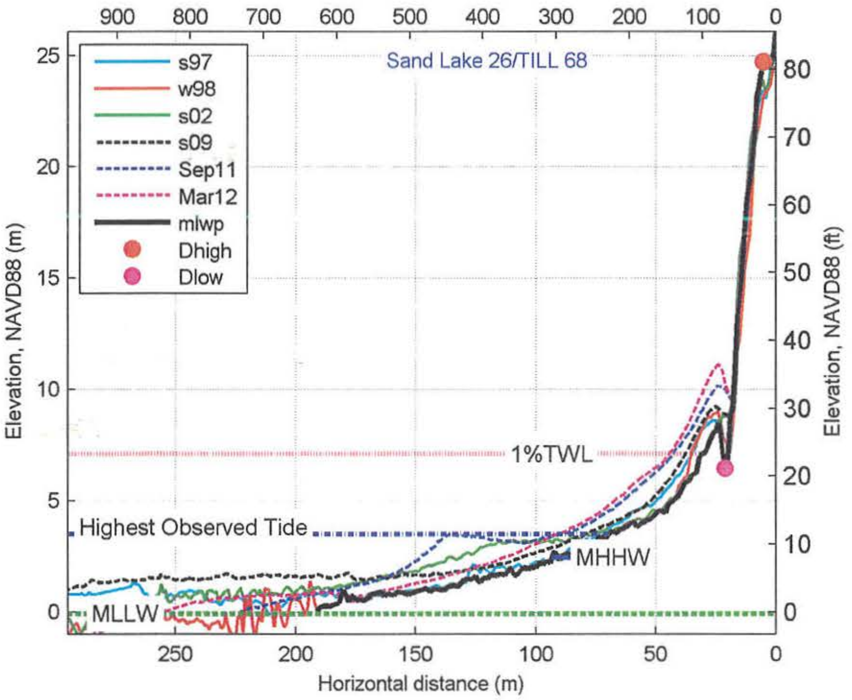


**fm_slk 26**



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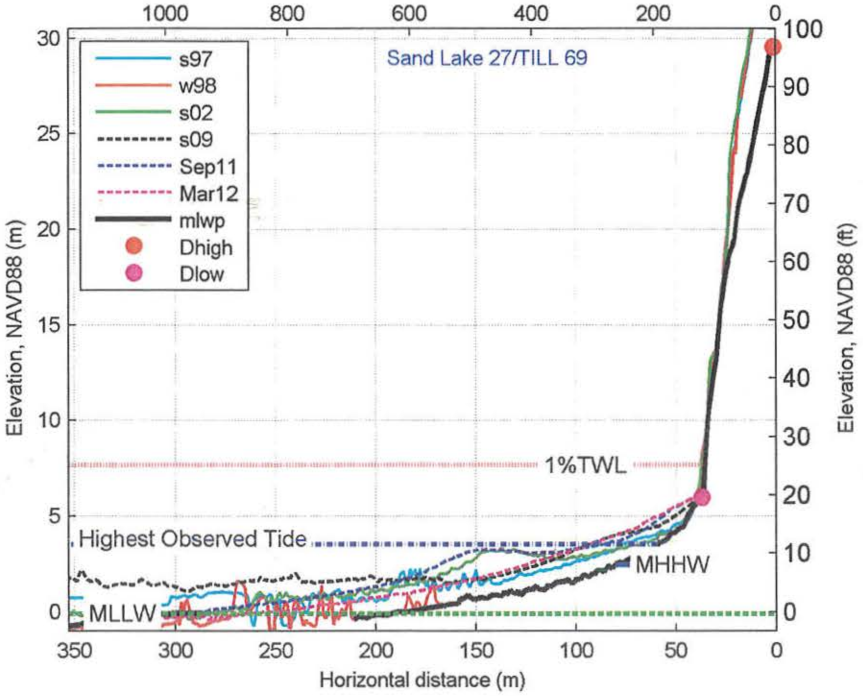

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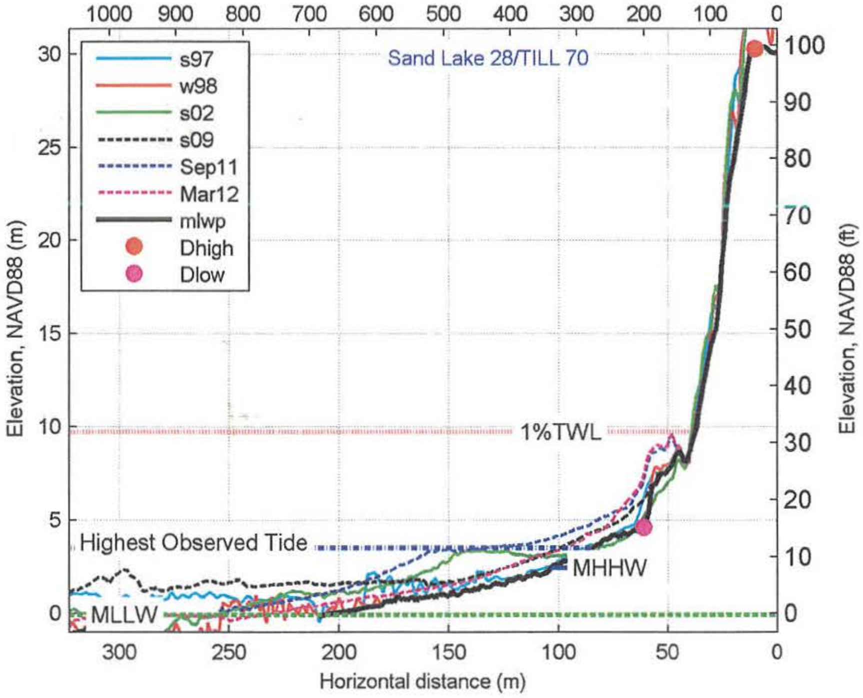

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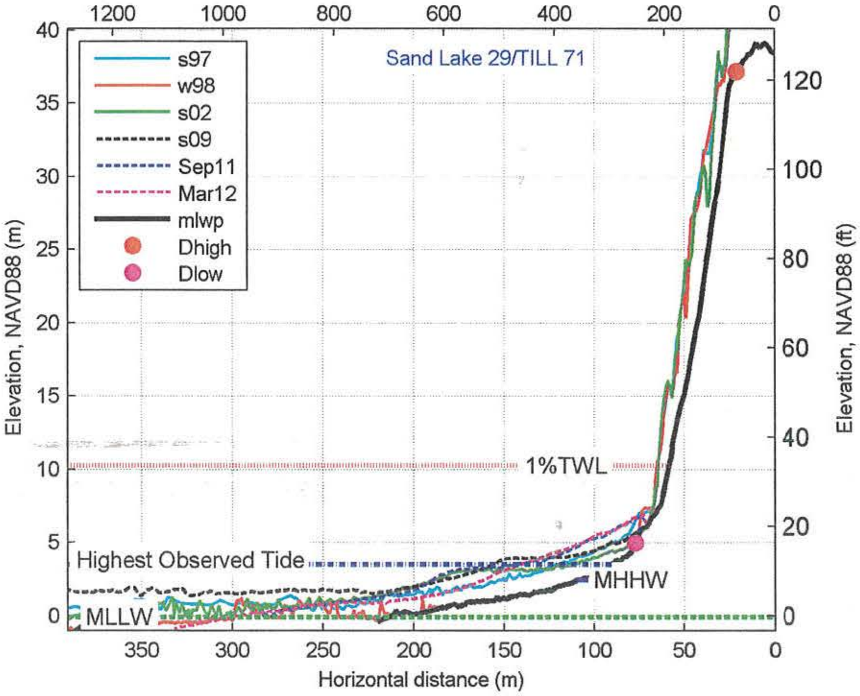

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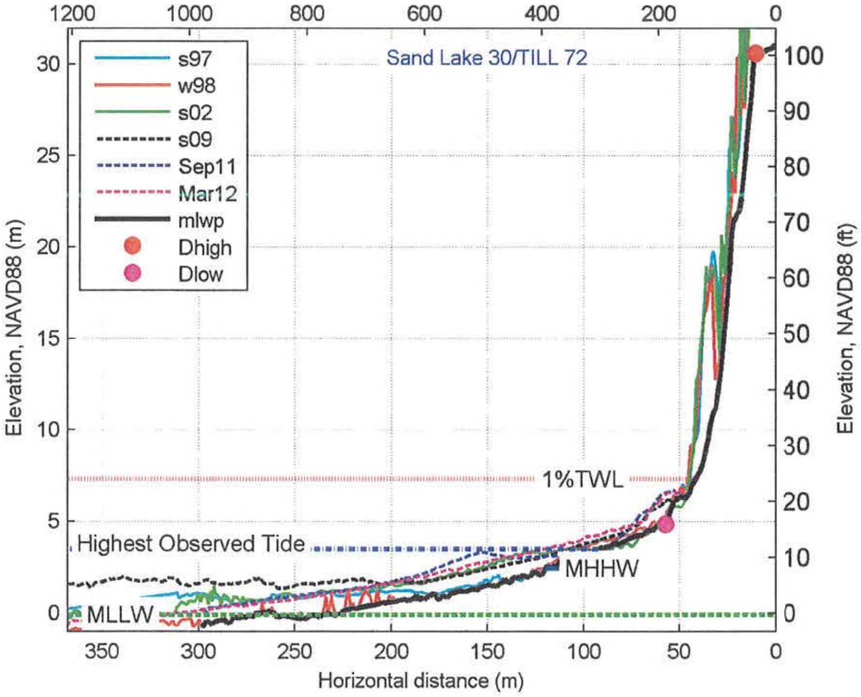

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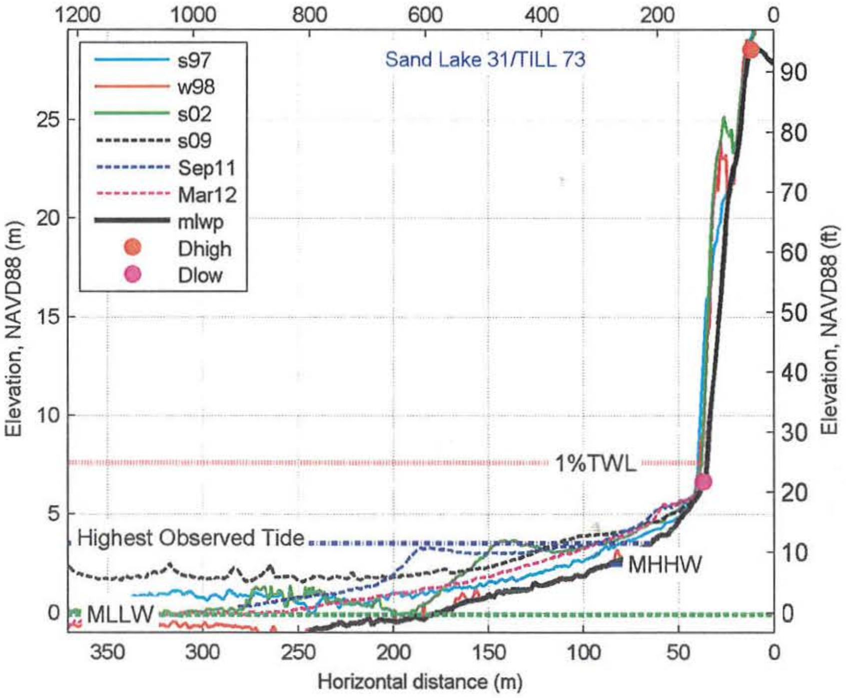

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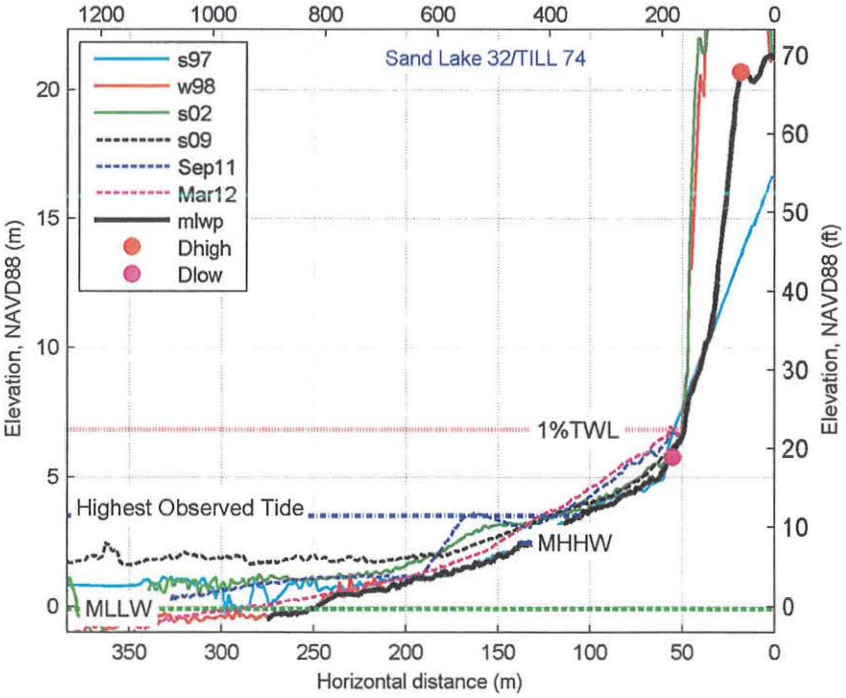

### *11.4.4 Netarts Spit*

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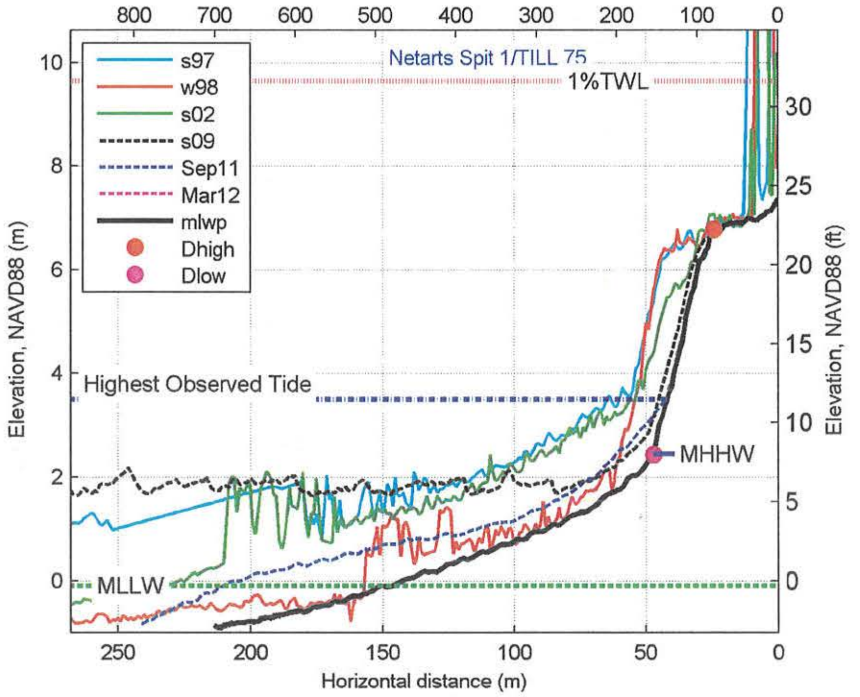
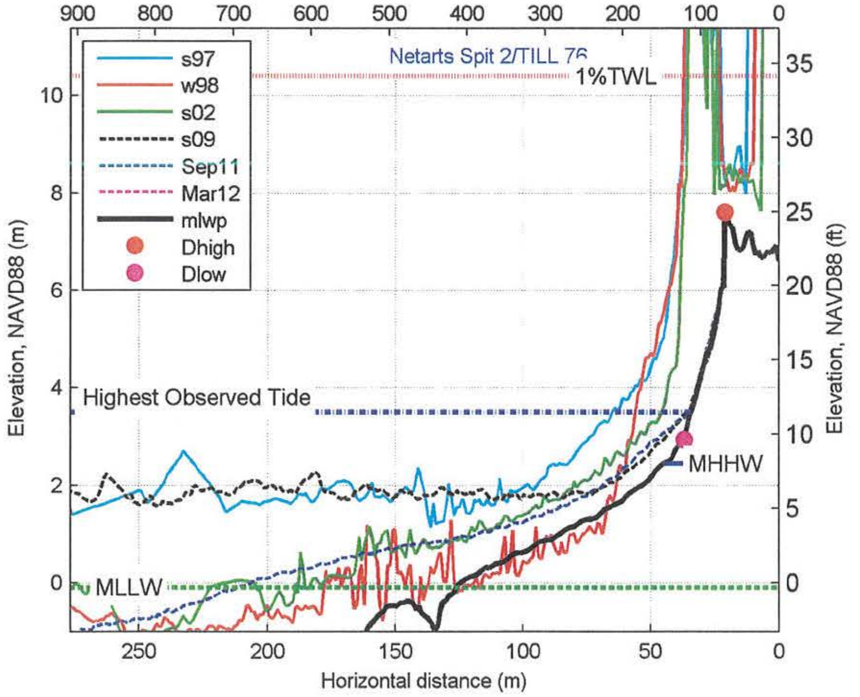
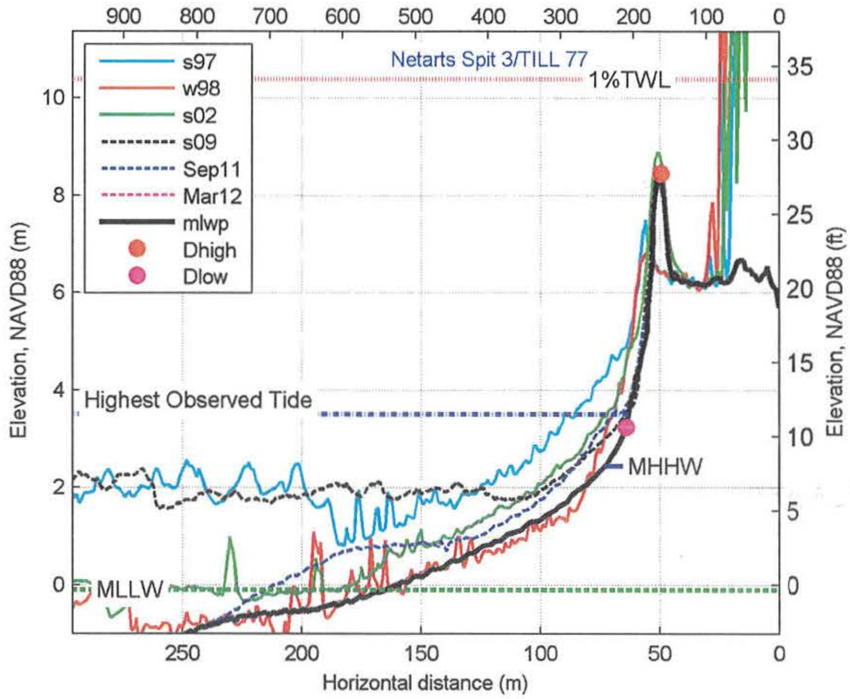


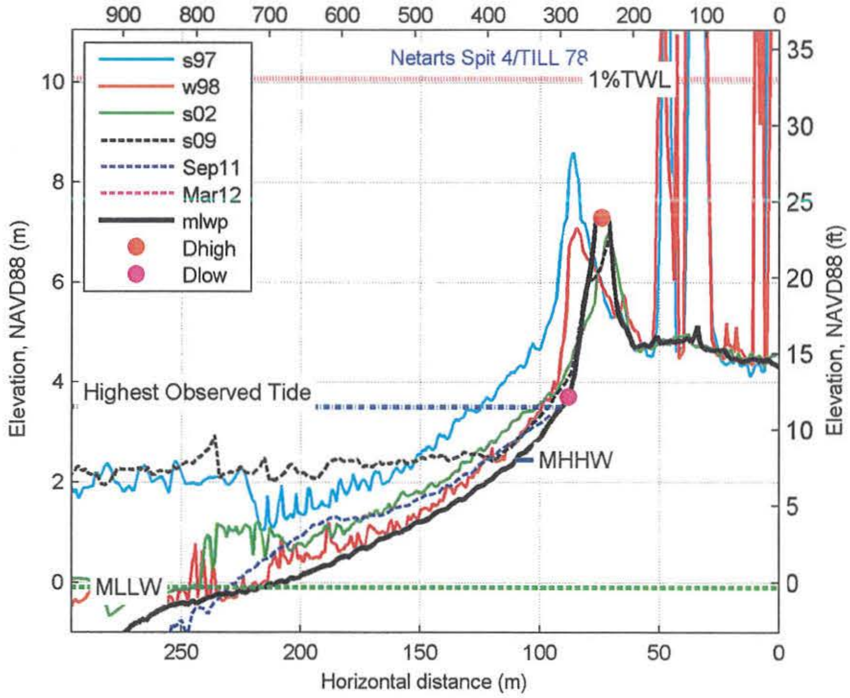
**fm_netarts 2**



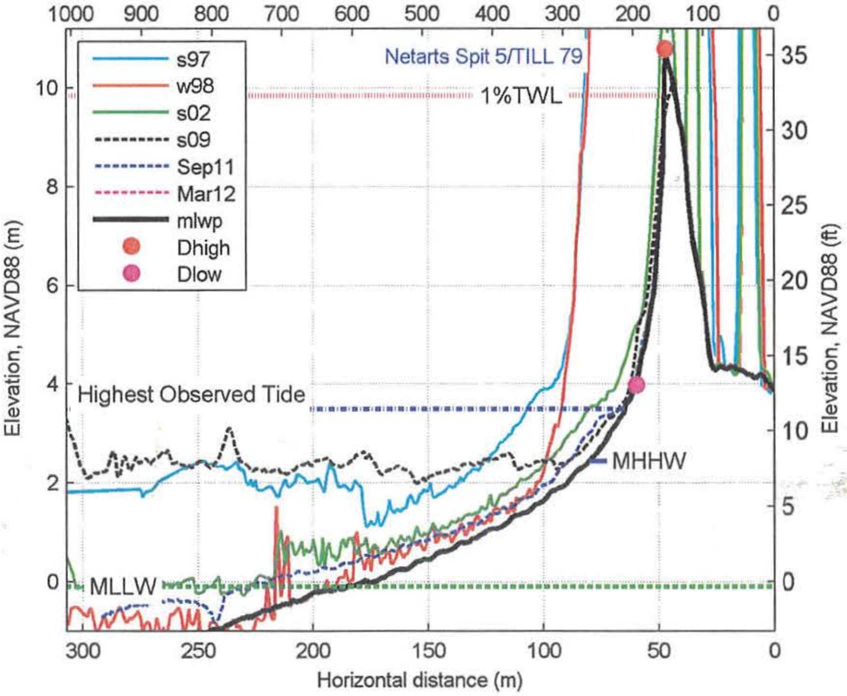
**fm_netarts 3**



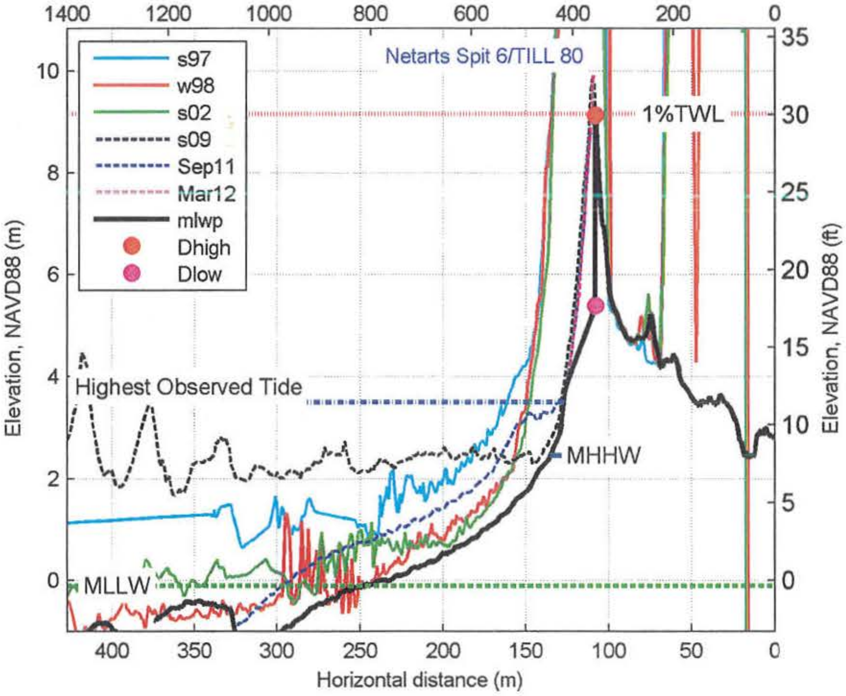
**fm_netarts 4**



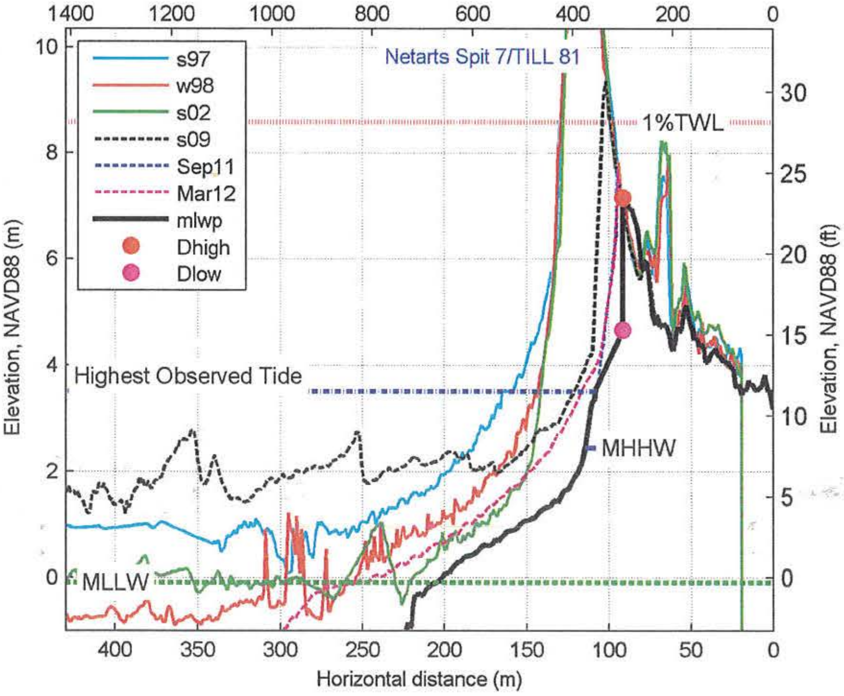
**fm_netarts 5**



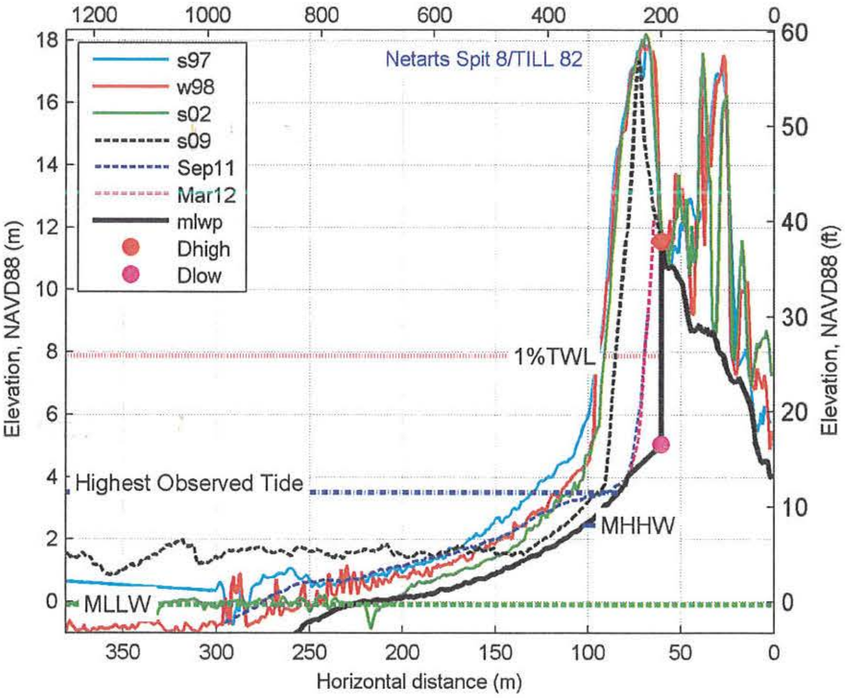
**fm_netarts 6**



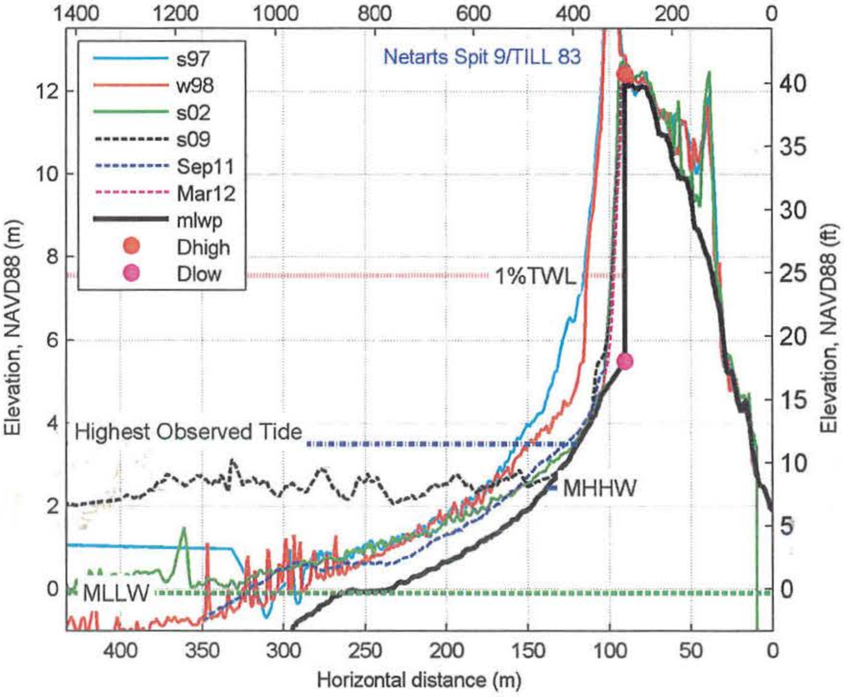
**fm_netarts 7**



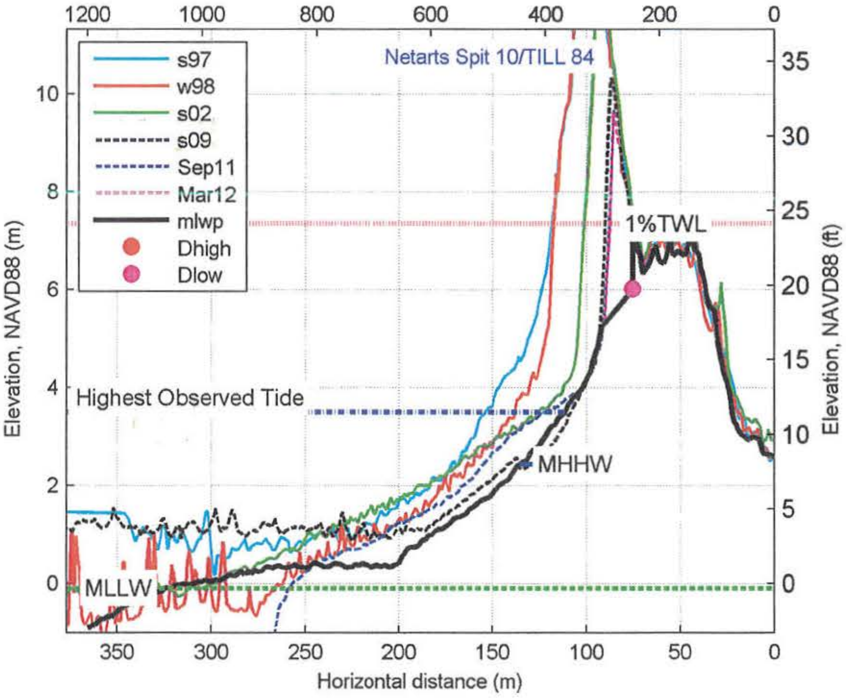
**fm_netarts 8**



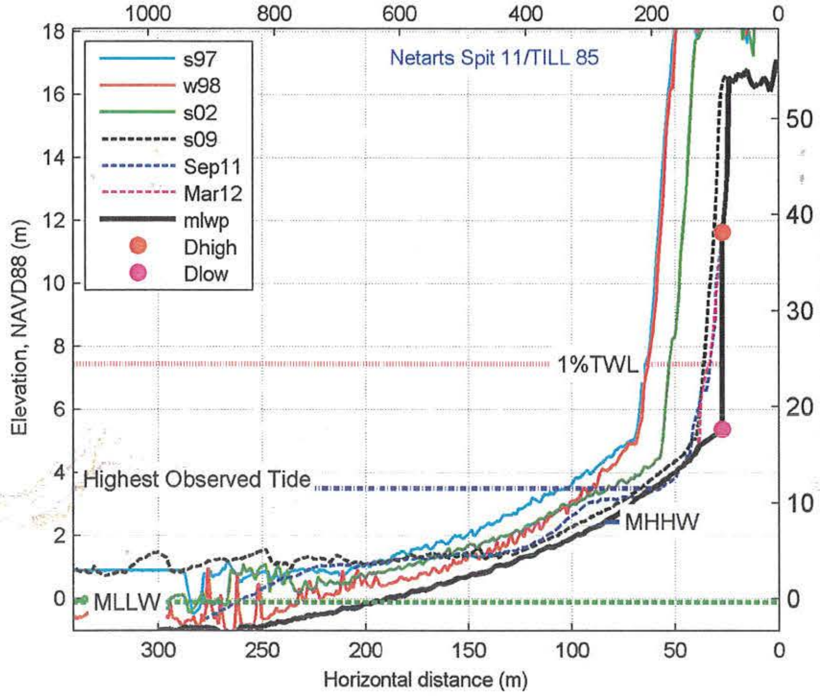
**fm_netarts 9**



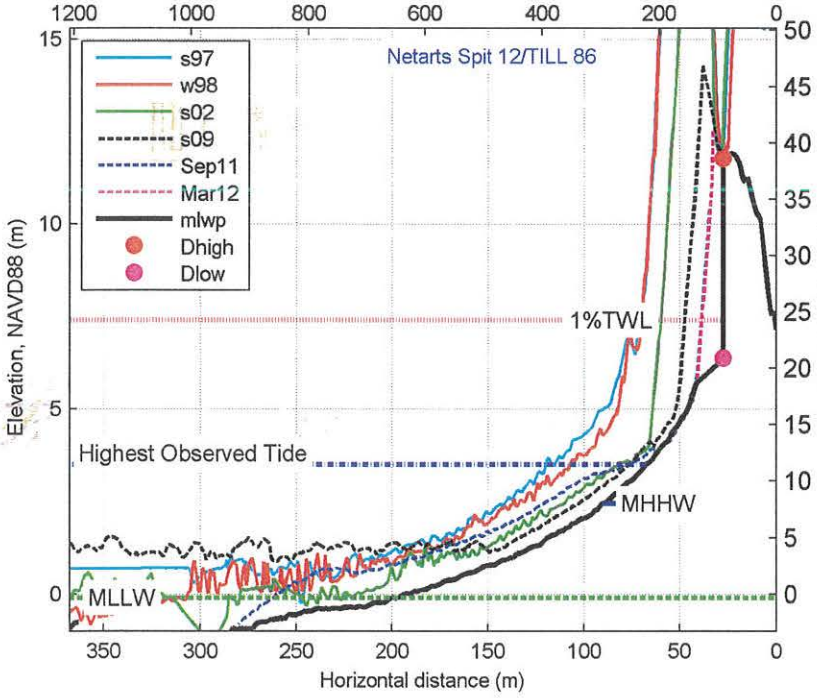
**fm_netarts 10**



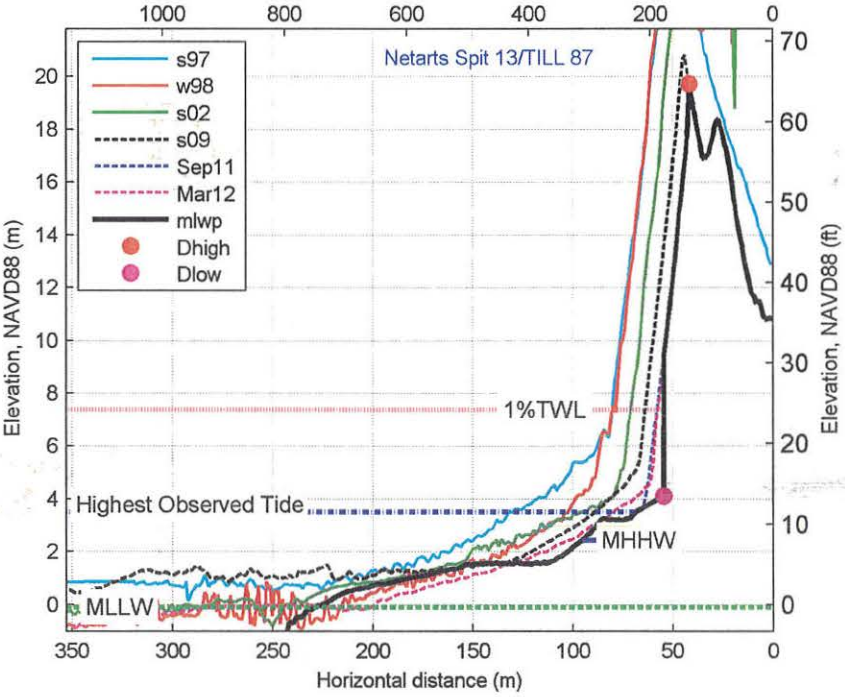
**fm_netarts**
**11**



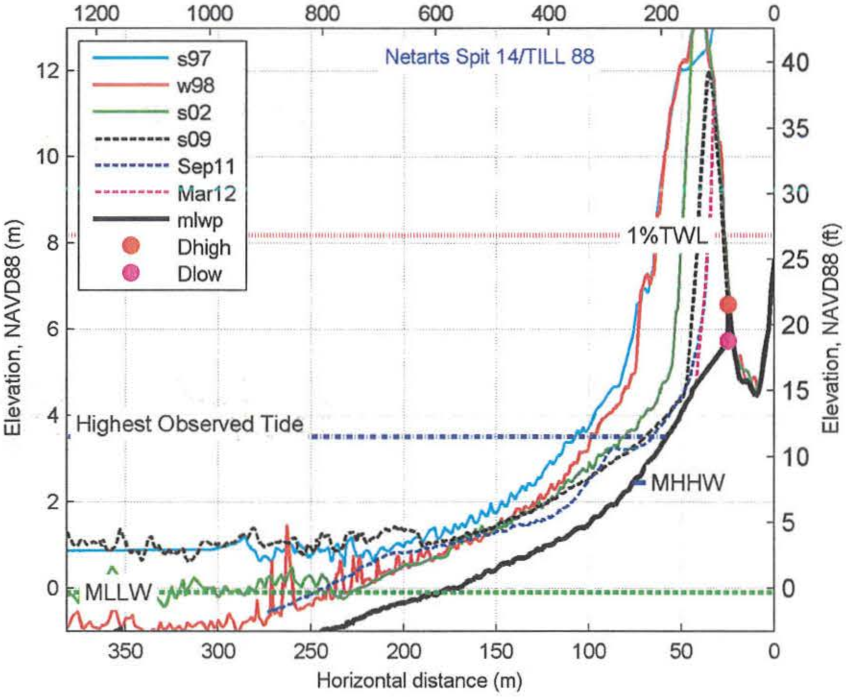
**fm_netarts**
**12**



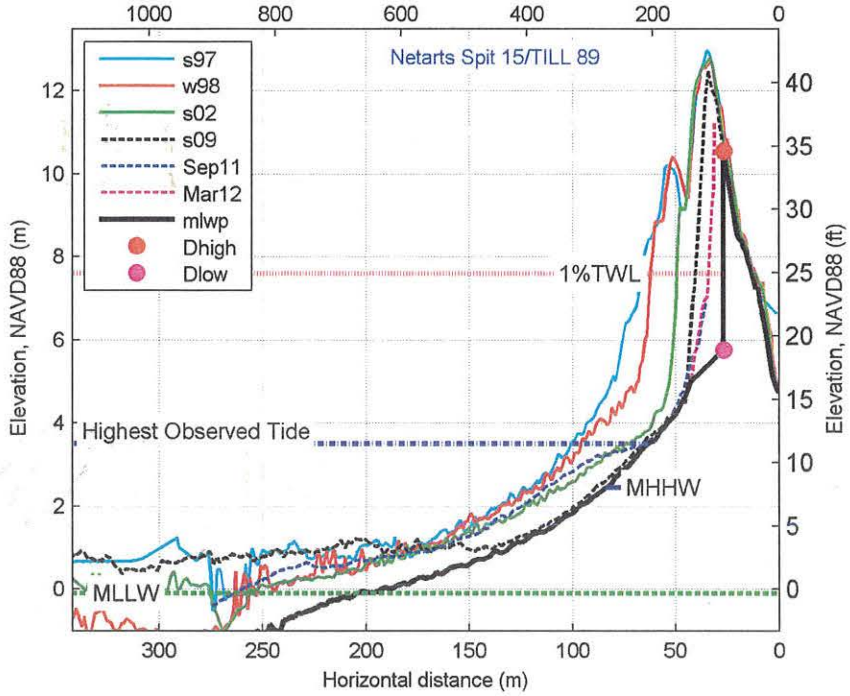
**fm_netarts
13**



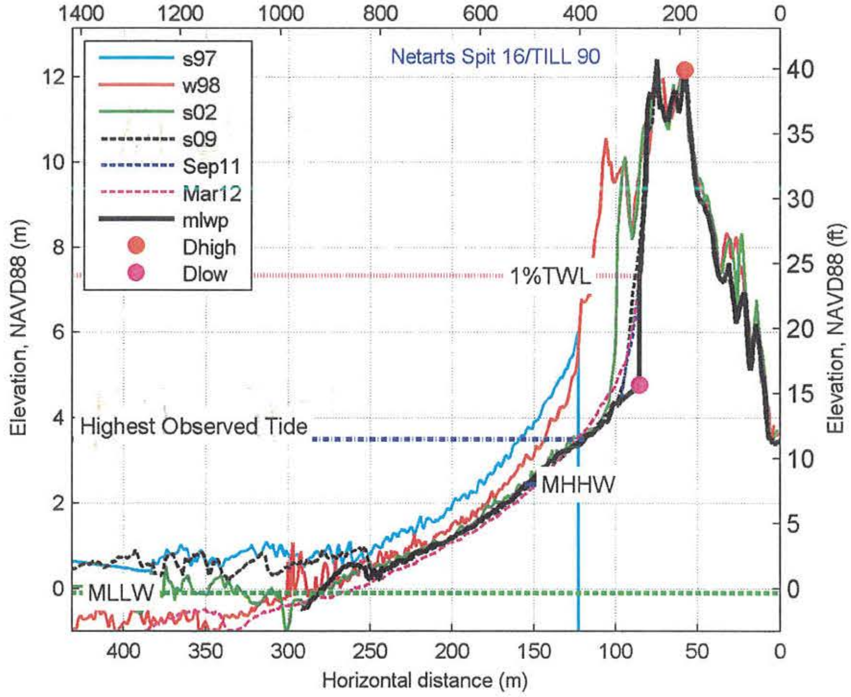
**fm_netarts
14**



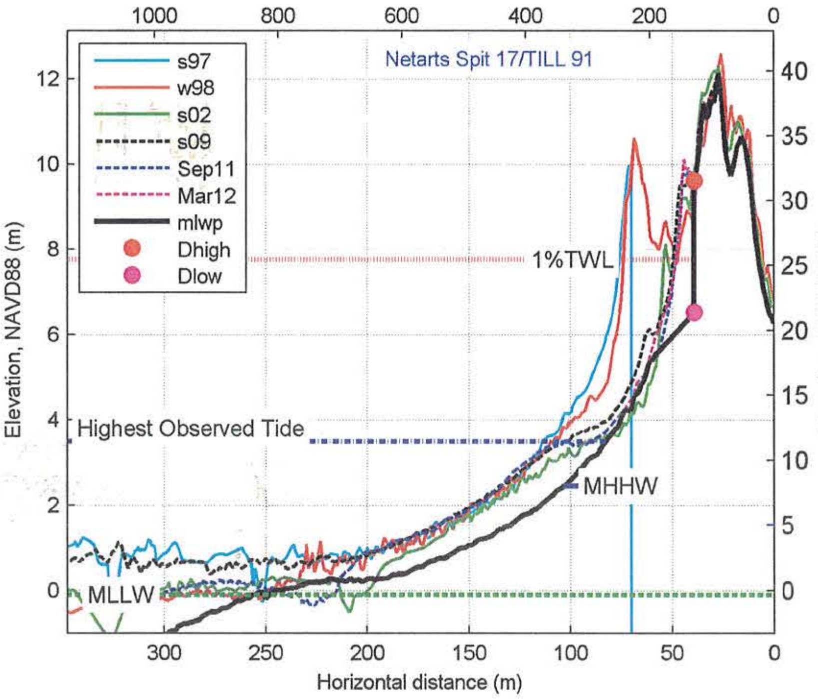
**fm_netarts
15**



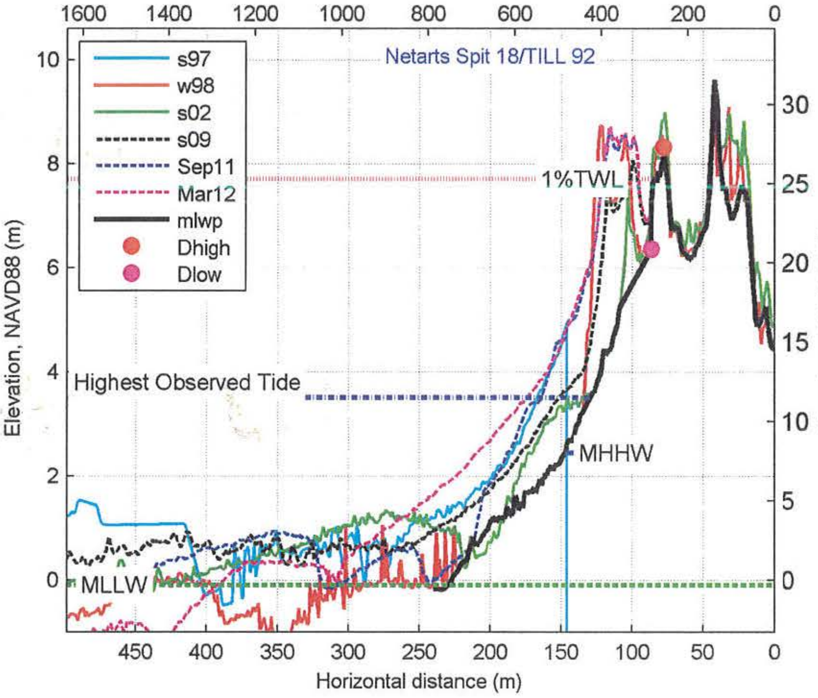
**fm_netarts
16**



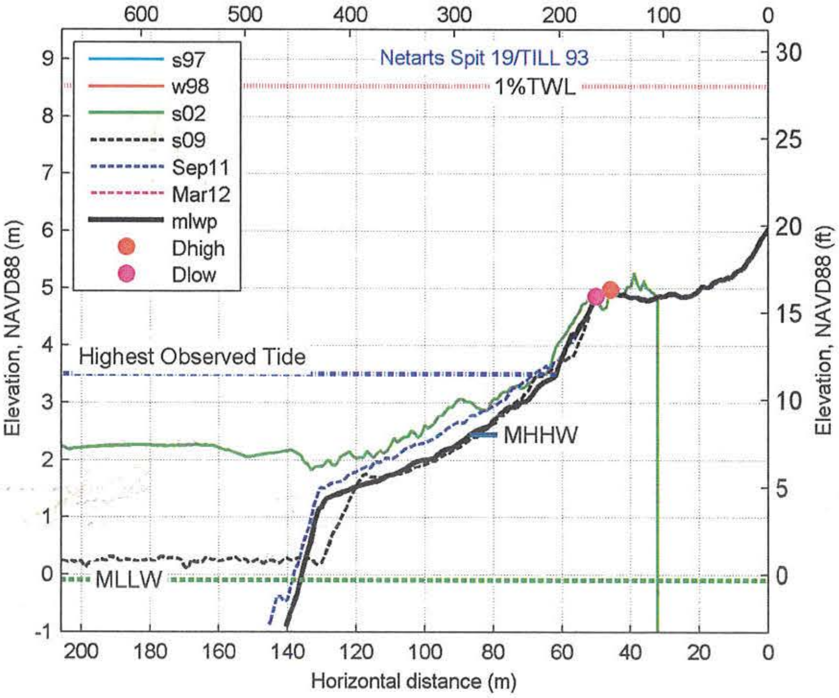
**fm_netarts
17**



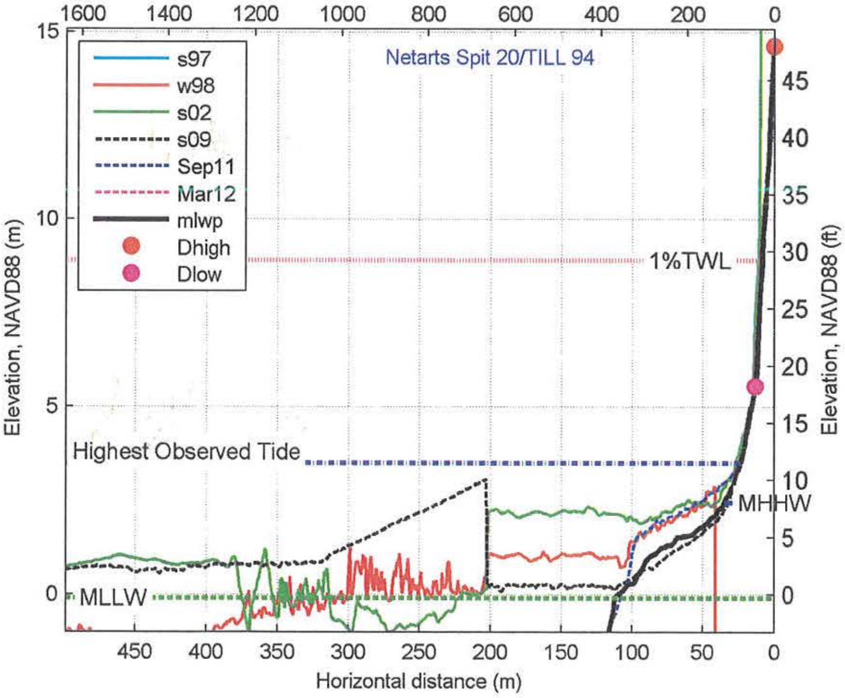
**fm_netarts
18**



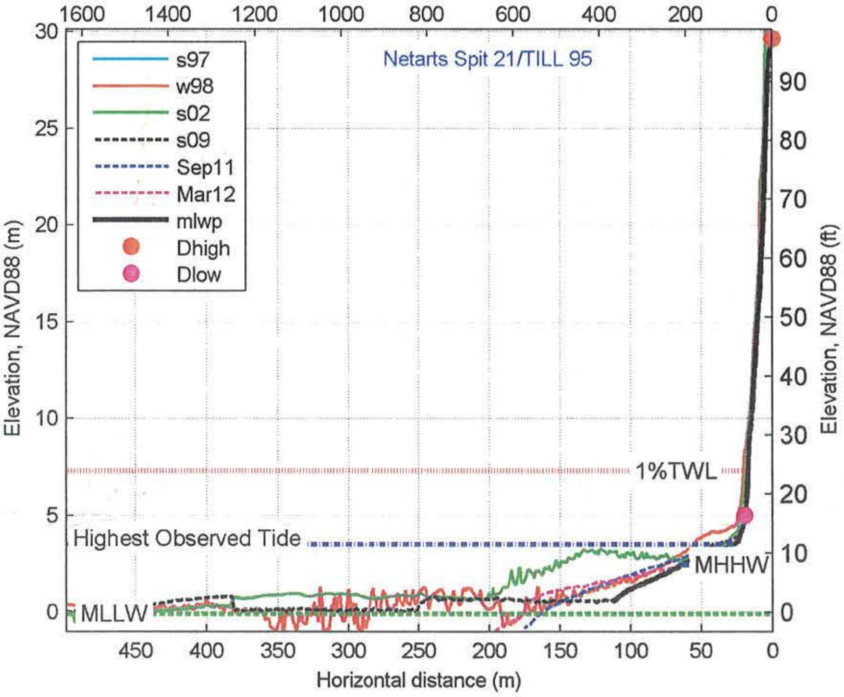
**fm_netarts
19**



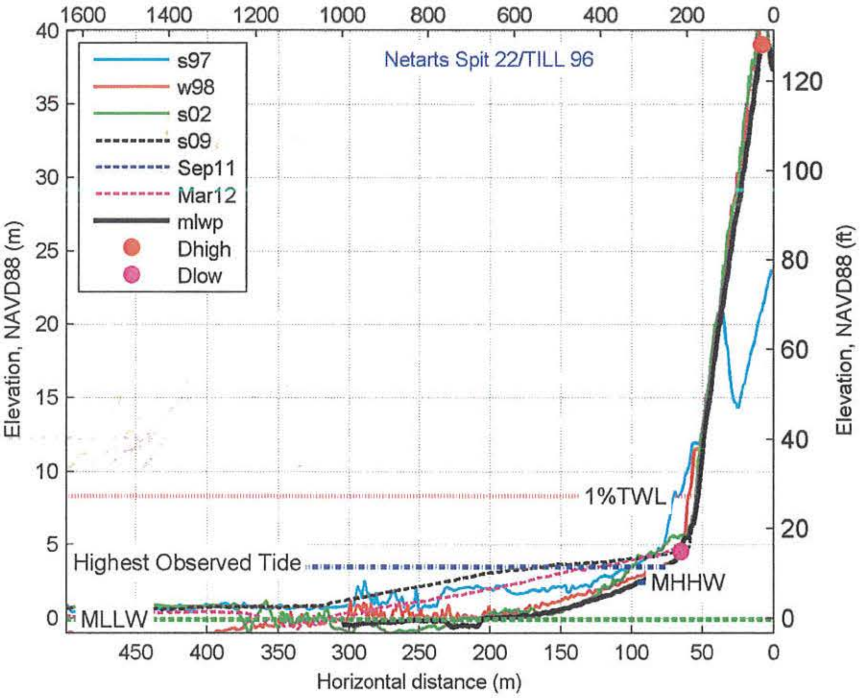
**fm_netarts
20**



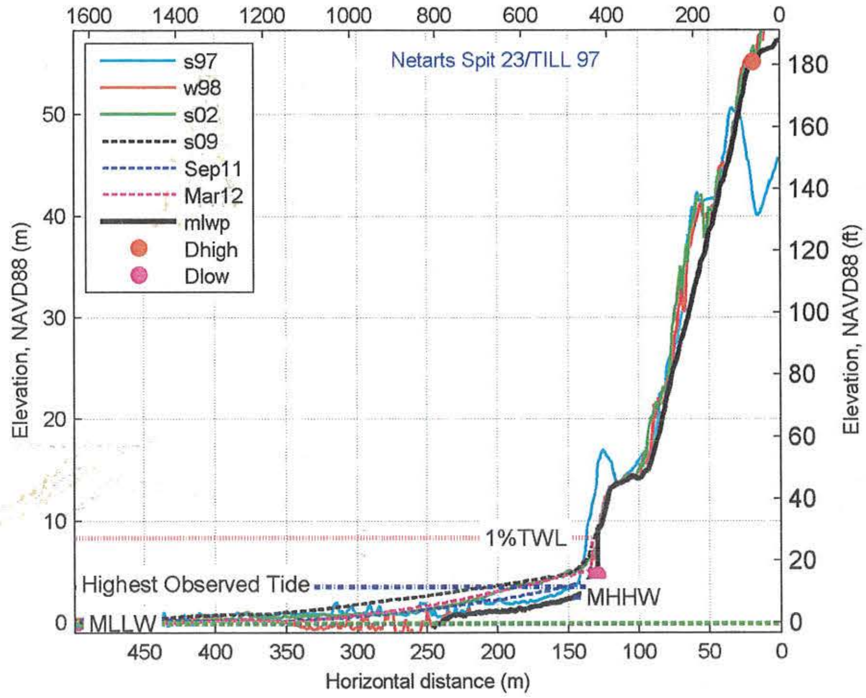
**fm_netarts
21**



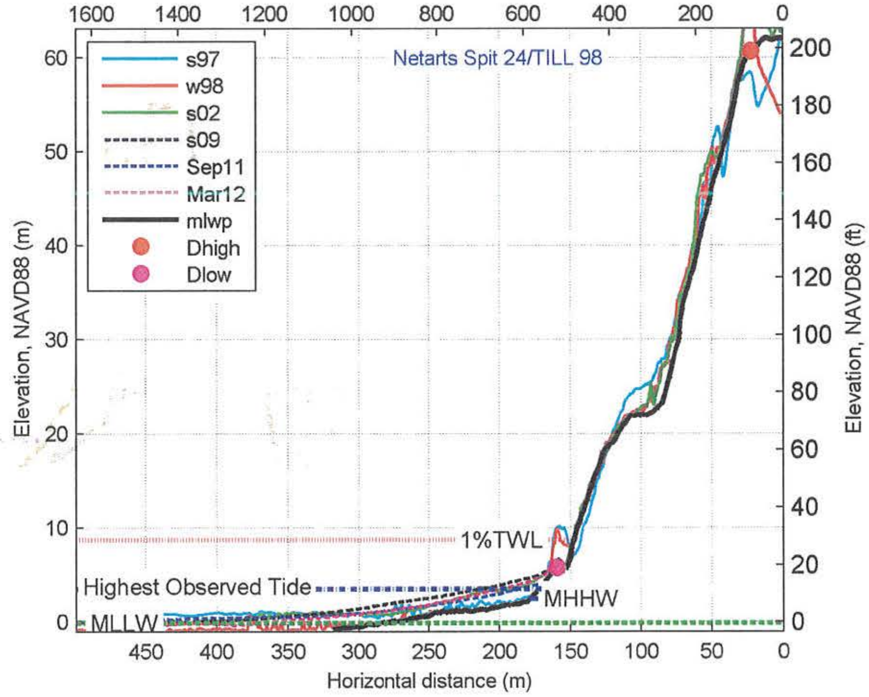
**fm_netarts
22**



**fm_netarts
23**



**fm_netarts
24**



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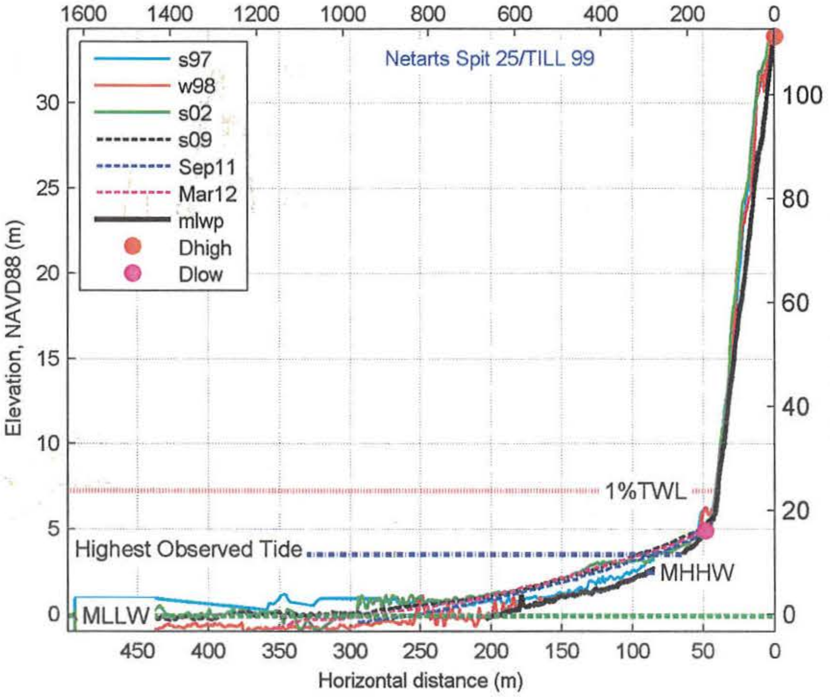
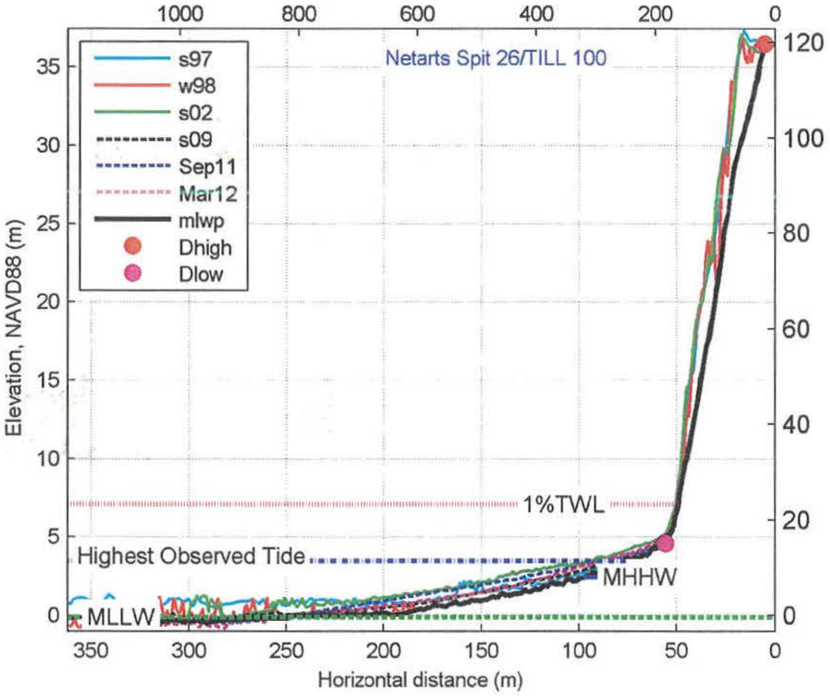
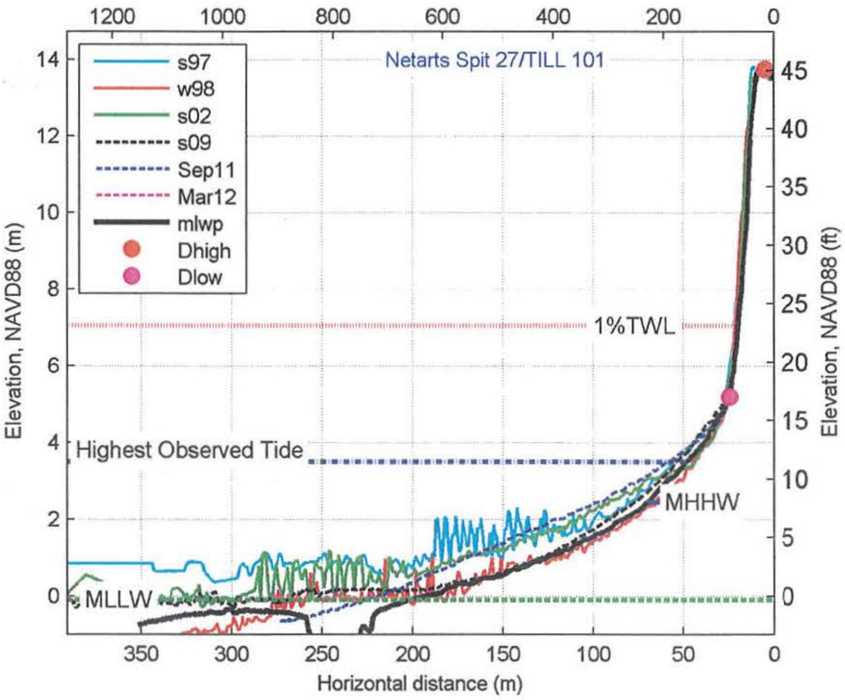
25**



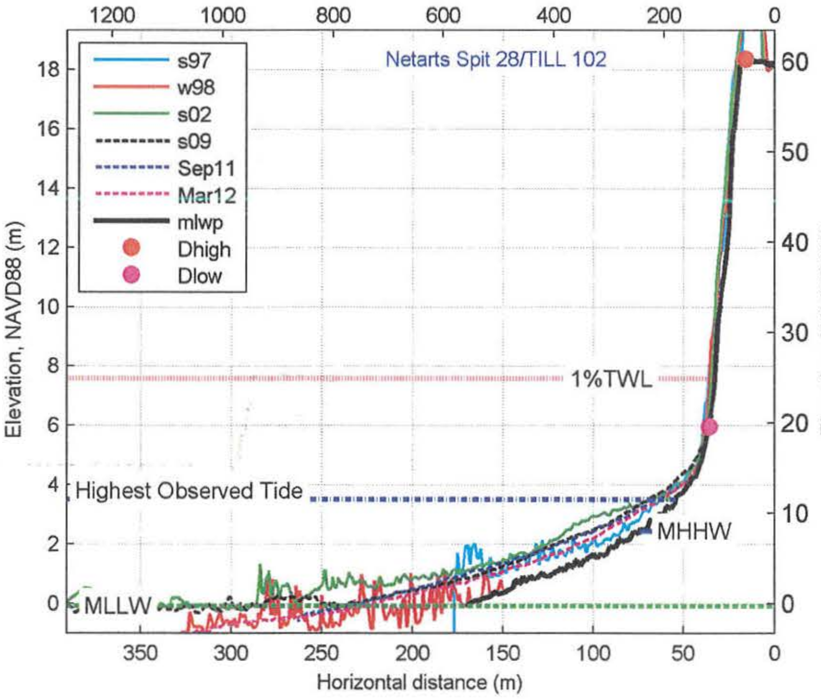
**fm_netarts
26**



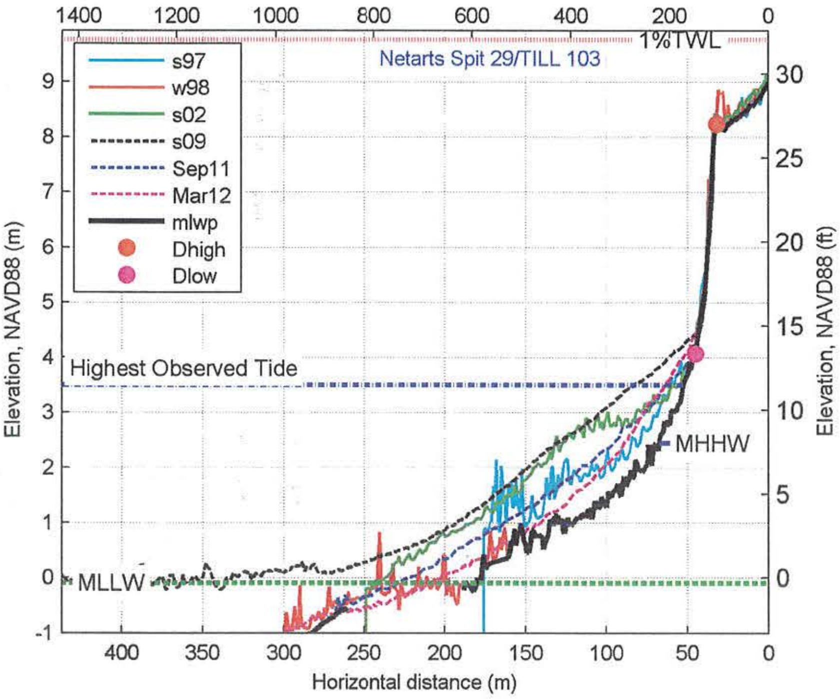
**fm_netarts**
**27**



**fm_netarts**
**28**

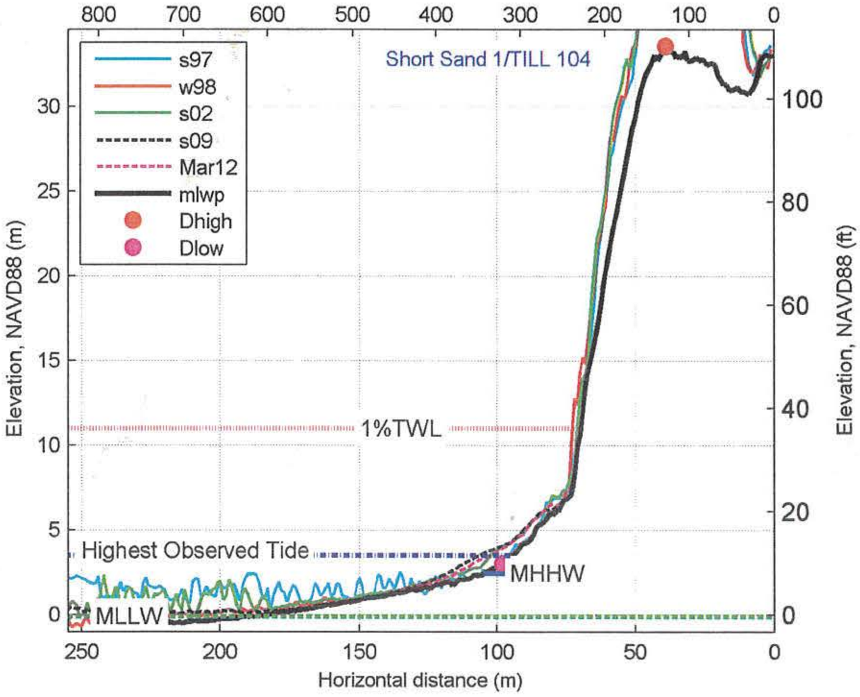


**fm_netarts**
**29**

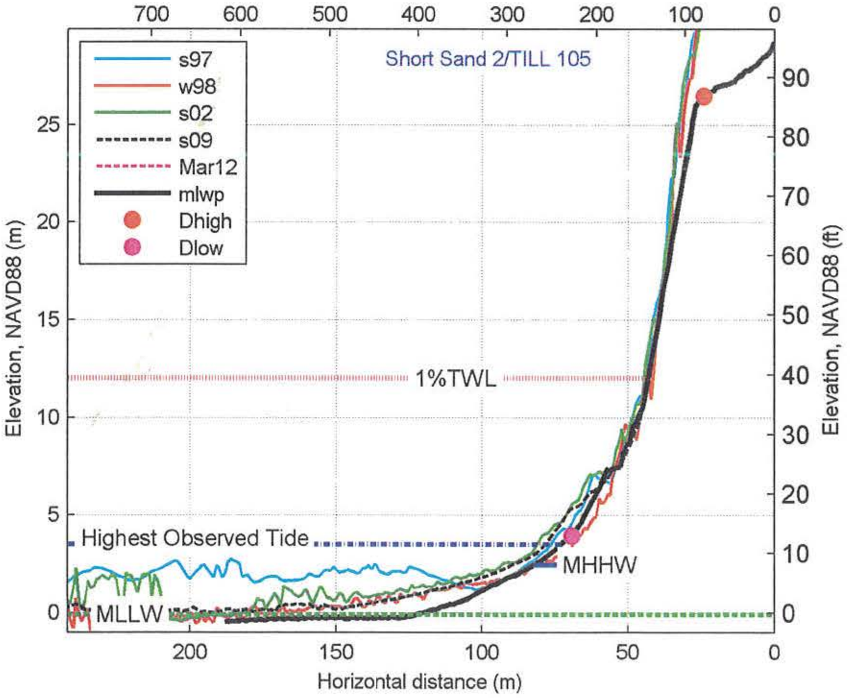


### *11.4.5 Short Sand Beach*

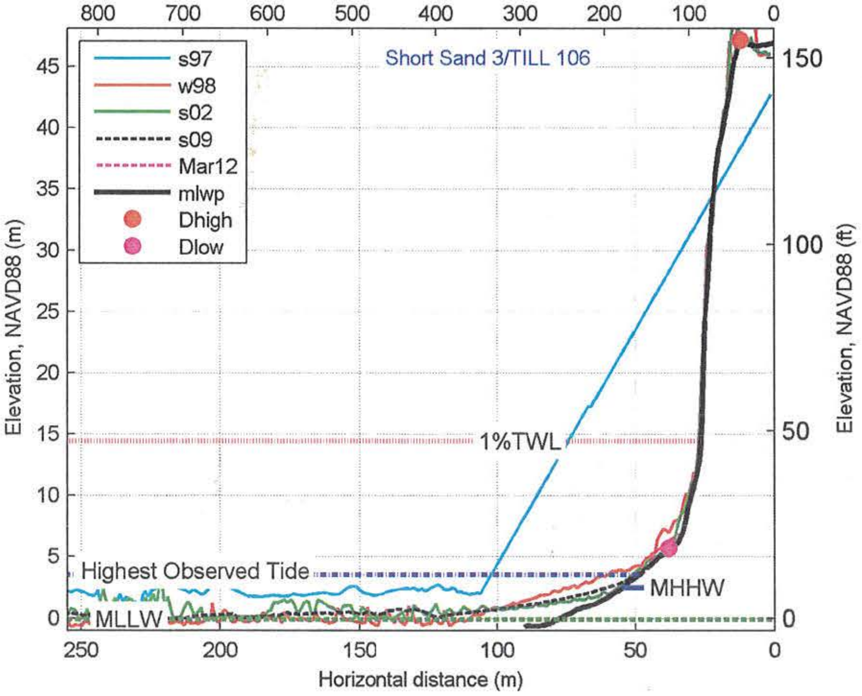
fm_ss 1



fm_ss 2

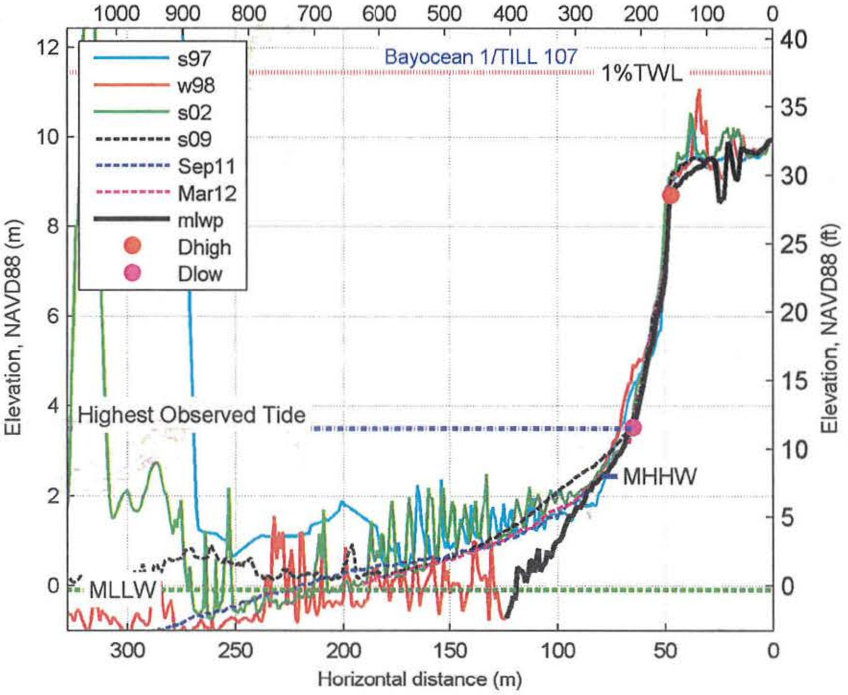


fm_ss 3

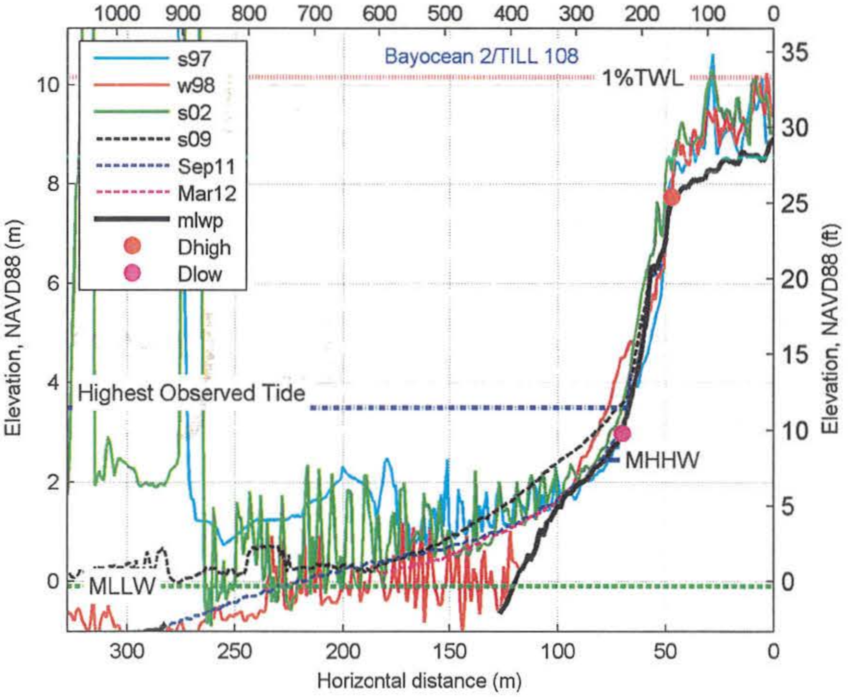

Short Sand 3/TILL 106
800
700
600
500
400
300
200
100
0
s97
w98
s02
s09
Mar12
mlwp
Dhigh
Dlow
45
40
35
30
25
20
15
10
5
0
Elevation, NAVD88 (m)
150
100
50
0
Elevation, NAVD88 (ft)
1%TWL
Highest Observed Tide
MHHW
MLLW
250
200
150
100
50
0
Horizontal distance (m)

### *11.4.6 Bayocean Spit*

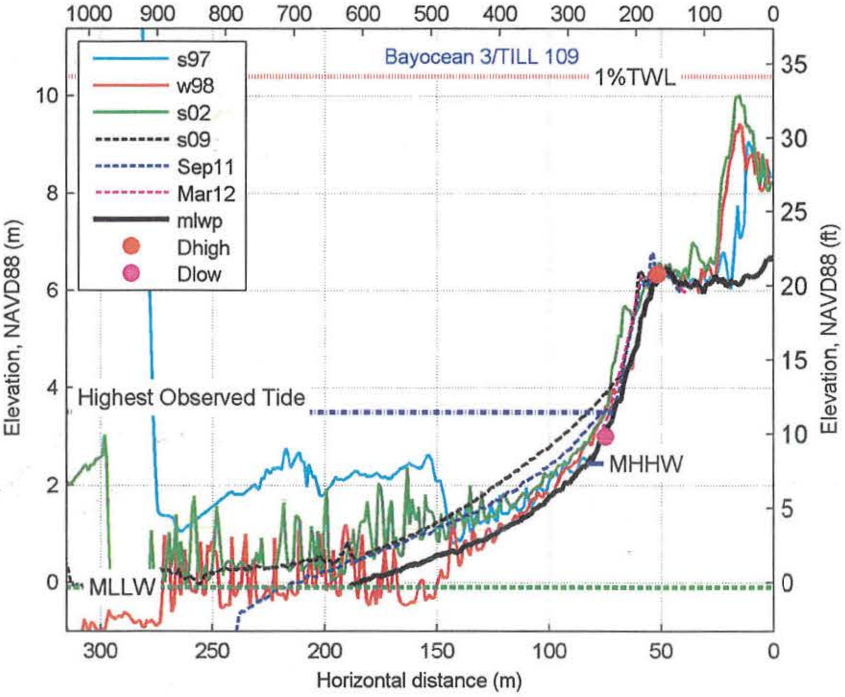
**fm_bay 1**



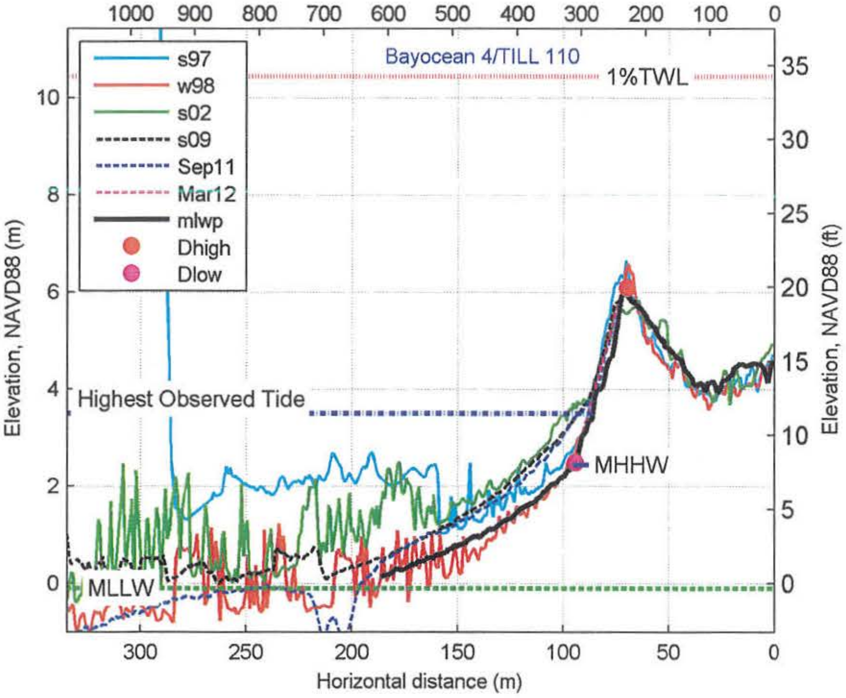
**fm_bay 2**



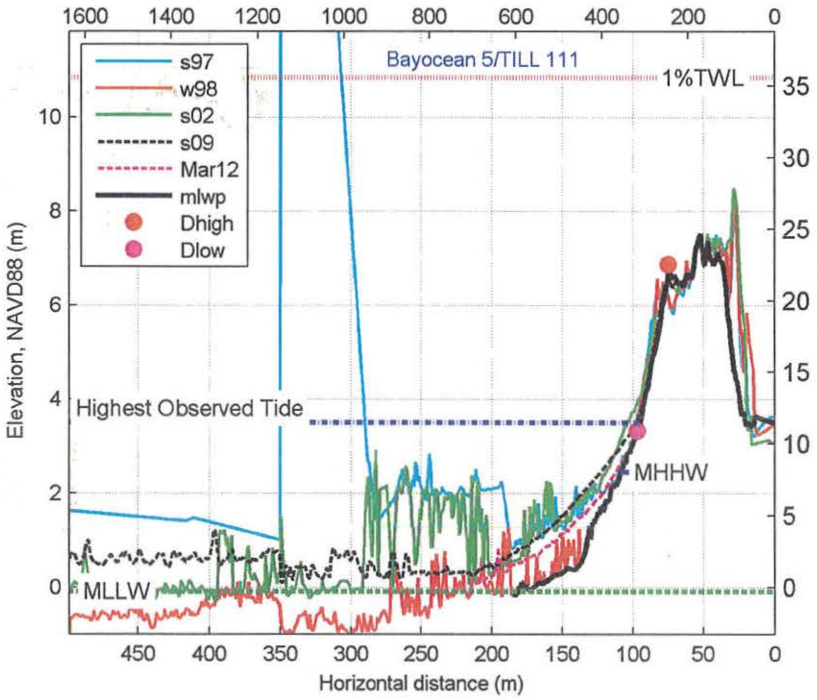
fm_bay 3



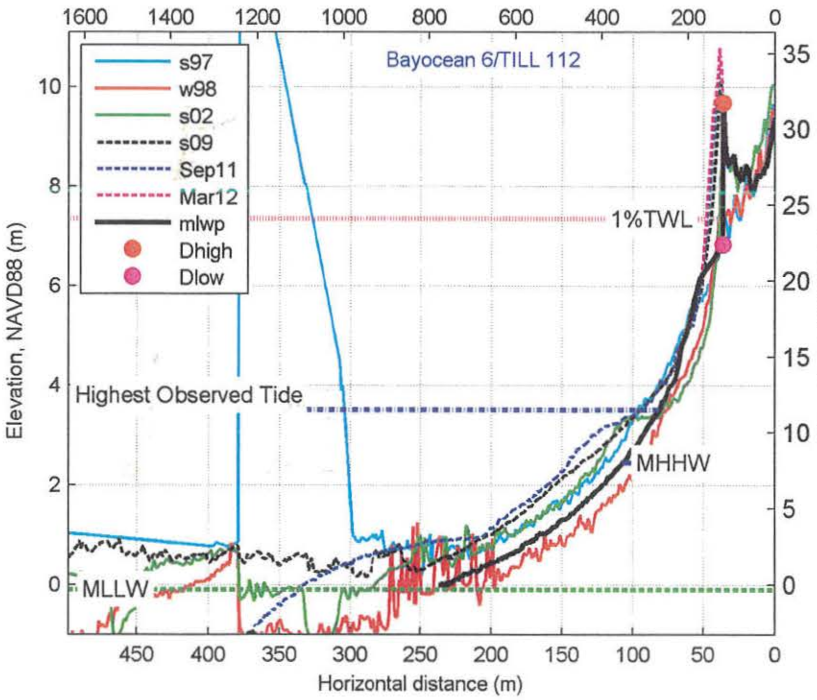
fm_bay 4



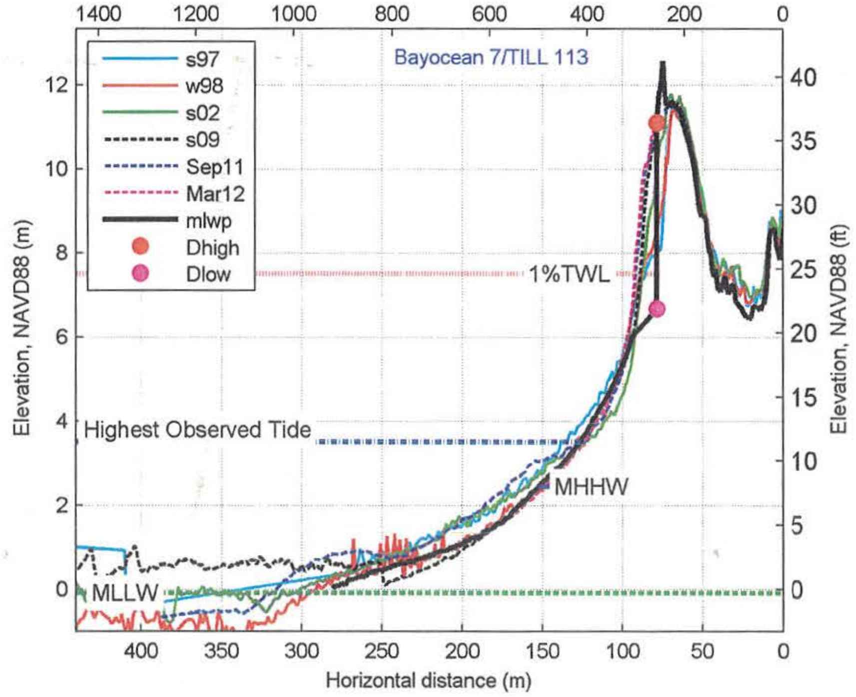
**fm_bay 5**



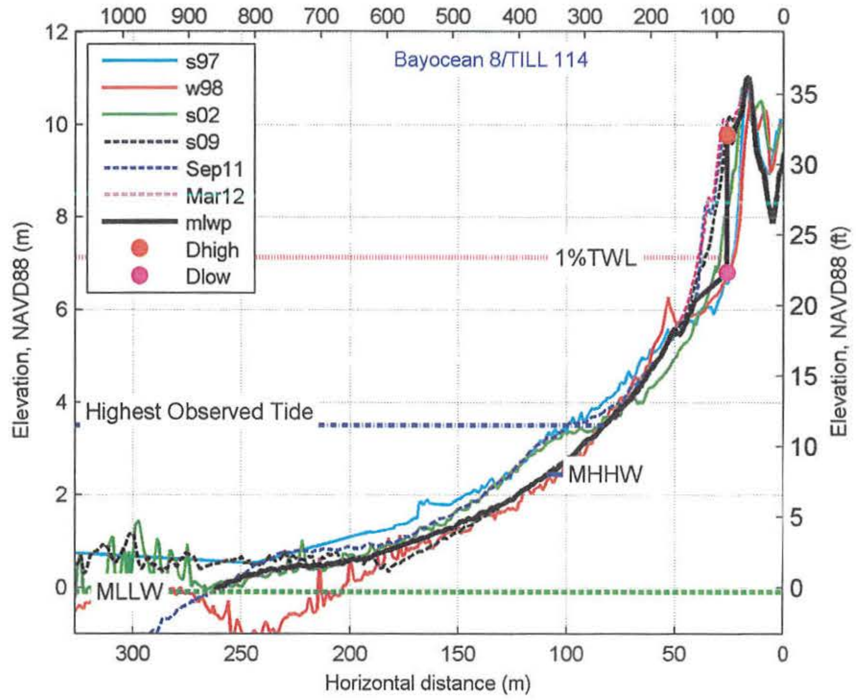
**fm_bay 6**



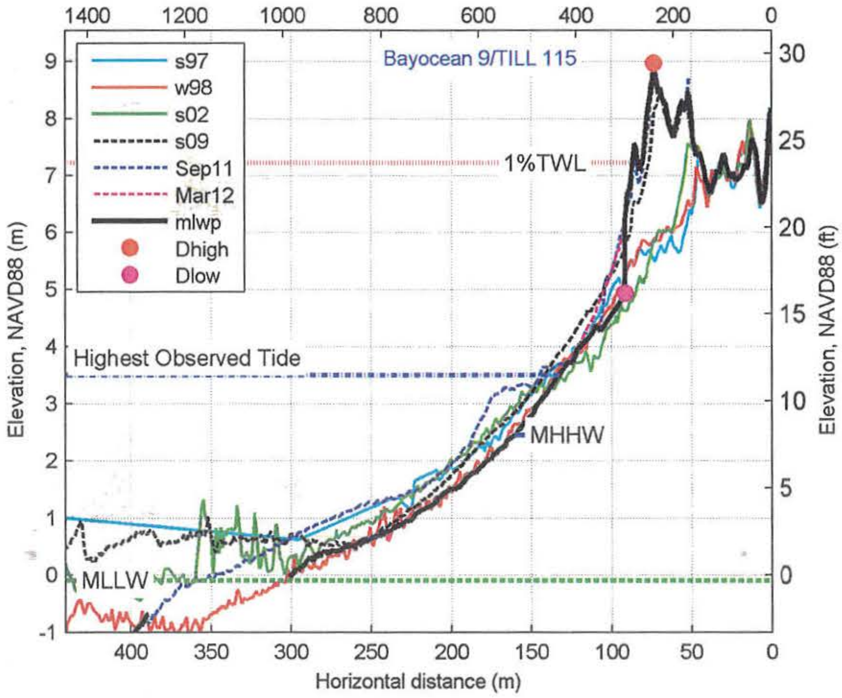
fm_bay 7



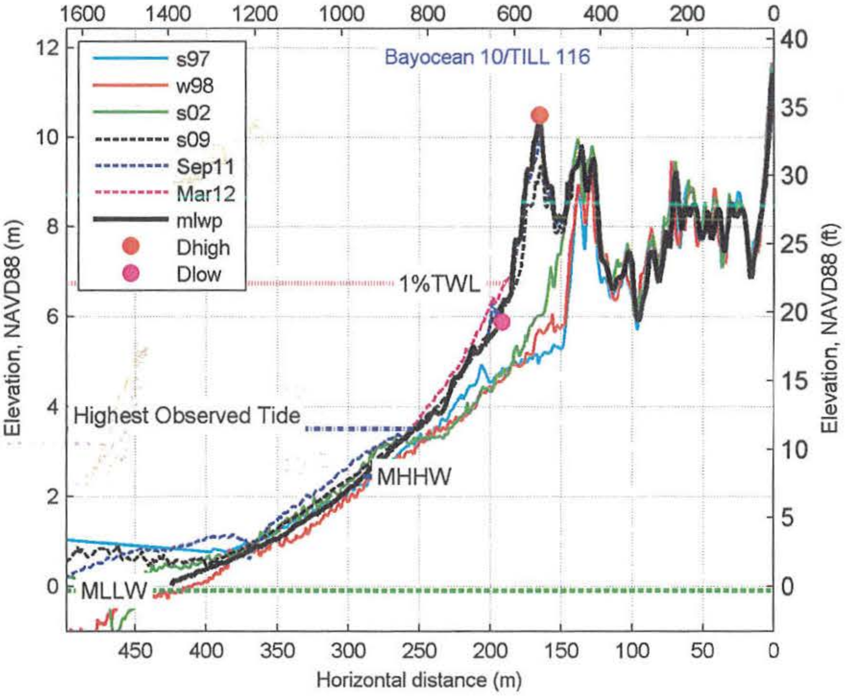
fm_bay 8



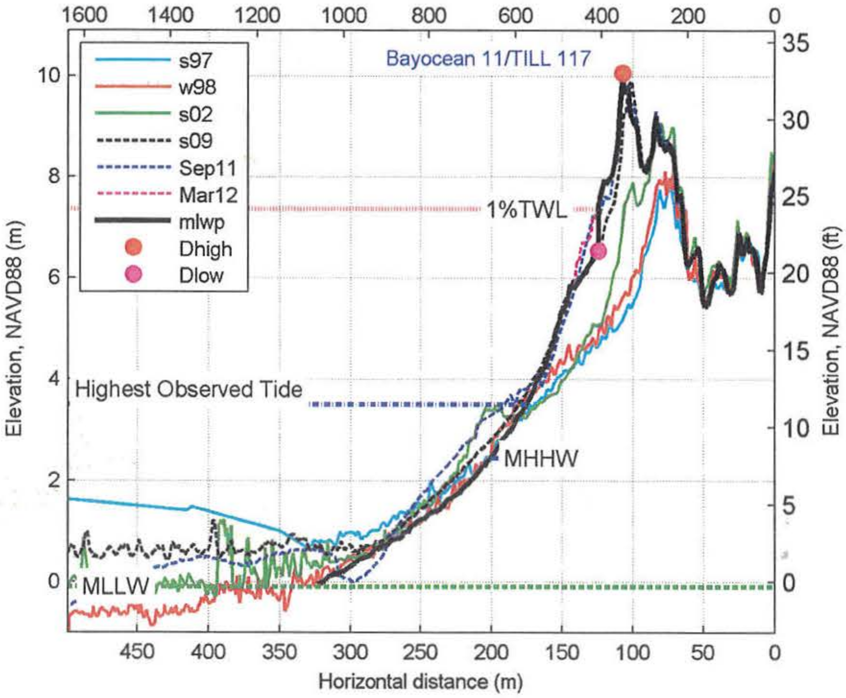
**fm_bay 9**



**fm_bay 10**

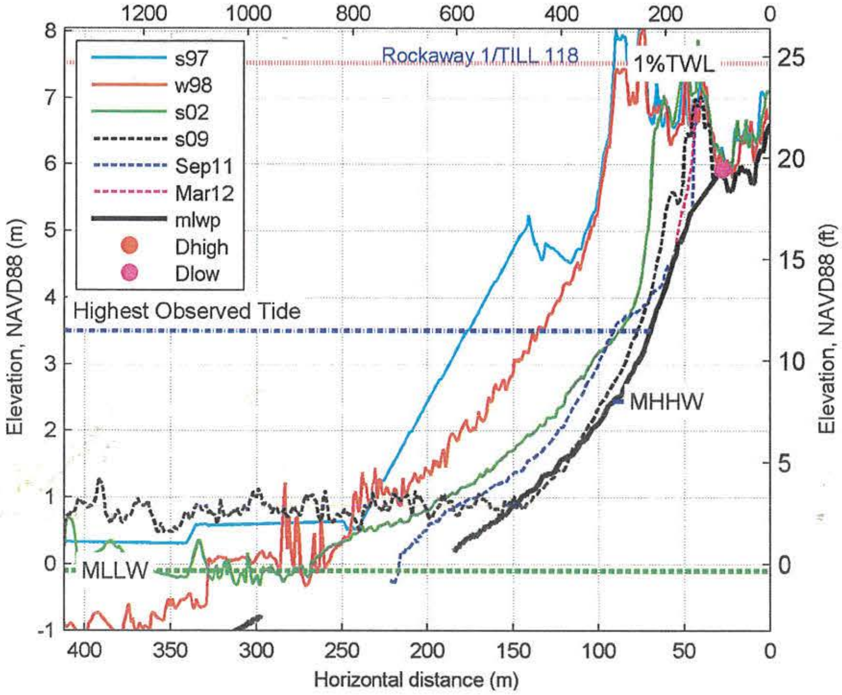


**fm_bay 11**

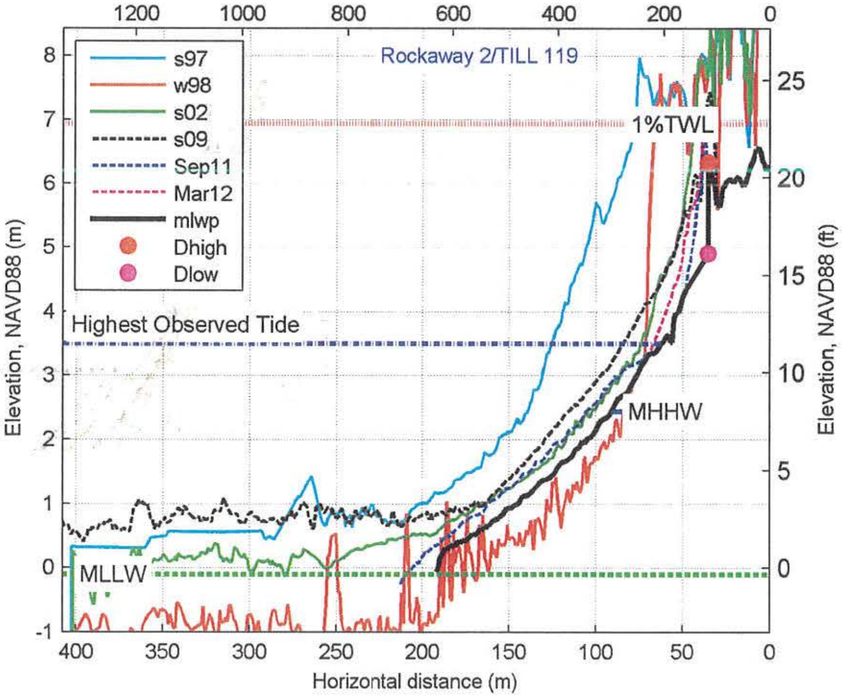

Bayocean 11/TILL 117
s97
w98
s02
s09
Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
1600
1400
1200
1000
800
600
400
200
0
10
8
6
4
2
0
35
30
25
20
15
10
5
0
450
400
350
300
250
200
150
100
50
0
Horizontal distance (m)
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)

### *11.4.7 Rockaway*

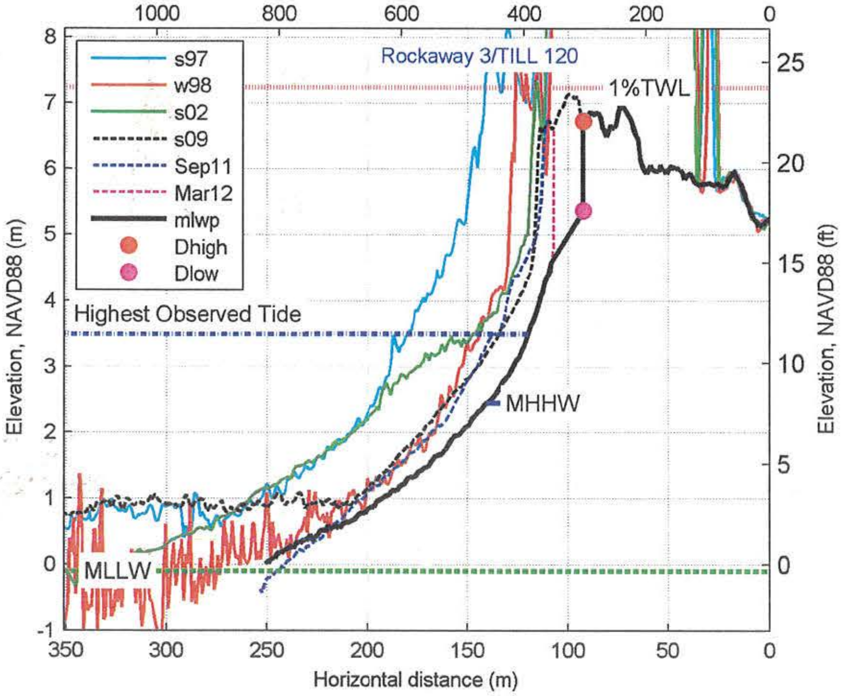
**fm_rck 1**



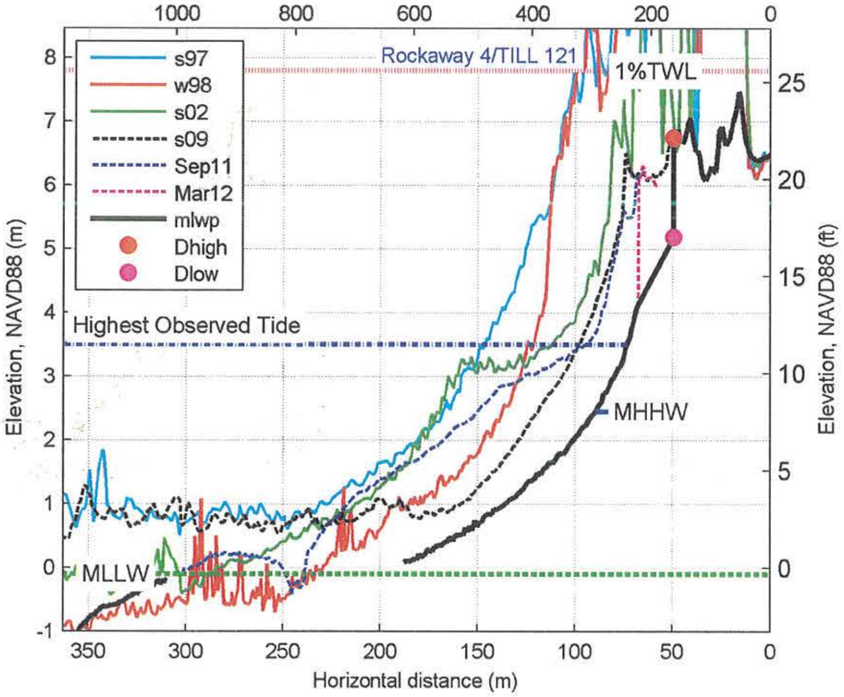
**fm_rck 2**



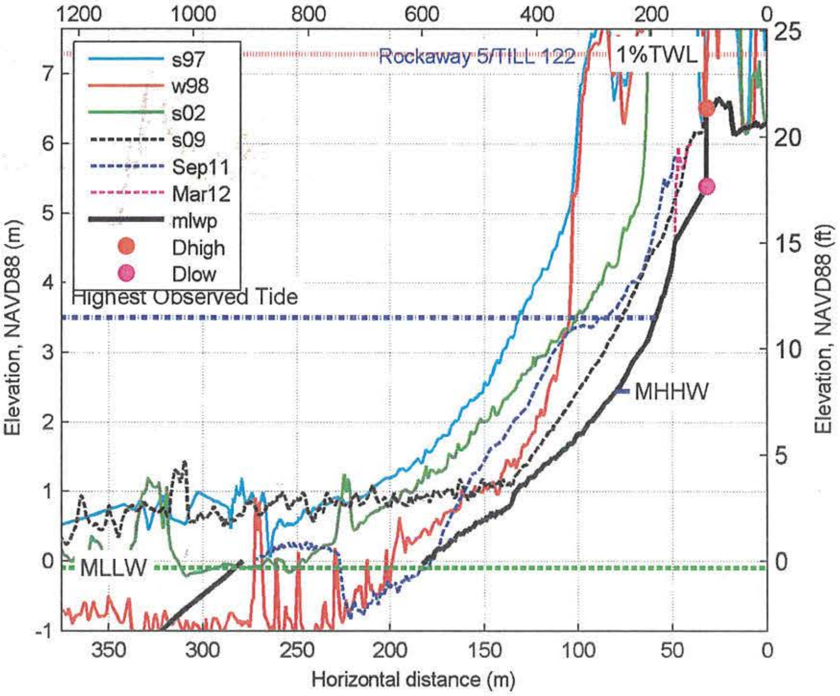
**fm_rck 3**



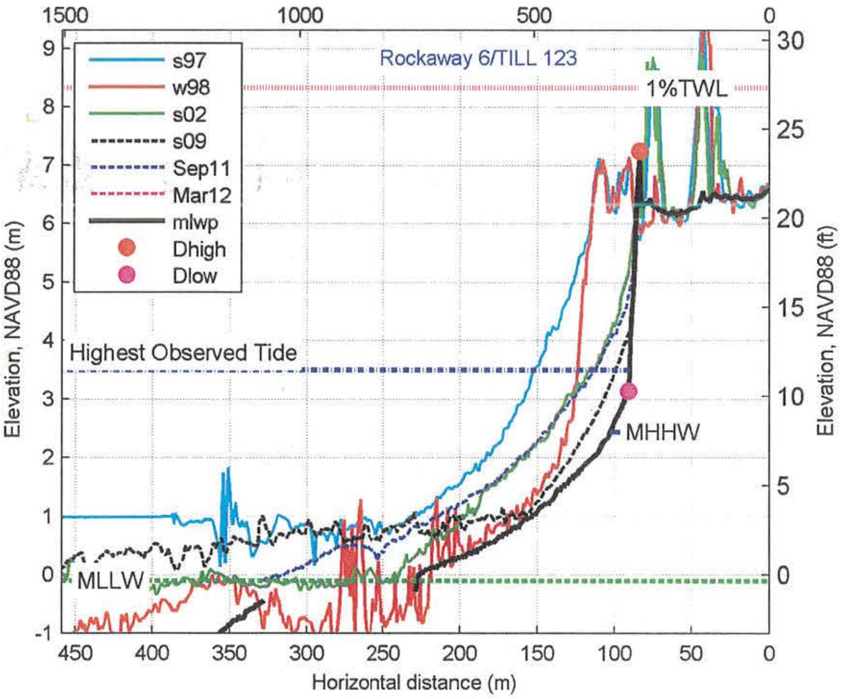
**fm_rck 4**



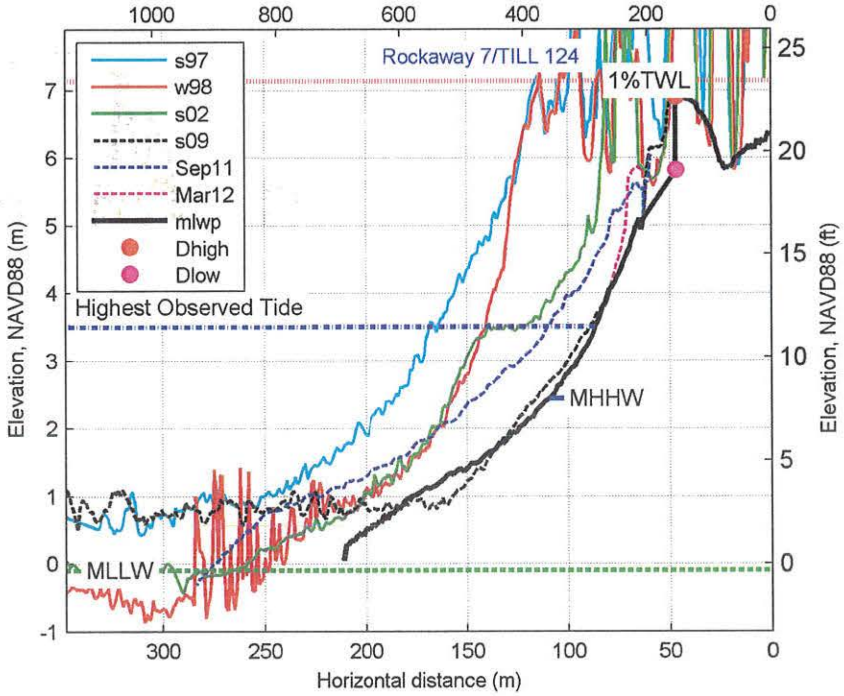
**fm_rck 5**



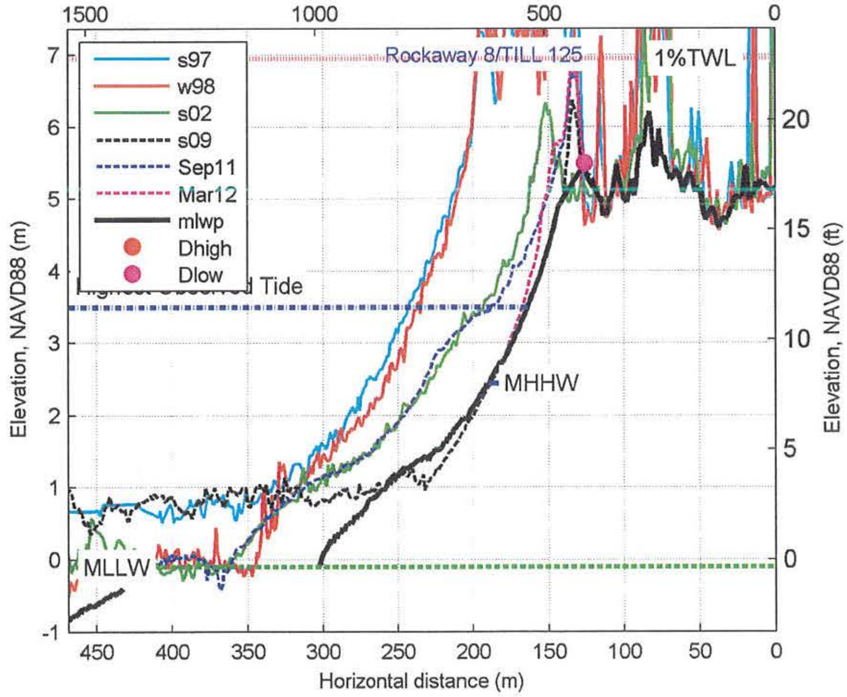
**fm_rck 6**



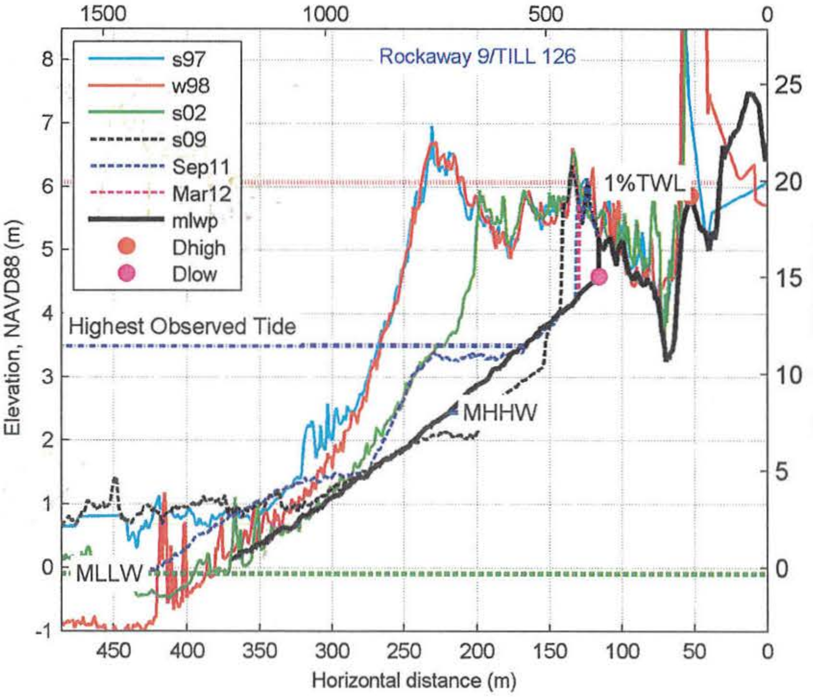
**fm_rck 7**



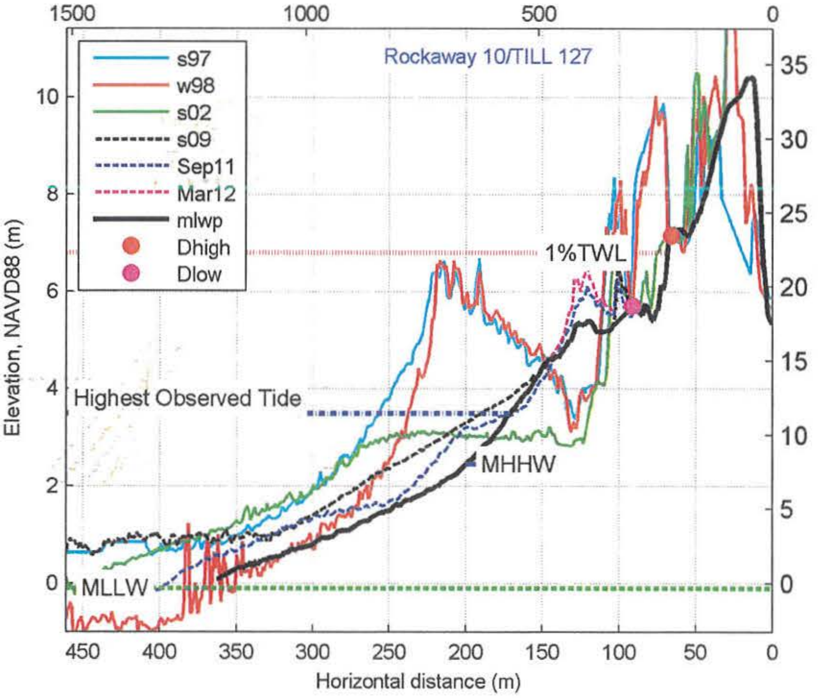
**fm_rck 8**



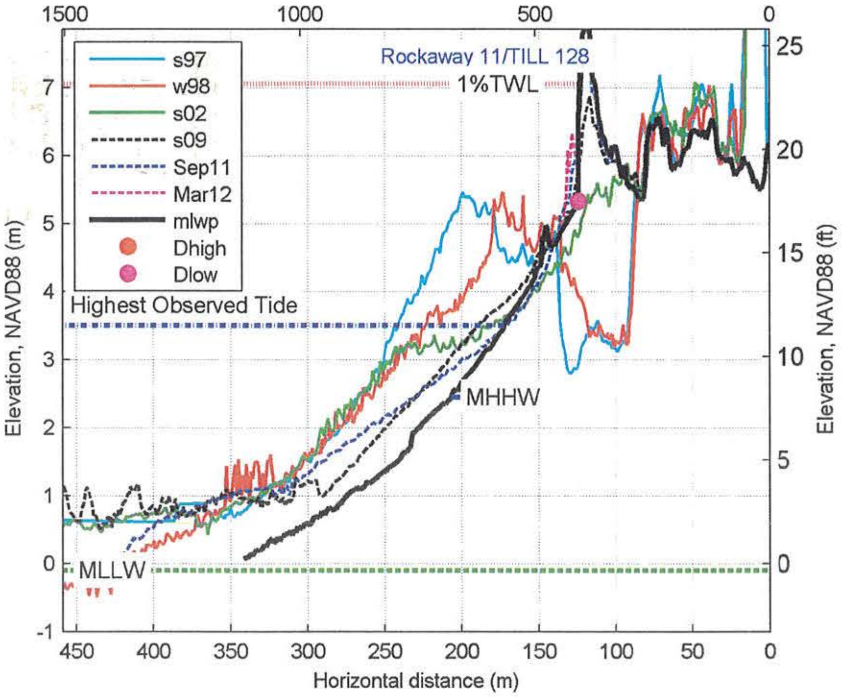
**fm_rck 9**



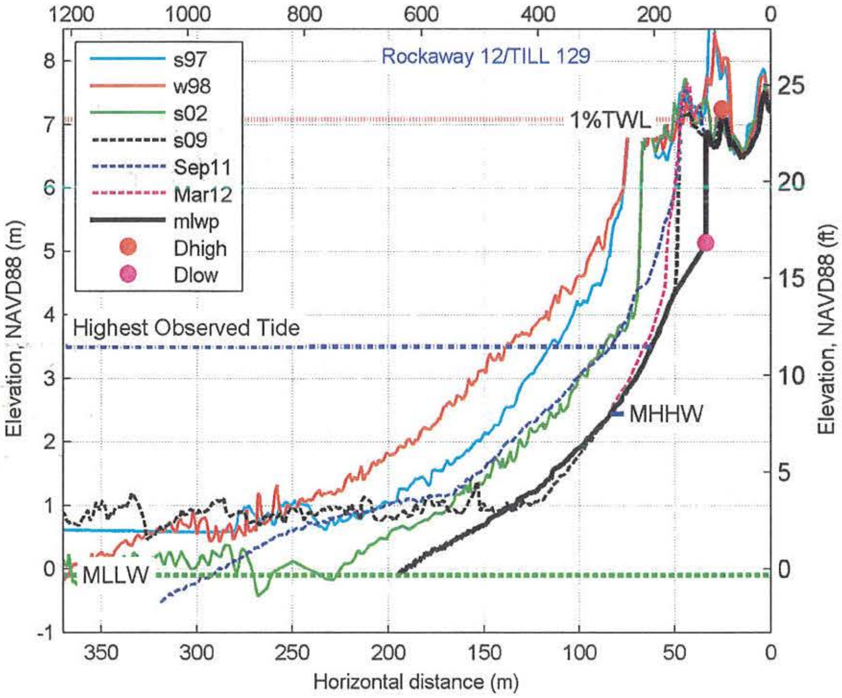
**fm_rck 10**



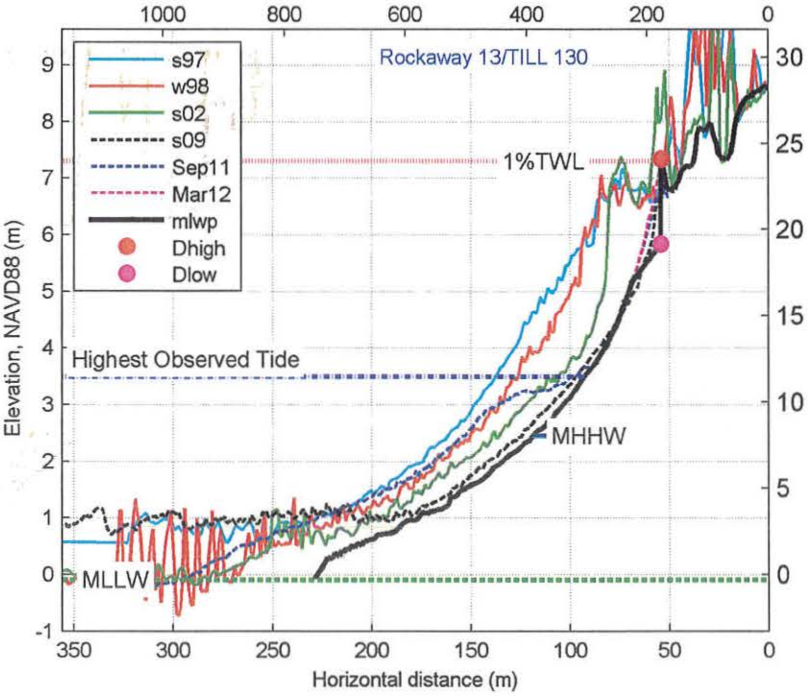
**fm_rck 11**



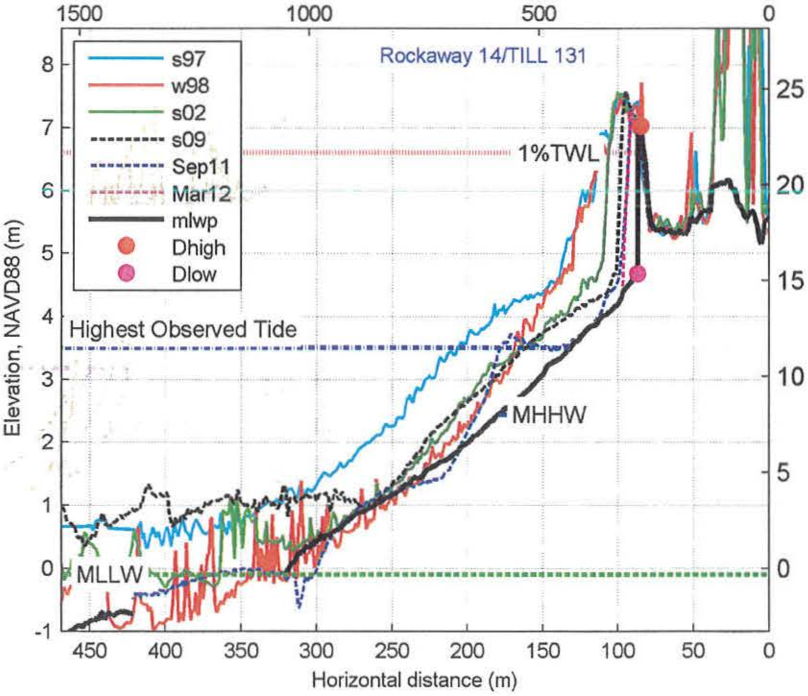
**fm_rck 12**



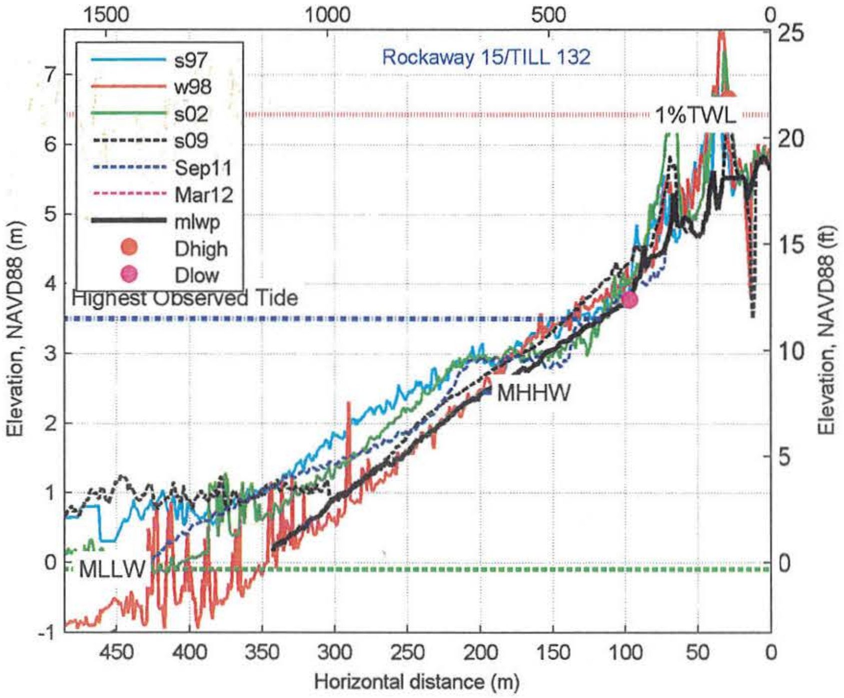
**fm_rck 13**



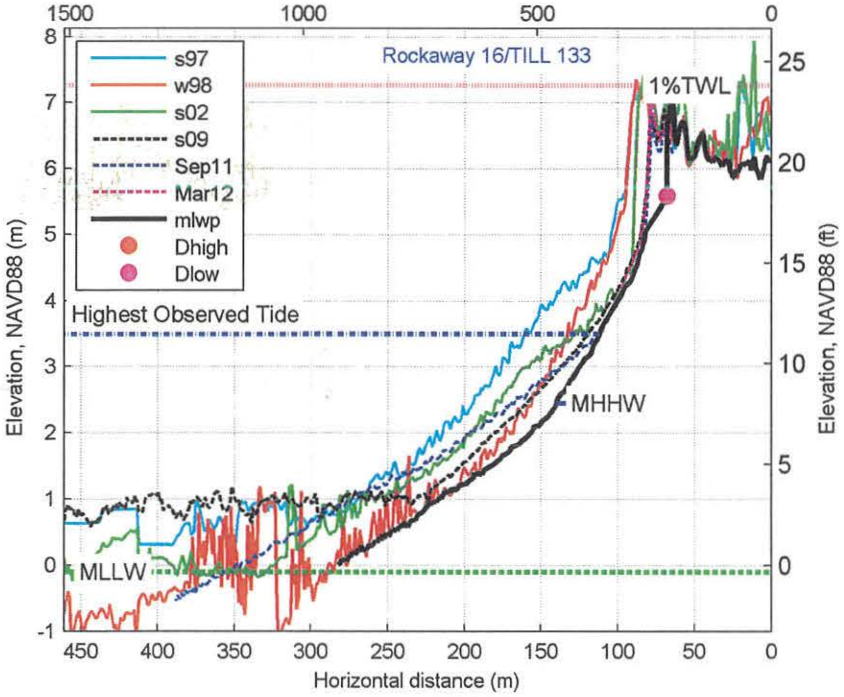
**fm_rck 14**



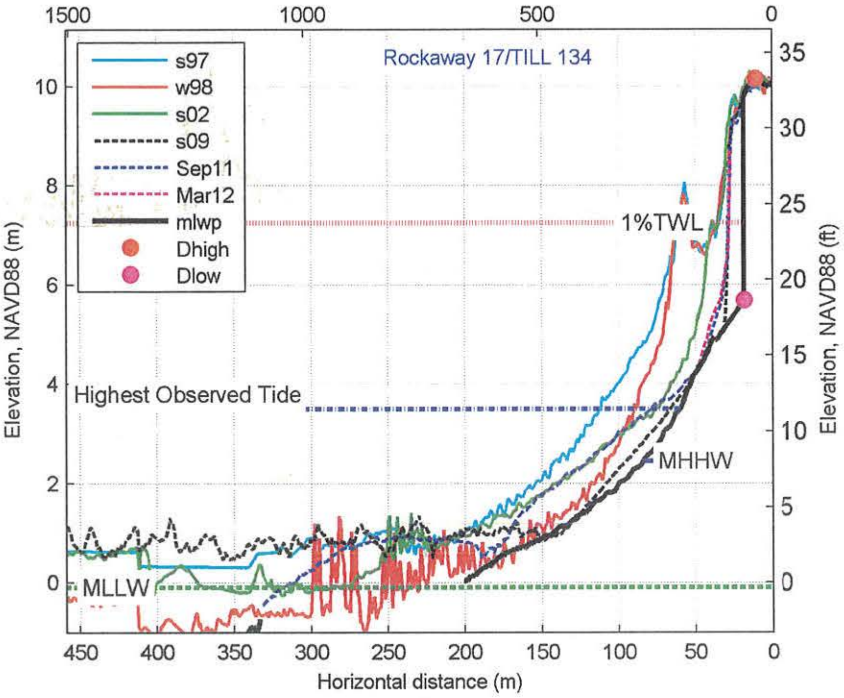
**fm_rck 15**



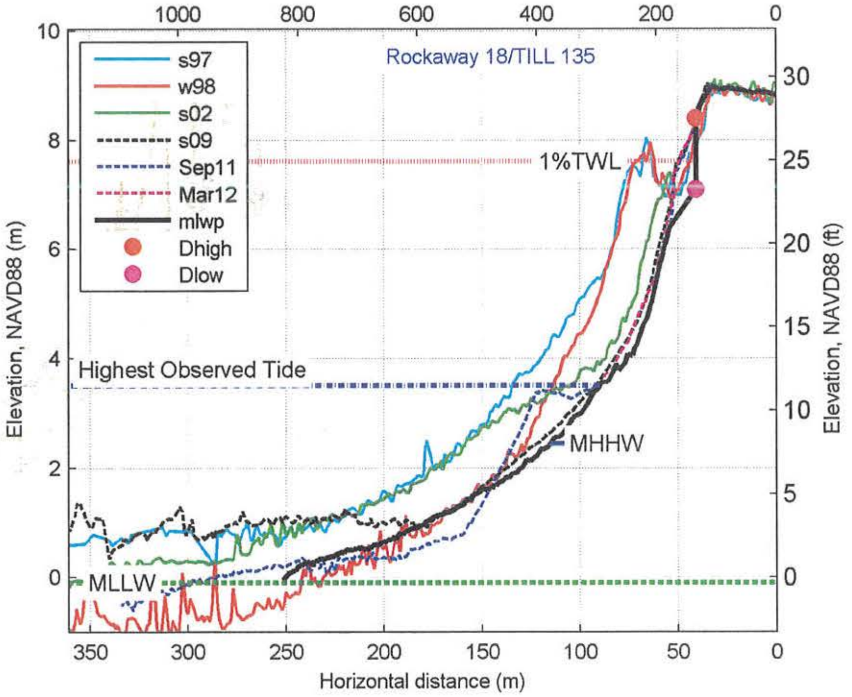
**fm_rck 16**



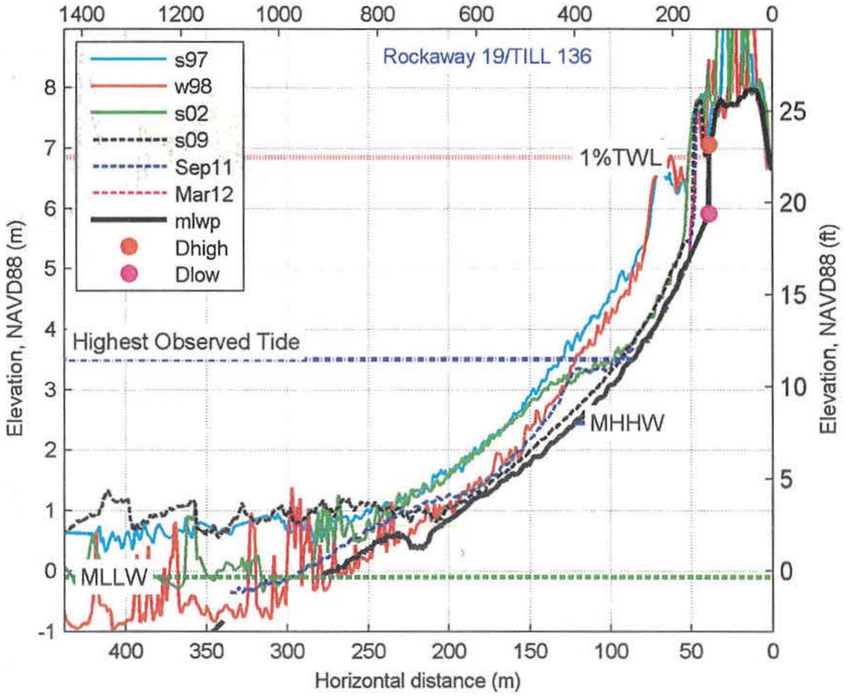
**fm_rck 17**



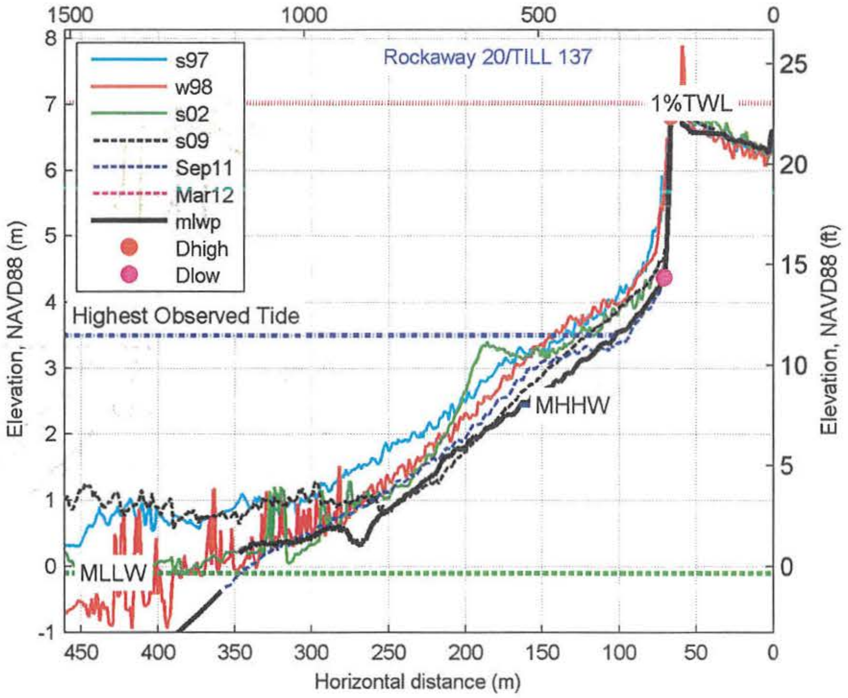
**fm_rck 18**



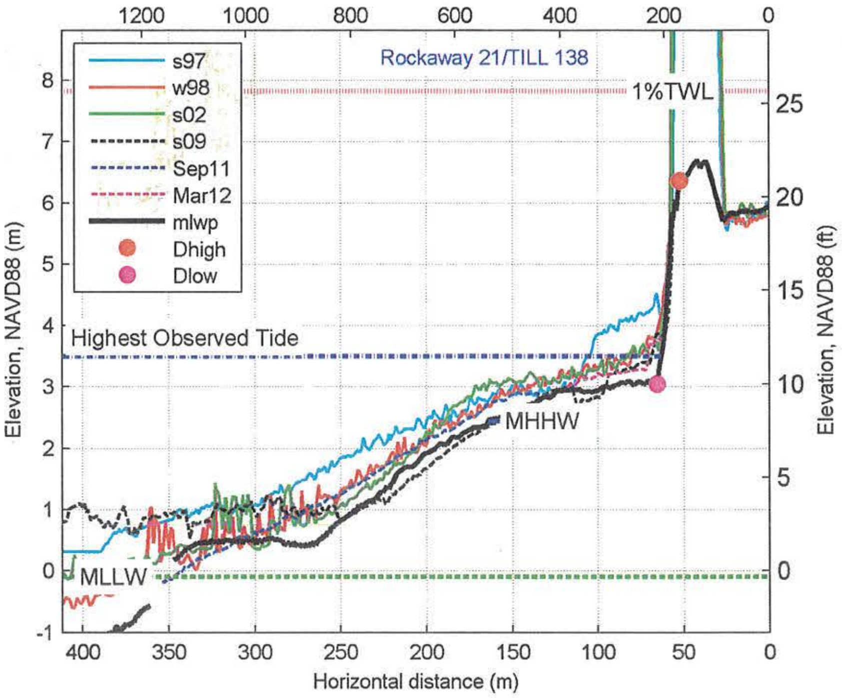
**fm_rck 19**



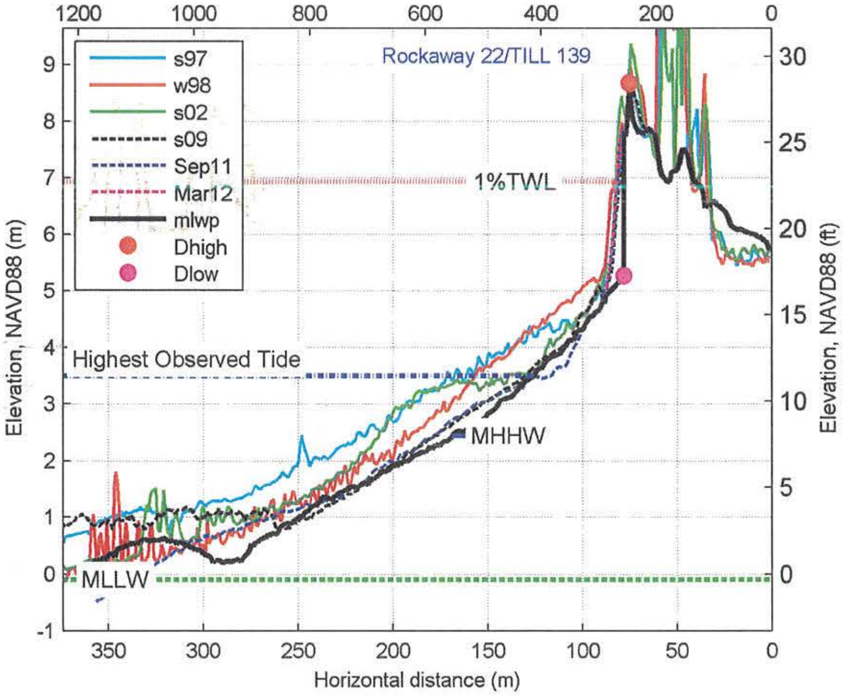
**fm_rck 20**



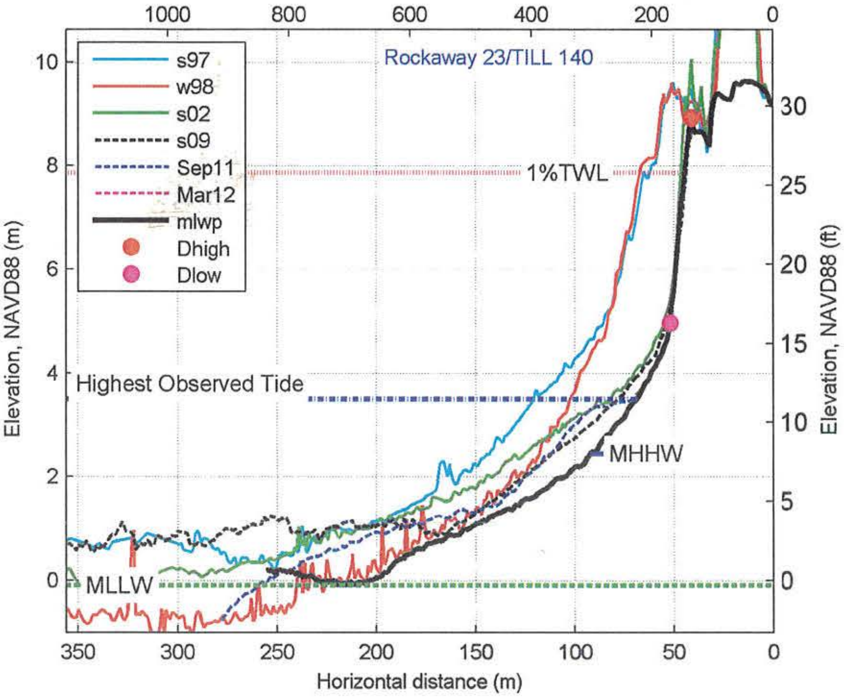
**fm_rck 21**



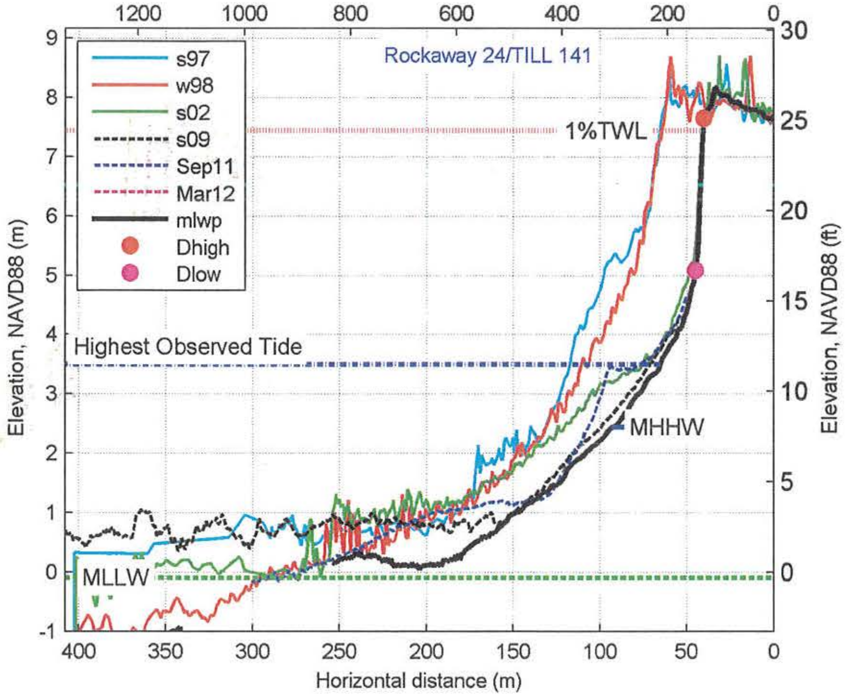
**fm_rck 22**



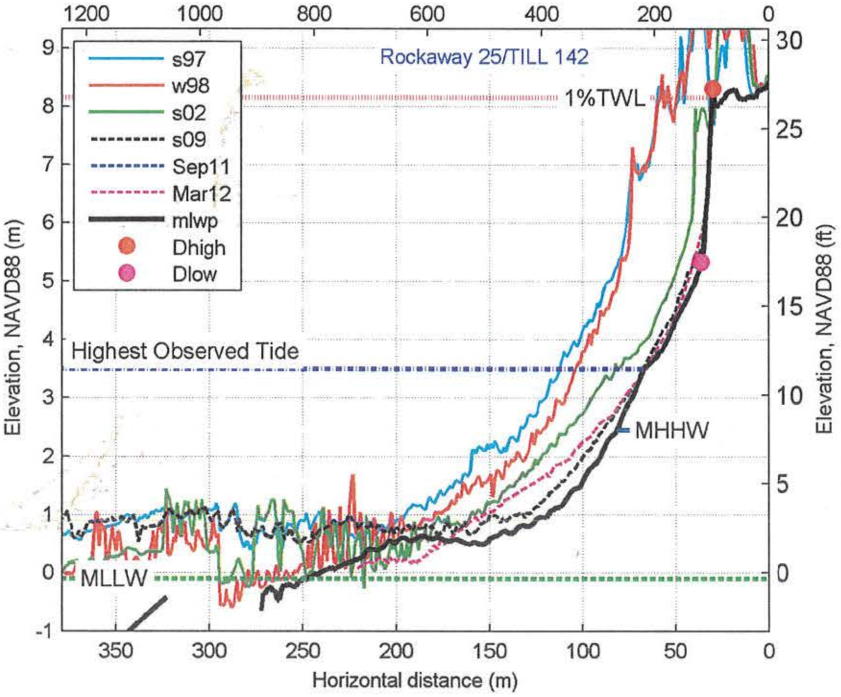
**fm_rck 23**



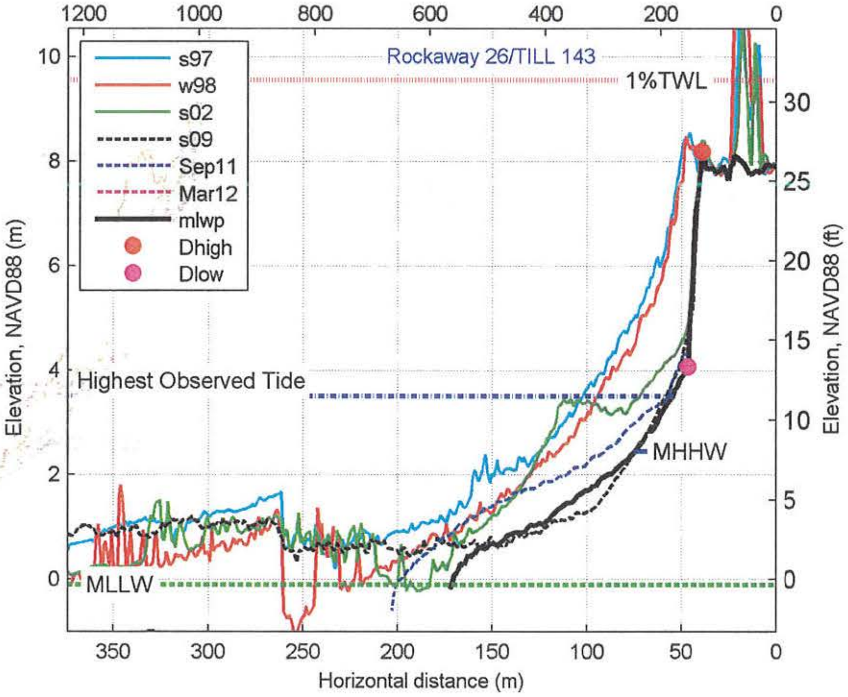
**fm_rck 24**



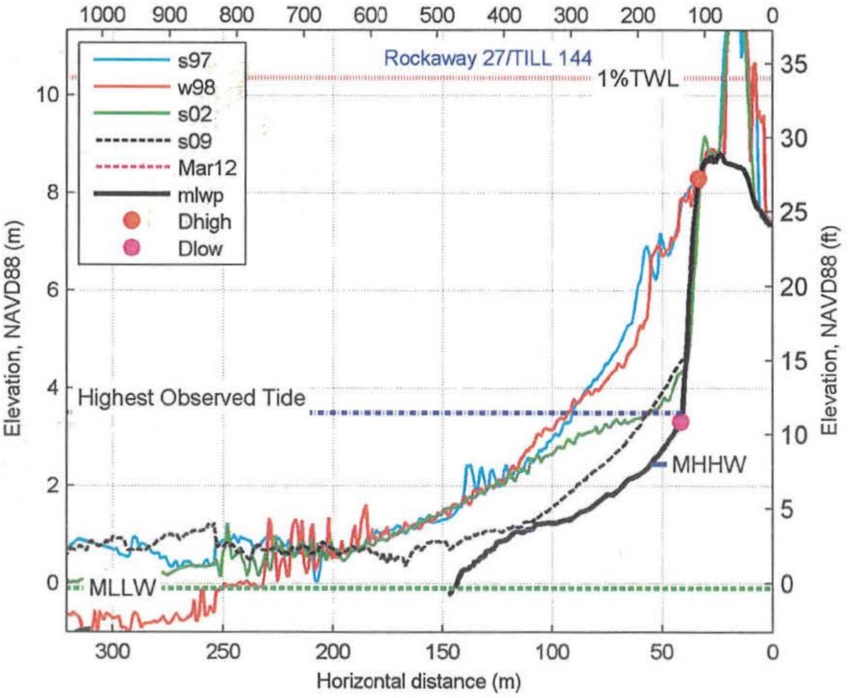
**fm_rck 25**



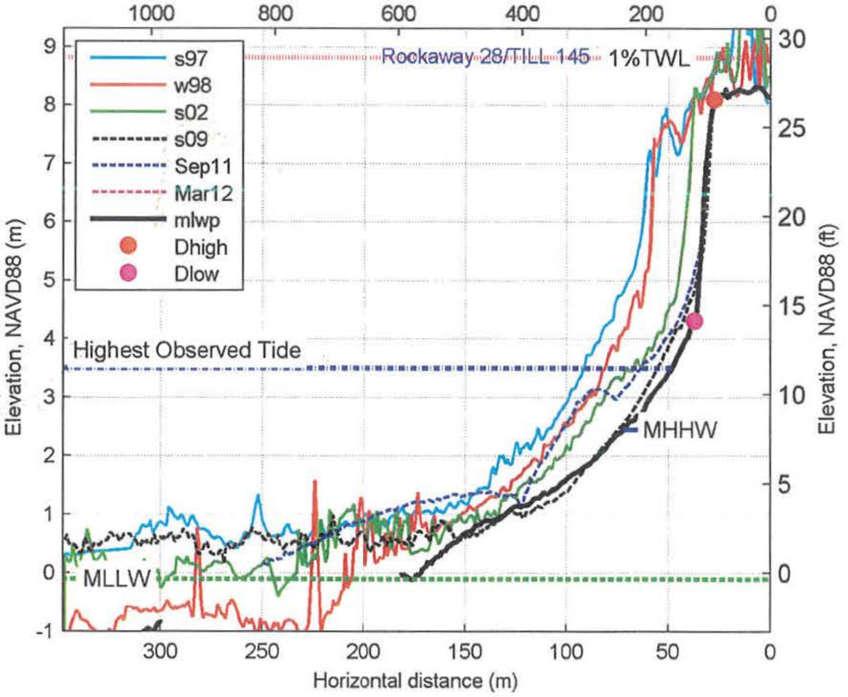
**fm_rck 26**



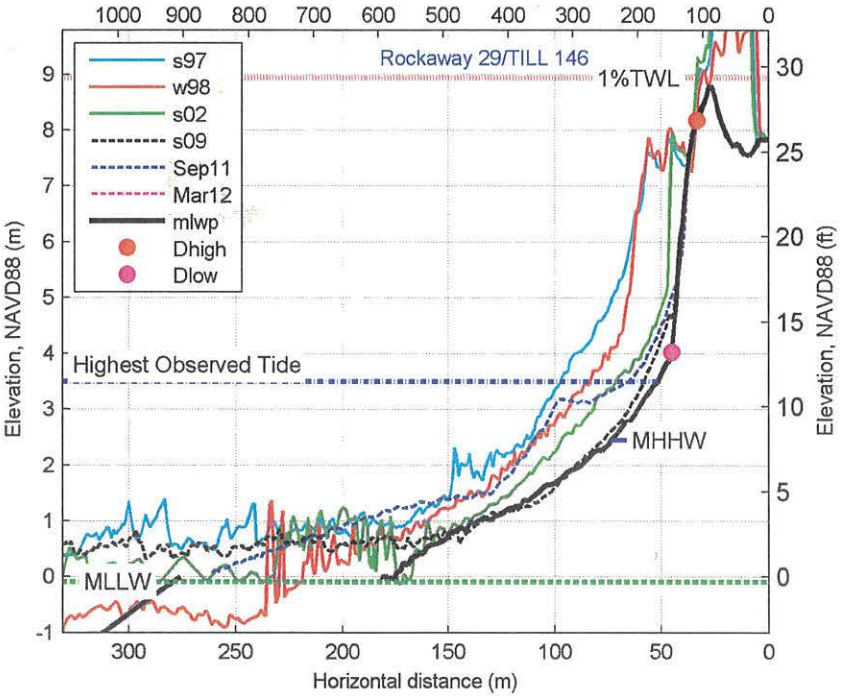
fm_rck 27



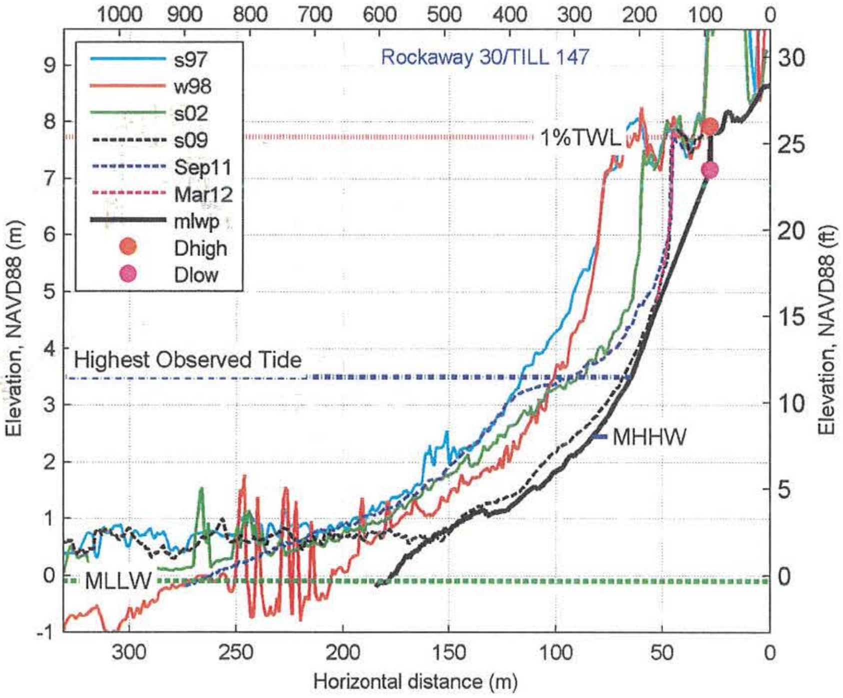
fm_rck 28



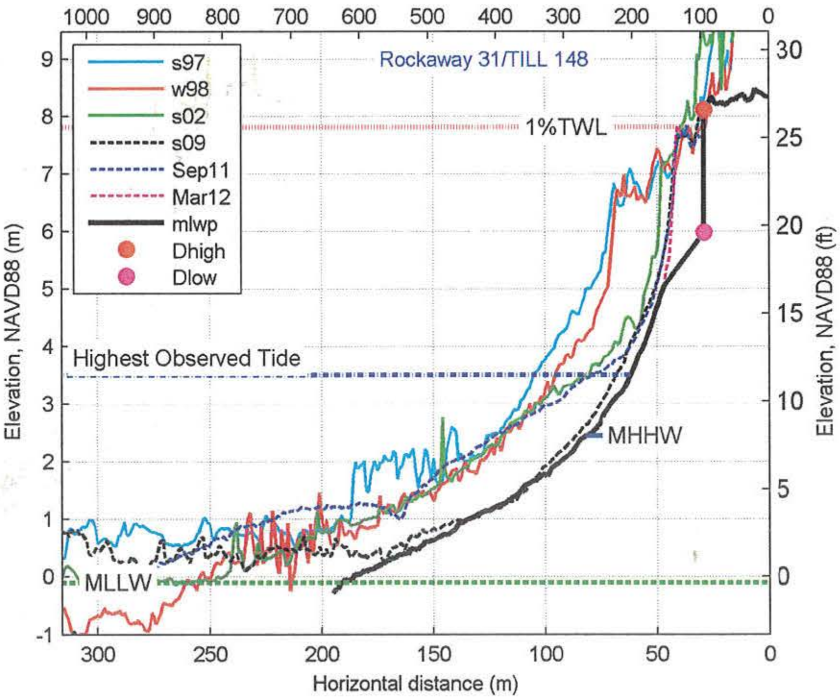
**fm_rck 29**



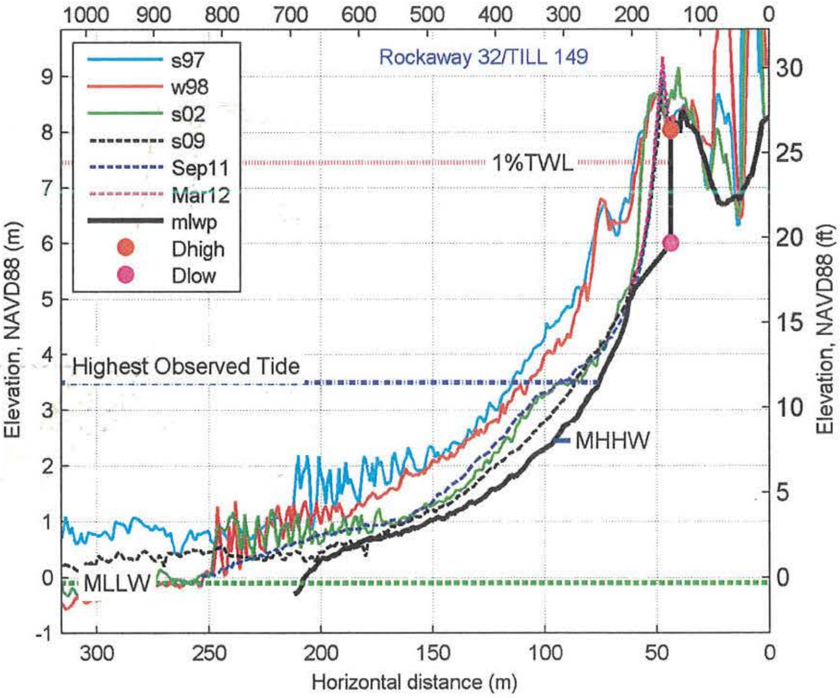
**fm_rck 30**



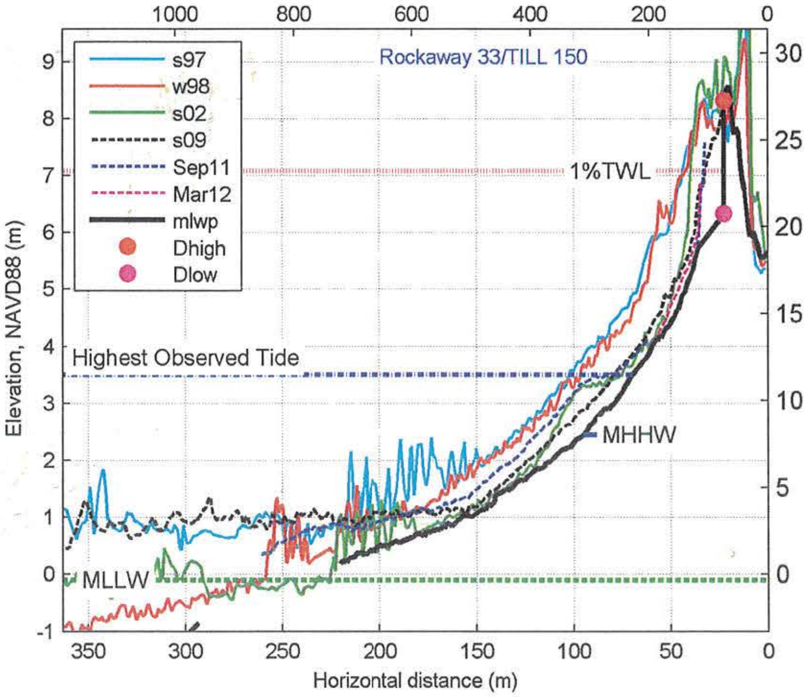
**fm_rck 31**



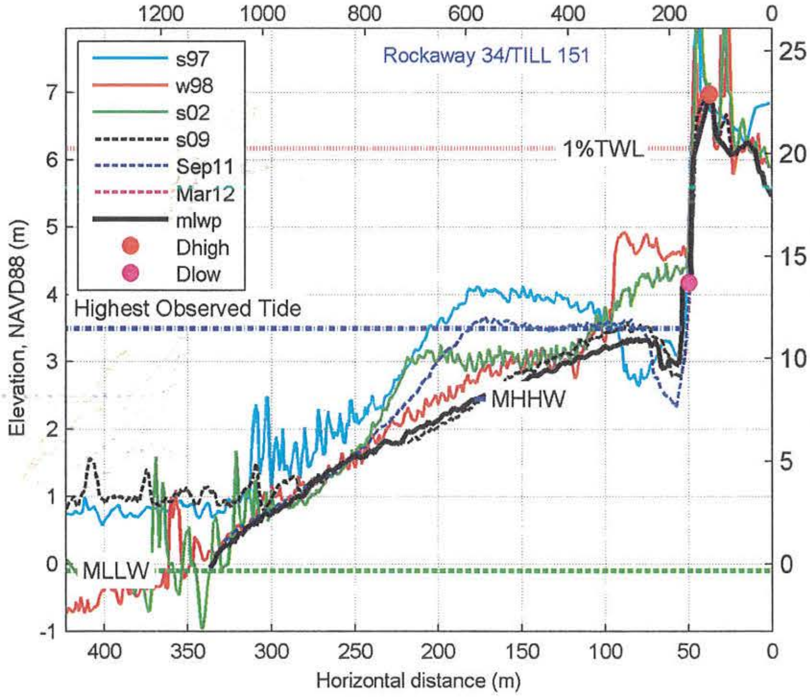
**fm_rck 32**



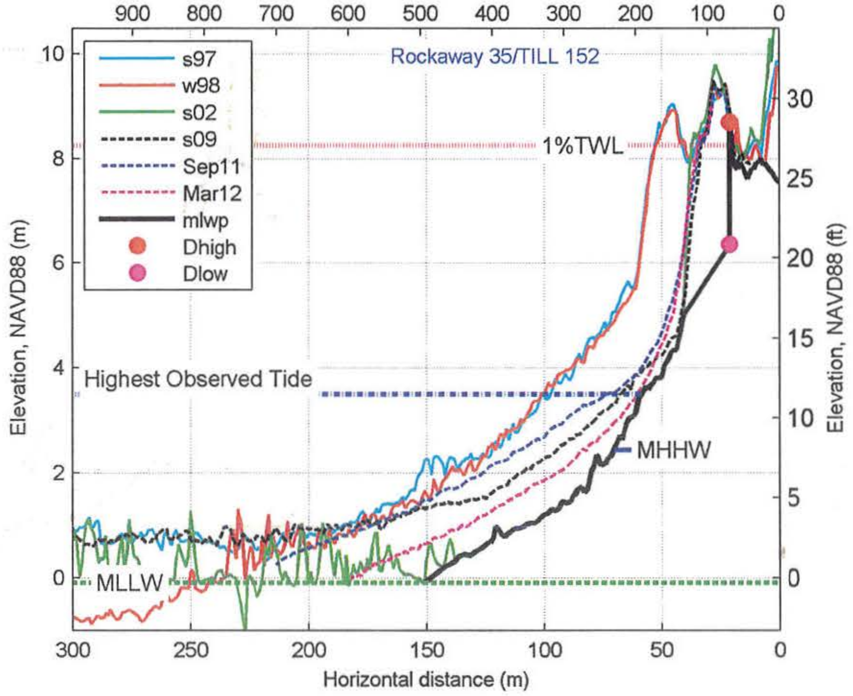
**fm_rck 33**



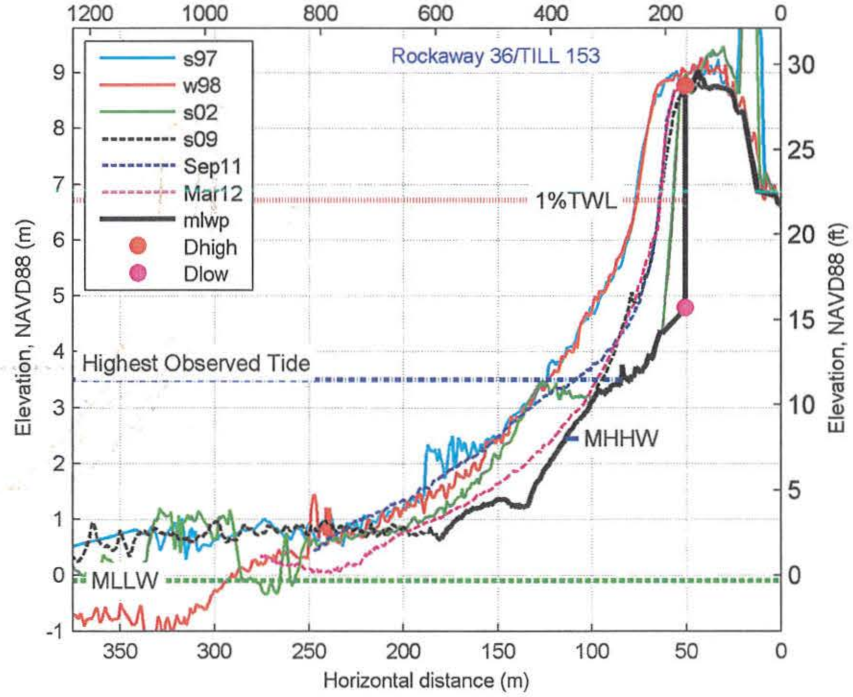
**fm_rck 34**



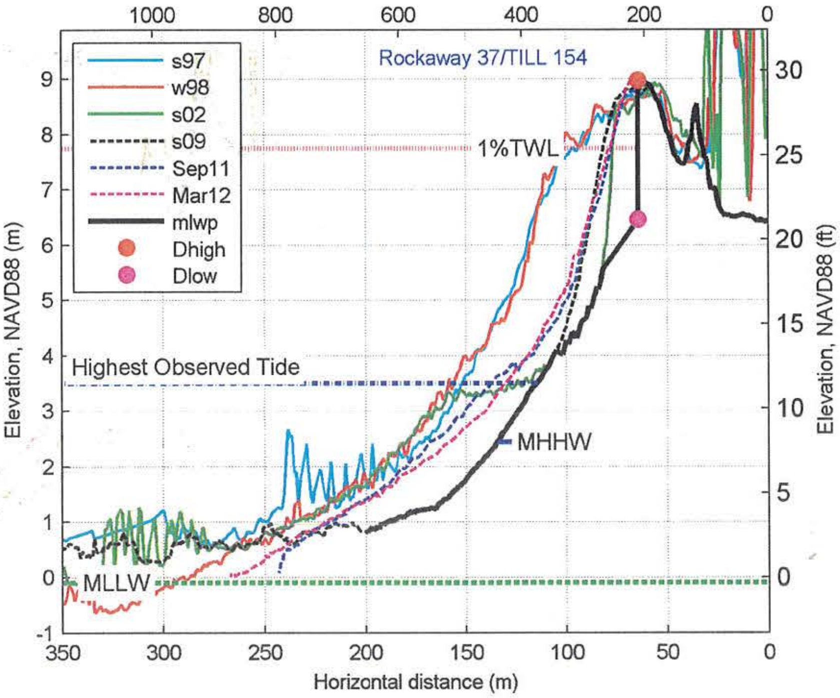
**fm_rck 35**



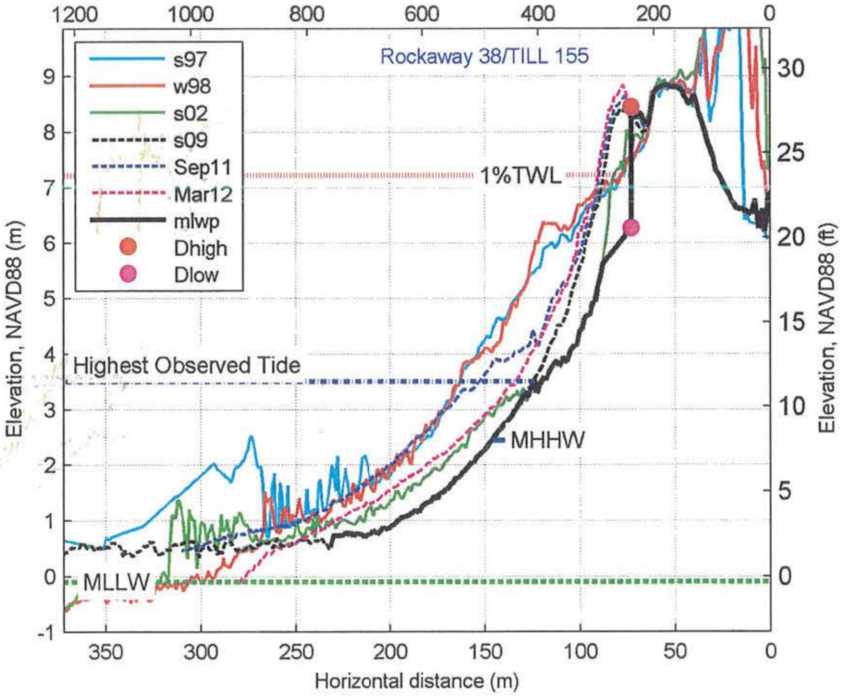
**fm_rck 36**



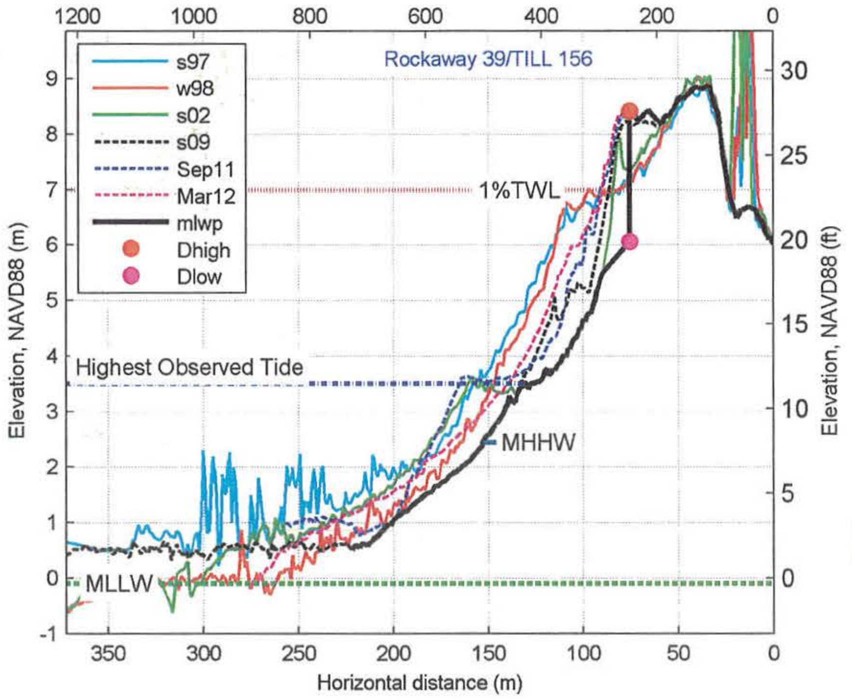
**fm_rck 37**



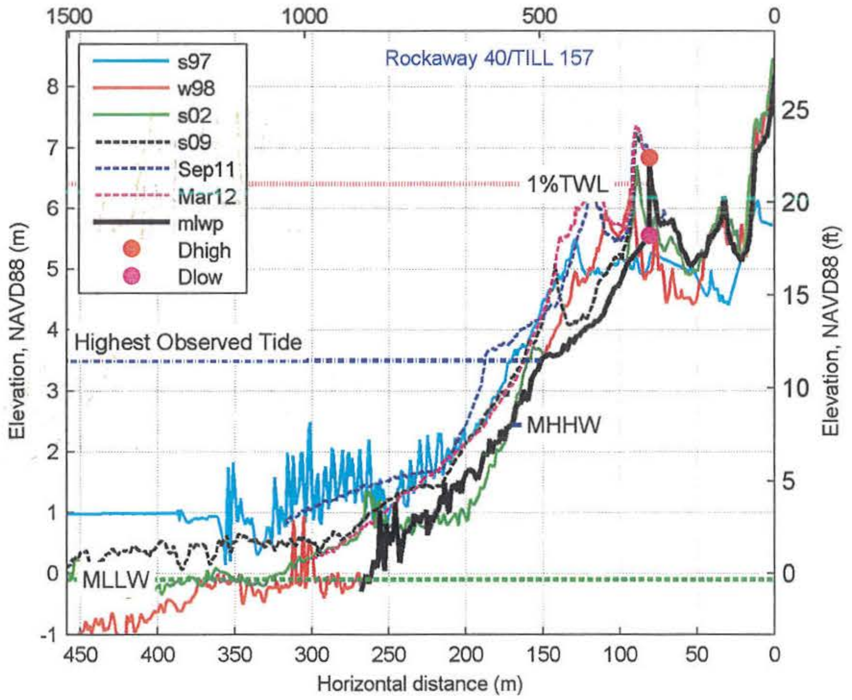
**fm_rck 38**



**fm_rck 39**

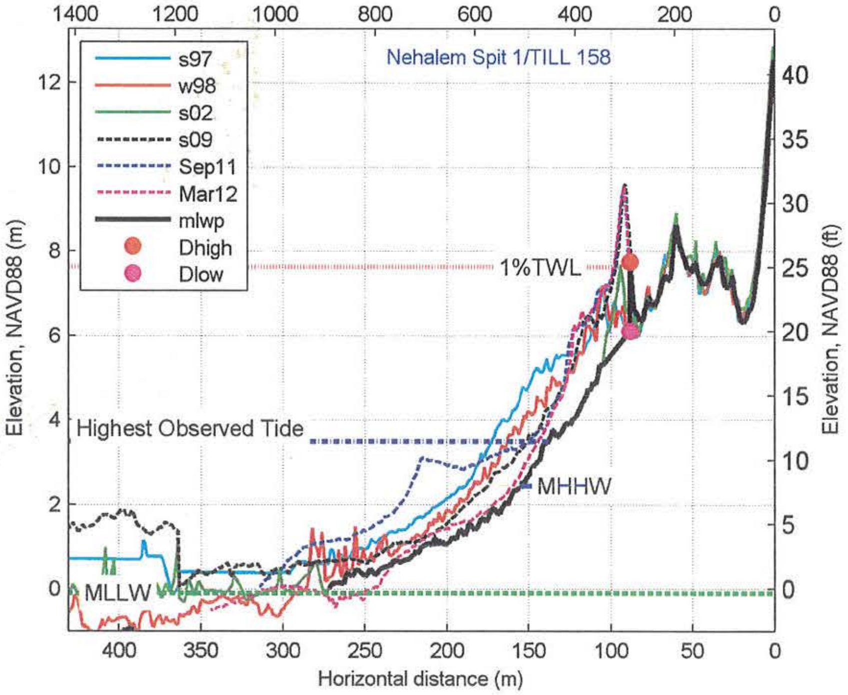


**fm_rck 40**

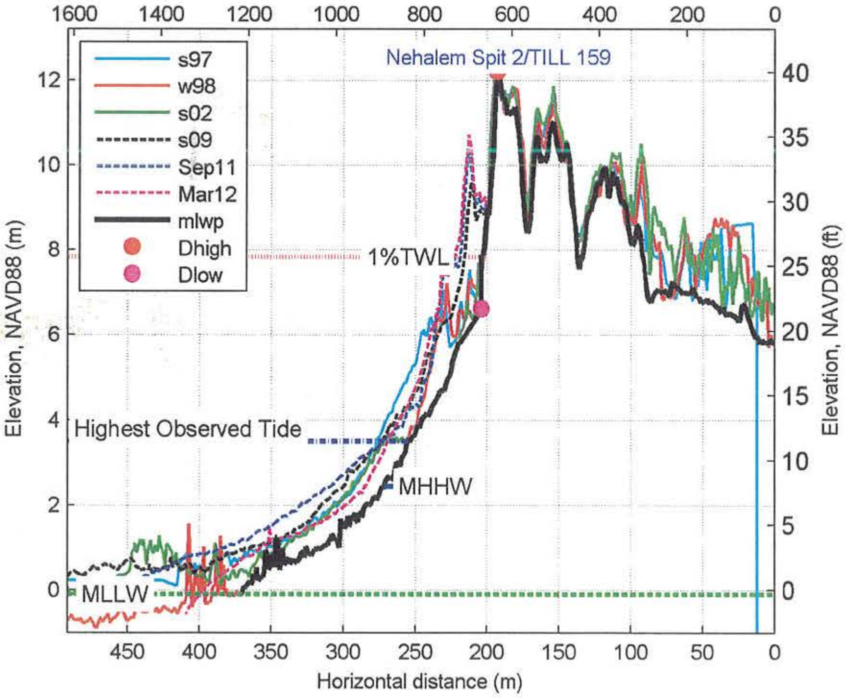


### *11.4.8 Nehalem Spit*

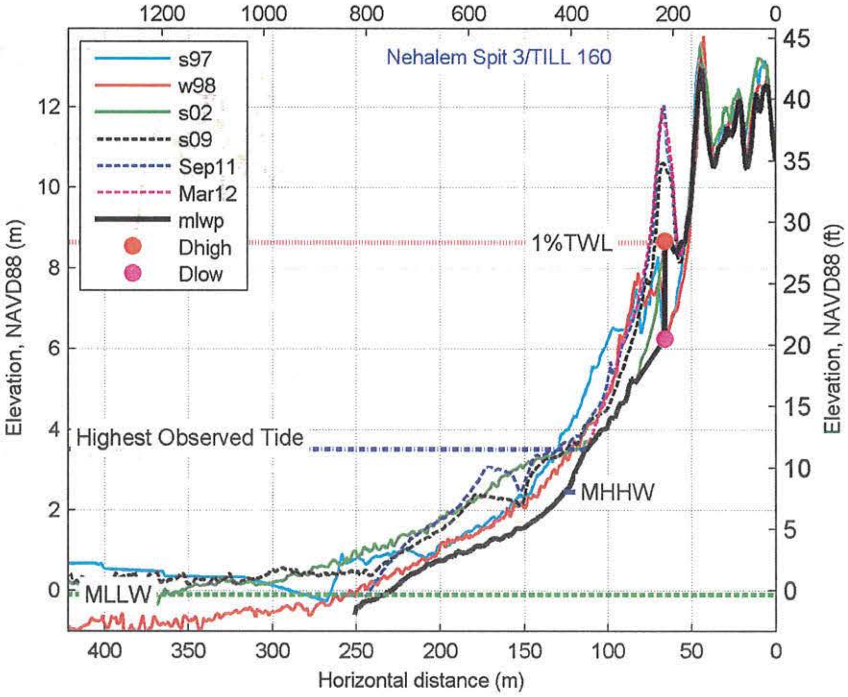
**fm_neh 1**



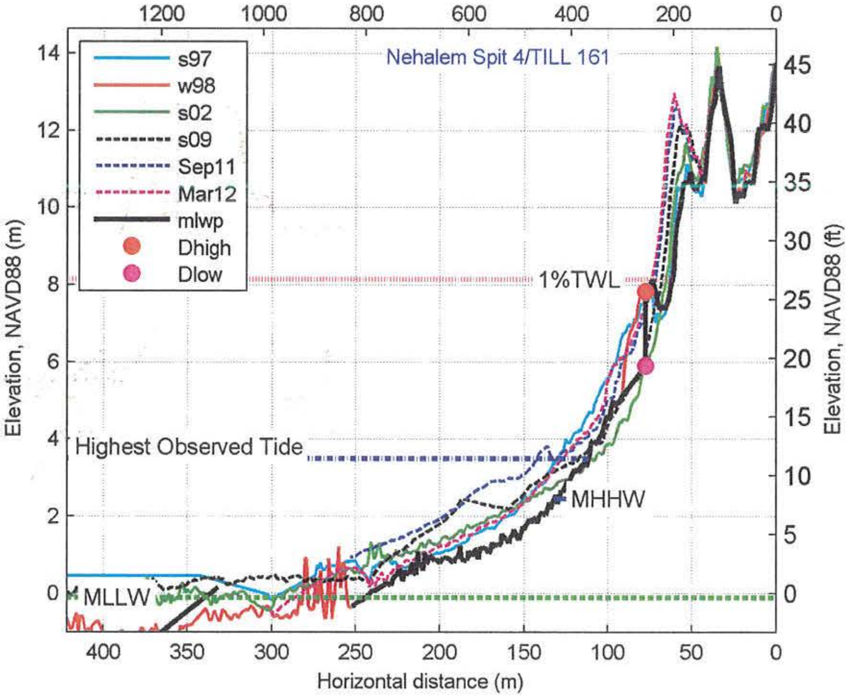
**fm_neh 2**



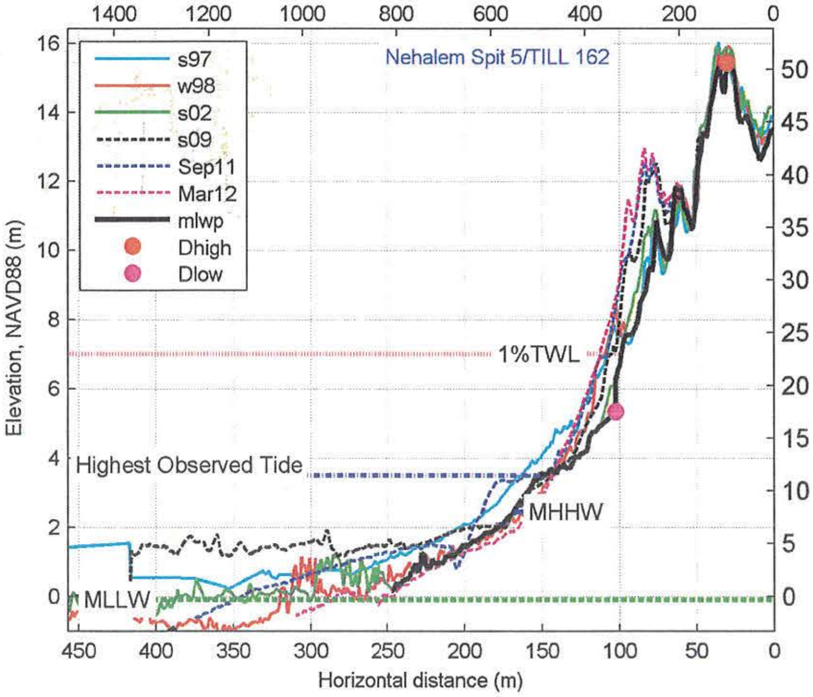
**fm_neh 3**



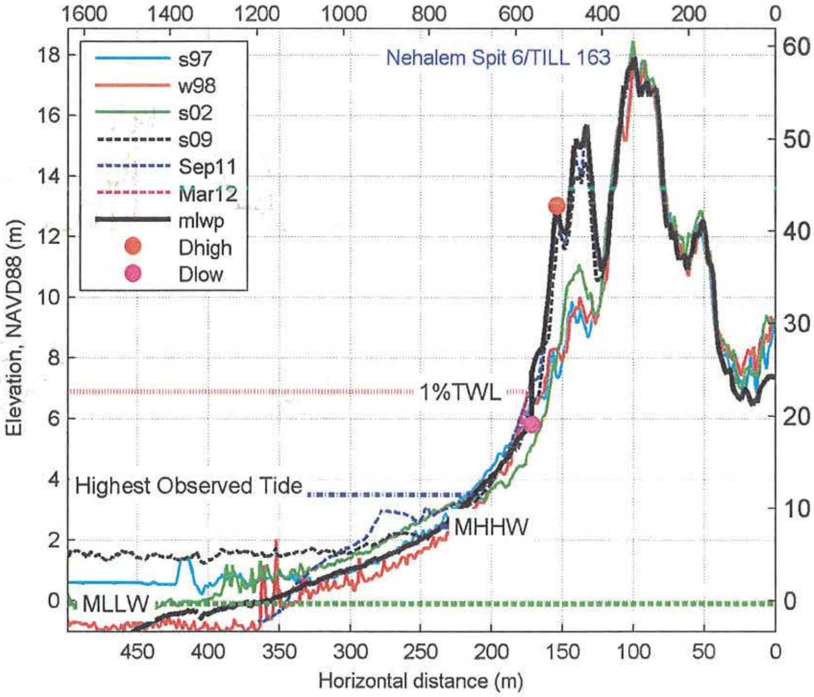
**fm_neh 4**



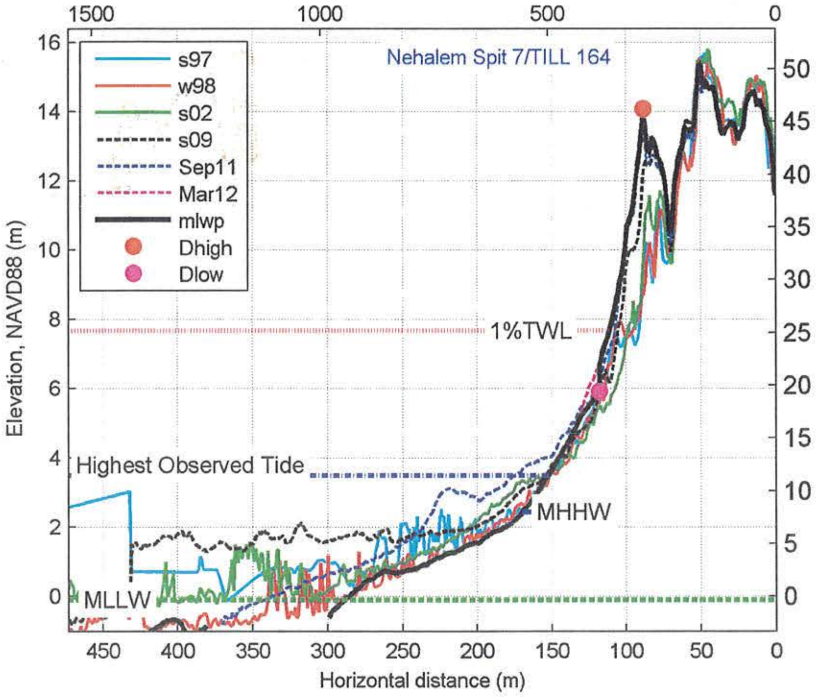
**fm_neh 5**



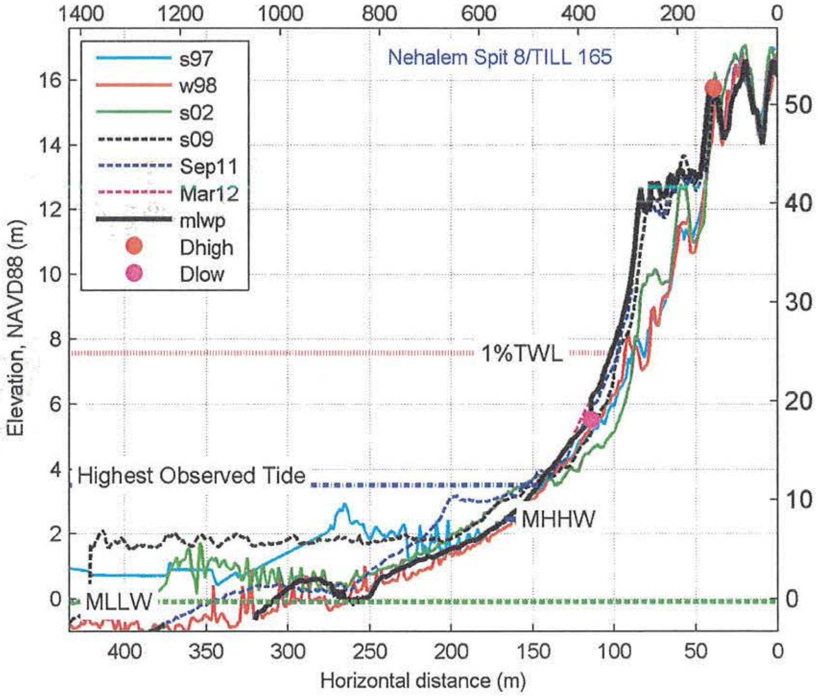
**fm_neh 6**



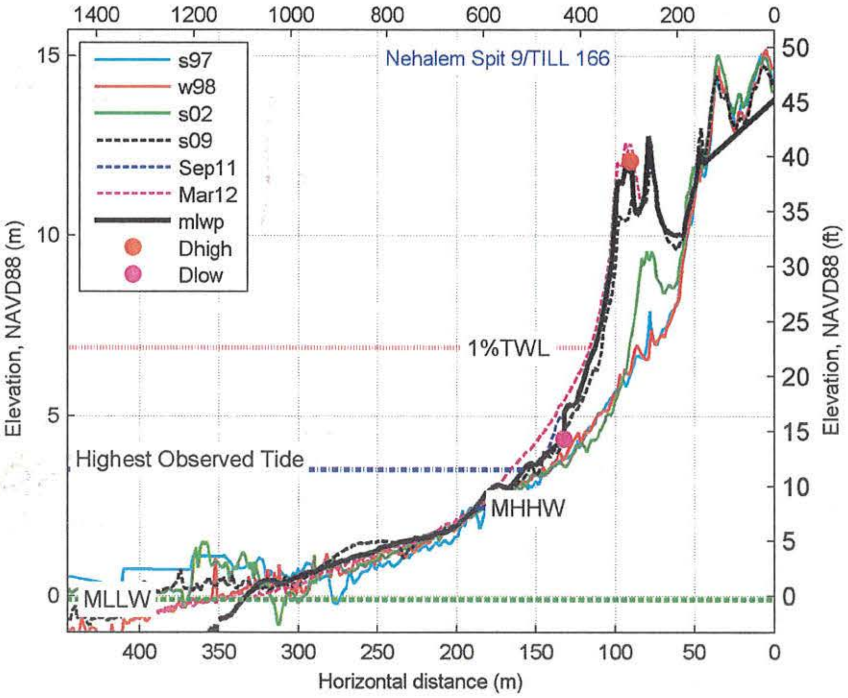
**fm_neh 7**



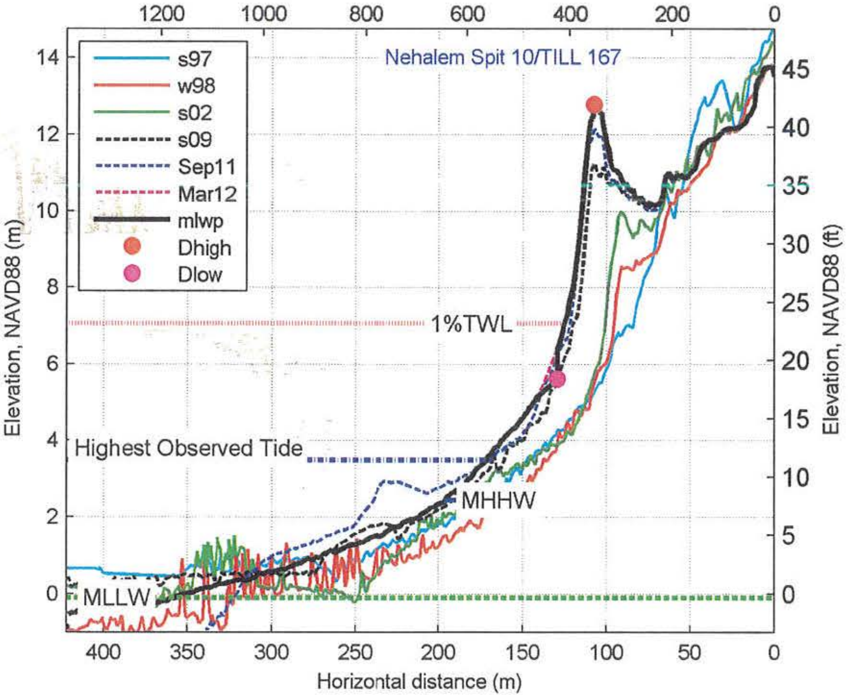
**fm_neh 8**



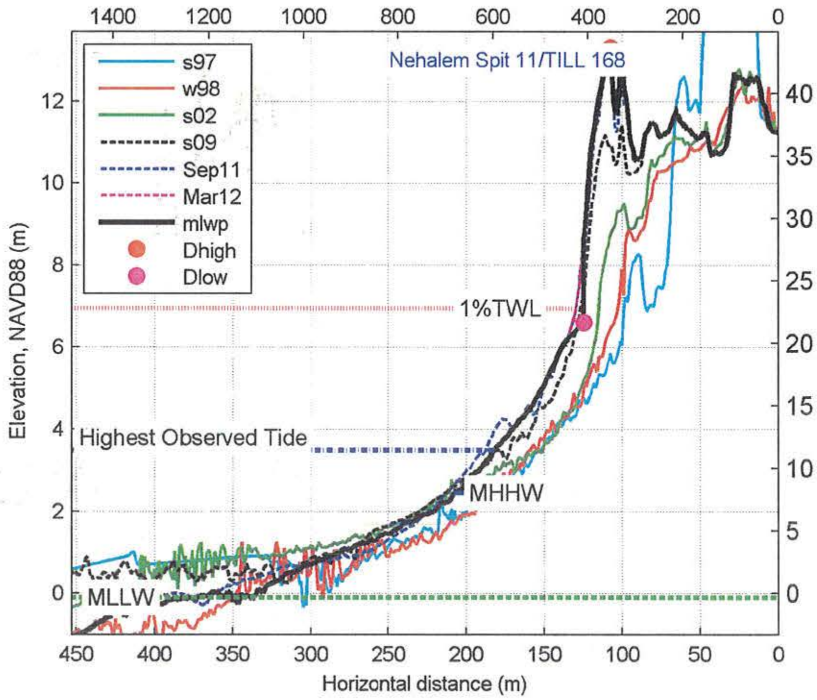
**fm_neh 9**



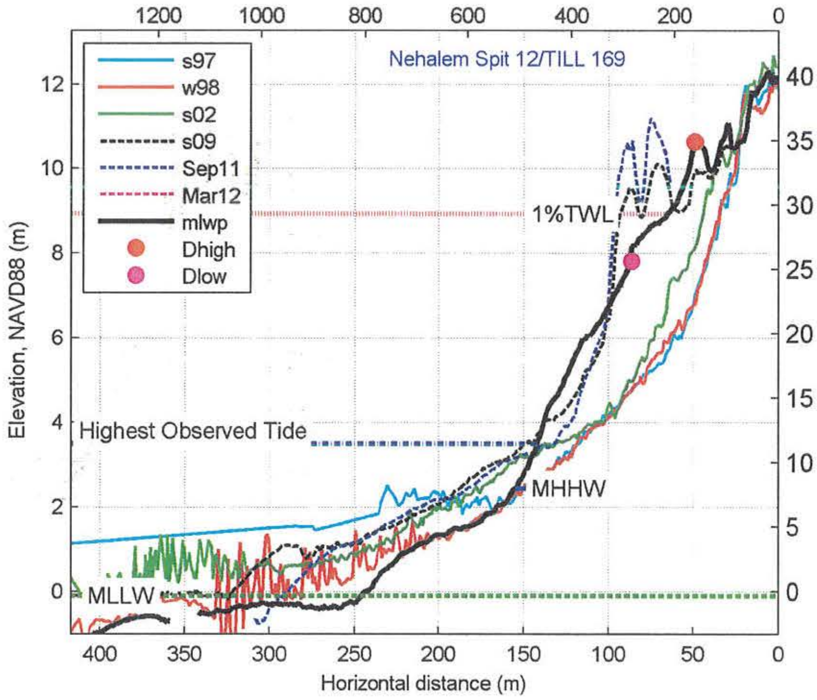
**fm_neh 10**



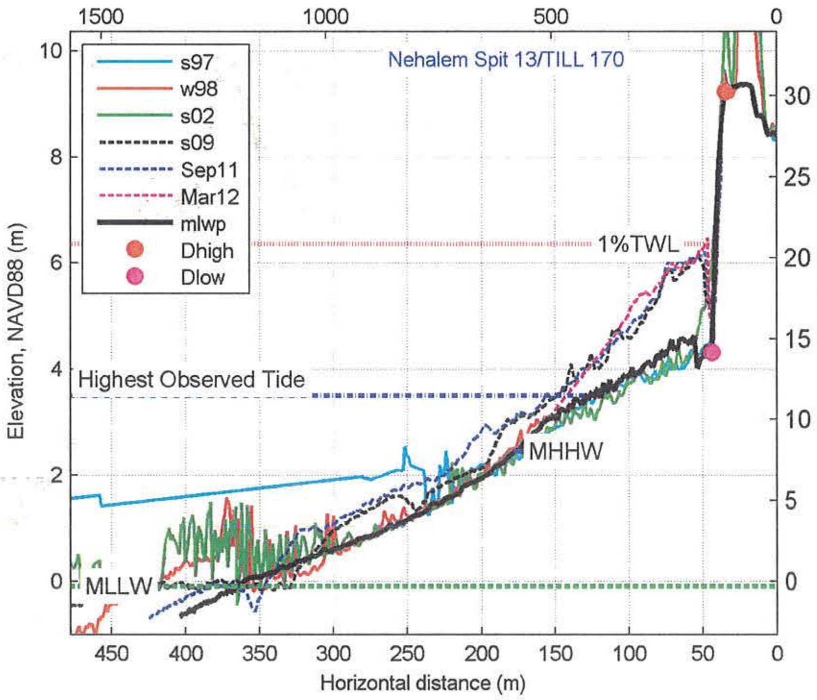
**fm_neh 11**



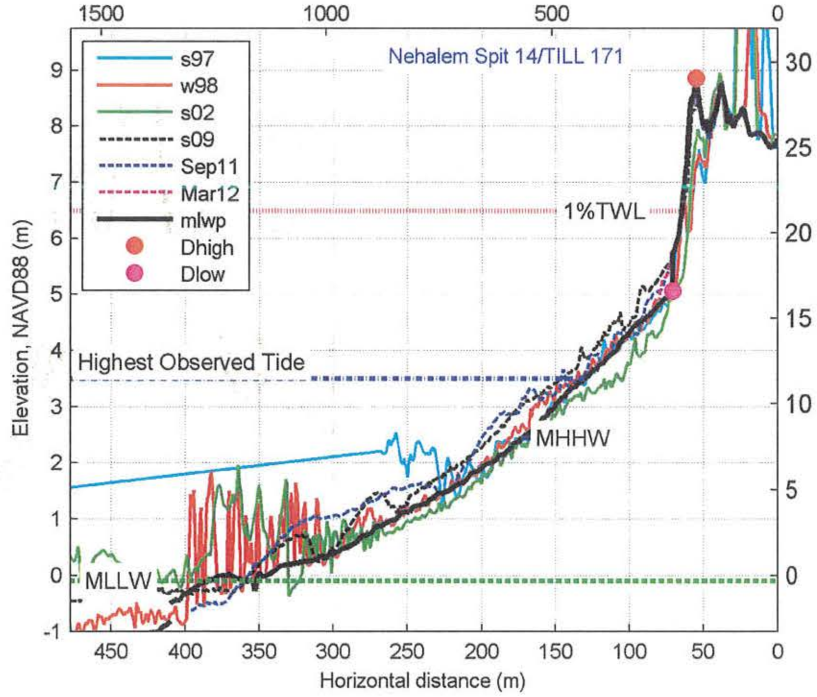
**fm_neh 12**



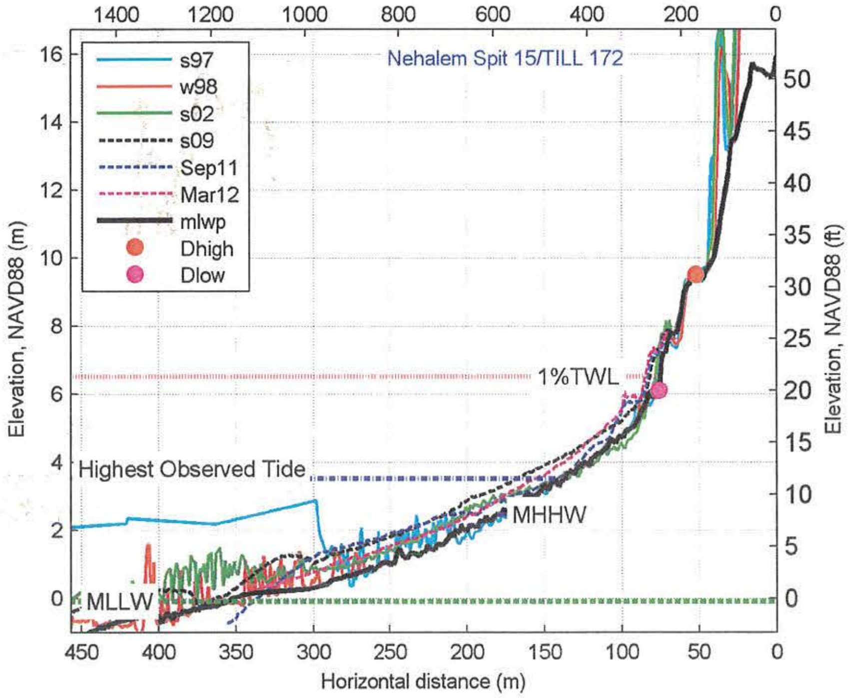
**fm_neh 13**



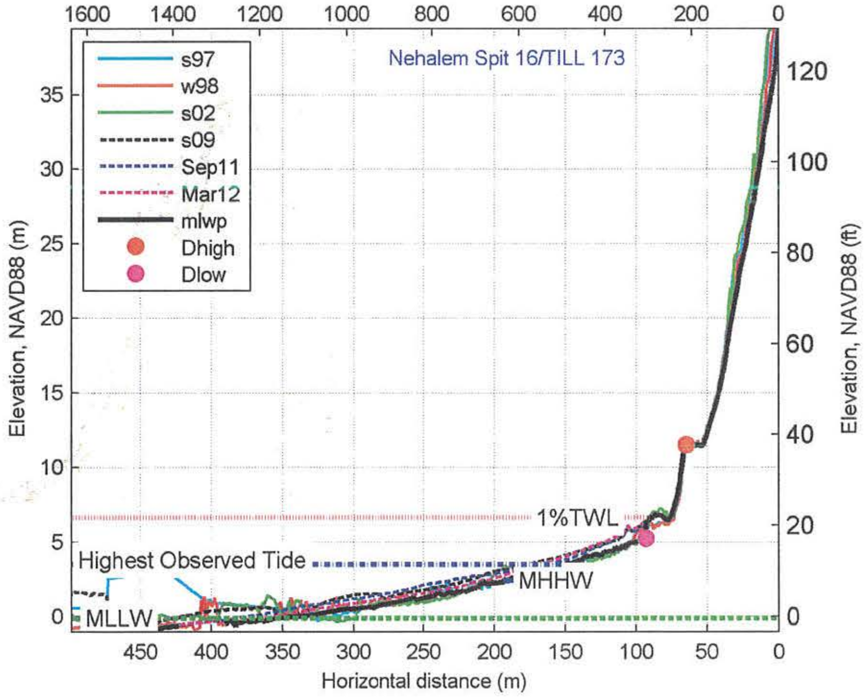
**fm_neh 14**



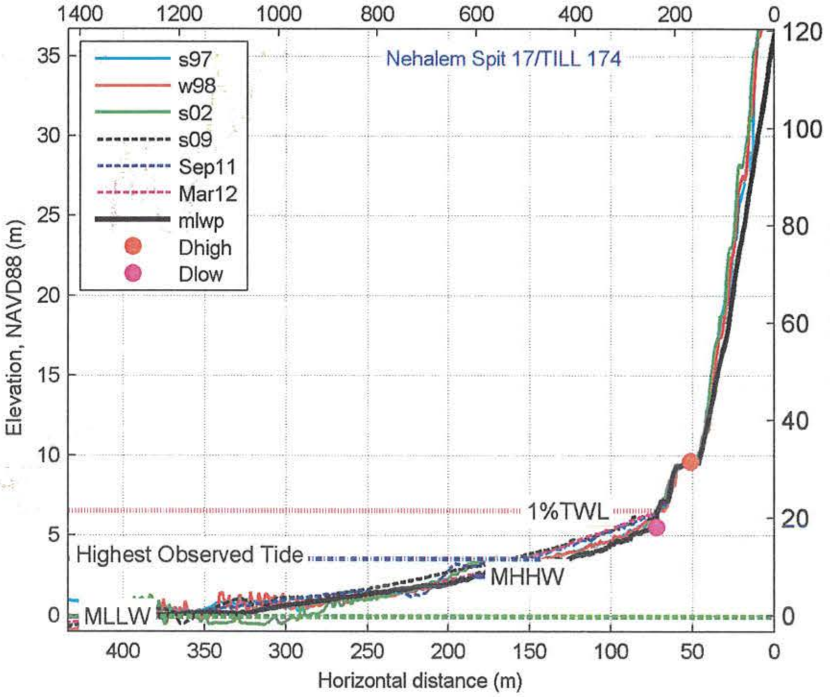
**fm_neh 15**



**fm_neh 16**



**fm_neh 17**



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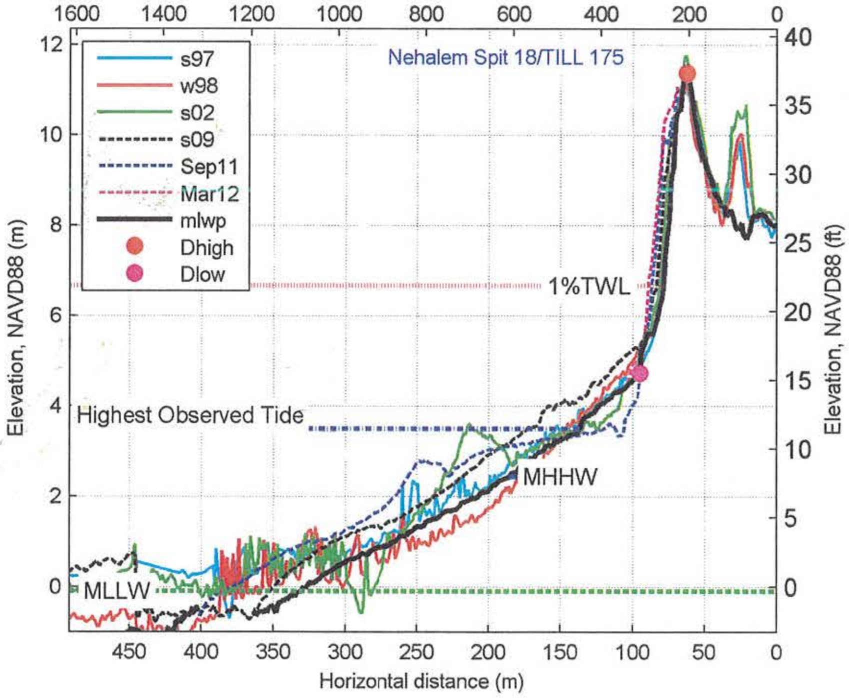

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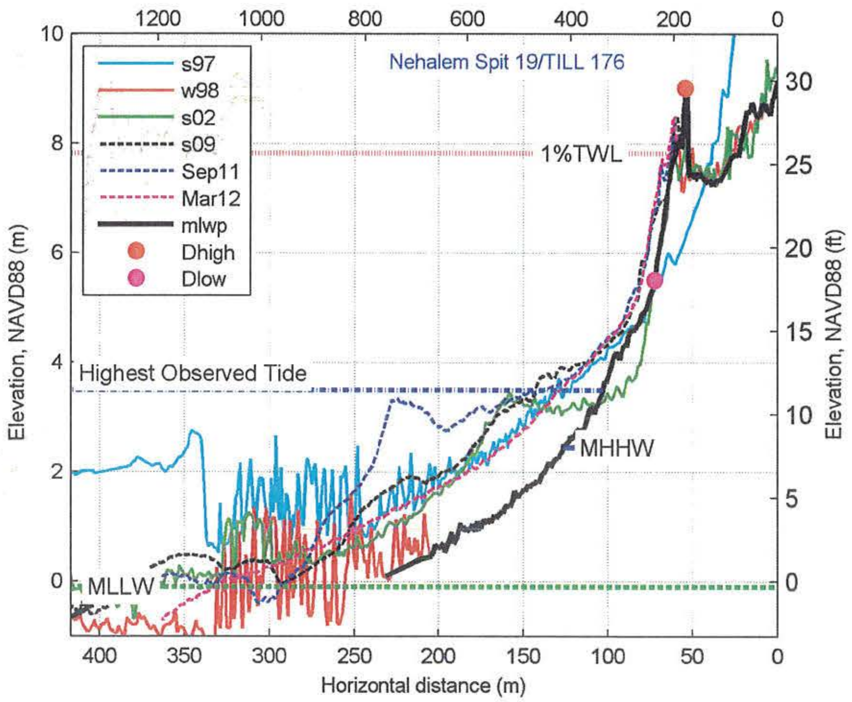

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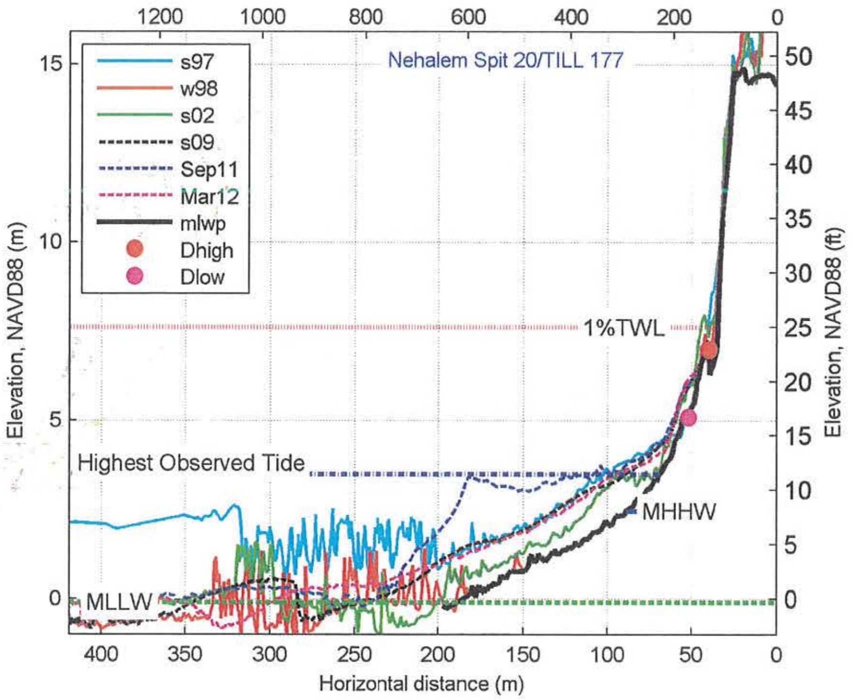

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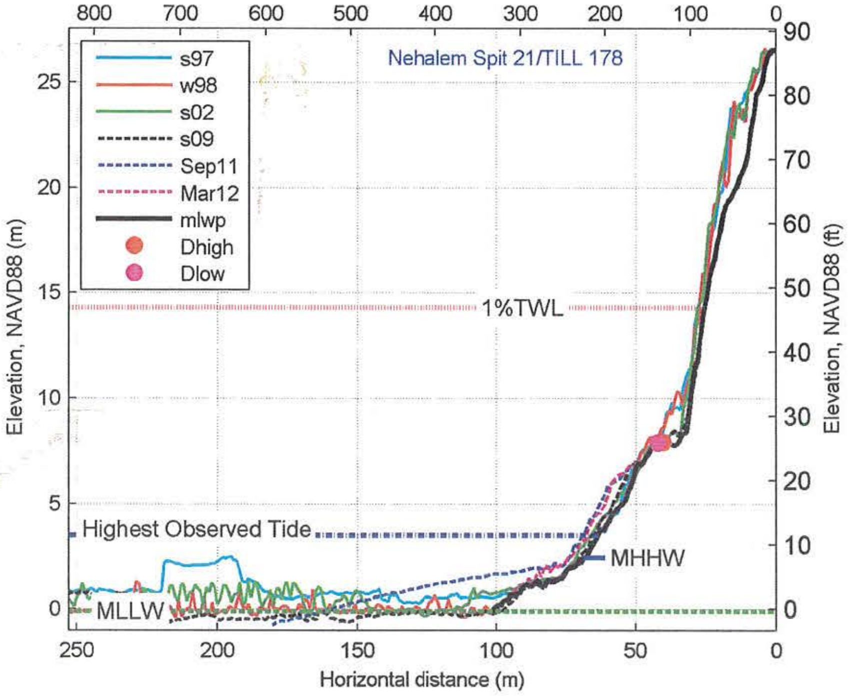
Nehalem Spit 21/TILL 178
s97
w98
s02
s09
Sep11
Mar12
mlwp
Dhigh
Dlow
1%TWL
Highest Observed Tide
MHHW
MLLW
800
700
600
500
400
300
200
100
0
90
80
70
60
50
40
30
20
10
0
25
20
15
10
5
0
250
200
150
100
50
0
Horizontal distance (m)
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)

## 11.5 Appendix D: Supplemental Transect Overtopping Table

| **Profiles** | **Transect** | **Dist_3 (≥0.91 m)** | **Dist_2 (>0.61 <0.91 m)** | **Dist_1 (≤0.31 m)** | ***h*V2 > 5.7 m3/s2 (m)** | **Comment** |
|---|---|---|---|---|---|---|
| Neskowin | TILL 2_3524 | | | | | Mapped to $D_{high}$ |
| | TILL 2_3521 | | | | | Mapped to splashdown distance |
| | TILL 2_3517 | | | | | Mapped to splashdown distance |
| | TILL 3_3514 | | | | | Mapped to $D_{high}$ |
| | TILL 3_3508 | | | | | Mapped to $D_{high}$ |
| | TILL 3_3506 | | | | | Mapped to $D_{high}$ |
| | TILL 3_3504 | | | | | Mapped to $D_{high}$ |
| | TILL 3_3502 | | | 24.98 | 47.03 | Mapped overtopping |
| Netarts | TILL 79_2035 | 6.08 | 45.44 | 96.74 | 151.89 | Mapped overtopping |
| | TILL 79_2033 | | | | | Forced transition from overtopping at TILL 79_2035 to meet the PFD |
| | TILL 135_857 | | | | | Mapped to $D_{high}$ |
| | TILL 135_856 | | | | | Mapped to $D_{high}$ |
| | TILL 147_783 | | | | | Mapped to $D_{high}$ |
| | TILL 147_778 | | | | | Mapped to $D_{high}$ |

## Allison Hinderer

**From:** Sarah Mitchell <sm@klgpc.com>
**Sent:** Tuesday, July 27, 2021 2:23 PM
**To:** Sarah Absher; Allison Hinderer
**Cc:** Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
**Subject:** EXTERNAL: RE: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence (Part 6 of 6)
**Attachments:** Exh 3 - DOGAMI O-20-04 Report.pdf

**Importance:** High

[**NOTICE:** This message originated outside of Tillamook County -- **DO NOT CLICK** on **links** or open **attachments** unless you are sure the content is safe.]

Please include the attached in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing. This is part 6 of 6.

As I mentioned below, we will also be submitting additional items later this afternoon for inclusion in the record and the BOCC packet, so would you please keep an eye out for those as well? Thank you very much.

Best,
Sarah

KELLINGTON
LAW GROUP

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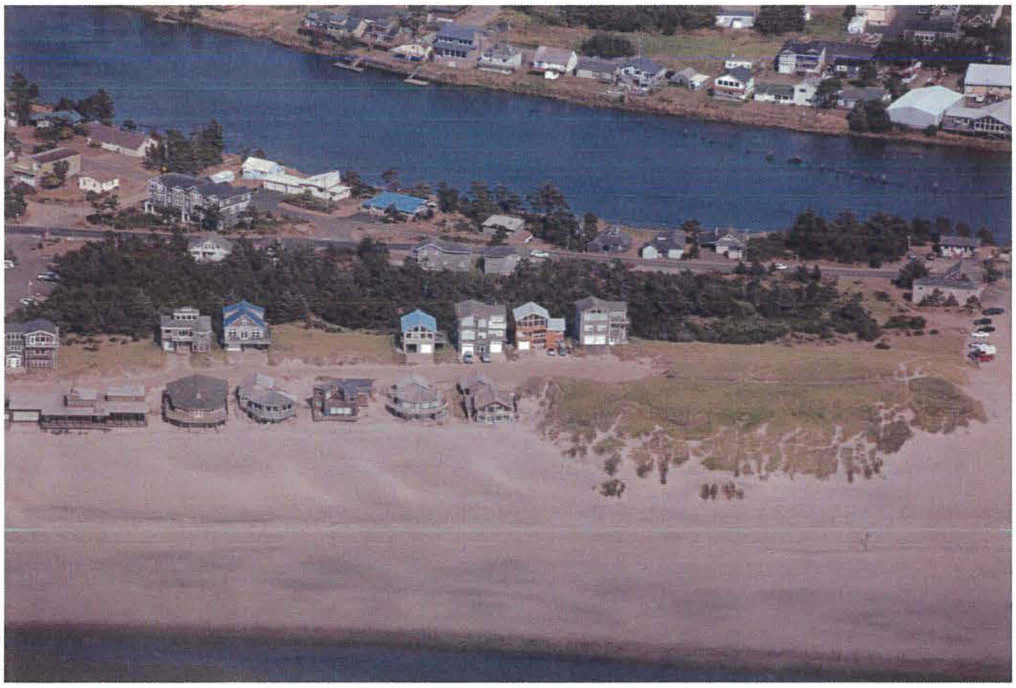
State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

### OPEN-FILE REPORT O-20-04

# TEMPORAL AND SPATIAL CHANGES IN COASTAL MORPHOLOGY, TILLAMOOK COUNTY, OREGON

by Jonathan C. Allan[1]



2020

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[1] Oregon Department of Geology and Mineral Industries, Coastal Field Office, P.O. Box 1033, Newport, OR 97365

## DISCLAIMER

This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information. This publication cannot substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from the results shown in the publication.

*Cover photograph: Contemporary and historical dune development at Pacific City, Tillamook County. Photo taken by E. Harris, August 12, 2011.*

## WHAT'S IN THIS REPORT?

New lidar based mapping along the Tillamook County coast provides updated spatial extents of beaches and dunes that may be subject to existing and future storm-induced wave erosion, runup, overtopping, and coastal flooding. Side-by-side maps of the spatial extent of beaches and dunes in 1975 and now show changes that have taken place. These data will help communities implement Oregon Statewide Planning Goal 18: Beaches and Dunes.

Oregon Department of Geology and Mineral Industries Open-File Report O-20-04
Published in conformance with ORS 516.030

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https://www.oregongeology.org
https://oregon.gov/DOGAMI/

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## GEOGRAPHIC INFORMATION SYSTEM (GIS) DATA

*See the digital publication folder for files.*
*Geodatabase is Esri® version 10.1 format. Metadata is embedded in the geodatabase and is also provided as a separate .xml format file.*

**tillamook_dune_geodb.gdb:**
  **Feature dataset: dune_polygons**
    *feature classes:*
      *BeachesandDunes_orcoast_original* (polygon)
      *BeachesandDunes_revised_tillamook_2020* (polygon)

Beaches & Dunes 2020.lyr – layer file providing symbology for the feature class *BeachesandDunes_revised_tillamook_2020*

## ABSTRACT

The objective of this study was to produce updated information on the spatial extent of beaches and dunes in Tillamook County that may be subject to existing and future storm-induced wave erosion, runup, overtopping, and coastal flooding. These data are of importance to the Department of Land Conservation and Development and the seven coastal counties of Oregon in order to implement Statewide Planning Goal 18: Beaches and Dunes.

Oregon Statewide Planning Goal 18 requires local jurisdictions adopt a beach and dune overlay zone in their comprehensive plan, which may be used to manage development on or near beaches and dunes. Regional mapping of the coastal geomorphology of the Oregon coast to define the extent of its beaches and dunes was originally undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service (USDA, 1975). However, in the intervening 45 years, much has changed on the coast. Of particular importance has been the proliferation of European beach grasses that have helped stabilize many coastal dune systems, while many areas of the Tillamook County coastline have experienced significant erosion, especially since the late 1970s. In addition, new technologies such as lidar are now providing unprecedented levels of detail, enabling scientists to more accurately map the spatial extents of both the contemporary and historical foredune systems. These three factors combined necessitate that the USDA (1975) overlay zone be updated to reflect contemporary conditions. As a result of the updated mapping, our analyses indicate the following broad-scale changes:

- Overall, areas defined as open sand (OS) have decreased by about ~67% since the 1970s, from 2,335 acres to 767 acres. Most of this change can be directly attributed to anthropogenic effects, particularly the introduction of European beach grass (*Ammophila arenaria*) as well as stabilization from shore pine (*Pinus contorta*) and other native plant species.
- Areas subject to existing coastal hazards, which include active foredunes (FDA) and, new in 2020, reactivated foredunes (FDR), indicate an overall slight increase in their spatial extent. However, within discrete sections of the littoral cells, some areas have experienced significant loss of active foredunes, including the Rockaway Beach area, followed by Nestucca Spit and Nehalem Spit.
- Areas classified as recently stabilized foredune (FD) have seen a significant expansion (~45% increase) in spatial coverage, increasing from ~287 acres in the 1970s to ~522 acres in 2020. Consistent with the changes seen on active foredunes, the increase in stabilized foredunes can be attributed to the proliferation of dune grasses and other native trees and shrubs.

## 1.0 INTRODUCTION

The Oregon Department of Land Conservation and Development (DLCD) and Tillamook County Department of Community Development commissioned the Oregon Department of Geology and Mineral Industries (DOGAMI) to undertake detailed mapping of beach and dune features in Tillamook County. The purpose for such mapping is to produce updated information on the extent of the contemporary beach and foredune system that may be subject to future storm-induced erosion, runup, overtopping, and coastal flooding. These data are of importance to DLCD and the county in order to improve implementation of Statewide Planning Goal 18: Beaches and Dunes (https://www.oregon.gov/lcd/OP/Pages/Goal-18.aspx). Specifically, Oregon Statewide Planning Goal 18 requires that local jurisdictions adopt a beach and dune overlay zone in their comprehensive plan, which may be used to manage development on or near such features.

Regional mapping of the beaches and dunes of the Oregon coast was originally undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service (U.S. Department of Agriculture Soil Conservation Service [USDA], 1975). However, much has changed along the Oregon coast over the past 45 years, so the original maps are both inaccurate and importantly lack sufficient resolution to support current land use planning efforts. Some of the largest changes to have taken place along the coast include:

- The rapid expansion of European beach grass (*Ammophila arenaria*), which has helped to stabilize many dune systems;
- Encroachment of human development into foredune areas;
- Dune management activities such as foredune grading and planting;
- Changes in beach and dune morphology due to either coastal erosion or accretion;
- Construction of coastal engineering used to mitigate erosion hazards; and,
- Shoreline changes at the mouths of estuaries controlled by jetties.

Accordingly, the purpose of this project is to produce modern maps of beach and dune features along the Tillamook County coastline, defined in a geographical information system (GIS) and informed by historical and contemporary aerial photographs, airborne lidar, coastal erosion and FEMA flood modeling (Allan and others, 2015), and recent coastal change analyses and monitoring undertaken along the beaches of the county (Allan and Priest, 2001; Allan and Hart, 2007, 2008; Allan and others, 2009; Allan and Harris, 2012). Although the geospatial data used today to define the various mapping units are much improved, the original USDA (1975) nomenclature consisting of 12 core mapping units is retained, and in some cases is modified or refined. Finally, it is recognized that the six other Oregon coastal counties face similar challenges with beach and dune overlays that are presently outdated. Accordingly, the mapping and accompanying report undertaken for Tillamook County may be used as a framework for similar mapping of beaches and dunes in these coastal counties.

## 2.0 COASTAL GEOLOGY AND GEOMORPHOLOGY

Tillamook County is located on the northwest Oregon coast, between latitudes 45° 45′ 49.49″ N (Cape Falcon) and 45° 3′ 54.88″ N (Cascade Head), and longitudes 124° 1′ 15.57″ W and 123° 17′ 59.88″ W (**Figure 1**). The terrain varies from low-elevation sandy beaches and dunes on the coast to elevations over 1,000 m (e.g., Rogers Peak reaches 3,706 ft [1,130 m]) farther inland. The coastal strip is approximately 65 miles (104 km) in length and varies in its geomorphology from broad, low-sloping sandy beaches backed by dunes, to beaches backed by engineered structures, cobble and boulder beaches adjacent to the headlands, and cliff shorelines (Allan and others, 2015). In these areas sand entrained by wind is carried up into the dunes where the sand becomes trapped by plants (primarily beach grass). Where vegetation is absent or sparsely present, the dunes are able to drift in response to the prevailing wind direction. In some areas, the drifting dune sand can become a nuisance as the sand accumulates in and around coastal properties, while in other areas the migrating dune may engulf buildings, contributing to their eventual destruction (Komar, 1997).

The formation of dunes is dependent on three simple requirements:

- A sufficient supply of sediment;
- A prevailing wind. Wind speed is especially important as strong winds entrain and mobilize sediments across the beach and carry sand up into the developing dunes. Wind direction is also important as it governs the types of dunes that could develop; and,
- Obstacles to trap the sand such as woody debris, vegetation, and micro-topography.

Where sediment supply is sufficient, dunes provide effective coastal protection and at a significantly lower cost when compared with coastal engineering structures (Woodhouse, 1978). Along the Tillamook County shoreline, the bulk of the coastline is dominated by barrier spits, backed by dunes of varying ages. In recent decades, however, parts of the coast have experienced significant coastal erosion, requiring the construction of coastal engineering in order to mitigate the erosion hazards (e.g., Neskowin, Pacific City, and Rockaway Beach).

Prominent headlands formed of resistant basalt (e.g., Cascade Head, Cape Meares, Cape Lookout, and Neahkahnie Mountain) provide natural barriers to alongshore sediment transport (Komar, 1997), effectively dividing the Tillamook County coastline into four littoral cells (**Figure 1**). These are:

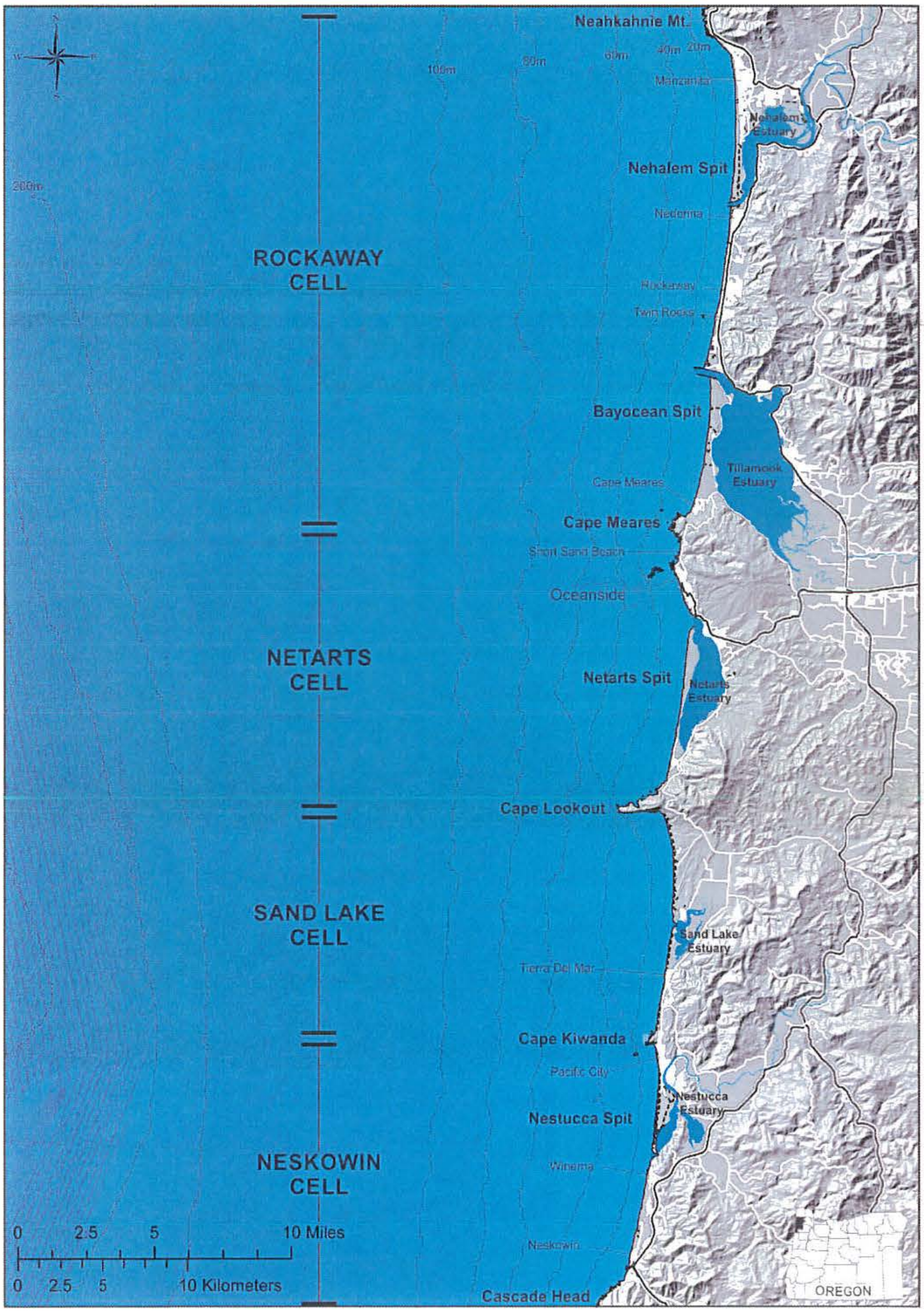
- Neskowin (~ 8.9 miles [14.3 km]), extends from Cascade Head to Cape Kiwanda;
- Sand Lake (~ 8.2 miles [13.2 km]), extends from Cape Kiwanda north to Cape Lookout;
- Netarts (~ 9.9 miles [15.9 km]), extends from Cape Lookout to Cape Meares; and,
- Rockaway (~ 17.5 miles [28.2 km]), extends from Cape Meares to Neahkahnie Mountain in the north.

Each of these cells is further divided into a series of subcells due to the presence of five estuaries (from south to north: Nestucca, Sand Lake, Netarts, Tillamook, Nehalem), two of which (Tillamook and Nehalem) are stabilized by prominent jetties (**Figure 1**). The county also is characterized by several major rivers (Nestucca, Nehalem, Miami, Tillamook, Trask, Kilchis, and Wilson Rivers) that terminate in the estuaries. Due to their generally low flows and the terrain they are eroding, these rivers carry little beach sediment out to the open coast but instead deposit most of their sediment in the estuaries (Clemens and Komar, 1988). Hence, the beaches of Tillamook County receive very little sediment along the coast today other than from erosion of the backshore.

## 2.1 Local Geology

The predominant geologic unit along coastal Tillamook County consists of latest Holocene beach sand present along the full length of the coastline (Cooper, 1958). Interspersed between the sand are invasive basalt bodies of the Miocene Columbia River basalt, such as Neahkahnie Mountain at the northern end of the county coastline, and flows of Columbia River Basalt that form the prominent headlands such as at Cape Meares and Cape Lookout (Schlicker and others 1972; Wells and others, 1994, 1995; Smith and Roe, 2015). These latter rocks are described as fine grained. In all cases, rockfalls and landslides in these latter units are actively providing new material (gravel and cobbles) to the beaches, albeit at relatively slow rates. These failures contribute to the formation of extensive cobble and boulder berms, which accumulate along their northern/southern flanks, where beaches have merged up against the headlands (Allan and others, 2006).

**Figure 1. Location map of the Tillamook County coastline, including key place names.**



South of Cape Lookout and north of the Sand Lake estuary, part of the beach is backed by bluffs, which have an average height of 24 m (Allan and Harris, 2012) and consist of medium-grained sandstone and interbedded siltstone of the Astoria Formation. Adjacent to the bluffs, sand dune sheets have accreted and ramped up against the marine terraces, before spilling over and inundating large areas in landward of the bluffs. Astoria Formation sandstone and siltstone also characterize the geology of Cape Kiwanda, adjacent to Pacific City. Eocene-Oligocene basaltic sandstone of the Alsea Formation is also prominent along a small section of the coast adjacent to Porter Point, located just south of the Nestucca estuary mouth. These sediments are massive basaltic sandstone that is predominantly fine to medium grained (Schlicker and others, 1972; Wells and others, 1994, 1995; Smith and Roe, 2015).

The contemporary beach and dune system characteristic of Tillamook County is, in geologic terms, young, having begun to form around 5,000–7,000 years ago, as the rate of post-glacial sea level rise slowed as it approached its current level (Komar, 1997). At this stage the prominent headlands would have begun to interrupt sediment transport, leading to the formation of barrier spits and beaches within the headland-bounded littoral cells.

Much of the beach sand present on the beaches of Oregon consists of grains of quartz and feldspar. The beaches also contain small amounts of heavier minerals (e.g., garnet, hypersthene, augite, and hornblende), which can be traced to various sediment sources along the Pacific Northwest coast (Clemens and Komar, 1988). Concentrations of augite, a product of erosion of the volcanic rocks present throughout the county, are especially abundant along the Tillamook County coast. This suggests that at the time, rivers and streams were carrying these sediments out to the coast where they mixed with other sediments. It is possible that concentrations of augite likely increased during the past 150 years as human settlement accelerated, leading to increased deforestation (Peterson and others, 1984; Komar and others, 2004), which correspondingly contributed to increased sediment loads in the various rivers. However, although some of these sediments reached the open coast, the bulk of the sediments are retained in the estuaries due to generally low discharge levels characteristic of the rivers (Komar and others, 2004).

Prior to the 1940s, many of the barrier spits were devoid of significant vegetation. With the introduction of European beach grass (*Ammophila arenaria*) in the early 1900s and its subsequent proliferation along the Oregon coast, the dunes and barrier spits eventually stabilized. The product today is an extensive foredune system, which consists of large "stable" dunes containing significant volumes of sand. Accompanying the stabilization of the dunes, humans have settled on them, building in the most desirable locations, typically on the most seaward foredune.

## 3.0 METHODOLOGY

An initial meeting was held with DLCD staff to discuss the overall study approach. This included evaluating the existing Beach and Dune Overlay Zone in a geographical information system (GIS), developed by DLCD from the original 1975 mapping. These data were used to establish the baseline on which the updated GIS layer was developed. **Table 1** identifies the key beach and dune classifications that are used in the revised mapping, including their accompanying DLCD classification where applicable, and derived originally from USDA (1975). In addition, we define six new classifications in **Table 1**, including:

- Artificial Active Foredune (AFDA) – An artificial foredune constructed from geotextile sand bags and planted with dune grass. This category is unique to Cape Lookout State Park where such a structure was constructed;
- Reactivated foredune (FDR) – In several areas the existing foredune has been:

1. completely removed such that coastal processes are presently eroding into the previously stabilized foredune (FD); and,
2. extreme total water levels are expected to inundate portions of the backshore (e.g., FD or DS) landward of the active foredune (FDA). The latter results are based on the work of Allan and others (2015).

- Coastal Landslides (LD) – Derived from coastal landslide mapping undertaken by Allan and Priest (2001), as well as more recent landslide failures observed and documented by the author;
- Fluvial and Estuarine Deposits (FED) – Defined from geologic mapping undertaken by Wells and others (1994) and compiled in the Oregon Geologic Database Compilation (OGDC-6; Smith and Roe, 2015). The OGDC is a digital geologic map and database covering the entire state and depicting the best available geologic mapping in any location;
- Coastal Lakes (LK) from e.g., ; and,
- Wetland (WL) – These data stem from the National Wetlands Inventory (https://www.fws.gov/wetlands/) compiled by the U.S. Fish and Wildlife Service (USFWS).

These latter classifications simply help to better define additional geographic and geologic features evident along the Tillamook County coastline but not explicitly addressed by USDA (1975). Definitions of the original mapping nomenclature are described by USDA (1975) and are not repeated here.

**Table 1. Beach and dune overlay zone nomenclature (after USDA, 1975).**

| Associated Dune Category | Inventory Classification | DLCD Classification | Mapping Unit |
|---|---|---|---|
| Active Beach and Foredune | beach | Beach | B |
| | active foredune | Foredune, Active | FDA |
| | active dune hummocks | Hummocks, Active | H |
| Recently Stabilized Dunes | recently stabilized foredune | Foredune, Conditionally Stable | FD |
| | inland foredune | | IFD |
| | dune complex | Dune Complex | DC |
| | younger stabilized dunes | Dune, Younger Stabilized | DS |
| Older Stabilized Dunes | older stabilized dunes | Dune, Older Stabilized | ODS |
| Inland Dunes | open dune sand | Dune, Active/Dune, Parabolic | OS |
| | open dune sand conditionally stable | Dune, Conditional Stable | OSC |
| | active inland dune | Dune, Active | AID |
| Interdune Forms | wet interdune | Interdune | W |
| | wet deflation plain | Deflation Plain | WDP |
| | wet mountain front | | WMF |
| Estuary | wet surge plain | | WSP |
| | wet flood plain | | WFP |
| Other | coastal terrace | | CT |
| | **New:** | | |
| | artificial active foredune | | AFDA |
| | reactivated foredune (subject to erosion/flooding) | | FDR |
| | coastal landslide | | LD |
| | fluvial and estuarine deposits | | FED |
| | lake | | LK |
| | wetland | | WL |

## 3.1 Previous Coastal Hazard Studies

Because the foundation of the Beach and Dune Overlay Zone reflects those areas subject to active coastal change (either erosion or accretion), and/or may be impacted by storm wave runup, overtopping, and flooding, the revised mapping undertaken here was strongly guided by existing information available from a number of recent coastal investigations. These include coastal erosion hazard studies (Allan and Priest, 2001; Stimely and Allan, 2014), beach and shoreline monitoring efforts undertaken along the Tillamook County coastline (Allan and Hart, 2007, 2008) and continuing (e.g., http://nvs.nanoos.org/BeachMapping), analyses of lidar data (Allan and Harris, 2012), and recently completed geomorphic, erosion analyses, coastal flood modeling, and mapping (Allan and others, 2015).

## 3.2 Lidar

Beach and dune morphology was mapped for this study largely from light radar (lidar) data collected by DOGAMI in 2009. Lidar is a remote sensing technique consisting of x, y, and z values of land topography that are derived using a laser ranging system and geo-located using an onboard Real-Time Kinematic Differential Global Positioning System (RTK-DGPS). The lidar data have a vertical accuracy of ~0.1 m (0.3 ft), while the horizontal accuracy is ~1 m (3 ft). Because lidar collected by DOGAMI consisted of multiple laser returns, processing of these data enabled the production of bare-earth rasters of the ground surface; i.e., the vegetation was able to be stripped off, leaving just the ground elevation.

Analyses of these data were previously undertaken by Allan and Harris (2012) in order to define various beach, dune, and bluff morphological characteristics (e.g., tidal-datum based shorelines, cross-sections, and a variety of geomorphic features including the beach-dune toe, foredune toe, dune crest, dune heal, bluff toe, and bluff crest). These data were subsequently refined and updated by Allan and others (2015). Additional information concerning post-2009 beach and shoreline changes were determined from lidar collected in 2016 on behalf of the USGS, from recent observations of beach profile and shoreline changes measured using RTK-DGPS by DOGAMI staff (e.g., http://nvs.nanoos.org/BeachMapping), and from modern aerial images of the coastline.

## 3.3 Aerial Imagery

Although lidar is the foundation on which the geomorphic mapping is based, valuable geomorphic information may also be gleaned from analyses of repeat aerial photographic imagery of the coast collected over the last century.

The earliest compilation of aerial photographs of Oregon coast was undertaken in 1939 by the U.S. Army Corps of Engineers. Unfortunately, the images are simply stereo (pairs) images that have never been rubber-sheeted or ortho-rectified. Orthorectification is an approach used to process imagery in order to account for optical distortions (e.g., tilt or relief) with the goal of yielding an image that is planimetrically correct that is fixed to a geospatial coordinate system, enabling the data to be viewed and analyzed in GIS.

In order to rubber-sheet the images, the 1939 aerial photographs were added to ArcGIS and processed using the Georeferencing suite of tools. This is accomplished by identifying common ground control points (e.g., road junctions, bridges, buildings, rock outcrops) that can be identified in the 1939 images and in contemporary (1994, 2000, 2004, 2009, 2014, 2016) orthorectified images (or lidar) collected for the State of Oregon. Using this approach, twenty-six 1939 photos were able to be georeferenced for Tillamook County, enabling comparisons to be made against modern images of the coastline and from lidar. These data were extremely useful for understanding early historical changes in the morphology of the barrier spits, including the proliferation of dune grasses on the dunes and their subsequent stabilization of the dunes.

Imagery acquired by the Oregon Department of Transportation (ODOT) in 1967 (Ruggiero and others, 2013) was also examined. These aerial photographs extend along the entire coast of Oregon and reflect a collection of 1,611 photographs along roughly 50 to 60 flight paths for the open ocean beaches (no bays). The photographs were taken at 1:6,000 scale, such that 1 inch on the photograph is 500 ft (152 m) on the ground. The images were originally processed and orthorectified for DOGAMI by the Washington Department of Ecology using Leica Photogrammetry Suite, controlled by a digital elevation model developed from 2002 lidar data.

## 3.4 Wet Interdunes

The USDA (1975) beach and dune mapping identified many areas among the dunes as either *Wet Deflation Plain*, *Wet Mountain Front*, or *Wet Interdune*. These sites reflect areas characterized by high water tables such that the areas are either underwater or are seasonally covered in water. In the large majority of cases, these classifications are analogous to areas delineated as "wetland." To that end, the USFWS National Wetland Inventory[1] was downloaded for Oregon and examined in a GIS. Identified wetlands were added to the revised beach and dune overlay.

## 3.5 Estuary Shoreline and Storm Flood Water Level

The USDA (1975) beach and dune mapping include two additional geospatial attributes defined as the *Wet Surge Plain* and *Wet Flood Plain*. The *Wet Surge Plain* was defined by USDA (1975) as the area between the lowest and highest tides within an estuary and delineated as the drift line; no additional explanation is provided as to how the drift line was identified, such as from aerial imagery or early National Ocean Service (NOS) topographic "T" Sheets. The *Wet Flood Plain* is essentially that area that can be reasonably expected to be inundated under a flood condition. Again, no specific information is provided that describes how it was mapped.

For the purposes of the revised mapping, a more refined approach involved adopting a tidal datum-based shoreline and then extrapolating the defined tidal shorelines from lidar. For the *Wet Surge Plain*, we used an elevation of 7.9 ft (2.4 m, relative to NAVD88), which equates to the Mean Higher High Water (MHHW) tidal datum defined for the Garibaldi tide gauge station by NOAA NOS. The NOS defines MHHW as "the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch"[2] and is a reasonable approximation for the *Wet Surge Plain*. For the *Wet Flood Plain*, we used an elevation of 11.5 ft (3.5 m, relative to NAVD88), which equates to the highest observed tidal elevation at the same gauge. This latter elevation reflects a storm flood, whereby the elevated water levels are a function of the combined effects of high tide, plus a storm surge component, plus riverine flooding. In both cases, contours for the predefined elevations were extracted from 2009 DOGAMI lidar data.

In a number of areas, changes in the configuration of the estuary have occurred since the lidar data were collected in 2009, necessitating a need to adjust the boundary of the *Wet Surge Plain*. This was achieved by using recently collected digital ortho imagery (e.g., 2016) to evaluate any spatial changes that may have ensued in the estuary shoreline between 2009 and 2016.

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[1] https://www.fws.gov/wetlands/Data/State-Downloads.html

[2] https://tidesandcurrents.noaa.gov/datum_options.html

# 4.0 RESULTS

The primary results associated with this latest mapping effort is contained in an Esri geodatabase "tillamook_dune_geodb.gdb". The feature dataset file "BeachesandDunes_revised_tillamook_2020" contains the updated geospatial information and includes the following key attributes: "Codes", "Feature", "Feature_2", "Notes", "Coastal_hazard", and "Cell". This contrasts with the original geospatial overlay, which only included information specific to the codes and feature class. In the updated overlay, 'Codes' and 'Features' are identical to information included in the original mapping. "Feature_2" includes secondary information relating to the feature class (e.g., younger/older deposits, wet (due to ocean flooding) etc.). The "Notes" attribute includes additional information about the respective feature (e.g., pre or post-jetty foredunes) or source information (e.g., landslide data from Allan and Priest (2001) or from field observations). The "Coastal_hazard" attribute includes specific hazard information unique to that feature, including whether it is subject to current wave erosion, runup, overwash and inundation processes, or may be impacted in the near future. Finally, the "Cell" attribute categorizes the geomorphic units by littoral cell or subcell.

Here we will briefly describe and summarize some of the key changes that have taken place along the Tillamook County ocean shore. The approach taken is to focus initially on broad scale changes that can be observed in the landscape, followed by a series of brief qualitative descriptions of changes identified within each littoral cell identified in **Figure 1**.

## 4.1 Countywide Beach and Dune Changes

**Figure 2** presents pie charts depicting changes in the coastal geomorphology of Tillamook County from the 1970s to the present. Data inputs used to generate the pie charts are derived from the change in surface area of the respective geomorphic unit over time; note that USDA (1975) defined "Beach" for only Nehalem and Bayocean Spit and ignored the other areas. The overall focus of **Figure 2** is a subset of the suite of USDA classifications identified in **Table 1**, with emphasis on those geomorphic units closest to the beach and as such directly dependent on coastal and aeolian processes for their formation and evolution. These units include the active foredune (FDA), reactivated foredune (FDR, new in 2020), recently stabilized foredune (FD), dune complexes (DC), hummocks (H), and areas characterized as having open sand (OS). The reason for focusing on these specific units is that they are of greatest significance under Goal 18. The values listed for each pie in **Figure 2** reflect the acreage associated with the six units used here, while the proportions of each pie graphic are based on the sum of the combined acreage of the six units. Thus, Figure 2's significance is less about the actual proportions (which may be of interest), and more about the degree of change that has taken place from one time period to the next. **Table 2** includes cell specific information of the actual change in acreage over the time period for each unit, and expressed as a summary total for the entire county; results shown in Table 2 reflect a smaller subset of the suite of units defined in **Table 1**.

As can be seen in **Figure 2** (left), a significant portion of the county coastline in the 1970s was classified as open sand (totaling ~2,335 acres [9.5 km$^2$]), while the amount of active and stabilized foredune were ~685 and 287 acres respectively. Hummocky terrain and dune complex (essentially a complex mix of different units) made up comparably smaller portions of the county coastline. As a result of anthropogenic effects associated with dune planting (especially *Ammophila arenaria*) and the proliferation of shore pine (*Pinus contorta*) and other coastal shrubs and trees since the 1970s, there has been a significant decrease in the amount of open sand present throughout the county. Overall, **Figure 2** (right) indicates the open sand class has decreased by 67% to ~767 acres in 2020. The bulk of this reflects a shift toward these areas now being reclassified as younger stabilized dunes (DS). Of interest, although the total area of active foredune (FDA) remains essentially unchanged for the entire county (**Figure 2**), changes within individual subcells indicate some loss (Table 2). For example, Rockaway Beach is characterized by the largest decrease in active foredunes (−61 acres), followed by Nestucca Spit and Nehalem Spit. Losses in the Rockaway Beach area are compounded by the fact that previously stabilized dune areas are now being actively eroded into reactivated foredune (FDR), or are subject to wave runup, overtopping, and inundation during extreme storms. Conversely, the proliferation of beach grass (and other anthropogenic effects) throughout the county has resulted in an expansion in recently stabilized foredune (FD), which have seen an increase of ~82%. Similarly, the expansion of dune hummocks (H) and dune complex (DC) throughout the county can be attributed to anthropogenic effects associated with jetty construction (e.g., Bayocean Spit tip) or rehabilitation (e.g., both sides of Nehalem Bay mouth), which resulted in rapid seaward progradation of the shoreline, limiting foredune development in those areas, until such time as the rate of advance slowed and approached equilibrium. In other areas, hummock terrain can be linked with spit breaching such as on Nestucca Spit and mid-way along Bayocean Spit.

Figure 2. Pie charts depicting Tillamook County countywide changes over time for select coastal geomorphic units. Values shown for each pie reflect the acreage of that unit. Note: totals for the 1970s (3,588 acres) and for 2020 (2,656 acres) differ by ~930 acres.

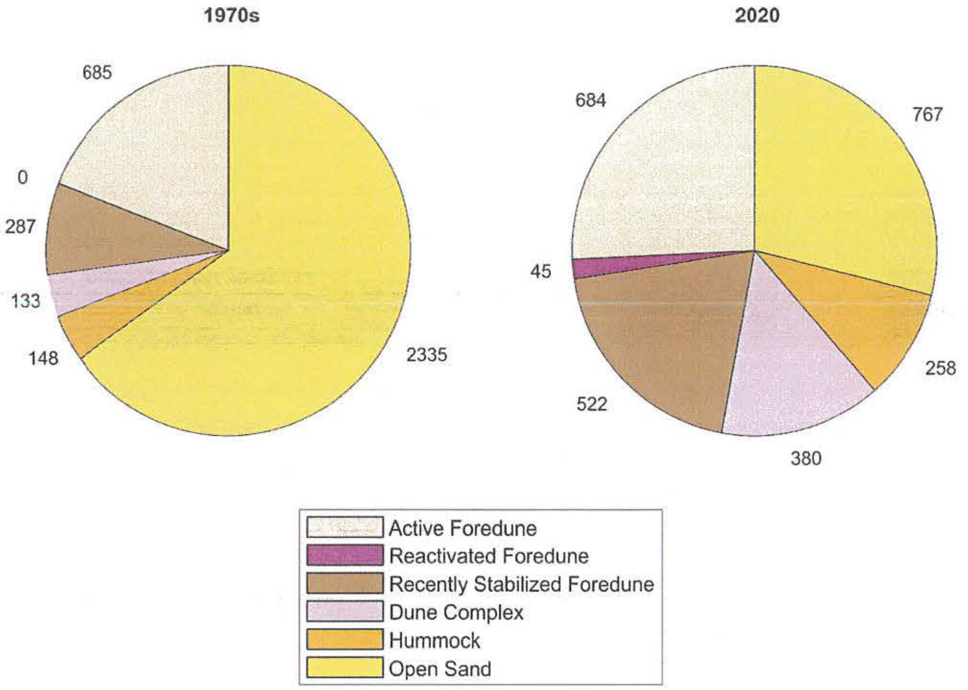


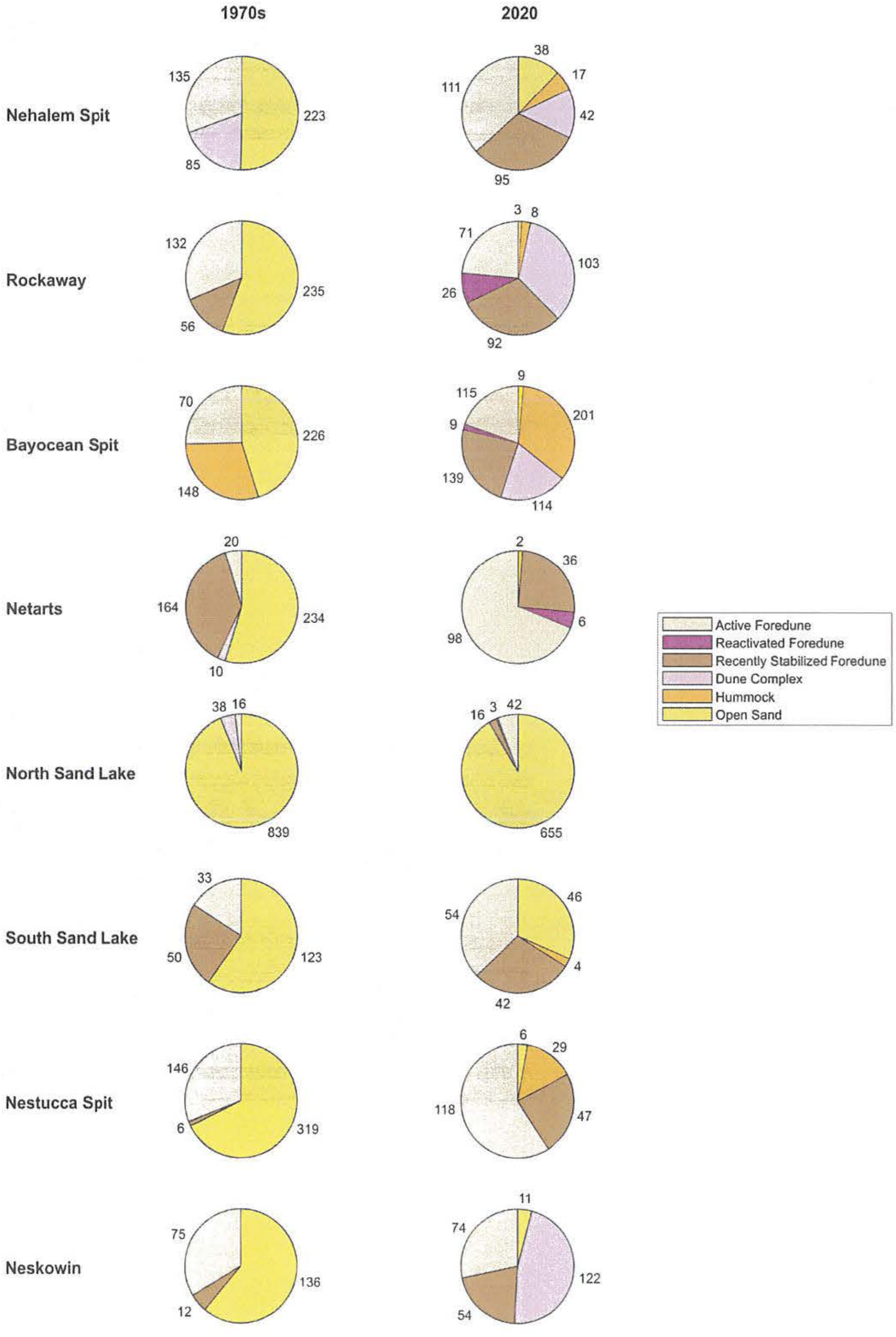
**Table 2. Change in acreage of various coastal geomorphic units identified in Tillamook County from the 1970s to 2020.**

| Code | Description | Nehalem Spit | Rockaway | Bayocean Spit | Netarts Spit | North Sand Lake | South Sand Lake | Nestucca Spit | Neskowin | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| B | Beach | 161.1 | 367.7 | 214.0 | 370.0 | 253.7 | 280.2 | 199.6 | 268.3 | 2,114.6 |
| FDA | Active Foredune | −24.3 | −61.1 | −11.6 | 77.8 | 26.1 | 21.1 | −27.3 | −1.1 | −0.4 |
| FDR | Reactivated Foredune | 0 | 26.4 | 9.1 | 6.4 | 3.3 | 0 | 0 | 0 | 45.2 |
| FD | Recently Stabilized Foredune | 95.4 | 35.8 | 139.1 | −127.5 | 16.2 | −7.8 | 40.9 | 42.5 | 234.6 |
| DC | Dune Complex | −42.2 | 102.7 | 113.5 | −9.9 | −38.1 | 0 | 0 | 121.7 | 247.6 |
| H | Hummocks | 17.1 | 8.1 | 52.5 | 0 | 0 | 3.5 | 28.5 | 0 | 109.6 |
| DS | Younger Stabilized Dunes | 275.3 | 625.2 | −141.7 | 126.4 | 237.7 | −20.9 | −18.2 | 1.4 | 1,085.0 |
| OS | Open Sand | −185.5 | −232.3 | −217.6 | −232.7 | −183.7 | −77.4 | −313.1 | −125.6 | −1,567.9 |
| W | Interdune | −193.8 | 0 | 3.8 | −54.1 | −521.9 | 0 | 0 | 0 | −766.0 |
| WDF | Wet Deflation Plain | 0 | −73.2 | −48.1 | 38.5 | 0 | 18.0 | −179.3 | 0 | −244.3 |
| WMF | Wet Mountain Front | −29.6 | −129.3 | 0 | −59.3 | −195.7 | −82.0 | −69.9 | −147.9 | −713.7 |
| WL | Wetland | 123.2 | 339.7 | 164.1 | 157.7 | 690.3 | 93.9 | 219.8 | 272.7 | 2,061.4 |

## 4.2 Nehalem Spit

Figure 3 presents summary pie charts of the same six geomorphic units identified in Figure 2, but now broken down according to each subcell; values provided are the actual unit acres, while summary changes are provided in Table 2. Figure 4 presents a map showing the complete suite of geomorphic units based on the original mapping (left) compared with present-day conditions (right). Overall, the area designated as active foredune has decreased by 18% (~24 acres) since the 1970s. Much of this change reflects improvements in base map accuracy due to the use of lidar data, coupled with improved geomorphic designation of the primary frontal dune and modeling of the erosion, wave runup, and inundation extents (Allan and others 2015). The jetties at the mouth of Nehalem Bay were originally constructed between 1916 and 1918 and later rehabilitated in the early 1980s (Lizarraga-Arciniega and Komar, 1975). Following construction of the jetties, Nehalem Spit advanced seaward. However, the shoreline did not straighten and tended to recurve landward near the jetties; the latter is evident in the curvilinear nature of the dunes near the spit tip (Figure 4). The reason for this was because the jetties were constructed low and quite porous, allowing sand to migrate across the jetty and into the estuary.

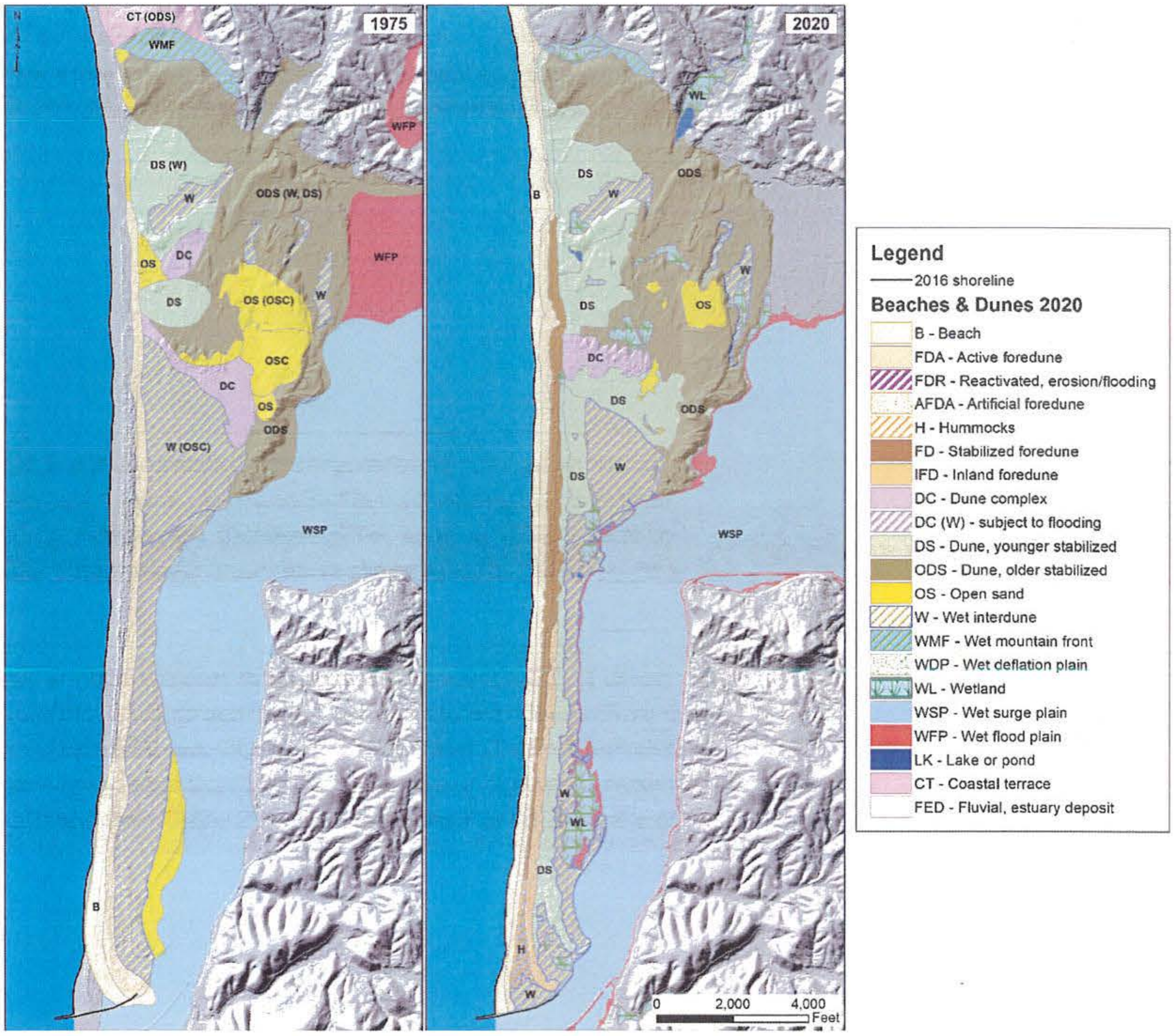
**Figure 3.** Pie charts depicting coastal geomorphic unit changes defined for each Tillamook County subcell. Values shown for each pie reflect acres of land, drawn from Table 2. Pie proportions are a function of the combined value of the six units presented in the figure, and their sums are not necessarily the same from 1970 to 2020.



With rehabilitation of the jetties in the 1980s, the beach stabilized and advanced seaward, leading to the formation of an entirely new active foredune system, while resulting in stabilization of the previously active foredune. Hence, evident from both Figure 3 and 4 is the appearance of the stabilized foredune designation (FD), which is now present along two thirds of the spit. Lidar mapping has also helped refine the number of foredunes present on the spit, which now reflect at least four sequences of development, with the most landward extent (DS) probably reflecting the pre-jetty position of the beach and dune.

Other notable features along Nehalem Spit include the reduction in areas designated as open dune sand (OS), and the presence of hummock terrain near the estuary mouth and between the present-day active foredune and an inland foredune. Refinements in both the wet surge plain and wet flood plain better characterize those areas impacted by daily tides as well as high water events.

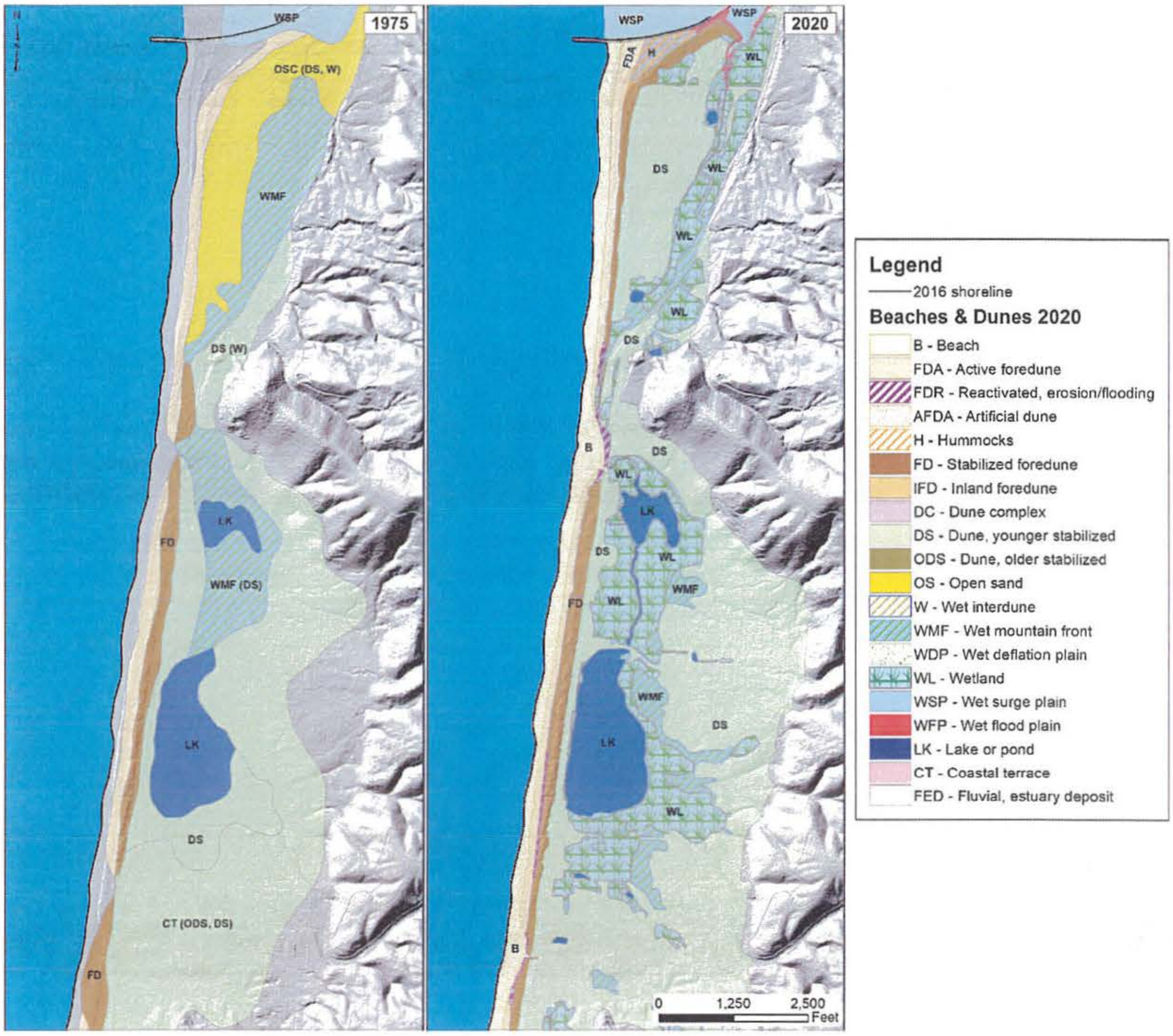
**Figure 4. Beach and dune geomorphic mapping classifications for Nehalem Spit. (*left*) original USDA (1975), (*right*) updated version.**



## 4.3 Rockaway Beach

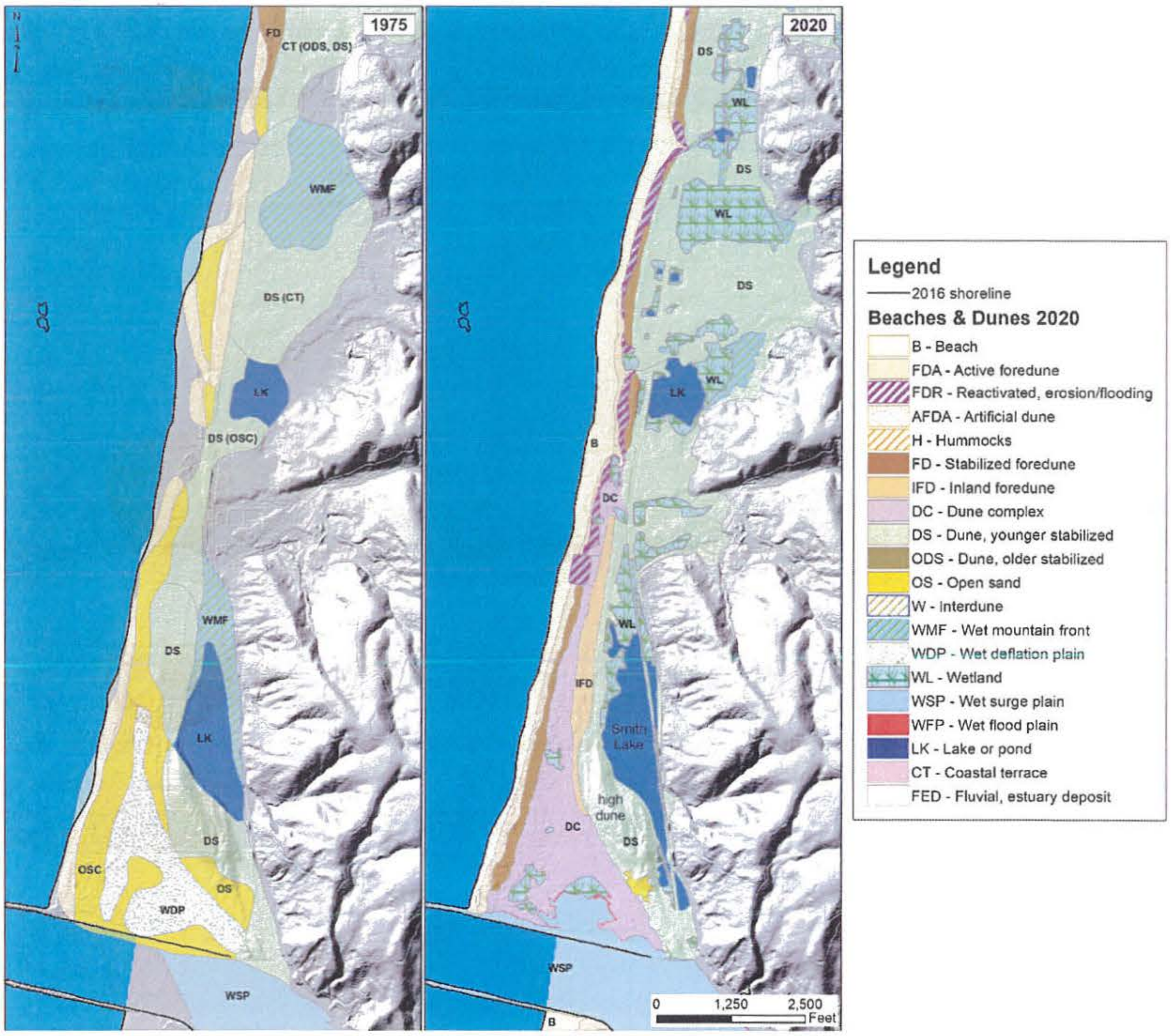
Figure 5 and Figure 6 present maps showing the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for the Rockaway Beach and the Twin Rocks areas. Beginning with Rockaway, the most obvious changes have occurred in the north adjacent to the mouth of Nehalem Bay where previous areas of open sand (Figure 5, left) have since been stabilized (Figure 5, right). As noted in section 4.2 for Nehalem Spit, these changes reflect improvements to the jetty undertaken in the early 1980s, which caused the shoreline to build seaward. As can be seen in Figure 4 and Figure 5, associated with this advance was stabilization of the previous foredune and the formation of a new active foredune seaward of it. In fact, our analyses reveal a more contiguous foredune system today compared with the 1970s. Of interest also is the inclusion of a new geomorphic unit (FDR) that reflects erosion into the former stabilized foredune. This new class is especially prevalent along the Rockaway Beach and Twin Rocks shoreline and is reflective of the fact that this area has been undergoing significant erosion since at least 1997. The erosion is especially acute at Manhattan Beach wayside near the north central area of Figure 5, such that it has all but eliminated portions of the previous active foredune. To the south, development has encroached onto the dune, and much of the Rockaway Beach area today is now engineered (i.e., riprap) as a result of erosion effects that have occurred since 1997 (Allan and Hart, 2008; Allan and others, 2009). Other notable changes include the proliferation of wetland-designated areas throughout the area, which are found concentrated in areas defined previously as wet mountain front or wet interdunes (i.e., areas subject to high water tables and periodic standing water).

**Figure 5.** Beach and dune geomorphic mapping classifications for Rockaway Beach. (*left*) original USDA (1975), (*right*) updated version.



Between Twin Rocks and the mouth of Tillamook Bay, areas designated as open sand have now been virtually eliminated, the exception being a small designated area of high dune by Smith Lake, near Barview (Figure 6). Erosion hazards have also increased along most of the shore to the point where it is now considered to be chronic, such that the previous active foredune has been eliminated in a number of areas (FDR). As a result, erosion is continuing and is now cutting landward into older dune features that formed both prior to and immediately following jetty construction (completed in 1917) at the mouth of Tillamook Bay. Finally, a large area defined previously as a wet deflation plain (Figure 6, left) has been redefined as dune complex (Figure 6, right) since this feature can be attributed entirely to coastal nearshore processes that resulted in rapid beach and shoreline advance following construction of the north Tillamook jetty (Komar, 1997), as opposed to wind-dominated processes.

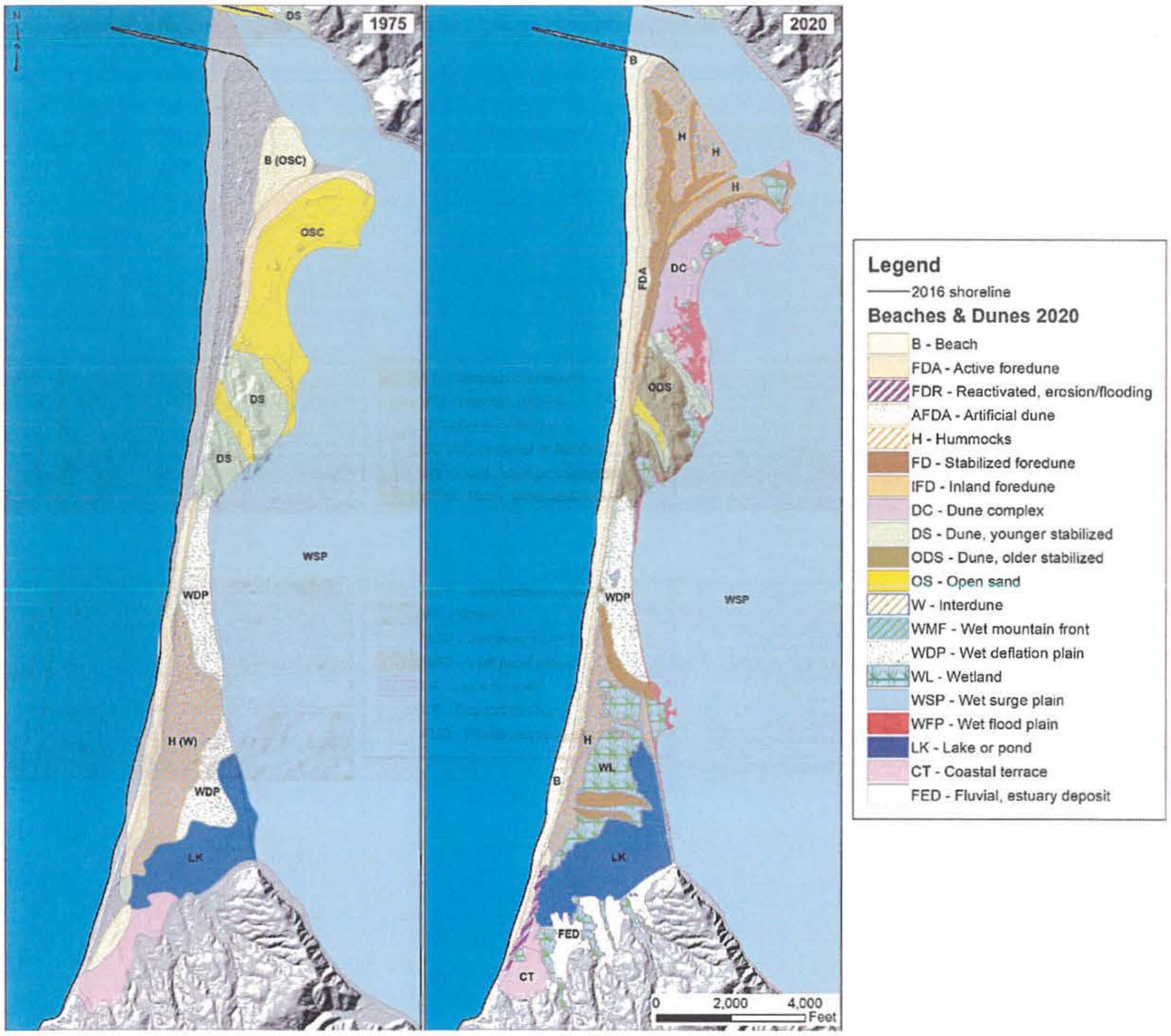
Figure 6. Beach and dune geomorphic mapping classifications for Twin Rocks. (*left*) original USDA (1975), (*right*) updated version.



## 4.4 Bayocean Spit

Figure 7 shows changes in the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for Bayocean Spit. Several interesting features are apparent from the updated mapping. For context, the original mapping would have occurred prior to completion of the south Tillamook Jetty, which was finished in 1974. Hence, along the spit tip one can see evidence of varying stages of foredune development that occurred as the jetty was being built, with the shoreline transitioning from a curvilinear shape at the tip, to a more linear feature as sand aggraded against the jetty as it was being built. As can be seen from Figure 7, there is evidence of at least two stabilized foredunes (FD) that run parallel to the existing active foredune (FDA). Between these dunes is an area of hummock terrain, indicative of the rapid pace in which the shoreline advanced, followed by a period of slower growth, enabling the foredune to begin developing.

**Figure 7. Beach and dune geomorphic mapping classifications for Bayocean Spit. (*left*) original USDA (1975), (*right*) updated version.**



Immediately south of the pre-jetty spit tip is a large area of open sand conditional (OSC, **Figure 7**, *left*) that has since been stabilized by dune grasses, shore pine, and other coastal shrubs. This section has been redefined as a dune complex because it is still evolving toward a stabilized younger dune state. A section of parabolic dunes in the north central portion of the spit previously classified as younger stabilized dune (DS) has been redefined as older stabilized dune (ODS); the original distinction between the two units is largely based on soil development. However, this section is almost certainly much older than originally identified by the USDA (1975) with extensive forest and soil development (evident in early 1939 photos of the area) and observed by Cooper (1958), such that calling it a younger stabilized dune (DS) would be inconsistent with other ODS designations used by the USDA (1975) elsewhere. Moreover, (Cooper, 1958) speculated on the longevity of these dune features noting that they have almost certainly been around for a long time given the size of the dune features and their persistence in having survived any potential shifts in the location of the estuary mouth, which likely has remained in the north. Evident also in **Figure 7** (left), is that at the time of mapping USDA (1975) did not identify an active foredune in front of the older dunes, suggesting that this site was probably experiencing intense erosion, essentially truncating the dunes.

The erosion of Bayocean Spit is especially well documented, culminating with the spit breaching in the late 1940s (Komar, 1997; Allan and Priest, 2001). The cause of the erosion was entirely due to construction of the north Tillamook jetty (completed in October 1917), which interrupted the natural supply of sediment. During the construction phase, changes in the inlet channel and the adjacent shorelines soon became evident. North of Tillamook Bay, sand accumulated rapidly and the shoreline advanced seaward at a rate almost equal to the speed at which the jetty was being constructed (Komar 1997). Between 1914 and 1927, the coastline just north of the jetty advanced seaward some 975 m (3,200 ft). However, by 1920 the rate of sand accumulation on the north side of the jetty had slowed, so that the position of the shoreline was much the same as it is today. In the south, the shoreline near Cape Meares retreated some 200 m (650 ft). The erosion was particularly severe between 1927 and 1953, with the mean shoreline retreating at a rate of ~ 2.4 to 3 m/yr (~8 to 10 ft/yr), culminating with the cutting away of a 1,220 m (4,000 ft) section of the spit on November 13, 1952, breaching the spit. The geomorphic evidence of the breach is clear in our updated geomorphic mapping (**Figure 7**, *right*). As can be seen in the south-central portion of the spit, curved stabilized foredunes (FD) are evident in the landscape, while the bulk of the area between the relict foredunes is characterized by hummock terrain and/or wetlands. In the far south, adjacent to Cape Meares, portions of this area are subject to wave overtopping and inundation of the backshore (FDR), while much of the terrain above the community is characterized by active landsliding.

Finally, it is worth noting that the degree of the post-jetty changes identified in **Figure 7** (right) is indicative of the speed at which the entire spit adjusted and eventually stabilized. This process began to occur almost immediately after construction on the south Tillamook Bay jetty started. As a result, conditions today now reflect an extensive active foredune system that effectively developed over a very short period. Ongoing beach monitoring by the author indicates that the southern half of the spit is largely stable (neither eroding nor accreting), while the northern half of the spit is presently accreting at rates of ~0.6 to ~1 m (2-3 ft) per year[3].

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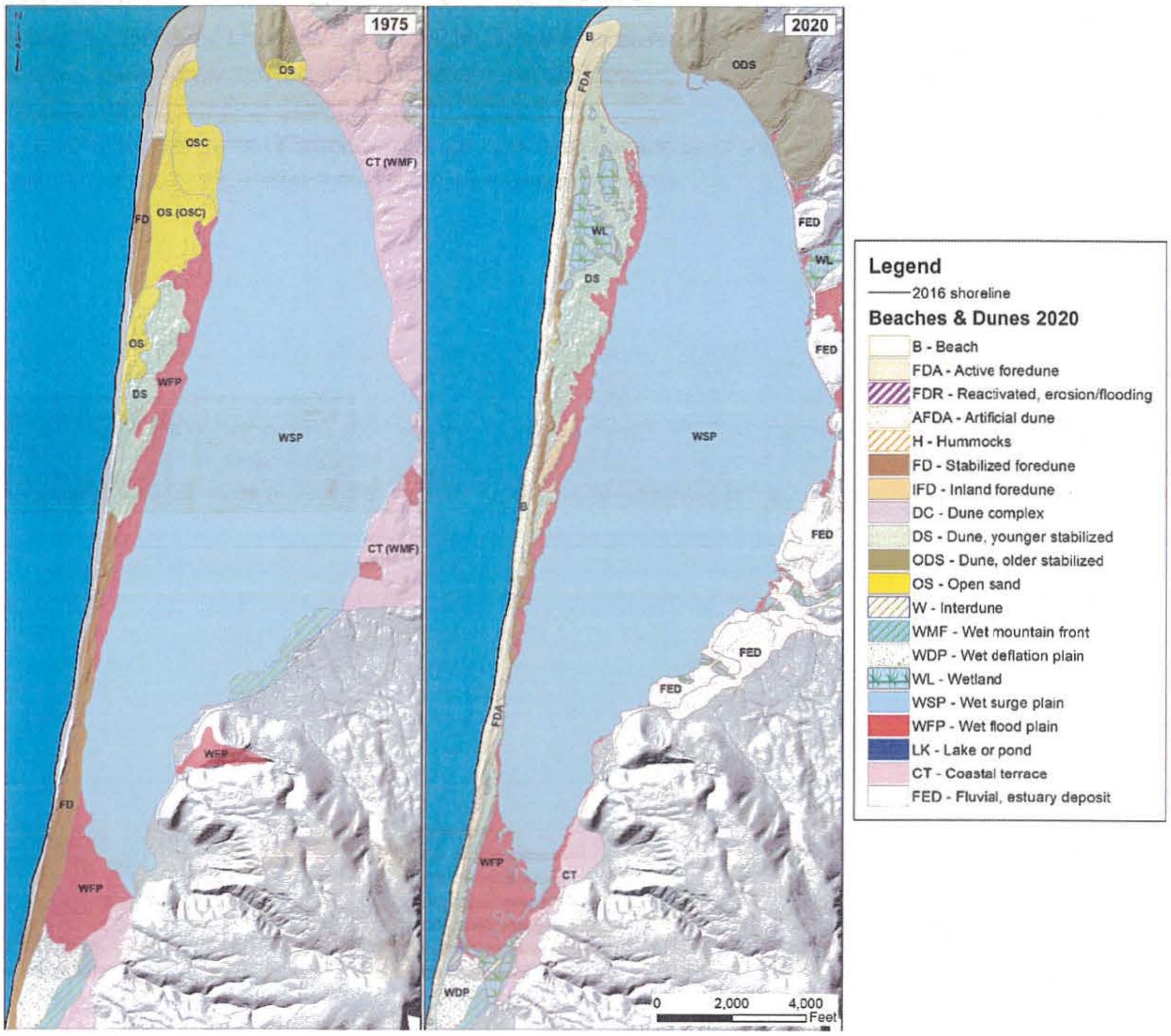
[3] http://nvs.nanoos.org/BeachMapping?action=oiw:beach_mapping_point:bay06:plots:trends (after Allan and Hart, 2008)

## 4.5 Netarts Spit

Updated mapping of the beaches and dunes along Netarts Spit is presented in **Figure 8**. Consistent with other areas, the most notable change reflects the stabilization of open sand areas and their conversion to younger stabilized dunes. This change reflects a decrease in the total acreage of open sand areas by 232.7 acres (**Table 2** and **Figure 3**). Apparent also are changes in the large areas defined as stabilized foredune (FD), evident in **Figure 8** (left), much of which has been redefined as active foredune (FDA, **Figure 8** [right]). While we don't disagree with the original interpretation, it is puzzling that the USDA (1975) did not map any active foredune along the spit other than a small area near the spit tip. Finally, it is worth mentioning that prior to the 1980s, Netarts Spit may have been stable. However, since the 1980s the spit has experienced some of the fastest rates of erosion in the county, which has continued to the present (Komar, 1986, 1998; Allan and others, 2006). The culmination of the erosion occurred at the south end of the cell at Cape Lookout State Park, where Oregon State Parks constructed an artificial foredune to mitigate the erosion.

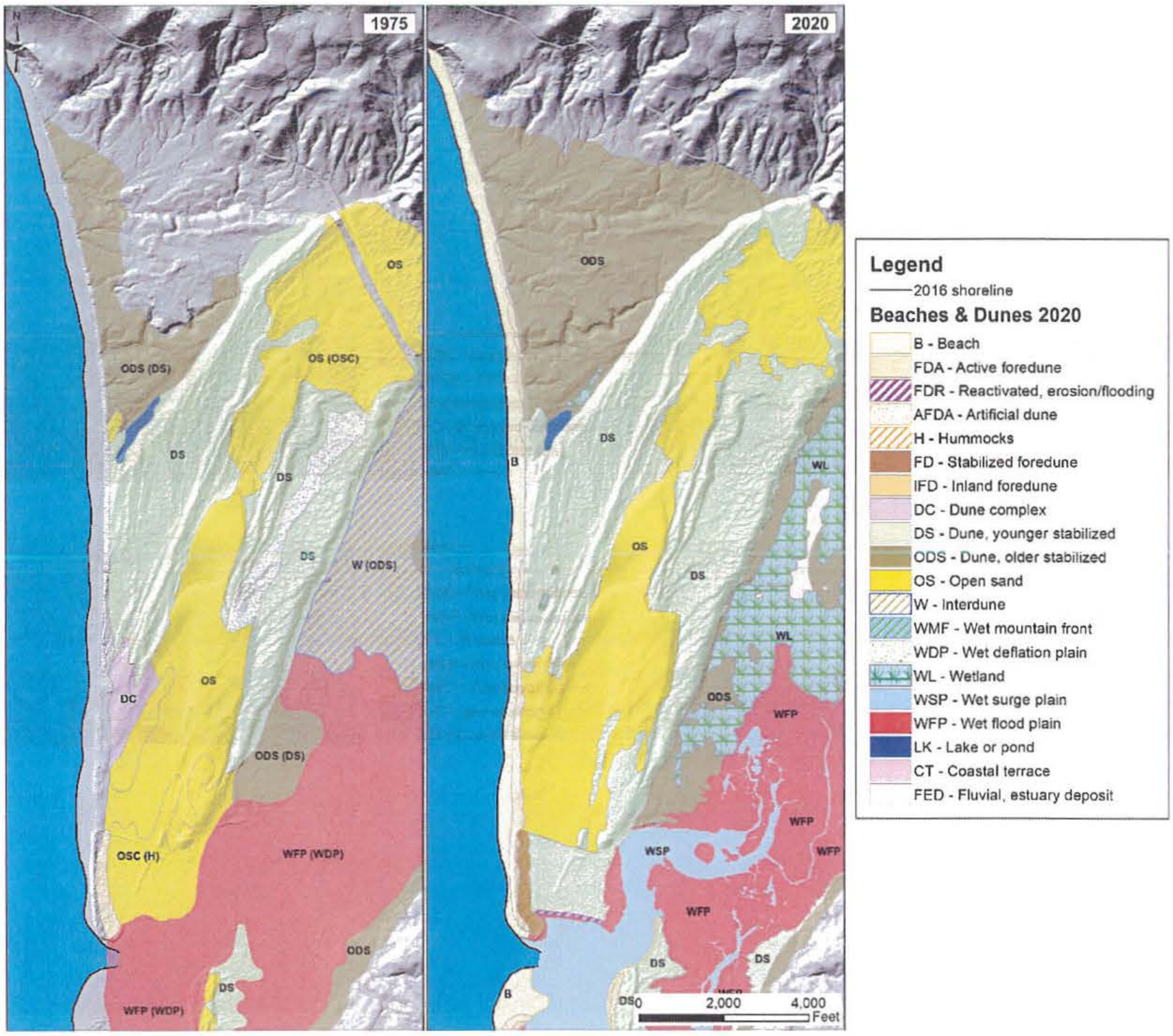
**Figure 8.** Beach and dune geomorphic mapping classifications for Netarts Spit. (*left*) original USDA (1975), (*right*) updated version.



## 4.6 Northern Sand Lake

Updated mapping of the beaches and dunes along the northern half of the Sand Lake littoral cell is presented in **Figure 9**. The main refinements to the latest mapping include designations of the active foredune (where applicable), improvements to the wet flood zone and wet surge plain, and updates to the extent of open sand in the area. Of the four littoral cells in Tillamook County, the Sand Lake cell has the largest area of open sand remaining, the bulk of which is located in the northern half of the cell (**Figure 9**). However, since the 1970s, open sand in this area has decreased by about 22%, from a high of 839 acres to ~655 acres today (**Table 2** and **Figure 3**). Much of this reflects the stabilization of areas in the south, adjacent to the estuary, and to a lesser extent in the northeast. A small area in the south adjacent to the estuary has been mapped as reactivated foredune (FDR) and is presently being eroded into by ocean waves from the southwest. Areas of older stabilized dunes (ODS) in the north have expanded significantly based on the mapping of Wells and others (1994).

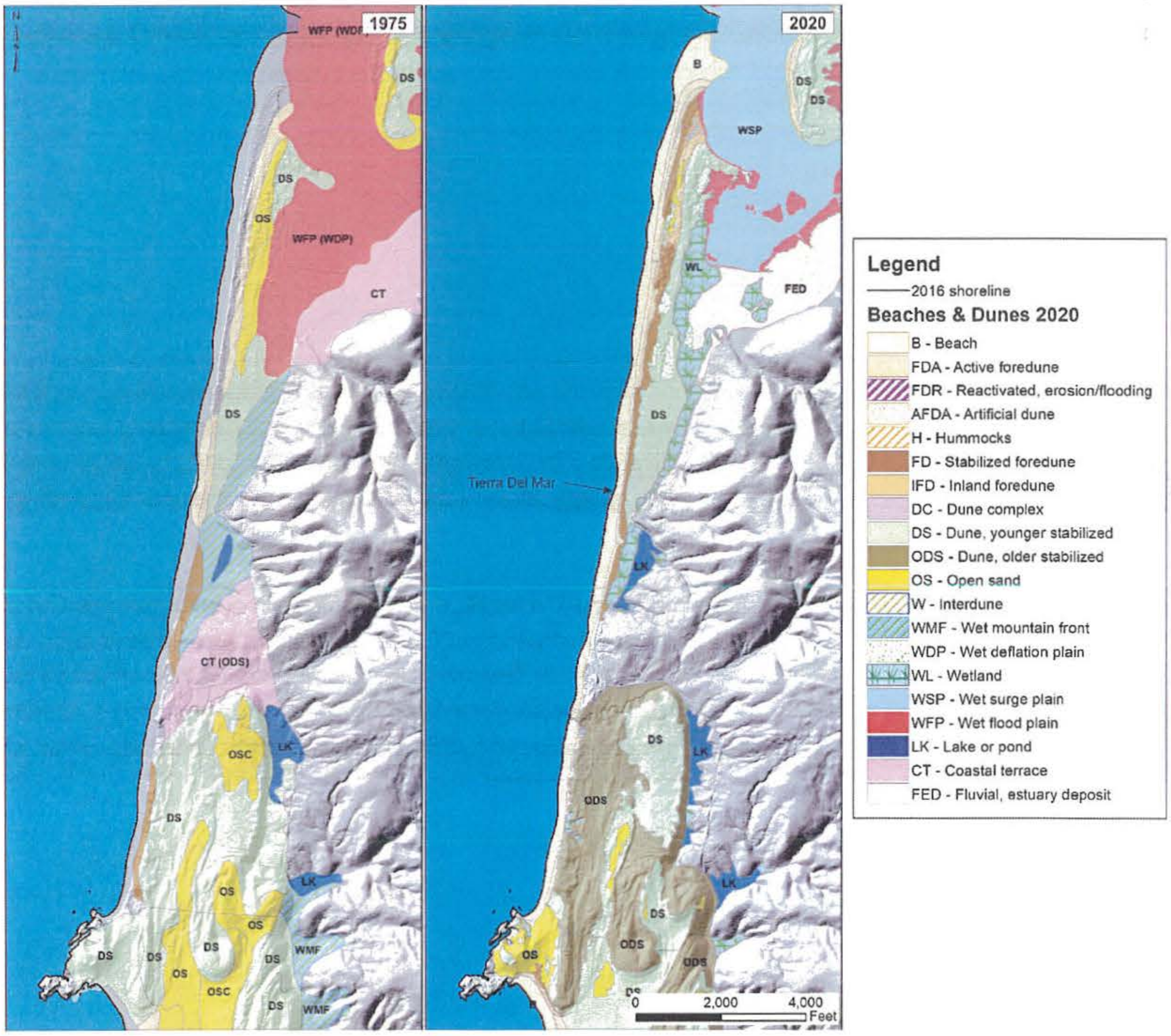
**Figure 9. Beach and dune geomorphic mapping classifications for northern Sand Lake. (*left*) original USDA (1975), (*right*) updated version.**



## 4.7 South Sand Lake

**Figure 10** shows changes in the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for the southern half of the Sand Lake littoral cell. Our updated mapping indicates that areas designated as open sand (OS) have been reduced by ~63% since the 1970s (**Figure 3**). The bulk of these changes occurred north of Tierra De Mar out on the spit, and in the south, just north of Pacific City. Stabilized foredunes (FD) have contracted slightly, while active foredunes have expanded by ~64%. Other notable changes include the inclusion of fluvial/estuarine deposits (mapped by Wells and others [1994]) located adjacent to the estuary, and the reclassification of areas designated as younger stabilized dunes (DS) to older stabilized dunes (ODS) based on an evaluation of 1939 aerial photos of the area. Finally, refinements to the wet surge plain and wet flood plain indicate more realistic tidal effects, along with flood potential (**Figure 10**).

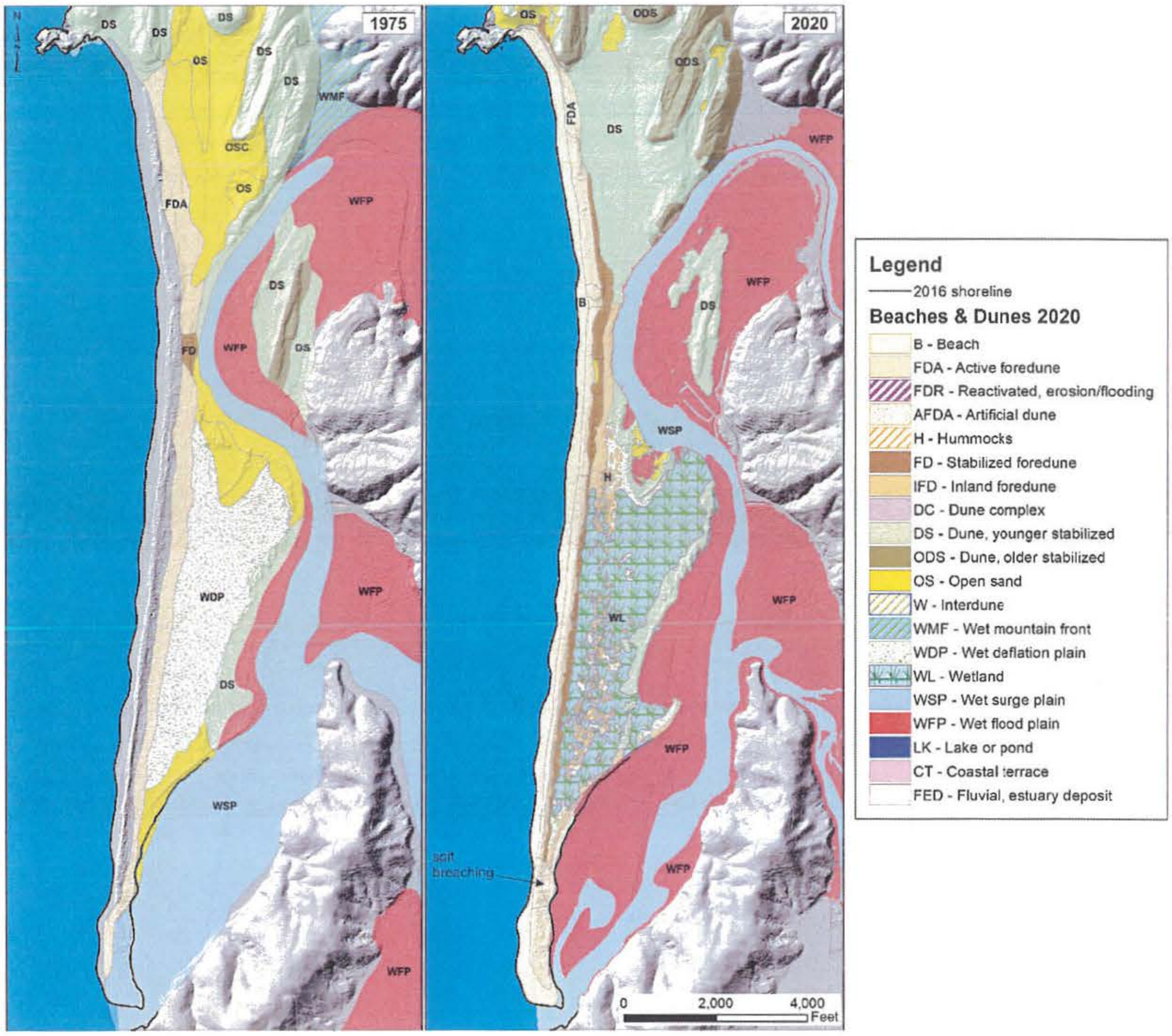
**Figure 10. Beach and dune geomorphic mapping classifications for southern Sand Lake. (*left*) original USDA (1975), (*right*) updated version.**



## 4.8 Nestucca Spit

Updated mapping of the beaches and dunes along Nestucca Spit is presented in **Figure 11**. As can be seen from the figure, the largest change since the 1970s is the dramatic reduction in areas defined as having open sand, the bulk of which was concentrated in the north, near Cape Kiwanda. Thus, while the area of open sand has contracted, the updated mapping indicates that much of this has been converted to younger stabilized dunes (DS). Refinements to the active foredune area indicate that it has contracted by about 29%, while stabilized foredunes (FD) have expanded substantially. Near the spit tip, evidence of spit breaching that took place in 1978 remains evident in the landscape today. Finally, the large area defined as wet deflation plain has been re-designated as a mixture of wetland (WL, USFWS National Wetland Inventory), hummock terrain, and wet deflation plain.

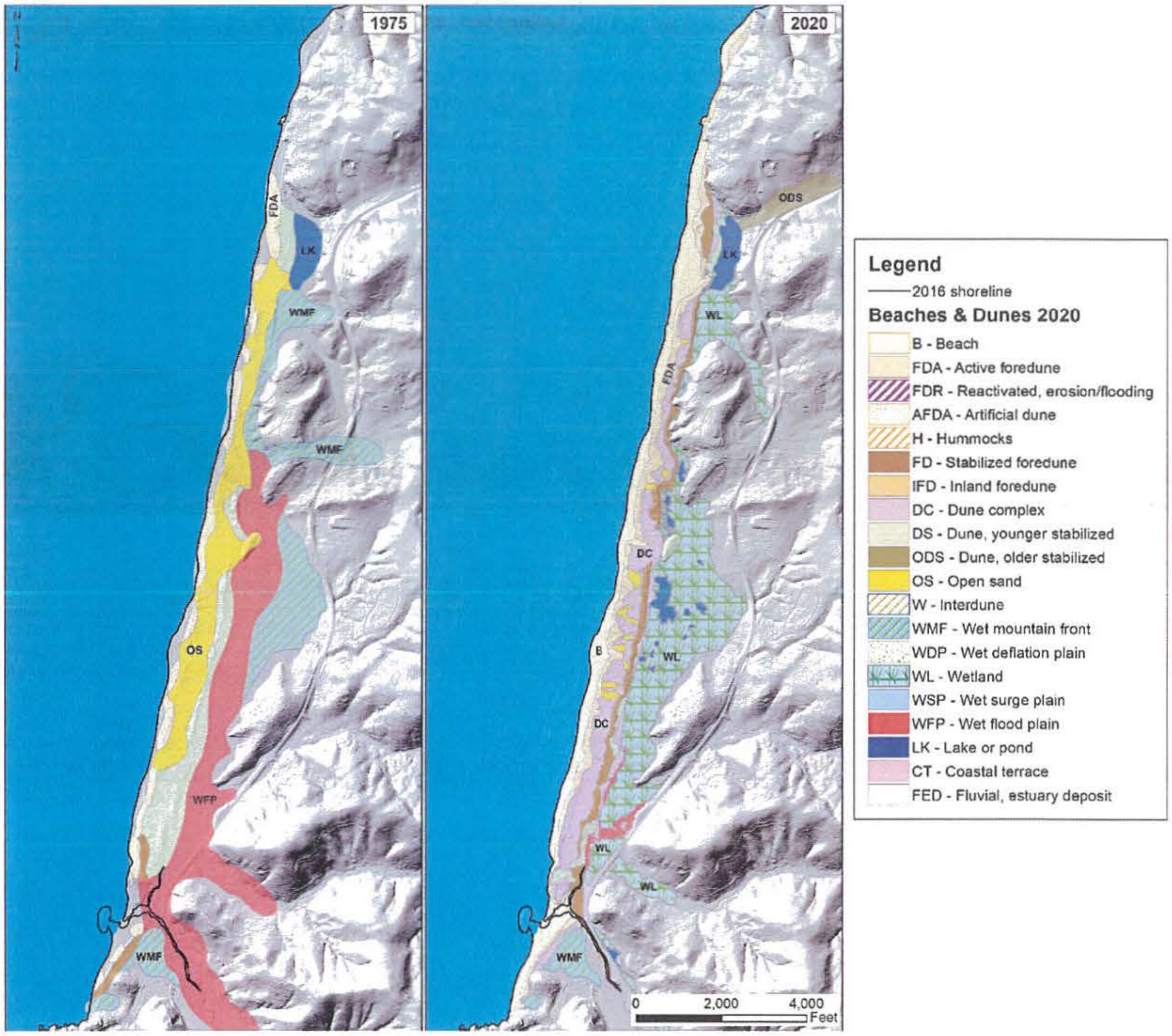
**Figure 11. Beach and dune geomorphic mapping classifications for Nestucca Spit and Pacific City. (*left*) original USDA (1975), (*right*) updated version.**



## 4.9 Neskowin

Figure 12 shows changes in the suite of coastal geomorphic units based on the original mapping (left) compared with present-day conditions (right) for the Neskowin area. Consistent with other areas in Tillamook County, the largest change reflects the overall decrease (98%) in areas characterized as open sand. The remaining pockets of open sand are largely confined to areas where dune blowouts have occurred, due to aeolian and/or wave runup-inundation processes. Consistent with the decrease in open sand areas has been a shift toward stabilized foredunes, which are now spread along the length of the Neskowin shoreline. Because the area landward of the foredune exhibits a complex history with many factors contributing to its overall development, it is designated dune complex (DC). Finally, with refinements in the wet flood plain toward using a tidal datum-based shoreline, the wet flood plain in 2020 is significantly smaller when compared with the area mapped in the 1970s.

**Figure 12. Beach and dune geomorphic mapping classifications for Neskowin. (*left*) original USDA (1975), (*right*) updated version.**



## 5.0 CONCLUSION

The objective of this pilot beach and dune mapping study has been to produce updated information on the spatial extent of the beach and foredune system in Tillamook County that may be subject to existing and future storm-induced wave erosion, runup, overtopping, and coastal flooding. These data are of importance to DLCD and the coastal counties of Oregon in order to improve implementation of Statewide Planning Goal 18: Beaches and Dunes. Specifically, Oregon Statewide Planning Goal 18 requires that local jurisdictions adopt a beach and dune overlay zone in their comprehensive plan, which may be used to manage development on or near such features. Regional mapping of the original beaches and dunes overlay zone of the Oregon coast was undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service (USDA, 1975). However, much has changed on the Oregon coast, requiring that the USDA (1975) overlay zone be updated to reflect current conditions. As noted throughout this report, some of the largest changes to have taken place along the coast include:

- The rapid expansion of European beach grass (*A. arenaria*), which has helped to stabilize many dune systems;
- Encroachment of human development into foredune areas;
- Dune management activities such as foredune grading and planting;
- Changes in beach and dune morphology due to either coastal erosion or accretion;
- Construction of coastal engineering used to mitigate erosion hazards; and,
- Shoreline changes at the mouths of estuaries controlled by jetties.

Although the updated beaches and dune overlay zone maintains the core classification structure developed originally by the USDA (1975), it does include several new classes that address changes in the coastal geomorphology of Tillamook County. Importantly, the geospatial attributes associated with the GIS are now much refined, so that they account for comments and notes made by the author and include specific references to their susceptibility to coastal hazards.

Analyses presented here clearly demonstrate the transformation of the coast over the past 45 years. Of particular note has been the overall reduction in areas defined as open sand (OS), which has decreased by ~67% since the 1970s. Most of this change can be directly attributed to anthropogenic effects, particularly the introduction of European beach grass (*Ammophila arenaria*) as well as stabilization from shore Pine (*Pinus contorta*) and other native plant species. Although the bulk of this transformation can be attributed to a shift toward younger stabilized dunes (DS), the expansion of areas defined as active foredune (FDA) and stabilized foredunes (FD) is a testament to the role humans have played in driving these changes.

## 6.0 ACKNOWLEDGMENTS

This project was funded under award #17054 by the Oregon Coastal Management Program (OCMP) of the Department of Land Conservation and Development agency. We thank Meg Reed for her assistance throughout this project, discussion on approach, and constructive comments on the technical report.

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## Allison Hinderer

| | |
|---|---|
| **From:** | REED Meg * DLCD <Meg.REED@dlcd.oregon.gov> |
| **Sent:** | Tuesday, July 27, 2021 3:52 PM |
| **To:** | Sarah Absher; Allison Hinderer; Public Comments |
| **Cc:** | SNOW Patty * DLCD; PHIPPS Lisa * DLCD; Shipsey Steven; WADE Heather * DLCD |
| **Subject:** | EXTERNAL: DLCD Written Comments on 851-21-000086-PLNG-01 and 851-21-000086-PLNG |
| **Attachments:** | DLCDletter_7.27.21_851-21-000086-plng-01-goalexceptionrequest.pdf |

Hi Sarah,

Please find attached DLCD's letter regarding the hearing on applications 851-21-000086-PLNG-01 and 851-21-000086-PLNG with the Tillamook Board of County Commissioners tomorrow.

Also, I would like to sign up to give public comment virtually at the hearing tomorrow.

Thank you,
Meg

DLCD
**Meg Reed**
Coastal Shores Specialist | Oregon Coastal Management Program
Pronouns: She/her
Oregon Department of Land Conservation and Development
Cell: 541-514-0091 | Main: 503-373-0050
meg.reed@dlcd.oregon.gov | www.oregon.gov/LCD

*My email address has changed. Please update your records to reflect my new email address: meg.reed@dlcd.oregon.gov. Note that your Outlook Cache may need to be cleared.*

Oregon
Kate Brown, Governor

**Department of Land Conservation and Development**
Oregon Coastal Management Program
810 SW Alder Street, Suite B
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July 27, 2021

Mary Faith Bell, Chair
Tillamook County
Board of County Commissioners
201 Laurel Avenue
Tillamook, OR 97141

Re: 851-21-000086-PLNG-01: Goal Exception Request
851-21-000086-PLNG: Floodplain Development Permit Request

Dear Chair Bell and Tillamook County Commissioners,

Thank you for the opportunity to provide written testimony for the goal exception request, #851-21-000086-PLNG-01, and for the floodplain development permit request, #851-21-000086-PLNG. These requests are seeking approval of an exception to Statewide Planning Goal 18, Implementation Requirement 5, to place a beachfront protective structure along the westerly lots of the Pine Beach Subdivision and five oceanfront lots to the north located within the Barview/Twin Rocks/Watseco Unincorporated Community Boundary. Please enter this letter into the record of the hearing on the subject requests.

This testimony will focus on the following topics: beachfront protective structure limitation of Goal 18 policy; reasons exception pathway to seek a goal exception; comments by the Tillamook County Planning Commission; and proposed beachfront protective structure design.

**Date Limitation of Beachfront Protective Structures**

The above referenced properties (15 tax lots) are seeking a pathway to place a beachfront protective structure (BPS) along the oceanfront to mitigate ocean flooding and erosion. Goal 18, Implementation Requirement (IR) 5 states:

> *Permits for beachfront protective structures shall be issued only where development existed on January 1, 1977. Local comprehensive plans shall identify areas where development existed on January 1, 1977. For the purposes of this requirement and Implementation Requirement 7 'development' means houses, commercial and industrial buildings, and vacant subdivision lots which are physically improved through construction of streets and provision of utilities to the lot and includes areas where an exception to (2) above has been approved.*

After much research, County planning staff have determined that the five lots that are part of the George Shand Tracts subdivision, Tax Lots 3000, 3100, 3104, 3203 and 3204 of Section 7DA in Township 1 North, Range 10 West of the Willamette Meridian, Tillamook County, Oregon, do meet the definition of development under Goal 18, IR 5, and thus do **not** need an exception to the goal for the placement of a BPS.

On the other hand, the County has concluded that the ten tax lots that are part of the Pine Beach Replat Unit #1 do not meet the definition of development because they were developed after 1977. These are Tax Lots 114 through 123, of Section 7DD in Township 1 North, Range 10 West of the Willamette Meridian, Tillamook County, Oregon. The County's determination was made based upon the following information:

- Utilizing the 1977 aerial imagery from the Army Corps of Engineers, the County determined that qualifying development (residential, commercial, or industrial buildings) was not present on any of these tax lots.
- Although the original plat "Pine Beach" was recorded in 1932 containing 121 lots, the County has found that the entire plat, with the exception of Second Street between Pacific Highway and Ocean Boulevard and the separate ownerships along Second Street, was vacated in 1941. The Pine Beach Replat was then subsequently approved in 1994. Thus, on January 1, 1977, there was no eligible development on the oceanfront parcels at this site and it was not part of a statutory subdivision. Additionally, the replat in 1994 was processed by the County as a new subdivision and the resulting lots are in a significantly different configuration than the Pine Beach subdivision plat of 1932. This resulted in a new subdivision.

Based on the County staff determinations for the above referenced parcels, the George Shand Tracts parcels meet the definition of development under Goal 18, IR 5 and therefore do not need a goal exception for the placement of a BPS, while the Pine Beach Replat Unit #1 parcels do not meet the definition of development under Goal 18, IR 5 and therefore do need a goal exception to the 1977 development date limitation of Goal 18 for the placement of a BPS, in addition to any local criteria.

It is unclear from the Planning Commission recommendation to the Board of County Commissioners whether the Planning Commissioners decided that all or part of this area needs a goal exception. Tillamook County must make the threshold determination of eligibility for BPS very clear for each of the tax lots under this goal exception request. State law authorizes a county to take a goal exception for uses not allowed by the goal or to allow a use authorized by a statewide planning goal that cannot comply with the approval standards for that type of use. If an area was developed on January 1, 1977, then a county need not, and cannot lawfully, take an exception to Goal 18, IR 5. Previous case law has affirmed that a goal exception cannot be taken for a use that the goal allows. *DLCD v. Yamhill County*, 183 Or App 556, 53 P3d 462 (2002). That makes sense, because the statutory definition of an "exception" is that the amendment to the comprehensive plan does "not comply with some or all goal regulations applicable to the subject property." ORS 197.732(1)(b)(B). *See also* OAR 660-004-0022 (use not allowed by the goal); OAR 660-004-0020(2)(b) (areas that do not require an exception). Thus, the initial determination before the County is whether the applications are for properties that were not developed on January 1, 1977.

## Reasons Exception Pathway

The applicants suggest multiple pathways for approving their goal exception request. The Planning Commission determined that there is only one avenue for these applicants, which is a general "reasons" exception and that the applicants only need an exception to Goal 18 IR 5, not IR 2. The department agrees.

Part II of Statewide Planning Goal 2 provides a process a local government can follow when taking an "exception" to one of the land use goals, when unique circumstances justify that the state policy should not apply. The rules governing exceptions are provided in OAR chapter 660, division 4. There are several goals and goal provisions to which a specific pathway is outlined, but for those where no other specific pathway exists or fits, a general "reasons" exception applies.

The department agrees with the Planning Commission that a general "reasons" exception to Goal 18 is necessary for the lots that are not eligible for BPS under Goal 18 and that the proper administrative rule provisions are those of OAR 660-004-0022(1) and OAR 660-004-0020.

The homes that exist in the application area were built in conformance with the other provisions of Goal 18, specifically Goal 18, IR 2. The houses were **not** built in an active foredune or in a dune area subject to ocean flooding at the time of development, which means they did not need an exception to Goal 18, IR2. The other goal exceptions (to Goals 3, 4, 11, and 14) that allow for the Barview/Twin Rocks/Watseco community to be residentially developed, do not specify the exact location of development on each parcel in this unincorporated community. Additional zoning requirements dictate those limits, and in the case of these ocean-fronting parcels, Tillamook County applied the Beach & Dune Overlay Zone of their Land Use Ordinance. The houses were built in the eastern portions of their respective parcels to comply with the prohibition areas of Goal 18 for residential development. The department understands the applicants to argue that the exceptions to Goals 3, 4, 11, and 14 allowed the development to be placed, and because those homes are now in a foredune subject to ocean flooding, they automatically have or should be allowed by right to have an exception to Goal 18, IR2. However, the rules provide that an "exception to one goal or goal requirement does not ensure compliance with any other applicable goals or goal requirements for the proposed uses at the exception site." OAR 660-004-0010(3). The notion of an implied or precautionary exception, as the applicants suggest, is not supported by law. Furthermore, an exception to exclude certain lands from the requirements of Goals 3, 4, 11, and 14 does not exempt the County from the requirements of any other goals, including Goal 18, for which the County has not taken an exception. OAR 660-004-0010(3). A goal exception is an affirmative act that is incorporated into a comprehensive plan. Tillamook County has identified and adopted specific exception areas for Goal 18, IR 2 in the County's Comprehensive Plan (Part 6 of the Beaches and Dunes Element). The lands in the application are not part of an existing goal exception under Goal 18 and are not reflected in the Tillamook County Comprehensive Plan. Nor do these homes need a retroactive exception to Goal 18, IR 2, as the applicants suggest.

The question at hand is not whether these properties need an exception to exist where they are, but whether they can install a beachfront protective structure to protect the existing development. The applicants are seeking an exception to the date-based limitation on the placement of beachfront protective structures for Goal 18 because they were developed after January 1, 1977. Therefore, only a general "reasons" exception to Goal 18, IR 5 is needed in this case (OAR 660-004-0022(1)).

Recent LUBA decisions, subsequent to this application, also provide additional guidance on the matter:

- Coos County: https://www.oregon.gov/luba/Docs/Opinions/2021/05-21/20002.pdf
- City of Coos Bay: https://www.oregon.gov/luba/Docs/Opinions/2021/05-21/20012.pdf

In brief, these LUBA decisions note that taking a reasons exception is a high bar and the applicant and jurisdiction must follow the reasons exception process closely and carefully to demonstrate the need.

The department agrees with the County Staff Report, dated May 27, 2021, page 5, which states: "staff also finds that an exception to one goal or goal requirement (ex. Goals 11 and 14) does not ensure compliance with any other applicable goals or goal requirements, in this case for the proposed construction of the beachfront protective structure. Staff finds the Applicants must meet the burden of proof to satisfy the applicable exception criteria without the sole basis of argument that other exceptions have already been taken".

**OAR 660-004-0022 Reasons Necessary to Justify an Exception Under Goal 2, Part II(c)**
As mentioned above, the provisions of OAR 660-004-0022 specify the pathway for the applicants for the ineligible properties. Specifically, OAR 660-004-0022(1) provides:

*(1) For uses not specifically provided for in this division, or in OAR 660-011-0060, 660-012-0070, 660-014-0030 or 660-014-0040, the reasons shall justify why the state policy embodied in the applicable goals should not apply. Such reasons include but are not limited to the following:*
*(a) There is a demonstrated need for the proposed use or activity, based on one or more of the requirements of Goals 3 to 19; and either*
*(A) A resource upon which the proposed use or activity is dependent can be reasonably obtained only at the proposed exception site and the use or activity requires a location near the resource. An exception based on this paragraph must include an analysis of the market area to be served by the proposed use or activity. That analysis must demonstrate that the proposed exception site is the only one within that market area at which the resource depended upon can reasonably be obtained; or*
*(B) The proposed use or activity has special features or qualities that necessitate its location on or near the proposed exception site.*

An application that does not satisfy these provisions fails and may not be approved.

**OAR 660-004-0020 Goal 2, Part II(c), Exception Requirements**
If the provisions of OAR 660-004-0022(1) are found to be satisfied, the review may then turn to the provisions of OAR 660-004-0020. In addition to the above, there are four tests to be addressed when taking an exception, which are set forth in Statewide Planning Goal 2, Part II and more specifically in OAR 660-004-0020(2)(a) – (d). Those criteria are:

1) *Reasons that justify why the state policy embodied in the applicable goal should not apply;*
2) *Areas which do not require a new exception cannot reasonably accommodate the use;*

3) *The long-term environmental, economic, social and energy consequences resulting from the use of the proposed site with measures designed to reduce adverse impacts are not significantly more adverse than would typically result from the same proposal being located in areas requiring a goal exception other than the proposed site; and*
4) *The proposed uses are compatible with other adjacent uses or will be so rendered through measures designed to reduce adverse impacts.*

It is imperative that the County focus on these standards when evaluating the exception application for the lots deemed ineligible within the Barview/Twin Rocks/Watseco Unincorporated Community Boundary. As already stated, the other exception pathways the applicants argue for are not relevant in this case and those arguments cannot be the basis for an exception decision.

**Findings Made by the Tillamook County Planning Commission**

A staff memo dated July 21, 2021, summarizes the findings made by the Tillamook County Planning Commission to recommend approval of these requests. Of particular concern to the department is the following statement:

"It is not right to deny a property owner the same opportunities to protect their property that others are afforded due to grandfathered rights that allow them to take action for protection of their property. (Properties where 'development' existed on January 1, 1977.)"

This finding cannot be used to justify a goal exception. Goal 18, IR 5 is a 'grandfather clause' to allow development already in existence at the time the policy was adopted to use shoreline armoring, while new development must account for shoreline erosion through non-structural approaches. As seen in previous case law, "the purpose of a 'grandfather clause' is to prevent hardship to individuals who have existing uses. A 'grandfather clause' is enacted to preserve rights, not to grant additional rights." *Spaght v. Dept. of Transportation*, 29 Or App 681, 686, 564 P2d 1092 (1977) (citation omitted).

Here, the Planning Commission seems to assert that the Goal 18, IR 5 grandfather clause for developed properties should grant the same rights to other properties that were not developed. That interpretation is contrary to the purpose of Goal 18, IR 5, which is in part to preserve the rights to protect a developed property with a BPS, while providing that future development occur in a manner that does not rely on BPS in order to afford the natural functions of the beach and dunes to continue. To construe otherwise is to defeat a primary purpose of Goal 18. In addition, "the exceptions process is not to be used to indicate that a jurisdiction disagrees with a goal." OAR 660-004-0000(2). Therefore, not agreeing with the policy does not authorize the County to use that disagreement as a basis for a valid goal exception decision.

During the Planning Commission's deliberation at the July 15th hearing of these applications, there was discussion of the County's obligations, particularly under Goal 7, to protect these properties from ocean flooding and erosion. Goal 7 obligates jurisdictions to plan for natural hazards by adopting inventories, policies and implementing measures in their comprehensive plans to reduce risk to people and property from natural hazards. The Goal does not obligate the County to protect life and property indefinitely once development has occurred, but to consider natural hazards in the course of planning. The County is not compelled by the Goal 7 requirements to grant the exception, nor would the County be out of compliance with Goal 7 in the absence of the exception. What the applicants are seeking is an exception to allow them to place a beachfront protective structure to mitigate the impacts of coastal erosion and flooding. The proposed BPS is their preferred solution, which the regulations currently prohibit. It could be argued that the risk to persons and property could be addressed or even eliminated in other ways – such as removal or relocation of the houses and infrastructure.

**Proposed Beachfront Protective Structure**

The applicants put forth a specific design for a beachfront protective structure, referenced throughout the applications. The department has some concerns about the design as proposed.

BPS are not the ultimate solution to eliminate coastal hazard risks. The applicants claim that the proposed beachfront protection will solve all threats to the properties from coastal flooding and erosion and not incur further harm to either the beach or surrounding properties. It is important to note that erosion will continue to occur in this location and the impacts of climate change will continue to exacerbate those conditions. Beachfront protective structures can provide a level of protection for development from erosion and flooding but will need to be continually maintained and may fail over time. Additionally, the structures themselves will continue to impact the beach in this area by withholding sediment and fixing the shoreline in place, as has been seen in other beach systems. While one structure may not affect the system very much, the cumulative effects of armoring along the entirety of this system will have an impact over time, limiting north/south beach access as sea levels continue to rise. Beachfront protective structures do not conserve nor protect the beach and dune environment, they protect development from the impacts of coastal erosion.

The applicants have identified that nearly 90% of the Rockaway Subregion of the Rockaway littoral cell is eligible for BPS. While many of those homeowners may choose to armor their properties over the coming years and decades, many of those lots are not yet armored and those permitting decisions have not yet been made. Much of this sublittoral cell, and particularly the area of the subject properties, is not currently armored. If the County decides to approve this exception request and application for a BPS, the County is committing to a high level of shoreline armoring in this sublittoral cell. As has been observed in other beach systems, particularly in Lincoln Beach in Lincoln County, the proliferation of shoreline armoring has been detrimental to the natural functioning of the beach system. By approving additional armoring, the County is committing to a preference for private development protection over protection of the beach and dune resource.

Additionally, applicants claim that because the BPS will initially be erected on private property and buried with sand and vegetation that the structure will remain that way indefinitely and never become exposed. If this is the case, then they are assuming that sand nourishment, dune augmentation, and vegetation methods will work to mitigate the hazards, in which case they do not need a structure or a goal exception. However, if these non-structural methods are not sufficient, as the applicants argue elsewhere, then it is important to evaluate the structure assuming it will become exposed and located on the ocean shore and public beach. Assuming conditions remain similar to what the area has experienced over the past two decades, the beach will continue to narrow over time resulting in increased wave energy directed on the structure. Once located on the ocean shore and within the jurisdiction of Oregon Parks and Recreation Department (OPRD), the BPS will be an unpermitted structure that will have to seek a permit through OPRD. The Ocean Shore is defined as "the land lying between extreme low tide of the Pacific Ocean and the statutory vegetation line as described by ORS 390.770 or the line of established upland shore vegetation, whichever is farther inland."

The applicants argue that sand will build up over the revetment during summer months. However, this is an eroding coastline experiencing a net loss of sand; any sand placed on structures gets eroded quickly. El Nino conditions can cause hotspot erosion in the southern ends of littoral cells and accretion in the northern ends of littoral cells. Accretion of sand over beachfront protective structures in other parts of the Rockaway beach littoral cell does not guarantee the same will happen at the site of the proposed beachfront protection structure. Supplemental sand placement and re-vegetation will likely be needed here. Taking sand from the public beach, if that is proposed, will need to be permitted by OPRD. Applicants have also cited that the current vegetation is dying due to saltwater inundation from flooding. Any vegetation that is planted or replanted in this area will need to be tolerant of the saltwater flooding, and continually be maintained. The maintenance for this structure as proposed, especially with these additional requirements (buried in sand and vegetated), is perpetual and may not be possible over the long term.

The applicants do include an analysis of potential impacts from this proposed structure in regards to north/south beach access. However, these calculations are for present water level and wave conditions only and do not consider various sea level rise scenarios in the coming decades. As the shoreline continues to naturally erode back towards the BPS, the beach will most likely steepen in addition to the BPS itself presenting a steeper slope, which will result in different wave runup conditions. These processes could set up a feedback in which the wave runup continues to increase, resulting in more attack on the BPS and causing less 'safe hours' to walk past the structure in the north/south direction.

Independent of the decision regarding the Goal Exception request, if the Board approves the structure, DLCD supports the Planning Commission's recommendation to add conditions of approval to the permit, particularly to ensure applicants have the responsibility to maintain their structure in perpetuity and should the structure be uncovered, that the property owners obtain any new permits from the County and OPRD. Many BPS built along the Oregon coast are initially buried with sand and planted with beach grass or other vegetation. However, almost none of them retain that state for very long and it can become very difficult for homeowners to keep up with that level of maintenance because of costs and lack of sand supply, especially in highly erosive environments.

## Conclusion

To summarize, DLCD recommends that the County make a clear determination on the eligibility status of each of the 15 tax lots under the application and only evaluate a goal exception for those areas that need a goal exception to Goal 18, IR 5. As previously stated, a goal exception cannot be taken for a use already allowed by the goal. Additionally, the pathway of review for this application is a general "reasons" exception as provided in OAR 660-004-0020 and OAR 660-004-0022(1). Only the criteria for this pathway should be evaluated for a goal exception decision. The County cannot use a disagreement with the grandfather clause of Goal 18, IR 5 as the basis for granting a goal exception. Lastly, the department recommends that the County carefully review the proposed BPS and attach specific conditions of approval to the permit, if approved, to ensure the structure is built as designed and maintained in perpetuity by the owners.

DLCD wants and supports a better outcome for oceanfront development and infrastructure. We do not want to see homes falling into the ocean, but we also do not want to see a proliferation of armoring in all cases because it is a short-sighted solution that impacts the public beach. There are alternative outcomes to pursue, ones that require envisioning a coastal future that looks different from the coastline of the past. One that is more mindful of the hazards that are present in this environment and that will continue to get worse with climate change.

Thank you for this opportunity to comment. Please enter this letter into the record of these proceedings. If you have any questions, please contact Meg Reed, Coastal Shores Specialist, at (541) 514-0091 or meg.reed@state.or.us.

Sincerely,

Patty Snow, Coastal Program Manager
Oregon Coastal Management Program
Department of Land Conservation and Development

cc: Meg Reed, Oregon Department of Land Conservation and Development
Lisa Phipps, Oregon Department of Land Conservation and Development
Heather Wade, Oregon Department of Land Conservation and Development
Steven Shipsey, Oregon Department of Justice
Jay Sennewald, Oregon Parks and Recreation Department

## Allison Hinderer

**From:** Sarah Mitchell <sm@klgpc.com>
**Sent:** Tuesday, July 27, 2021 4:18 PM
**To:** Sarah Absher; Allison Hinderer
**Cc:** Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1@comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
**Subject:** EXTERNAL: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence
**Attachments:** Exh 4 - Tillamook-HNA-Final-Report - Buildable Lands Inventory BLI.pdf; Exh 5 - Tax Statements 2020-21.pdf

**Importance:** High

[**NOTICE:** This message originated outside of Tillamook County -- **DO NOT CLICK** on **links** or open **attachments** unless you are sure the content is safe.]

Hi Sarah and Allison,

Please include the attached exhibits in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. Would you please confirm your receipt? Thank you.

Best,
Sarah

KELLINGTON
LAW GROUP

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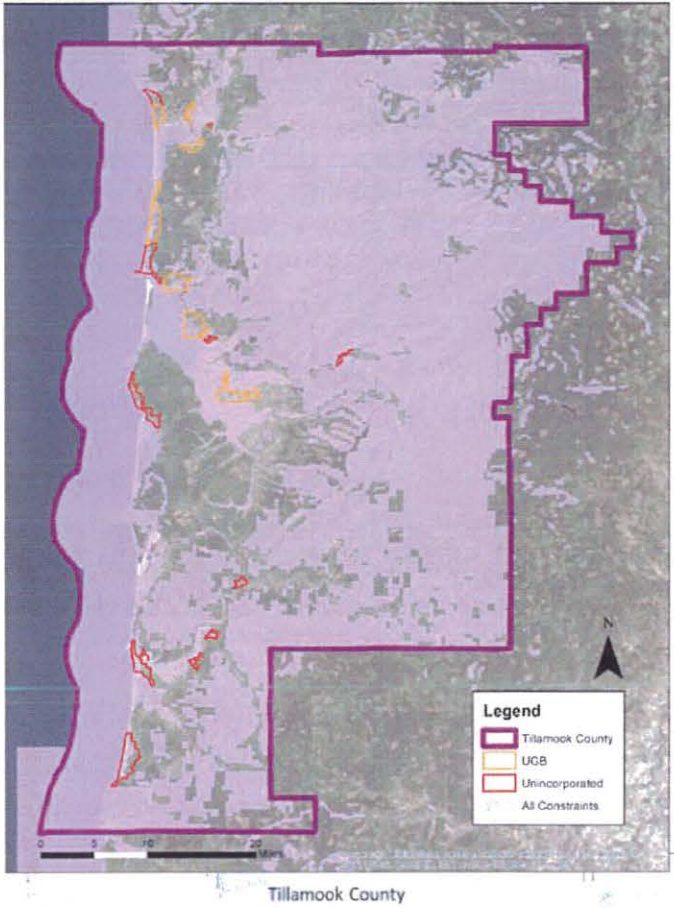
# Tillamook County

# Housing Needs Analysis



Tillamook County

Netarts

Pacific City - Woods

Neskowin

December 27, 2019

# ACKNOWLEDGEMENTS

This work is made possible through input provided by County staff and the Tillamook County Housing Commission. We specifically recognize and appreciate the time and attention dedicated to this work by the following participants.

**Tillamook County**

David Yamamoto (Tillamook County Commission Chair)

Bill Baertlein, (Tillamook County Commission Vice Chair, Liaison to County Housing Commission)

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Sarah Absher (Tillamook County Community Development Director)

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Barbara McLaughlin (North County)

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Erin Skaar (Non-Profit)

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**Interviews and Work sessions**

During the course of this assignment, FCS GROUP collected information gleaned from the following property owners, business owners, developers, and local planning commissions. We sincerely thank these individuals and collective bodies for sharing their time and attention.

- Todd Bouchard, developer/local resident
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- Thomas Kemper, nonprofit housing developer
- Jeff Schons and Mary Jones, Pacific City property owners/developers/business owners
- Paul Wyntergreen, City of Tillamook, City Manager
- Manzanita City Planning Commission
- Bay City Planning Commission

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# Section I. INTRODUCTION

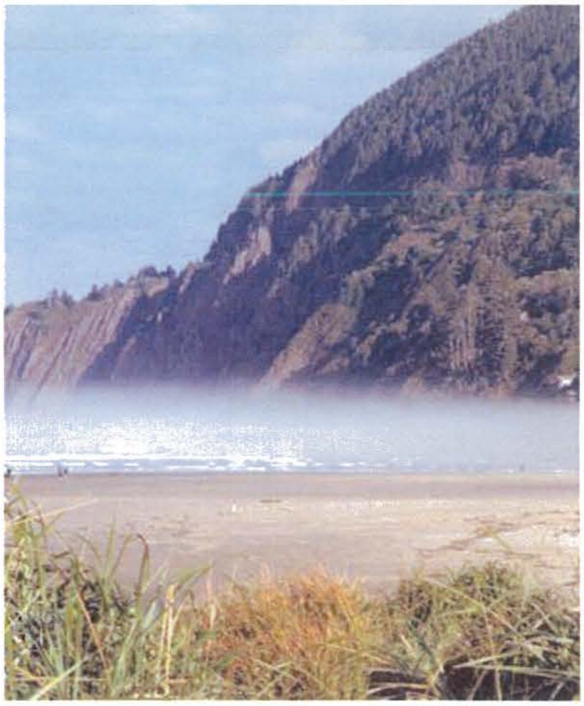
Tillamook County is widely known for its dramatic coastline, misty beaches and award winning dairy and seafood products. Tillamook County is located along the breathtaking northern Oregon Coast within 50 miles from the Portland and Salem metro regions.

Like many coastal communities, portions of Tillamook County are experiencing strong housing demand by part-time seasonal residents, especially in coastal "resort" communities. Over the past decade, new housing production has not nearly kept pace with the demand generated by permanent residents and seasonal home owners. With the majority of its housing, now controlled by part-time residents, vacancy rates have plunged to near zero and rents/prices have increased to record levels. This has led to a severe housing affordability challenge that is exacerbated by: environmental flood zone and agricultural land use constraints; limited vacant land area with adequate water, sewer and roadway infrastructure; and a growing service economy with limited family wage job opportunities.

These challenges continue to mount as employers struggle to fill job positions since workers are faced with very limited housing choices.

The Tillamook Housing Needs Analysis (HNA) is being conducted to ensure that the County can plan for coordinated housing growth in line with community preferences and market forces. The HNA includes the following:

- A determination of 20-year housing needs based upon long-term growth forecast of demand by permanent and seasonal population increases.
- An analysis of buildable vacant, part-vacant and re-developable land inventory (BLI) for land that's planned to accommodate housing.
- Identification of new housing goals, objectives, and policy actions that address housing opportunities.



# Section II. MARKET TRENDS AND FORECASTS

**This section of the HNA includes a forecast of housing needed to accommodate expected year round and seasonal population growth for Tillamook County.** The housing needs forecast represents a 20-year projection from the base year (2019) through year 2039. These technical findings are also consistent with the State of Oregon requirements for determining housing needs per Oregon land use planning Goals 10 and 14, OAR Chapter 660, Division 8, and applicable provision of ORS 197.295 to 197.314 and 197.475 to 197.490, except where noted.

## II.A. METHODOLOGY

The methodology for forecasting housing needs for Tillamook County considers a mix of demographic and socio-economic trends, housing market characteristics and long-range population growth projections. Population is a primary determinate for household formations—which in-turn drives housing need. Given the significance of coastal tourism and visitation, the demand for second homes and short-term rentals is also an important determinate in understanding future housing needs.

County-wide population, households, income and housing characteristics are described in this section using available data provided by reliable sources, such as the U.S. Census Bureau (Census and American Community Survey), the U.S. Department of Housing and Urban Development (HUD), Oregon Department of Housing and Community Services, Portland State University (PSU) and Tillamook County's Planning and Community Development department. Where trends and forecasts are provided by an identified data source, FCS GROUP has included extrapolations or interpolations of the data to arrive at a base year (2019 estimate) and forecast year (2039 projection).

The housing need forecast translates population growth into households and households into housing need by dwelling type, tenancy (owner vs. renter) and affordability level.

## II.B. DEMOGRAPHICS AND SOCIO-ECONOMICS

### Population

Since the year 2000, Tillamook County's permanent year-round population (including local cities) increased 8.6%, from 24,262 residents in 2000 to 26,348 in 2019. Population within Tillamook County is projected to increase to 29,284 over the next 20 years (0.5% avg. annual growth rate).

As population increases, the demand for all types of housing will increase. This HNA supports long-range planning focused on expanding the local housing inventory to accommodate baseline population growth.

**Population Growth Forecast** in AGR Tillamook County, Oregon, 2019-2039
Source: Portland State University Population Research Center

| 0.50% | 1.05% |
|---|---|
| Tillamook County | Oregon |

The long-range population forecast prepared by PSU's Population Research Center (PRC) expects 2,936 additional people to be added to Tillamook County by year 2039. This equates to an annual average growth rate (AGR) of 0.5%. Baseline population growth forecasts for Tillamook County and its incorporated areas is shown below in **Exhibit 2.1**.

Exhibit 2.1 Population Growth Forecast

|  | Estimate 2019 | Forecast 2039 | Proj. Change 20 Years | Proj. AGR (2019-2039) |
|---|---|---|---|---|
| Oregon | 4,209,177 | 4,954,640 | 745,463 | 0.8% |
| Tillamook County | 26,348 | 29,284 | 2,936 | 0.5% |
| Bay City | 1,448 | 1,796 | 348 | 1.1% |
| Garibaldi | 802 | 875 | 73 | 0.4% |
| Manzanita | 910 | 1,209 | 299 | 1.4% |
| Nehalem | 1,272 | 1,642 | 370 | 1.3% |
| Rockaway Beach | 1,590 | 1,862 | 272 | 0.8% |
| Tillamook | 5,643 | 6,439 | 796 | 0.7% |
| Wheeler | 415 | 486 | 72 | 0.8% |
| Unincorporated | 14,261 | 14,971 | 710 | 0.2% |

**Source**: Portland State Population Research Center, 2017 estimate; 2017-2040 forecast, interpolated by FCS GROUP.
Compiled by FCS Group. AGR = average annual growth rate.
*Populations are based on Urban Growth Boundary

Tillamook County has a relatively older population in comparison to the Oregon average. In Tillamook County, nearly 24% of the population is 65 or older, compared to 16% for Oregon as a whole. The median age of residents in Tillamook County was 48 in 2017, compared with the State average of 39.2.

**Median Age**, Tillamook County, Oregon, 2017
Source: U.S. Census Bureau, 2013-2017 American Community Survey, compiled by FCS Group

| 48.0 | 39.2 |
|---|---|
| Tillamook County | Oregon |

Tillamook County's average household size is 2.41 people per occupied household, which is slightly less than the statewide average of 2.5.

**Average Number of People per Unit**, Tillamook County, Oregon, 2017

Source: U.S. Census Bureau, 2013-2017 American Community Survey, compiled by FCS Group

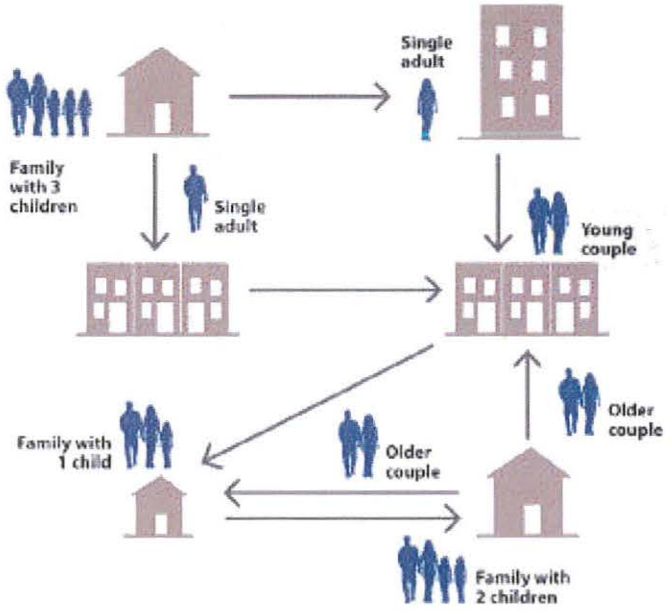
| 2.41 | 2.5 |
|---|---|
| Tillamook County | Oregon |

## Factors Affecting Housing Demand

There is a clear linkage between demographic characteristics and housing choice. As shown in the figure below, housing needs change over a person's lifetime. Other factors that influence housing include:

- Homeownership rates increase as income rises.
- Single family detached homes are the preferred housing choice as income rises.
- Renters usually have lower incomes than owners and are much more likely to choose multifamily housing options (such as apartments or plexes) over single-family housing.
- Very low-income households (those earning less than 50% of the median family income) are most at-risk for becoming homeless if their economic situation worsens.
- The housing available to households earning between 50% and 120% of the median family income is crucial to middle-income residents, and is often referred to "missing middle" housing stock or "workforce housing."
- Seasonal housing demand by part time residents will continue to occur primarily in coastal communities that provide access to recreational areas and services.

**Housing Life Cycle**



**Key definitions:**

**"Households"** consist of all people that occupy a housing unit.

**"Family"** is a group two or more people (one of whom is the householder) related by birth, marriage, or adoption and residing together.

The relationship between demographic changes and housing needs can be used to forecast future housing needs. Three main demographic changes affecting housing in Tillamook County include:

## Generational Cohorts

As people age, their housing requirements change with time. **Exhibit 2.2** summarizes the current (2017) distribution of major generational cohorts of people living in Tillamook County.

### Greatest/Silent Generation (those born before 1925 to 1945)

This includes retirees better than age 74, who were raised during the Great Depression, Word War I or World War II. This cohort currently accounted for 9% of the county's population in 2017. As they reach their 80s some move into assisted living facilities with convenient health care services and transit access. Meanwhile, others will leave the county to be closer to family or medical services.

### Baby Boom Generation (those born 1946 to 1964)

Baby boomers (currently age 55 to 74) accounted for 32% of Tillamook County residents in 2017. The boomer population segment has been growing more rapidly than the other cohorts over the past 10 years and many are now entering their retirement years. Boomers usually prefer to "age in place" but may downsize or move in with family members, sometimes opting to reside in accessory dwellings off the main house.

### Generation X (born early 1965 to 1980)

Gen X (currently includes people between age 39 to 54) accounted for 17% of Tillamook County residents in 2017. GenX households often include families with children, and many prefer to live in single family detached dwellings at various price points.

### Millennials (born early 1980s to early 2000s)

Millennials (currently in their twenties or thirties) accounted for 21% of Tillamook County residents in 2017. Younger millennials tend to rent as they establish their careers and/or payback student loans. Working millennials often become first-time homebuyers, opting to purchase smaller single-family detached homes or townhomes.

### Generation Z (born mid-2000s or later)

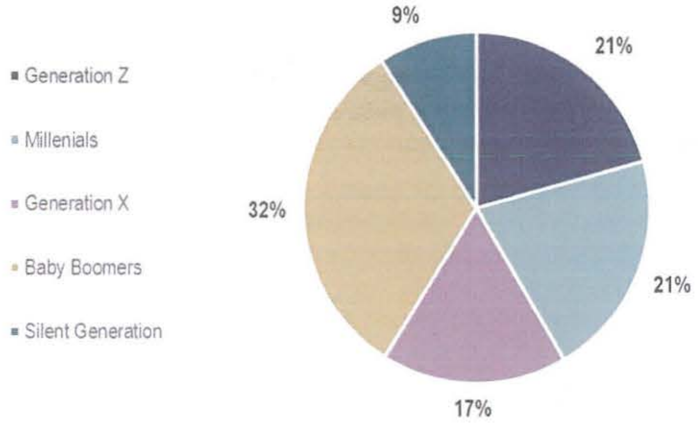
GenZ includes residents age 19 or less, which accounted for 21% of Tillamook County residents in 2017. This segment mostly includes children living with Gen Xers or Millennials.

### Families with Children living at home

This category includes a subset of Baby Boomers, Gen Xers and millennials. Taken as a whole, this category constitutes a significant proportion of Tillamook County's population; and is expected to increase moderately over the next two decades. Families prefer to live in a variety of housing types (detached homes or townhomes/plexes) at price points commensurate with their family income.

**Exhibit 2.2**

**Population Share** by Generational Cohort, Tillamook County, 2013-2017



Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates, Table B01001

## Income Characteristics

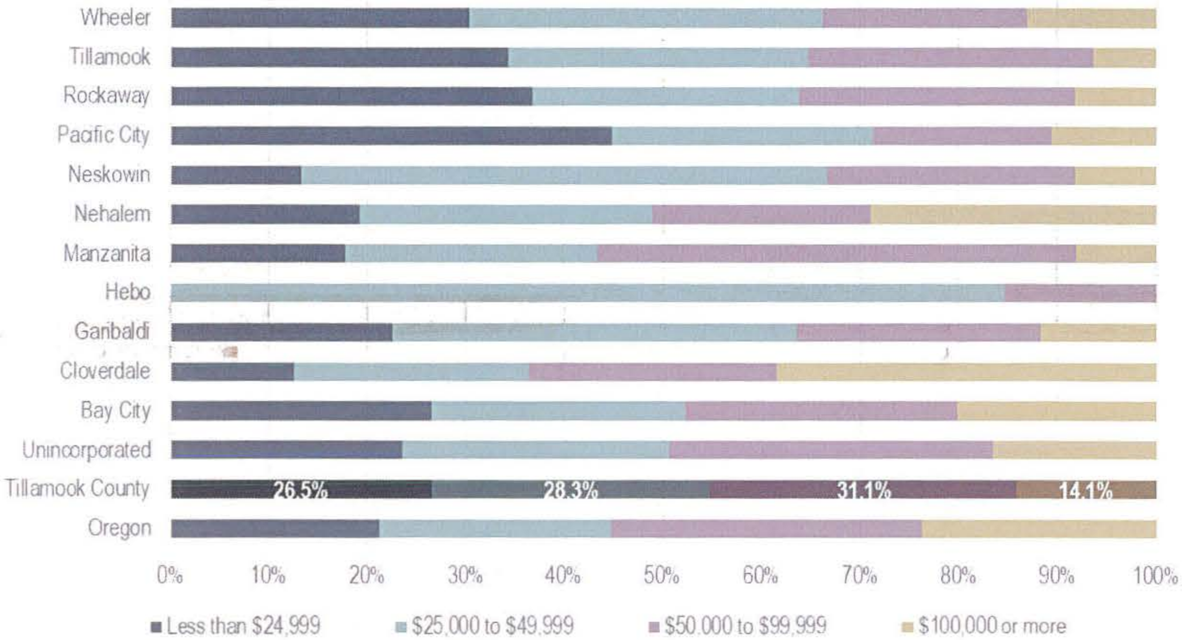
The median household income in Tillamook County ($45,061) is well below incomes observed statewide in Oregon ($56,119).

As shown in **Exhibit 2.3**, Tillamook County in comparison with Oregon, has a higher share of low-income residents (earning less than $30,000), and a lower share of middle- and upper-income residents (those earning more than $50,000). Countywide incomes vary significantly between communities, with Hebo, Pacific City, Rockaway and City of Tillamook residents having relatively lower incomes compared with Manzanita and Nehalem.

It should be noted that this analysis focuses on local cities and Census Defined Places, since those are the communities for which comparative data are available. There are additional small communities in Tillamook county, such as Oceanside, Netarts and Beaver, which do not have readily available statistics. While such small communities are vital, they are referenced here within the unincorporated county area.

Exhibit 2.3

**Household Income**, Tillamook County, Other Comparison Cities, Oregon, 2017



Source: U.S. Census Bureau, 2013-2017 American Community Survey (Table B19001), compiled by FCS Group

## II.C. EXISTING HOUSING CHARACTERISTICS

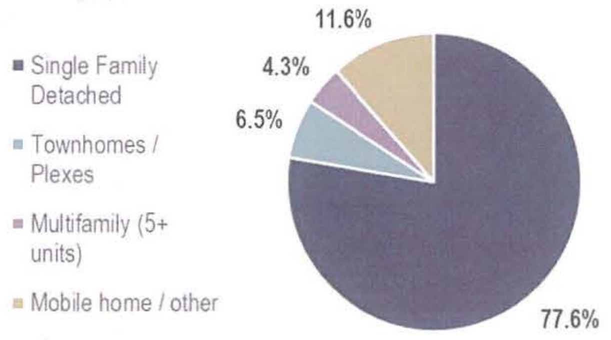
An analysis of historical development trends and local housing market dynamics provides insight regarding how the housing market functions. Findings indicate that changes in demographic and socio-economic patterns over the next two decades will result in a shift in housing demand from what is now predominantly single-family detached housing to wider mix of housing types.

### Housing Inventory and tenancy

The existing housing stock in Tillamook County is dominated by single family detached (low density development) which accounts for just over three-fourths of the inventory. This is well above the state average of 63.7%. Mobile homes/other housing types comprise the remaining 11.6% of the inventory. Townhomes/plexes (medium density development) accounts for 6.5% of the inventory. Multifamily apartments and condos (with more than 5 units per structure) currently comprise only 4.3% of the inventory (see **Exhibit 2.4**).

Exhibit 2.4

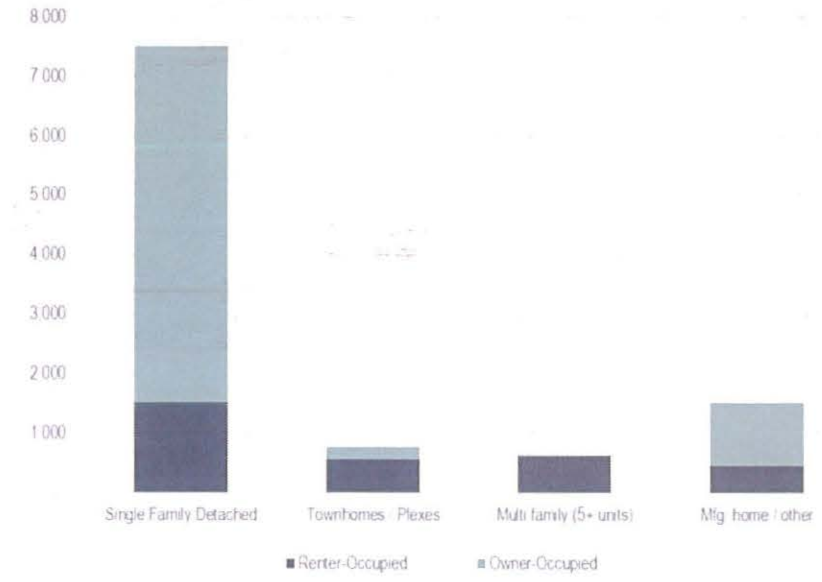
**Households** by Housing Type, Tillamook County, 2017



The overall housing tenancy in Tillamook County mirrors the Oregon statewide average, with 69% of the permanent residents owning their homes, and the remaining 31% renting. As shown in **Exhibit 2.5**, most homeowners reside in single family detached homes or mobile homes (including manufactured housing). Renters occupy all types of housing, and constitute the majority of demand for townhomes/plexes and multifamily apartments.

Exhibit 2.5

**Tenancy** by Type of Housing, Tillamook County, 2017

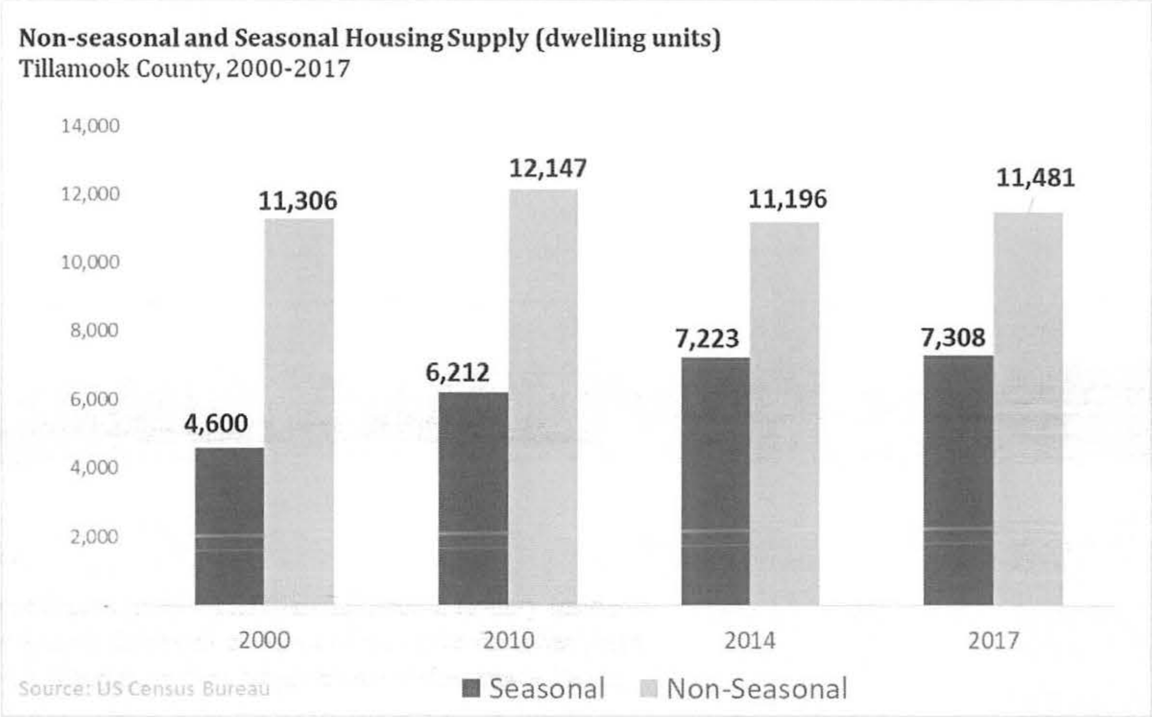


## Seasonal Housing Inventory and Vacancy Rates

The prior housing study that was prepared for Tillamook County, *Creating a Healthy Housing Market for Tillamook County*, March 2017 (by CZB), noted that the housing market in Tillamook County has two distinct parts. There is a ***coastal market*** with strong demand from upper-income households, investors, second home buyers and retirees. And there is an ***interior market*** concentrated largely around Tillamook and other inland communities, such as Bay City. This market has a relatively older and less expensive housing inventory, which is more attainable to local residents. The demand for both seasonal housing and year-round non-seasonal demand is rising, as indicated in **Exhibit 2.6**.

Of Tillamook County's 18,789 total housing units, 44%, were classified as having "seasonal ownership" in 2017, up from 38% in 2010, according to the U.S. Census American Community Survey.

Exhibit 2.6

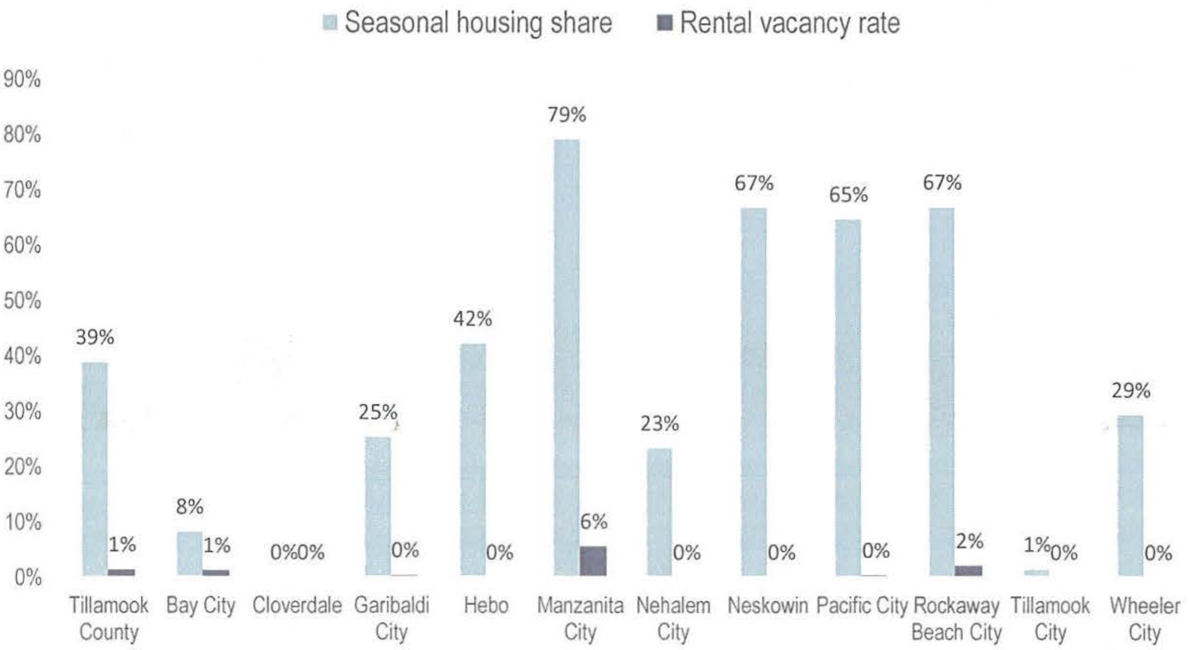


Source: US Census Bureau

The seasonal housing inventory varies significantly by location, with the City of Tillamook, Bay City and Cloverdale having the lowest rates of seasonal homeownership and coastal resort areas such as Rockaway Beach and Manzanita having the highest levels at 74% and 87%, respectively.

As shown below in **Exhibit 2.7,** the vacancy rates for non-seasonal (year round rental housing) is well below 1% in all areas and near zero in Cloverdale, Gribaldi, Hebo, Nehalem, Neskowin and Wheeler. In comparison, the statewide average housing vacancy rate was 9.3% in 2017.

**Exhibit 2.7 Vacancy Rates by Housing Type**



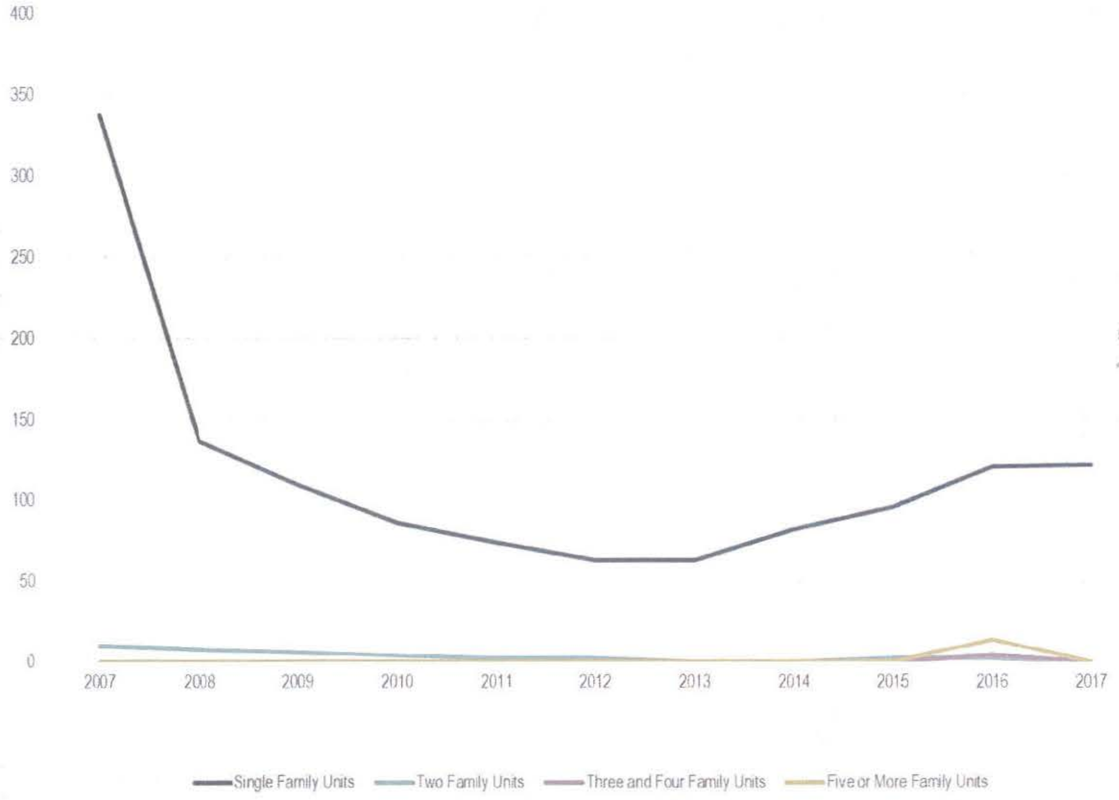
## Housing Construction Permitting Activity

During the past decade new housing construction in Tillamook County has been dominated by single family housing. Despite falling sharply following the recession, the county has issued an average of 117 single family permits annually for new construction since 2007. Issuance of new permits has picked up since its low of 2013 (**Exhibit 2.8**).

Housing production has not nearly kept up with the pace of demand. Between 2007 and 2017, about 120 new dwellings were added throughout Tillamook County annually with the vast majority as second homes. Most new housing construction has occurred in coastal "resort" towns, such as Manzanita, Neskowin, Pacific City and Rockaway Beach, where 66%-80% of the total housing stock is now owned by part-time residents. During this same time frame, it is estimated that about 80-90 existing dwelling units were converted to seasonal units or short-term vacation rentals each year. As such, the permanent year-round housing inventory in Tillamook County has been decreasing at a time when nearly 60 households were moving into the county each year.

### Exhibit 2.8

**Building Permits Issued**, Tillamook, 2007-2017



Source: HUD Government website, SOCDS Building Permits Database 2007-2017

## Housing Affordability

The median home price in Tillamook County was approximately $323,000 (2019, 1st Q), which is slightly below the median home price in Oregon as a whole. As shown in **Exhibit 2.9**, year-over-year, home prices in Tillamook County increased by 12.2% from $288,000 in 2018 to $323,000 in 2019.

**Median Home Sales Price**, Tillamook County, Oregon, January 2018 to 2019

**$323,000**
Tillamook County

**$346,100**
Oregon

In general, home values declined following the Great Recession (2009 to 2014), then began a steady ascent. In Tillamook County, it is estimated that median home prices have increased by over 40%

between 2014 and 2019. During this same time frame, median household income levels in Tillamook County increased only 21%; thereby creating a major housing affordability challenge.

Based on active home listings and average sales over the past two years in Tillamook County, there is less than a three month supply of homes priced under $300,000; and only a four to five month inventory of homes priced $300,000 to $500,000. For comparison, a healthy housing market is considered to have a six month housing inventory.

Exhibit 2.9

**Homes Sales and Inventory, Tillamook County**

| Sales Price Level | Recent Sales (past 2 years) | Avg. Sales Per Month (past 2 years) | Current Listings | Remaining Inventory (months) |
|---|---|---|---|---|
| Sales Price Level | | | | |
| Less than $100,000 | 175 | 7.3 | 4 | 0.5 |
| $100,000 to $199,999 | 384 | 16.0 | 27 | 1.7 |
| $200,000 to $299,999 | 556 | 23.2 | 61 | 2.6 |
| $300,000 to $399,999 | 421 | 17.5 | 70 | 4.0 |
| $400,000 to $499,999 | 270 | 11.3 | 57 | 5.1 |
| $500,000 or more | 298 | 12.4 | 124 | 10.0 |
| Total | 2,104 | 88 | | |

**Source:** Zillow.com; analysis by FCS 9/3/19.

**Median Home Price Sales Trends in Select Markets**

| | Aug-18 | Aug-19 | Change % |
|---|---|---|---|
| Tillamook County | $288,000 | $323,000 | 12.2% |
| Bay City | $213,000 | $244,000 | 14.6% |
| Nehalem | $372,000 | $415,000 | 11.6% |
| Neskowin | $425,000 | $457,000 | 7.5% |
| Pacific City | $292,000 | $323,000 | 10.6% |
| Rockaway Beach | $255,000 | $294,000 | 15.3% |
| Tillamook City | $251,000 | $283,000 | 12.7% |

**Source:** Zillow.com; analysis by FCS Group 1/24/18.

Median rents are also slightly lower in Tillamook County compared with the Oregon statewide average. However, in many communities within Tillamook County, rents are now on par with or have surpassed the statewide average (**Exhibit 2.10**).

Exhibit 2.10

**Median Gross Rent**, Tillamook, Tillamook County, Oregon, Other Comparison Cities, 2013-2017

Source: U.S. Census Bureau 2013-2017 American Community Survey 5-Year Estimates (Table B25064)

## Housing Cost Burdens

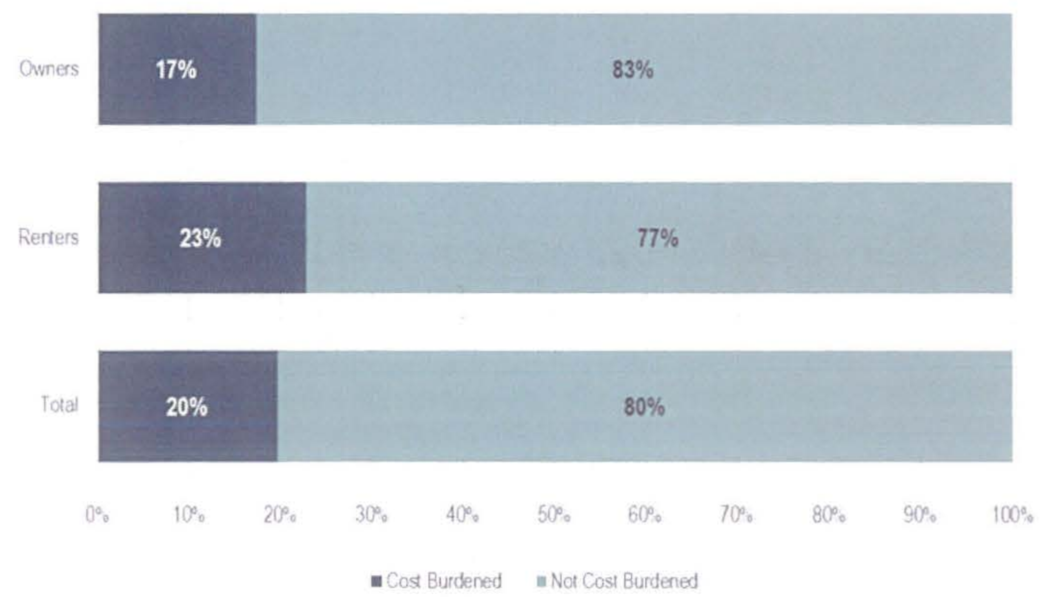
According to the U.S. Housing and Urban Development (HUD) standards, households are considered "cost burdened" if they pay over 30% of their income on housing. Households are "severely cost burdened" if they pay over 50% of their income on housing.

Despite relatively low housing costs, the fact that there limited numbers of family wage jobs makes finding attainably priced housing difficult for many residents. Approximately 23% of the renters and 17% of the owners in Tillamook County are severely cost burdened (see **Exhibit 2.11**).

Exhibit 2.11

**Severe Housing Cost Burden** by Tenure, Tillamook County, 2013-2017

Based on the assumption that the cost burden threshold is 50% of income



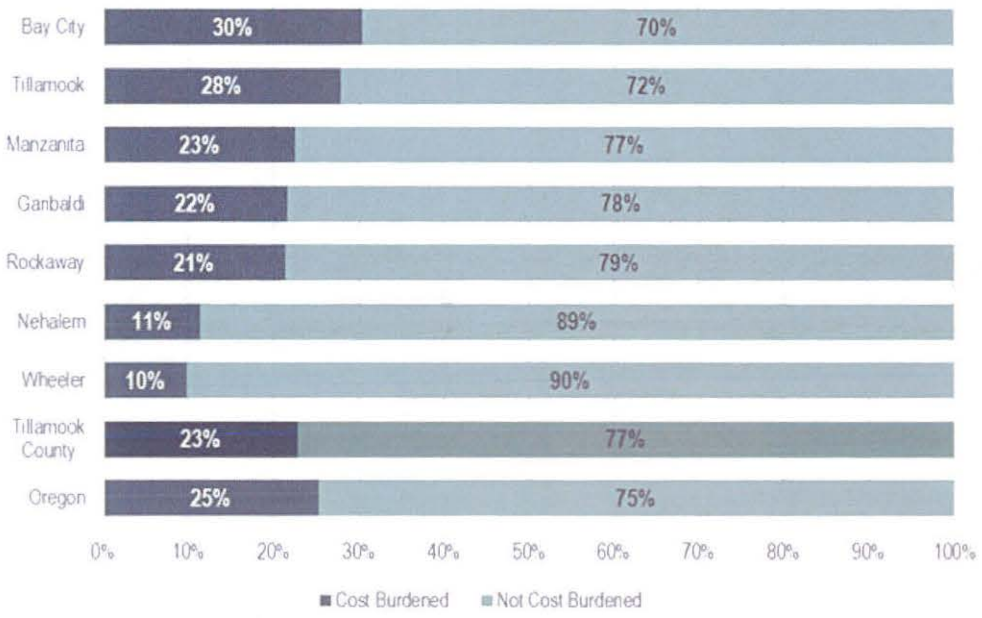
Severe rent burdens vary widely between local areas. For example, Wheeler faces severe rent burden rates of just 10%, while 30% of Bay City renters are severely rent burdened (see **Exhibit 2.12**).

**Exhibit 2.13** further illustrates the link between lower incomes and housing cost burdens. Over 80% of households earning less than $20,000 were cost burdened in Tillamook County. In fact, almost 60% of households earning less than $50,000 are paying more than 30% of their income in housing costs.

### Exhibit 2.12

**Severe Rent Cost Burden**, Tillamook County, Oregon, Other Comparison Cities, 2013-2017

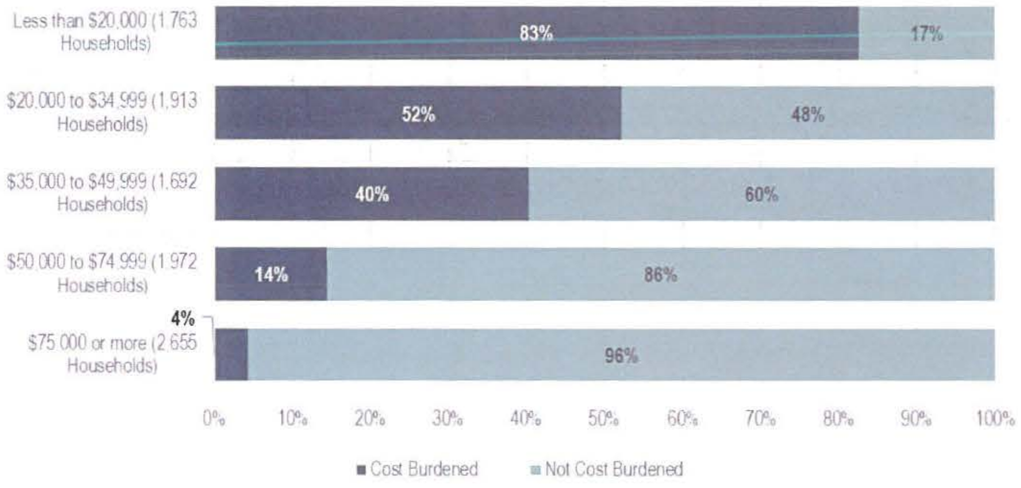
*Based on the assumption that the housing cost burden threshold is 50% of income



### Exhibit 2.13

**Housing Cost Burden** by Income, Tillamook County, 2013-2017

*Based on the HUD assumption that the cost burden threshold is 30% of income



## Workforce Housing Demand

Representatives from local businesses, school districts, hospitals and emergency service sectors (e.g., police and fire districts) have voiced concern over the lack of attainable housing for their employees. Many workers now travel very long distances to jobs in Tillamook County. According to U.S. Census stats, **almost one in four workers in Tillamook County commute greater than 50 miles each way (100 miles per day); which is double the statewide average**. Nearly one in three local workers now reside outside Tillamook County.

Note: These findings are based on U.S. Census On-the-Map Longintudinal Employer-Household Dynamics (LEHD) data which are based on tabulated and modeled administrative employer suvey data, which are subject to error. The Quarterly Workforce Indicators (QWI), LEHD Origin-Destination Employment Statistics (LODES), Job-to-Job Flows (J2J), and Post-Secondary Employment Outcomes (PSEO) are available online for public use.

Because the estimates are not derived from a probability-based sample, no sampling error measures are applicable. While no direct measurement of these joint effects has been obtained, precautionary steps are taken in all phases of collection and processing to minimize the impact of nonsampling errors.

As indicated in **Exhibit 2.14**, FCS GROUP has documented market gaps in Tillamook County's available housing inventory. Conversion of homes to seasonal and vacation rentals, low vacancy rates, and inadequate housing construction levels result in market gaps that can only be corrected by supply additions. Based on relatively low market capture rates, as of year 2017, there is a housing gap of approximately 406 units for housing units needed for moderate income households at 50% to 120% of the area median family income (MFI) level.

In addition, there is also a significant market gap for government assisted housing available to households earning less than 50% of the MFI level. This analysis indicates that the market gap for rental housing at this price point equates to over 600 dwellings. In light of inadequate levels of state and federal housing grants, we have assumed a 33% market capture rate or approximately 200 units of low income housing demand is needed at this time.

Exhibit 2.14 Existing Housing Market Gaps, Tillamook County

**Current Housing Market Gap for Housing at 50% to 120% MFI or higher, Tillamook County**

| | | Total Dwelling Units | Rental Units | Owner Units |
|---|---|---|---|---|
| Existing Workers in Tillamook County | 9,476 | | | |
| Long Distance commuters (over 100 miles per day) | 2,030 | | | |
| Market Demand Sensitivity Analysis | | | | |
| Low Capture Rate | 15% | 305 | 152 | 152 |
| Midpoint Capture Rate | **20%** | **406** | **203** | **203** |
| High Capture Rate | 25% | **508** | **254** | **254** |

Based on U.S. Census Bureau, On-The-Map data for Tillamook County, 2017.

**Current Market gap for Housing at less than 50% MFI, Tillamook County**

| Affordable Monthly Rent Costs * | Current # of Renter-Occupied Households | Estimated Available Rental Units at this rent level | Housing (Gap) or Surplus | Capture Rate for Analysis | Housing Needed (units) |
|---|---|---|---|---|---|
| Less than $500 | **1,139** | **528** | **(611)** | 33% | **202** |

Source: U.S. Census Bureau, American Community Survey, 2017. * Assumes 30% of income towards rent.

This analysis conservatively assumes that the level of near-term pent up market demand could support development of over 400 units of rental housing, with about half needed for households in the 50% to 120% of the MFI level for Tillamook County.

## II.D. FUTURE HOUSING NEEDS

The methodology includes three housing forecast scenarios which were reviewed and discussed by the Housing Committee. They include:

Scenario A Baseline Forecast

Scenario B Baseline + Workforce Housing Forecast

Scenario C Policy Scenario as modified version of Scenario 2

Scenario D Midpoint of low and high growth forecasts

### Scenario A: Baseline Housing Demand Forecast

The future (20 year) housing forecast for Tillamook County takes into account the population and socioeconomic and housing characteristics described earlier.

The baseline forecast applies the long term population forecast by Portland State University, and assumes that current household size, group quarters demand, vacancy rates and seasonal housing rates remain constant. With the baseline forecast, Tillamook County is projected to add 2,936 people which will require 2,305 new dwellings over the next 20 years. If the future housing demand is distributed within Tillamook County based on the current housing mix, the 20-year housing demand in the unincorporated areas would equate to 510 dwellings, and the various incorporated area UGBs would need to accommodate the remaining 1,795 housing unit (see **Exhibit 2.15**).

### Exhibit 2.15 Scenario A Baseline Forecast

**Baseline Housing Demand Forecast, Tillamook County, 2019-2039**

| | Net New Population[1] | Group Quarters Share | Group Quarters Pop.[2] | Avg. HH Size[2] | Occupied Dwellings[2] | Seasonal & Vacancy Rate[2] | Seasonal & Vacant Dwellings | Total Dwelling Need (excl. group quarters) |
|---|---|---|---|---|---|---|---|---|
| **Unincorporated areas** | **707** | 2.6% | 18.4 | 2.41 | **286** | **44.0%** | **225** | **510** |
| Tillamook UGB | 796 | 0.88% | 7.0 | 2.47 | **319** | 8.5% | 30 | **349** |
| Nehalem UGB | 370 | 0.00% | - | 3.43 | **108** | 25.0% | 36 | **144** |
| Bay City UGB | 348 | 0.00% | - | 3.43 | **101** | 14.6% | 17 | **119** |
| Manzanita UGB | 299 | 0.00% | - | 3.43 | **87** | 86.6% | 562 | **649** |
| Rockaway Beach UGB | 272 | 0.00% | - | 2.27 | **120** | 73.7% | 336 | **456** |
| Garibaldi UGB | 73 | 0.75% | 0.5 | 2.62 | **28** | 31.8% | 13 | **41** |
| Wheeler UGB | 72 | 1.45% | 1.0 | 2.62 | **27** | 29.4% | 11 | **38** |
| **Total** | **2,936** | **0.9%** | **27** | | **1,076** | **53.3%** | **1,229** | **2,305** |

**Notes:** [1] population forecast from PSU Population Research Center, interpolated by FCS GROUP; [2] based on 2017 ACS. Numbers may not add due to rounding.

## Scenario B: Baseline + Workforce Housing Forecast

This scenario includes the baseline housing forecast based on future growth along with a capture of a portion of the current market gap for workforce housing.

As discussed earlier in this report, there is a demonstrated "market gap" for workforce housing in Tillamook County. In this scenario, it is assumed that the overall housing demand over the next 20 years equates to the baseline demand described in Scenario A plus an additional 400 units of pent up demand for rental housing. This would include approximately 200 units of moderate income rental housing attainable to households earning 50% to 120% of the MFI; and another 200 units for households earning less than 50% of the MFI level.

This forecast scenario assumes that the majority of the housing production would occur in communities that can provide water and sanitary sewer service, with capacity that can be increased as needed to accommodate new housing development. As shown in **Exhibit 2.16**, the housing forecast under Scenario B equates to 2,730 dwelling units over 20 years.

Exhibit 2.16 Baseline + Workforce Housing Forecast Scenario B

| | Demand Dist. (Scenario A) | Demand Dist. (Scenario B) | Pent Up Rental Workforce Housing Need (units) | Baseline Housing Need (Scenario A) | Total Housing Need (Scenario B) |
|---|---|---|---|---|---|
| Tillamook UGB | 15% | 25% | 106 | 349 | 455 |
| Nehalem UGB | 6% | 5% | 21 | 144 | 165 |
| Bay City UGB | 5% | 5% | 21 | 119 | 140 |
| Manzanita UGB | 28% | 10% | 43 | 649 | 691 |
| Rockaway Beach UGB | 20% | 10% | 43 | 456 | 499 |
| Garibaldi UGB | 2% | 5% | 21 | 41 | 62 |
| Wheeler UGB | 2% | 5% | 21 | 38 | 59 |
| Subtotal UGBs | 78% | 65% | 276 | 1,795 | 2,071 |
| **Unincorporated areas** | **22%** | **35%** | **149** | **510** | **659** |
| **Total Dwelling Units** | 100% | 100% | **425** | **2,305** | **2,730** |

## Scenario C: Coordinated Policy Forecast

This scenario assumes that same level of overall Countywide housing demand as with Scenario B, but takes into account the fact that many of the coastal communities may have achieved market prices for land and housing that is out of reach for most residents. Small cities and resort communities in Tillamook County may not be capable of accommodating all of the potential market demand. Limiting factors may include inadequate infrastructure (particularly sewer) and environmental risks associated with developing housing in floodways, floodplains and tsunami hazard areas.

As shown in **Exhibit 2.17**, with this scenario it is assumed that the share of housing demand that will be accommodated within incorporated cities is 59% of total demand, down from about three quarters of total demand in the prior scenarios. Hence, the level of demand that would need to be addressed within unincorporated portions of Tillamook County would increase to 41% of the Countywide housing demand, compared with 22% to 24% in Scenarios A and B.

Exhibit 2.17 Housing Market Share by Scenario

| | Demand Dist. (Scenario A) | Demand Dist. (Scenario B) | Demand Dist. (Scenario C) | Total Housing Need (Scenario C) |
|---|---|---|---|---|
| Tillamook UGB | 15% | 17% | 30% | 819 |
| Nehalem UGB | 6% | 6% | 5% | 137 |
| Bay City UGB | 5% | 5% | 5% | 137 |
| Manzanita UGB | 28% | 25% | 5% | 137 |
| Rockaway Beach UGB | 20% | 18% | 10% | 273 |
| Garibaldi UGB | 2% | 2% | 2% | 55 |
| Wheeler UGB | 2% | 2% | 2% | 55 |
| Subtotal UGBs | **78%** | **76%** | **59%** | **1,611** |
| **Unincorporated areas** | **22%** | **24%** | **41%** | **1,119** |
| **Total Dwelling Units** | 100% | 100% | 100% | **2,730** |

## Comparison of Housing Forecast Scenarios

These findings indicate that the future housing market in Tillamook County is expected to remain strong, barring natural disasters or global or national economic downturns. Population increases due largely to second home investors will likely account for just over half of the future housing demand. In order for housing prices and rents to be attainable to households at 120% or less of the local median income level for the County ($45,060), for sale housing would need to be priced at $299,000 or less and rentals priced at $1,352 or less (per month for 2 bedroom unit). For additional analysis of housing affordability levels, please refer to **Appendix A.**

**Exhibit 2.18** provides a comparison of the housing demand within local areas for each of the three forecast scenarios. The findings indicate a low and high range of housing needs along with a mid-point demand forecast, which is referred to as Scenario D.

Exhibit 2.18

**Tillamook County 20-year Housing Forecast Scenarios (dwelling units)**

| | Scenario A | Scenario B | Scenario C |
|---|---|---|---|
| Tillamook UGB | 349 | 455 | 819 |
| Nehalem UGB | 144 | 165 | 137 |
| Bay City UGB | 119 | 140 | 137 |
| Manzanita UGB | 649 | 691 | 137 |
| Rockaway Beach UGB | 456 | 499 | 273 |
| Garibaldi UGB | 41 | 62 | 55 |
| Wheeler UGB | 38 | 59 | 55 |
| Subtotal UGBs | **1,795** | **2,071** | **1,611** |
| **Unincorporated areas** | **510** | **659** | **1,119** |
| **Total Dwelling Units** | **2,305** | **2,730** | **2,730** |

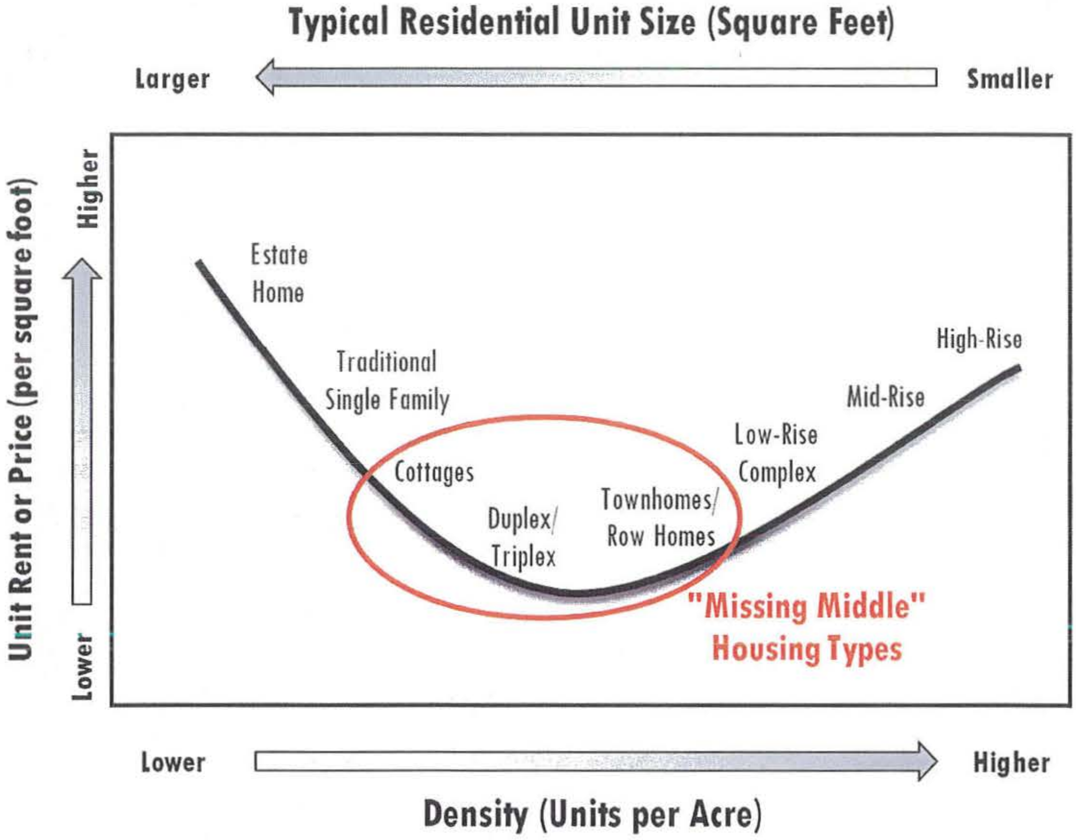
| | Low | High | Midpoint (Scenario D) |
|---|---|---|---|
| Tillamook UGB | 349 | 819 | 584 |
| Nehalem UGB | 137 | 165 | 151 |
| Bay City UGB | 137 | 140 | 138 |
| Manzanita UGB | 137 | 691 | 414 |
| Rockaway Beach UGB | 273 | 499 | 386 |
| Garibaldi UGB | 55 | 62 | 58 |
| Wheeler UGB | 55 | 59 | 57 |
| Subtotal UGBs | **1,141** | **2,435** | **1,788** |
| **Unincorporated areas** | 510 | 1,119 | 815 |
| **Total Dwelling Units** | **1,651** | **3,554** | **2,603** |

**Source:** prior exhibits.

## Projected Needs by Housing Type

In light of the current housing affordability challenges, the future demand for attainably priced housing within Tillamook County will need to increase measurably in the future. This would require development of affordable "missing middle" housing types, such as market rate and government assisted plexes, townhomes and apartments as well as cottage homes, manufactured homes and accessory dwelling units (ADUs). As shown in **Exhibit 2.19**, these housing types can be delivered at a lower cost and rent level per square foot than other housing types.

Exhibit 2.19

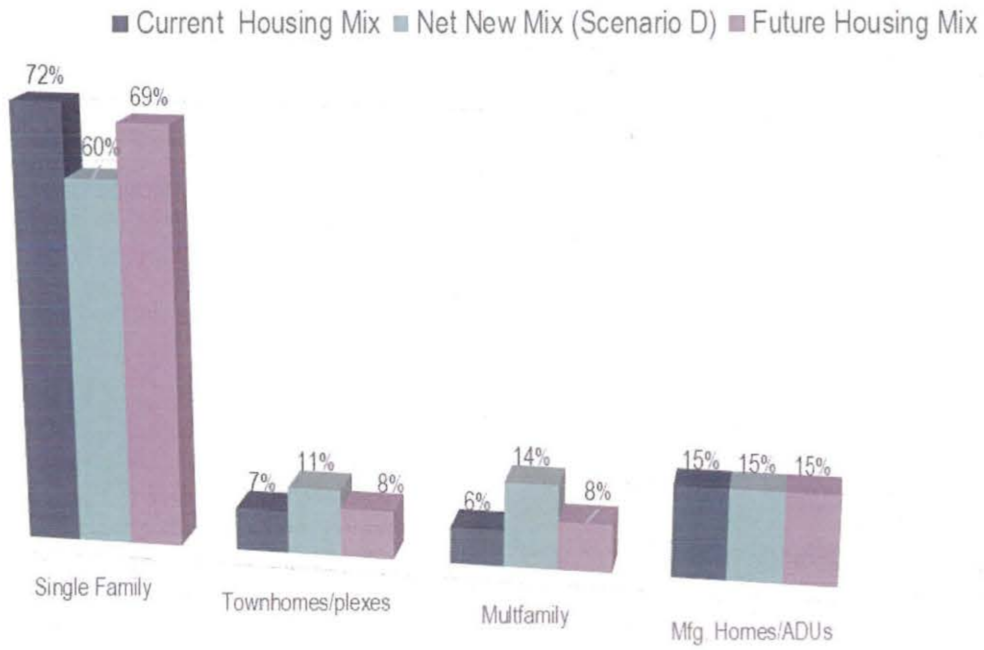


The forecasted housing mix that addresses future demand will likely consist of: 1,562 single-family detached homes (including cottage homes), 286 townhomes/duplexes/ADUs, 364 multifamily housing units and 390 manufactured housing units (see **Exhibit 2.20**). There will also be some "group quarters" housing demand for about 30 additional residents that will require shared living arrangements (such as congregate care or interim housing).

The graph below juxtaposes the housing mix in Tillamook County today compared with the projected mix of units to be added in the next twenty years and the overall housing mix observed in the county after twenty years. As shown in **Exhibit 2.21**, the Policy Scenario D would increase the overall share of multifamily, townhomes, and plexes in comparison to the current mix. The share of single family detached housing would decline and the share of manufactured housing would remain relatively constant.

Exhibit 2.20

**Tillamook County Housing Need:** Current and Future dwelling units



Source: U.S. Census Bureau 2013-2017 American Community Survey (Table B25032), and Scenario D forecast

At midpoint of the forecast scenarios (Scenario D), the net new housing need is expected to consist of: 1,796 owner-occupied dwellings and 807 renter-occupied dwellings. As shown in **Exhibit 2.21**, the types of housing that is most suited to meet qualifying income levels for home ownership vary by family income level. The owner and rental housing forecast that's suited to meet qualifying income levels is shown below

Exhibit 2.21 Current and Future Housing Mix, Scenario D

| | Current Housing Mix | Net New Housing Mix (Policy Scenario C) | Future Housing Mix |
|---|---|---|---|
| Single Family | 72% | 60% | 69% |
| Townhomes/Plexes | 7% | 11% | 8% |
| Multi family | 6% | 14% | 8% |
| Mfg. home / other | 15% | 15% | 15% |
| Total | 100% | 100% | 100% |

| | Current Housing Mix | Net New Housing Mix (Policy Scenario C) | Future Housing Mix |
|---|---|---|---|
| Single Family | 7,501 | 1,562 | 9,063 |
| Townhomes/Plexes | 781 | 286 | 1,067 |
| Multi family | 641 | 364 | 1,005 |
| Mfg. home / other | 1,531 | 390 | 1,921 |
| Total | **10,454** | **2,603** | **13,057** |

**Source:** prior exhibits.

As we consider the demand for housing by affordability level, the vast majority of housing demand needs will be from households at 120% or below of the Median Family Income level for Tillamook County (see **Exhibit 2.22**).

For additional analysis regarding housing affordability price points for owner occupied and renter occupied housing please refer to **Appendix A**.

**Exhibit 2.22 Forecasted Housing Demand by Affordability (Scenario D)**

| Approximate Attainable Home Price* | Owner-Occupied | Renter-Occupied | Total | Dist. % | Attainable Housing Products |
|---|---|---|---|---|---|
| Upper (120% or more of MFI) | 790 | 166 | 956 | 36.7% | Standard Homes, Townhomes, Condos |
| Upper Middle (80% to 120% of MFI) | 647 | 135 | 782 | 30.0% | Small Homes, Townhomes, Apartments |
| Lower Middle (50% to 80% of MFI) | 269 | 163 | 433 | 16.6% | ADUs, Townhomes, Mfgd. Homes, |
| Low (30% to 50% of MFI) | 90 | 190 | 279 | 10.7% | Govt. Assisted Apts. & Plexes |
| Very Low (less than 30% of MFI) | 0 | 153 | 153 | 5.9% | Govt. Assisted Apts. |
| **Total** | **1,796** | **807** | **2,603** | **100.0%** | |

*Assumes 30% of income is used for rental or mortgage payments. Derived from Appendix A.

## Projected Residential Land Needs

Using the mid-points of the housing demand forecasts, the buildable land that will be needed to accommodate planned housing production is shown in **Exhibit 2.23. At the midpoint of the growth forecast scenarios (Scenario D), the overall amount of residential land that will be needed within all of Tillamook County over the next 20 years equates to just over 1,340 buildable acres of land area.**

It should be noted that actual gross land needs could be much higher given the limited availability of sewer infrastructure capacity with in Tillamook County.

The forecast of residential land that is needed within each local community and incorporated cities is provided below by general land use type (low, medium and high density) for discussion and policy planning purposes.

Exhibit 2.23

**Tillamook County 20-year Housing Land Need Forecast at Midpoint**

| | | Housing Mix* | | | | Land Need (Buildable acres) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total Housing Need (Midpoint) | Very Low Density (single family homes) | Low Density (single family and mfg. homes) | Medium Density (townhomes, plexes) | Higher Density (apartments | Very Low Density | Low Density | Medium Density | Higher Density | Total Land Need (buildable acres) |
| Tillamook UGB | 584 | - | 292 | 124 | 169 | - | 97 | 21 | 14 | 132 |
| Nehalem UGB | 151 | - | 75 | 32 | 44 | - | 25 | 5 | 4 | 34 |
| Bay City UGB | 138 | - | 69 | 29 | 40 | - | 23 | 5 | 3 | 31 |
| Manzanita UGB | 414 | - | 207 | 88 | 120 | - | 69 | 15 | 10 | 94 |
| Rockaway Beach UGB | 386 | - | 193 | 82 | 112 | - | 64 | 14 | 9 | 87 |
| Garibaldi UGB | 58 | - | 29 | 12 | 17 | - | 10 | 2 | 1 | 13 |
| Wheeler UGB | 57 | - | 28 | 12 | 17 | - | 9 | 2 | 1 | 13 |
| Subtotal UGBs | **1,788** | **-** | **894** | **378** | **518** | - | **298** | **63** | **43** | **404** |
| **Unincorporated areas**** | **815** | **407** | 326 | 81 | - | **815** | 109 | 14 | - | **937** |
| Total | **2,603** | **407** | **1,220** | **460** | **518** | **815** | **407** | **77** | **43** | **1,341** |

*Assumes mix and density as follows:

| | City/Town Housing Mix | Unincorp. Area Mix** | Dwellings per acre (avg.) |
|---|---|---|---|
| Very Low Density* | 0% | 50% | 0.5 |
| Low Density | 50% | 40% | 3 |
| Medium Density | 21% | 10% | 6 |
| Higher Density | 29% | 0% | 12 |
| **Total** | **100%** | **100%** | |

Source: compiled by FCS GROUP based on midpoint of housing forecast scenarios and expected market demand.

# Section III. BUILDABLE LAND INVENTORY

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This section includes a summary of the residential buildable land inventory (BLI) in Tillamook County. The focus of this 2019 BLI analysis is on the following geographic areas:

- Tillamook County, unincorporated areas outside existing urban growth boundaries (UGBs)
- Tillamook UGB
- Manzanita UGB
- Bay City UGB

In addition to these locations, this report cites findings from prior adopted plans and BLI studies to ascertain buildable lands in the following locations:

- Garibaldi UGB
- Nehalem UGB
- Rockaway Beach UGB
- Wheeler UGB

## METHODOLOGY

As part of Tillamook County's Housing Needs Analysis process, an estimate of buildable lands was completed to assess the supply of available land for housing development in unicorporated areas as well as three cities that opted to update their land inventories at this time. The Buildable Lands Inventory (BLI) was completed in accordance with OAR 660-008-0005 (2) and guidance provided by the Department of Land Conservation and Development (DLCD).[1]

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[1] While Oregon state regulations pertaining to BLI methods apply only to UGBs of incorporated areas, the same methodology was applied to unincorporated portions of Tillamook County with one exception which was reviewed by the Housing Committee: the removal of 100-year flood zones from the vacant land inventory for unincorporated areas only. The BLIs for incorporated areas assume land within 100-year flood zones is considered to be unconstrained and buildable.

The objective of the residential BLI is to determine the amount of developable land available for future residential housing development. The steps taken to perform this analysis are as follows:

1. Create a unified environmental constraints layer. These are areas where land is unsuitable for development due to natural hazards
2. Generate the residential land base by identifying all taxlots that are zoned to allow residential development (either permitted outright or as a conditional use)
3. Subtract all environmentally constrained land from the residential land base
4. Classify land by development category (vacant, partially vacant, or redevelopable)
5. Calculate total net buildable acres by netting out land needed for public facilities such as roads and utility infrastructure and factoring a redevelopment rate for parcels deemed redevelopable

**Please refer to the separate Tillamook County Residential Buildable Land Inventory reports by Cascadia Partners for additional details regarding the methodology used for each location.**

## ALL AREAS OF THE COUNTY

An estimate of the total buildable land for residential development is provided in **Exhibit 3.1**. The results indicate that overall there is over 3,700 acres of buildable residential land area throughout the county, with the vast majority located in unincorporated areas.

It should be noted that the term density is used to reflect the average number of housing units per buildable acre on a particular site. Density is a relative term that generally reflects the type of housing that a land use zone is planned to accommodate. Based on local construction trends and market activity in Tillamook County, the density and housing types generally fall into the following categories:

- Very Low Density: 1 dwelling per 2 acres on average. Rural development typically relies on septic systems and connections to local water systems.
- Low Density: average of 3 dwellings per acre. Typically single family detached housing or mobile homes.
- Medium Density: 6-9 dwellings per acre. May include duplexes, townhomes and small lot cottage homes.
- High Density: typically 9-18 dwellings per acre. Includes townhomes and apartments.

## TILLAMOOK COUNTY (UNINCORPORATED AREAS)

Based on the BLI finding for the unincorporated portions of Tillamook County shown in **Exhibit 3.2 and Map 3.1**, approximately 2,135 acres of land are available in the residential buildable lands inventory. Not surprisingly, as most of unincorporated Tillamook County is rural, most of the land available falls under low density residential zoning (roughly 54%). Medium density residential and high density residential make up 34% and 10% of the residential buildable lands inventory respectively. Only 2% of the residential land base is comprised of land zoned as commercial / mixed-use.

Vacant land represents by far the largest opportunity for development, comprising more than 95% of the land available in the buildable lands inventory. While less partially vacant and redevelopable land is available, the location of specific parcels are important as they may represent geographies where development is highly desired (i.e., areas close to commercial cores) or where infrastructure (water and sewer) is available.

Exhibit 3.1: Summary of Residential Buildable Lands Inventory, Unicorp. Tillamook County (acres)

| | Relative Zoned Housing Density Class | | | | |
|---|---|---|---|---|---|
| **Location (BLI Source)** | **Very Low** | **Low** | **Medium** | **High** | **Total** |
| County Commercial (Cascadia 2019) | 30 | | 25 | | 54 |
| County Residential Zones (Cascadia 2019) | 1,710 | 286 | 11 | 11 | 2,017 |
| Manzanita UGB (Cascadia 2019) | | 52 | 69 | 6 | 127 |
| Neahkahnie (Cascadia 2019) | | 13 | 25 | 76 | 114 |
| Nehalem (2018) | | 207 | 95 | 43 | 345 |
| Nehalem (COG 2007) | | 36 | 94 | 19 | 149 |
| Neskowin (Cascadia 2019) | 235 | 158 | 2 | 0 | 395 |
| Netarts (Cascadia 2019) | | 59 | 56 | 18 | 133 |
| Oceanside (Cascadia 2019) | | 82 | 1 | | 82 |
| Pacific City (Cascadia 2019) | 30 | 49 | 34 | 83 | 196 |
| Tillamook UGB (Cascadia 2019) | - | - | 17 | 45 | 62 |
| Wheeler (COG 2007) | | 61 | 18 | | 79 |
| **Total** | **2,004** | **1,001** | **446** | **302** | **3,753** |

**Source:** various Tillamook County and local area Buildable Land Inventory studies, as noted.

Exhibit 3.2: Residential Buildable Lands Inventory, Unincorporated Tillamook County, 2019

| Housing Category | Vacant | Partially Vacant | Redevelopable | Total Buildable |
|---|---|---|---|---|
| Very low density Residential | 1,097 | 27 | 21 | 1,145 |
| Medium Density Residential | 694 | 29 | 4 | 727 |
| High Density Residential | 205 | 8 | 1 | 214 |
| Commercial / Mixed-use | 45 | 2 | 1 | 48 |
| Total: | **2,042** | **66** | **27** | **2,135** |

**Source:** Tillamook County Buildable Land Inventory by Cascadia Partners et al., September 2019.

### Incorporated Cities

In addition to the 2019 BLI studies by Cascadia Partners and FCS GROUP, other communities in Tillamook County have completed residential buildable land inventories (BLIs) within the last 15 years. The objective of the residential BLI is to determine the amount of developable land available for future residential housing development within the UGB. BLI highlights include the following

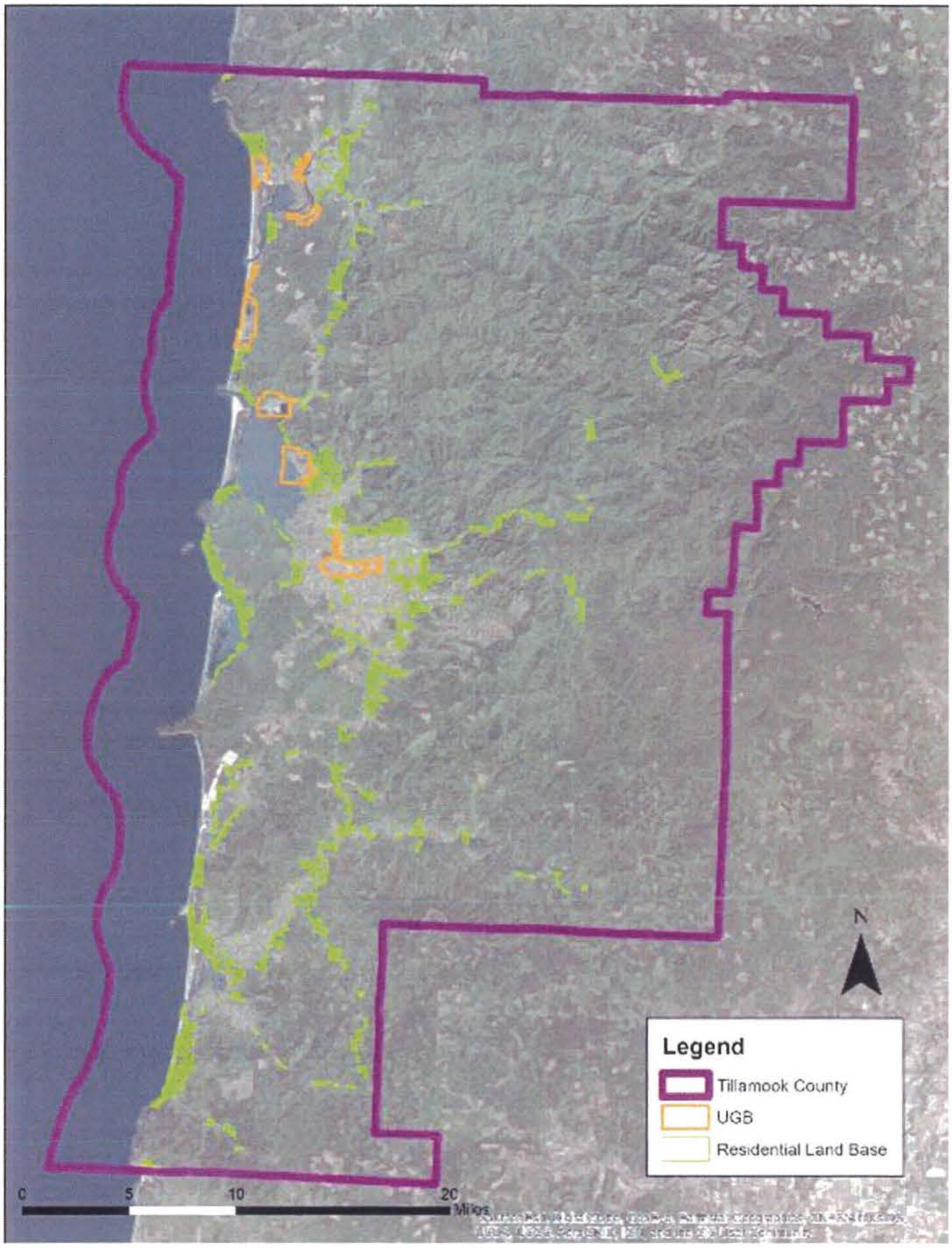
- **Tillamook:** draft findings by FCS GROUP/Cascadia Partners indicate that there is a current need for additional low- and medium-density zoned land area within the Tillamook UGB that ranges from approximately 48 to 76 acres of net buildable land area.
- **Nehalem:** according to the City of Nehalem, no residential land shortages were identified for the planning horizon (2007-2027) with an overall residential buildable land **surplus of 121.4 acres**. The City is in the process of approving a new buildable land inventory which indicates a **supply of 377.15 acres of residential land**. That BLI work is still in process.
- **Wheeler:** according to the City, no residential land shortages were identified for the planning horizon (2007-2027) with an overall residential buildable land **surplus of 66.7 acres**.
- **Rockaway Beach:** according to the City of Rockaway Beach, no residential land shortages were identified for the planning horizon (2007-2027) with an overall residential buildable land **surplus of 57 acres**.
- **Bay City:** Buildable Land Inventory is in process; however Housing Needs Analysis appears to be outdated.

- **Manzanita:** FCS/Cascadia identified a total land inventory of 122 net acres (residential zones) plus 4 acres of mixed use zoning (BLI adopted by City in Sept. 2019). This level of supply appears to be adequate for meeting the 20 year demand identified earlier in this report (94 acres at midpoint of low and high forecast scenarios).

These findings indicate the City of Tillamook may be able to justify a UGB expansion or a Comprehensive Plan amendment and with changes in zoning to allow for more housing. However, it is unlikely that other cities can do so in the near future.

In light of the significant level of housing demand outside the incorporated cities and their urban growth boundaries, and the desire to encourage more development in those locations, several local and state policy actions are identified in the next Section of this report for additional consideration.

Map 3.1 Residential Land Base, Unincorporated Tillamook County



# Section IV. ACTION PLAN

# POLICY RECOMMENDATIONS

This section summarizes relevant federal and state housing policies and identifies a set of Action Plan recommendations.

## RECENT POLICIES

Several recent policy changes have occurred at the federal, state and regional level that may affect the future housing supply and demand in Tillamook County.

### Federal Policies

**Tax Cuts and Jobs Act**

Passed in 2017, the Tax Cuts and Jobs Act initiates large scale federal tax reform. The reform made changes in many ways but most notable was the shift in the federal corporate tax rate, decreasing from 35% to 21%. The new tax cuts also lower most individual income tax rates, including the top marginal rate from 39.6 percent to 37 percent. The lower tax rates potentially affect Tillamook County and its municipalities because it makes tax free municipal bonds and affordable housing tax credits less attractive to investors because the relative advantage of lowering taxable income by investing in tax exempt bonds would decrease in most cases. However, with the adoption of measure 102 (see below), Oregon voters have expressed the need for investing in affordable housing bonds, and these state measures should mitigate the impact of this federal act.

**Low Income Housing Tax Credits**

The Low Income Housing Tax Credits program is a series of tax incentives administered by the IRS to encourage developers to construct affordable housing. Currently the program accounts for the largest source of new affordable housing in the U.S. In securing these credits, developers agree to rent out housing at an affordable level, often below market price (this is referred to as a use restriction). State agencies distribute credits to developers based on a state designed application process. These credits come in two forms, 9% (this raises about 70% of total cost) and 4% (this raises about 30% of the total cost), where 4% tax credits are often complimented with support from state bonds. In Oregon and in Tillamook County's case, Measure 102 (see below) should enable more funding of housing tax credit bonds and strengthen the effect of these tax credits on a for affordable housing development in Tillamook County.

## Oregon Policies

### Oregon's Statewide Housing Plan: "Breaking New Ground"

Oregon's 2018 Statewide Housing Plan is a long-term plan designed to increase housing in Oregon. The plan was researched and developed by Oregon Housing Community Services (OHCS) and its implementation will rely on OHCS in conjunction with local governments and private businesses. OHCS is Oregon's housing finance agency and as such the organization issues grants and loans to help facilitate home ownership in the state. OHCS regards housing in Oregon as a statewide crisis. Housing production has failed to keep up with Oregon's population growth therefore demand has outpaced supply, pushing up home prices. From 2000 to 2015, an additional 155,156 housing units would need to have been built throughout Oregon to keep up with demand.[2]

The Statewide Housing Plan calls for over 85,000 new units to be constructed for households earning below 30% of Median Family Income (MFI). The plan is outlined in six priorities and each promotes increased housing supply. Priorities include an increase housing supply that: (1) improves racial equity; (2) combats homelessness; (3) increases housing stability for families; (4) makes rent affordable; (5) proliferates homeownership; and (6) empowers rural communities. With this in mind, OHCS will triple the existing pipeline of affordable rental housing — up to 25,000 homes in the development pipeline by 2023.

The plan proposes increased access to housing through partnerships with community organizations, loans with low interest rates, better access to OHCS resources, funding grants for housing projects, improved technology, and streamlined processes with a foundation of collaboration. Implementation seems to rely on each area's ability to utilize and engage with OHCS as the plan clarifies goals and does not specify implementation policies.

### Senate Bill 1533

Enacted by the 2016 Oregon Legislature, this bill aims to promote affordable housing development through local regulations and a new source of funding: the Affordable Housing Construction Excise Tax (CET). The bill allows municipalities to adopt regulations that impose conditions on development for new multifamily structures (20 units or more per project), including: requirements for the inclusions of some affordable housing; or the option of paying an in-lieu fee (construction excise tax) not to exceed $1 per square foot of floor area for residential, and $0.50 per square foot for nonresidential structures (with a maximum cap of $25,000 per building or structure). For new

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[2] Up for Growth, "Housing Underproduction in the U.S.: Economic, Fiscal and Environmental Impacts of Enabling Transit-Oriented Smart Growth to Address America's Housing Affordability Challenge," Up For Growth National Coalition, 2018, 9.

affordable housing projects, this legislation supports special incentives including: full or partial exemption of ad valorem property taxes, SDC waivers or reductions and other incentives.

**Tillamook County voters soundly defeated a local CET ballot measure in 2017, and there is little appetite to pursue another CET at this time.**

### Measure 102: Passed by Oregon voters in November 2018

Measure 102 is intended to empower the collaborative partnerships described in Oregon's Statewide Housing Plan. Measure 102 amends the state's constitution to allow cities and counties to issue bonds for the construction of affordable housing construction without retaining 100% public ownership of the property. The goal is to allow local governments to pursue private public partnerships to better facilitate demand for housing.

# KEY FINDINGS AND POLICY RECOMMENDATIONS

Based on the 20-year population growth forecasts for Tillamook County (forecasted increase of 2,936 year-round residents) and seasonal housing and demographic characteristics, **the recommended housing needs for Tillamook County requires 2,305 to 2,603 net new dwelling units.** The Tillamook County Housing Needs Analysis supports a variety of housing is needed over the next 20 years, including approximately 1,692 owner-occupied dwellings and 911 renter-occupied dwellings.

## Recommended Actions

Market factors combined with limiting state and local land use policies have led to unprecedented housing challenges facing Tillamook County today. Addressing these challenges will require a coordinated effort by local and state government officials.

**Vacancy rates for long-term rental units are now near zero in most communities in Tillamook County.** While there is a strong and stable level of near term and long term demand for new housing construction throughout Tillamook County, there are very few local builders/developers that are focused on constructing the missing middle housing types needed for the workforce. To attract private investment and development of new workforce housing, a mix of local, state and federal policies, incentives and actions need to occur.

**Local Policies and Actions**

### Challenge: Relatively high land and development costs in coastal areas hamper financial viability of developing attainable workforce housing for permanent residents. As a result, Tillamook County has an existing deficit for "missing middle" housing.

Tillamook County is tied for the second highest rate of economically distressed households in Oregon. Cities including Tillamook and Bay City have the highest share of severe rent burdened households at 28% and 30% of households, respectively.

To help encourage or incentivize construction of missing middle housing priced at 120% or below of the median family income levels, the County should continue to pursue state OHCS housing investment grants and work with local cities to consider the following policies:

### Short-term Actions (1-2 years)

- ✓ Identify public-owned properties (excluding park/open space areas) that could be developed for a mix of housing types.
- ✓ Work with cities and sewer districts to update SDCs so that they are lower for smaller housing units than larger homes. Encourage SDC deferrals so that payments can be deferred for a period of time after building permit issuance for developments that contain deed restricted housing units.
- ✓ Consider a tax abatement program, such as the multiple-unit limited tax exemption program to promote development of affordable housing.
- ✓ Embark on a program that encourages Accessory Dwelling Units (ADUs) and "Cottage Homes" and "Tiny Home Communities" as an allowed use or conditional use within low density zones.
- ✓ Allow "lot size averaging" so that the site of individual lots in a short-plat development can vary from the zoned minimum or maximum density, in a manner that the overall development still meets average lot size requirements.
- ✓ Encouraging upper-level redevelopment and conversions in downtown Tillamook and other locations through financial assistance programs, such as use of urban renewal funds as loans.
- ✓ Tillamook County and its eligible local communities should leverage CDBG funds, state grants and bonds to help communities expand water, sewer and transportation infrastructure within areas planned for workforce housing through establishment of local improvement districts or reimbursement district programs.

### Long-term Actions (2-5 years)

**Challenge: locations with available sewer capacity are limited to areas such as the city of Tillamook.**

- ✓ Support Tillamook UGB expansion and potential rezoning efforts that result in additional housing development opportunities. The current Tillamook UGB contains 98 acres of buildable residential land inventory, yet residential land needs are forecasted to be up to 175 acres. In light of this finding the City and County should identify ways to increase low and medium density housing development opportunities through a UGB expansion
- ✓ Work local sewer and water districts to document their current and planned capacity levels to address future housing needs and inform the county wide housing strategy.

**Challenge: Tillamook County like many rural locations has a short supply of qualified residential construction workers and specialty contractors.** This results in higher housing prices as construction workers and crews must be obtained from the Willamette Valley region and temporarily housed.

- ✓ Facilitate development of trade related certification programs for people interested in residential construction and trades offered by Tillamook Bay Community College and Tillamook High School in partnership with home builders and general contractors.

### State Policies and Potential Actions[3]

**Challenge: Oregon planning requirements for urban areas hamstring local cities and counties ability to create coordinated and creative housing strategies.**

- ✓ Engage DLCD and Oregon Legislature to draft new planning guidelines for rural counties (e.g., population under 50,000) to adopt a coordinated county-wide Housing Needs Strategy. This would enable jurisdictions to prepare housing strategies that meet PSU's baseline forecasts countywide and allows for a localized allocation of housing and population (among cities and rural centers). This regional HNA approach would be intended to reflect unique market conditions and development opportunities and constraints in order to optimize the provision of more attainable housing.
- ✓ Engage DLCD and Oregon Legislature to include new state rules that allow rural development centers (outside UGBs) to rezone land for housing as long as there are adequate public facilities.

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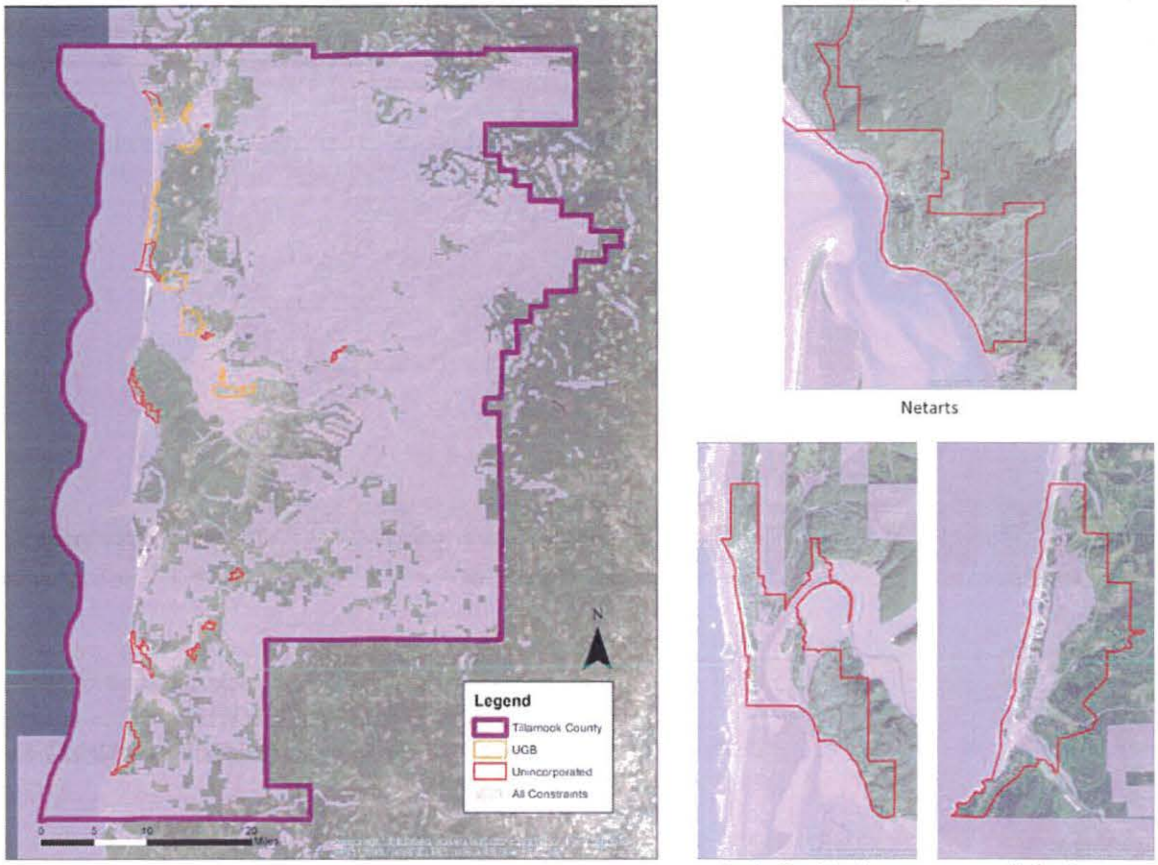
[3] Input received from DLCD staff regarding current interpretation of state rules applying to local HNAs and Economic Opportunity Analysis (EOA) compliance is provided in Appendix B.

**Challenge: Tillamook County has a large share of vacant lands in areas that are subject to frequent flooding and agricultural use restrictions.** This restricts the amount of development that is likely to occur in rural residential zones (see **Map 3.2**).

- ✓ The County should pursue Oregon Legislature initiated amendments to the Oregon Administrative Rules to allow property owners to transfer future development rights (TDRs) from environmentally sensitive areas (such as vacant land within floodplains and tsunami hazard zones) and agricultural areas onto receiving areas that are located in communities that can provide adequate public facilities, such as roads, sewer and water services.

**Map 3.2 Constrained Land Areas**



Tillamook County

Netarts

Pacific City - Woods

Neskowin

# APPENDIX A. HOUSING ATTAINABILITY ANALYSIS

**Appendix A. Housing Attainability Analysis for Tillamook County**

| **Median Family Income Level (2017)*** | **$45,061** | |
|---|---|---|
| | | |
| | | |
| **Market Segment by Income Level** | **Lower-end** | **Upper-End** |
| High (120% or more of MFI) | | 120% |
| Upper Middle (80% to 120% of MFI) | 80% | 120% |
| Lower Middle (50% to 80% of MFI) | 50% | 80% |
| Low (30% to 50%) | 30% | 50% |
| Very Low (less than 30% of MFI) | 30% | |
| | | |
| **Qualifying Income Level** | **Lower-end** | **Upper-End** |
| High (120% or more of MFI) | $54,073 | or more |
| Upper Middle (80% to 120% of MFI) | $36,049 | $54,073 |
| Lower Middle (50% to 80% of MFI) | $22,531 | $36,049 |
| Low (30% to 50%) | $13,518 | $22,531 |
| Very Low (less than 30% of MFI) | $13,518 | or less |
| | | |
| **Available Annual Housing Payment (@30% of income level)** | **Lower-end** | **Upper-End** |
| High (120% or more of MFI) | $16,222 | or more |
| Upper Middle (80% to 120% of MFI) | $10,815 | $16,222 |
| Lower Middle (50% to 80% of MFI) | $6,759 | $10,815 |
| Low (30% to 50%) | $4,055 | $6,759 |
| Very Low (less than 30% of MFI) | $4,055 | or less |
| | | |
| **Available Monthly Rent or Payment (@30% of income level)** | **Lower-end** | **Upper-End** |
| High (120% or more of MFI) | $1,352 | or more |
| Upper Middle (80% to 120% of MFI) | $901 | $1,352 |
| Lower Middle (50% to 80% of MFI) | $563 | $901 |
| Low (30% to 50%) | $338 | $563 |
| Very Low (less than 30% of MFI) | $338 | or less |
| | | |
| **Approximate Attainable Home Price**** | **Lower-end** | **Upper-End** |
| High (120% or more of MFI) | $299,000 | or more |
| Upper Middle (80% to 120% of MFI) | $199,000 | $299,000 |
| Lower Middle (50% to 80% of MFI) | $104,000 | $166,000 |
| Low (30% to 50%) | $62,000 | $104,000 |
| Very Low (less than 30% of MFI) | $62,000 | or less |

* based on U.S. Census American Community Survey 2013-17.

** High and upper middle income levels assume 20% down payment on 30-year fixed mortgage at 5% interest.

** Lower middle and low income levels assume 0% down payment on 30-year fixed mortgage at 5% interest.

**Source**: Housing and Urban Development guidelines, and U.S. Census data, analysis by FCS Group

**Tillamook County Owner-Occupied Housing Needs, 20-year Forecast***

| Family Income Level | Upper Range of Qualifying Income | Upper Range of Home Price* | Attainable Housing Products | Estimated Distribution of Owner-Occupied Units | Projected Owner-Occupied Units Needed |
|---|---|---|---|---|---|
| Upper (120% or more of MFI) | Greater than $54,073 | Greater than $299,000 | Standard Homes | 44% | 790 |
| Upper Middle (80% to 120% of MFI) | $54,073 | $299,000 | Small Homes, Townhomes | 36% | 647 |
| Lower Middle (50% to 80% of MFI) | $36,049 | $166,000 | Mfgd. Homes, Plexes | 15% | 269 |
| Low (30% to 50% of MFI) | $22,531 | $104,000 | Govt. Assisted | 5% | 90 |
| Very Low (less than 30% of MFI) | $13,518 | | | 0% | 0 |
| Total Dwelling Units | | | | **100%** | **1,796** |

**Assumes 30% of income is used for mortgage payment, with 5% interest, 30-year term with 20% downpayment for upper middle and high income levels, and 5% downpayment for lower income levels.*

**Tillamook County Renter-Occupied Housing Needs, 20-year Forecast***

| Family Income Level | Upper Range of Qualifying Income | Upper Range of Monthly Rent* | Attainable Housing Products | Estimated Distribution of Units | Projected Renter-Occupied Units Needed |
|---|---|---|---|---|---|
| Upper (120% or more of MFI) | Greater than $54,073 | Greater than $1,551 | Standard Homes, Townhomes, Condos | 21% | 166 |
| Upper Middle (80% to 120% of MFI) | $54,073 | $1,551 | Small Homes, Townhomes, Apartments | 17% | 135 |
| Lower Middle (50% to 80% of MFI) | $36,049 | $1,034 | ADUs, Townhomes, Mfgd. Homes, Plexes, Apts. | 20% | 163 |
| Low (30% to 50% of MFI) | $22,531 | $646 | Govt. Assisted Apts. | 23% | 190 |
| Very Low (less than 30% of MFI) | $13,518 | $388 | Govt. Assisted Apts. | 19% | 153 |
| Total Dwelling Units | | | | **100%** | **807** |

**Assumes 30% of income is used for rental payments.*

# APPENDIX B. DLCD STAFF INPUT

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**From:** "Phipps, Lisa" <lisa.phipps@state.or.us>
**Date:** Monday, December 16, 2019 at 10:40 AM
**To:** Paul Wyntergreen <pwyntergreen@tillamookor.gov>
**Subject:** FW: HNAs and EOAs

HI, Paul,
Here are the answers to the questions regarding the life span of a document and HNA approach. I met with Kevin Young in Salem to address these questions:

1) Do EOAs have a lifespan? The City of Tillamook had an EOA completed around 2013 and are now looking at updating their HNA, etc. Is it possible that a review of the EOA could show that it is still relevant (or mostly still relevant)? Would a letter just accompany that review showing it is still relevant? Or regardless, do they need to go through a full-blown process?

*In 2013 it should have projected a 20-year need for employment lands. Since then, best practice would be to track what has developed since that time so they have a current understanding of their inventory of employment lands. There's no requirement for periodic updates of EOAs at this time, but what often drives a local gov. to do that is running short on land supply. The most recently adopted EOA remains valid until it is replaced by an updated EOA. There's no expiration date, but if they run out of land it becomes pretty irrelevant.*

2) The City of Tillamook is currently having a BLI completed. I held a Planning Commission 101 workshop for the city before Thanksgiving and one of the questions that came up was whether it was acceptable to do a regional HNA? I know that 10-13 years ago, three of the cities and Tillamook County did a regional BLI and HNA with each community getting a HNA that was unique to them as well. So there was this broad overview of the area and its needs and then the community-specific HNAs were completed. Are you comfortable with this approach? Also, the commission asked about Safe Harbor and what pitfalls there might be in moving in that direction.

*I think a regional HNA makes sense, as we discussed. I would not encourage use of the safe harbor methods from Div. 24. Reportedly, those have not worked that well. They created quite a bit of confusion with the recent Dallas HNA.*[4]

Paul, I talked to Kevin about several different ways to approach the HNA. The first was to do an HNA just for the city, but one that included a regional overview given the City's place as the County seat and home of most of the industry. He thought that made good sense but wanted to make sure that in terms of any decisions that might come out of the HNA with this approach, that it was related to the city limits only – but that the overview could provide good context.
The second was that the City partner with the county (and other cities), to do a broader and more global HNA – however, in order for it to be of value for the City (in terms of UGBs, etc.) it would also need to include an HNA specific to the City of Tillamook (and the other cities).

Does that make sense? I did ask, that as you get closer, if we could hold a workshop for Tillamook and he said yes...if you want one!
Thanks!
Lis

**Lisa M. Phipps**
North Coast Regional Representative | Ocean/Coastal Services Division
Cell: 503-812-5448 | Main: 503-842-8222 ext 4004
lisa.phipps@state.or.us | www.oregon.gov/LCD

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[4] Note by T. Chase, FCS GROUP with respect to Safe Harbors. **"Safe harbor"** means an optional course of action that a local government may use to satisfy a requirement of Goal 14 (urbanization) based on projected population, and residential zoned density levels; and if the city needs to expand their urban growth boundary, a safe harbor analysis lends protections from appeals on certain elements which can cost time and money. A safe harbor approach per OAR 660-024-0040(1)-(8) is not the only way or necessarily the preferred way to comply with the requirements of a housing needs analysis. It was employed for the city of Dallas (along with other approaches) as an alternative way of looking at residential land need scenarios for the 20-year forecast. The Dallas City Council successfully adopted their HNA in December 2019 without appeal.

---

From: Paul Wyntergreen [mailto:pwyntergreen@tillamookor.gov]
Sent: Monday, December 16, 2019 2:11 PM
To: Phipps, Lisa <lphipps@dlcd.state.or.us>
Cc: Debbi Reeves <dreeves@tillamookor.gov>
Subject: Re: HNAs and EOAs

Thank you Lisa; this is very helpful and yes let's schedule up a workshop for February or March.

It is wonderful to see that a regional approach is a possibility. I am still a bit confused by your last couple of paragraphs; I understand that the City and the County (with other cities) would each do an HNA, but it is unclear as to whether the project demand could be allocated. Since High-premium cities at the beach will probably not produce sufficient approachable housing at rent levels that its service workers could afford, but places like Tillamook City could, is it allowable to assign additional growth allocation to certain cities if agreement is reached between communities?

***Paul Wyntergreen***
**City Manager**
**City of Tillamook**
**210 Laurel Avenue**
**Tillamook, OR 97141**

---

**From:** "Phipps, Lisa" <lisa.phipps@state.or.us>
**Date:** Friday, December 20, 2019 at 1:29 PM
**To:** Paul Wyntergreen <pwyntergreen@tillamookor.gov>
**Cc:** Debbi Reeves <dreeves@tillamookor.gov>
**Subject:** RE: HNAs and EOAs

Hi, Paul,
That is a great question with a good philosophical foundation. But, I am not sure that the laws have caught up with the realities of what regions like ours face. I will reach out again with the nuance described below, but my initial reaction, that while the regional approach will give people a better understanding of the how and why, the growth will still be confined to the PSU estimate for each city.

But, I will follow up.

Thanks, Lisa

**Lisa M. Phipps**
North Coast Regional Representative | Ocean/Coastal Services Division
Cell: 503-812-5448 | Main: 503-842-8222 ext 4004
lisa.phipps@state.or.us | www.oregon.gov/LCD

## Tax Statements 2020-21

| Account # | Map # | Tax 2020-21 |
|---|---|---|
| 399441 | 1N1007DD00114 | $8,969.35 |
| 399444 | 1N1007DD00115 | $5,075.78 |
| 399447 | 1N1007DD00116 | $5,456.46 |
| 399450 | 1N1007DD00117 | $2,329.53 |
| 399453 | 1N1007DD00118 | $5,566.80 |
| 399456 | 1N1007DD00119 | $2,329.53 |
| 399459 | 1N1007DD00120 | $5,249.30 |
| 399462 | 1N1007DD00121 | $5,451.05 |
| 399465 | 1N1007DD00122 | $5,181.77 |
| 399468 | 1N1007DD00123 | $7,609.27 |
| 62425 | 1N1007DA03000 | $5,787.17 |
| 62611 | 1N1007DA03100 | $5,419.97 |
| 355715 | 1N1007DA03104 | $5,261.53 |
| 62719 | 1N1007DA03203 | $2,647.78 |
| 322822 | 1N1007DA03204 | $2,647.78 |
|  | **TOTAL:** | **$74,983.07** |

*2020-21 county tax statements do not include taxes for Twin Rocks Sanitary District or Watseco-Barview Water District because those payments are made directly to the districts by the property owners.

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399441

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00114 |
| ACRES: | 0.36 |
| SITUS: | 17300 PINE BEACH WAY COUNTY |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-11 |

COGDALL, JOHN WILLIAM IV & LYNDA
39455 NW MURTAUGH RD
NORTH PLAINS OR 97133

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 366,590 | 336,830 |
| STRUCTURES | 1,169,580 | 1,238,690 |
| TOTAL RMV | 1,536,170 | 1,575,520 |
| TOTAL ASSESSED VALUE | 932,130 | 960,090 |
| EXEMPTIONS | | |
| NET TAXABLE: | 932,130 | 960,090 |
| TOTAL PROPERTY TAX: | 8,718.29 | 8,969.35 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 4,320.60 |
| NW REGIONAL ESD | 147.66 |
| TILLAMOOK BAY CC | 253.08 |
| EDUCATION TOTAL: | 4,721.34 |
| TILLAMOOK COUNTY | 1,486.79 |
| COUNTY LIBRARY | 624.06 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 462.09 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 251.54 |
| 4H-EXTENSION SD | 66.25 |
| EMCD-911 | 180.78 |
| TILLA TRANSPORTATION | 192.02 |
| TILLA SOIL & WATER CONS | 57.61 |
| GENERAL GOVT TOTAL: | 3,333.14 |
| COUNTY LIBRARY | 46.47 |
| TILLA CNTY BONDS AFTER 2001 | 250.68 |
| SCHOOL 56 BONDS AFTER 2001 | 502.22 |
| TILLA BAY CC BONDS AFTER 2001 | 115.50 |
| BONDS - OTHER TOTAL: | 914.87 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 8,969.35

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 8,700.27 | 5,859.98 | 2,989.79 |
| 02/16/21 | | | 2,989.78 |
| 05/17/21 | | 2,989.78 | 2,989.78 |
| Total | 8,700.27 | 8,849.76 | 8,969.35 |

TOTAL DUE (After Discount and Pre-payments) 8,700.27

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PLEASE RETURN THIS PORTION WITH YOUR PAYMENT

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2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399441**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 8,700.27 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 5,859.98 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 2,989.79 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

COGDALL, JOHN WILLIAM IV & LYNDA
39455 NW MURTAUGH RD
NORTH PLAINS OR 97133

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-008776-870027

29100003994410000298979000058599800008700274

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399444

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00115 |
| ACRES: | 0.27 |
| SITUS: | 17320 PINE BEACH WAY COUNTY |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-12 |

ROGERS, MICHAEL J &
ROGERS, CHRISTINE M
17231 NW DAIRY CREED RD
NORTH PLAINS OR 97133

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 366,590 | 336,830 |
| STRUCTURES | 303,230 | 321,130 |
| TOTAL RMV | 669,820 | 657,960 |
| TOTAL ASSESSED VALUE | 526,960 | 542,760 |
| EXEMPTIONS | | |
| NET TAXABLE: | 526,960 | 542,760 |
| TOTAL PROPERTY TAX: | 4,933.93 | 5,075.78 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,442.53 |
| NW REGIONAL ESD | 83.48 |
| TILLAMOOK BAY CC | 143.07 |
| EDUCATION TOTAL: | 2,669.08 |
| TILLAMOOK COUNTY | 840.52 |
| COUNTY LIBRARY | 352.79 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 261.23 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 142.20 |
| 4H-EXTENSION SD | 37.45 |
| EMCD-911 | 102.20 |
| TILLA TRANSPORTATION | 108.55 |
| TILLA SOIL & WATER CONS | 32.57 |
| GENERAL GOVT TOTAL: | 1,889.51 |
| COUNTY LIBRARY | 26.27 |
| TILLA CNTY BONDS AFTER 2001 | 141.71 |
| SCHOOL 56 BONDS AFTER 2001 | 283.92 |
| TILLA BAY CC BONDS AFTER 2001 | 65.29 |
| BONDS - OTHER TOTAL: | 517.19 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,075.78

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 4,923.51 | 3,316.17 | 1,691.93 |
| 02/16/21 | | | 1,691.93 |
| 05/17/21 | | 1,691.93 | 1,691.92 |
| Total | 4,923.51 | 5,008.10 | 5,075.78 |

TOTAL DUE (After Discount and Pre-payments) 4,923.51

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2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399444**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 4,923.51 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,316.17 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,691.93 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

ROGERS, MICHAEL J &
ROGERS, CHRISTINE M
17231 NW DAIRY CREED RD
NORTH PLAINS OR 97133

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-008807-492351

29100003994440000169193000033161700004923517

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399447

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00116 |
| ACRES: | 0.21 |
| SITUS: | 17340 PINE BEACH WAY COUNTY |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-13 |

FARR, DAVID L & FRIEDA F
17340 PINE BEACH WAY
ROCKAWAY BEACH OR 97136

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 364,400 | 334,830 |
| STRUCTURES | 471,550 | 499,240 |
| TOTAL RMV | 835,950 | 834,070 |
| TOTAL ASSESSED VALUE | 593,000 | 610,790 |
| EXEMPTIONS | 26,435 | 27,228 |
| NET TAXABLE: | 566,565 | 583,562 |
| TOTAL PROPERTY TAX: | 5,303.83 | 5,456.46 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,626.15 |
| NW REGIONAL ESD | 89.75 |
| TILLAMOOK BAY CC | 153.83 |
| EDUCATION TOTAL: | 2,869.73 |
| TILLAMOOK COUNTY | 903.71 |
| COUNTY LIBRARY | 379.32 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 280.87 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 152.89 |
| 4H-EXTENSION SD | 40.27 |
| EMCD-911 | 109.88 |
| TILLA TRANSPORTATION | 116.71 |
| TILLA SOIL & WATER CONS | 35.01 |
| GENERAL GOVT TOTAL: | 2,030.66 |
| COUNTY LIBRARY | 28.24 |
| TILLA CNTY BONDS AFTER 2001 | 152.37 |
| SCHOOL 56 BONDS AFTER 2001 | 305.26 |
| TILLA BAY CC BONDS AFTER 2001 | 70.20 |
| BONDS - OTHER TOTAL: | 556.07 |

TAX STATEMENT INFORMATION WAS SENT TO:
WFR Wells Fargo Real Estate Tax Services, LLC

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,456.46

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,292.77 | 3,564.89 | 1,818.82 |
| 02/16/21 | | | 1,818.82 |
| 05/17/21 | | 1,818.82 | 1,818.82 |
| Total | 5,292.77 | 5,383.71 | 5,456.46 |

TOTAL DUE (After Discount and Pre-payments) 5,292.77

↑ Tear Here *COURTESY STATEMENT IF LENDER IS SCHEDULED TO PAY* Tear Here ↑

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399447**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,292.77 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,564.89 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,818.82 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

FARR, DAVID L & FRIEDA F
17340 PINE BEACH WAY
ROCKAWAY BEACH OR 97136

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-004543-529277

29100003994470000181882000035648900005292770

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399450

PROPERTY DESCRIPTION

CODE: 5624
MAP: 1N1007DD00117
ACRES: 0.21

LEGAL: PINE BEACH REPLAT UNIT 1 LOT-14

CREEDON, JONATHAN C
7501 SE 17TH ST
VANCOUVER WA 98664

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 346,120 | 316,730 |
| STRUCTURES | 0 | 0 |
| TOTAL RMV | 346,120 | 316,730 |
| TOTAL ASSESSED VALUE | 242,420 | 249,690 |
| EXEMPTIONS | | |
| NET TAXABLE: | 242,420 | 249,690 |
| TOTAL PROPERTY TAX: | 2,264.25 | 2,329.53 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 1,123.65 |
| NW REGIONAL ESD | 38.40 |
| TILLAMOOK BAY CC | 65.82 |
| EDUCATION TOTAL: | 1,227.87 |
| TILLAMOOK COUNTY | 386.67 |
| COUNTY LIBRARY | 162.30 |
| GARIBALDI RFD | 120.18 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 65.42 |
| 4H-EXTENSION SD | 17.23 |
| EMCD-911 | 47.02 |
| TILLA TRANSPORTATION | 49.94 |
| TILLA SOIL & WATER CONS | 14.98 |
| GENERAL GOVT TOTAL: | 863.74 |
| COUNTY LIBRARY | 12.08 |
| TILLA CNTY BONDS AFTER 2001 | 65.19 |
| SCHOOL 56 BONDS AFTER 2001 | 130.61 |
| TILLA BAY CC BONDS AFTER 2001 | 30.04 |
| BONDS - OTHER TOTAL: | 237.92 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 2,329.53

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 2,259.64 | 1,521.96 | 776.51 |
| 02/16/21 | | | 776.51 |
| 05/17/21 | | 776.51 | 776.51 |
| Total | 2,259.64 | 2,298.47 | 2,329.53 |

TOTAL DUE (After Discount and Pre-payments) 2,259.64

↑ Tear Here — PLEASE RETURN THIS PORTION WITH YOUR PAYMENT — Tear Here ↑

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399450**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 2,259.64 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 1,521.96 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 776.51 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

CREEDON, JONATHAN C
7501 SE 17TH ST
VANCOUVER WA 98664

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-020934-225964

29100003994500000077651000015219600002259647

# REAL PROPERTY TAX STATEMENT

JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399453

## PROPERTY DESCRIPTION

CODE: 5624
MAP: 1N1007DD00118
ACRES: 0.21
SITUS: 17380 PINE BEACH WAY COUNTY
LEGAL: PINE BEACH REPLAT UNIT 1 LOT-15

ROBERTS, DONALD W 1/2 TRUSTEE &
ROBERTS, BARBARA A TRUSTEE &
503 RHODODENDRON DR
VANCOUVER WA 98661

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 364,400 | 334,830 |
| STRUCTURES | 354,970 | 375,470 |
| TOTAL RMV | 719,370 | 710,300 |
| TOTAL ASSESSED VALUE | 578,050 | 595,390 |
| EXEMPTIONS | | |
| NET TAXABLE: | 578,050 | 595,390 |
| TOTAL PROPERTY TAX: | 5,411.10 | 5,566.80 |

## TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,679.37 |
| NW REGIONAL ESD | 91.57 |
| TILLAMOOK BAY CC | 156.94 |
| EDUCATION TOTAL: | 2,927.88 |
| TILLAMOOK COUNTY | 922.02 |
| COUNTY LIBRARY | 387.00 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 286.56 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 155.99 |
| 4H-EXTENSION SD | 41.08 |
| EMCD-911 | 112.11 |
| TILLA TRANSPORTATION | 119.08 |
| TILLA SOIL & WATER CONS | 35.72 |
| GENERAL GOVT TOTAL: | 2,071.56 |
| COUNTY LIBRARY | 28.82 |
| TILLA CNTY BONDS AFTER 2001 | 155.46 |
| SCHOOL 56 BONDS AFTER 2001 | 311.45 |
| TILLA BAY CC BONDS AFTER 2001 | 71.63 |
| BONDS - OTHER TOTAL: | 567.36 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,566.80

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,399.80 | 3,636.98 | 1,855.60 |
| 02/16/21 | | | 1,855.60 |
| 05/17/21 | | 1,855.60 | 1,855.60 |
| Total | 5,399.80 | 5,492.58 | 5,566.80 |

TOTAL DUE (After Discount and Pre-payments) 5,399.80

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## PLEASE RETURN THIS PORTION WITH YOUR PAYMENT

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399453**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,399.80 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,636.98 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,855.60 |

FORWARDING SERVICE REQUESTED

$ Enter Payment Amount

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

ROBERTS, DONALD W 1/2 TRUSTEE &
ROBERTS, BARBARA A TRUSTEE &
503 RHODODENDRON DR
VANCOUVER WA 98661

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-020870-539980

29100003994530000185560000036369800005399800

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399456

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00119 |
| ACRES: | 0.21 |

LEGAL: PINE BEACH REPLAT UNIT 1 LOT-16

MUNCH, MICHAEL T TRUSTEE
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 346,120 | 316,730 |
| STRUCTURES | 0 | 0 |
| TOTAL RMV | 346,120 | 316,730 |
| TOTAL ASSESSED VALUE | 242,420 | 249,690 |
| EXEMPTIONS | | |
| NET TAXABLE: | 242,420 | 249,690 |
| TOTAL PROPERTY TAX: | 2,264.25 | 2,329.53 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 1,123.65 |
| NW REGIONAL ESD | 38.40 |
| TILLAMOOK BAY CC | 65.82 |
| EDUCATION TOTAL: | 1,227.87 |
| TILLAMOOK COUNTY | 386.67 |
| COUNTY LIBRARY | 162.30 |
| GARIBALDI RFD | 120.18 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 65.42 |
| 4H-EXTENSION SD | 17.23 |
| EMCD-911 | 47.02 |
| TILLA TRANSPORTATION | 49.94 |
| TILLA SOIL & WATER CONS | 14.98 |
| GENERAL GOVT TOTAL: | 863.74 |
| COUNTY LIBRARY | 12.08 |
| TILLA CNTY BONDS AFTER 2001 | 65.19 |
| SCHOOL 56 BONDS AFTER 2001 | 130.61 |
| TILLA BAY CC BONDS AFTER 2001 | 30.04 |
| BONDS - OTHER TOTAL: | 237.92 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 2,329.53

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 2,259.64 | 1,521.96 | 776.51 |
| 02/16/21 | | | 776.51 |
| 05/17/21 | | 776.51 | 776.51 |
| Total | 2,259.64 | 2,298.47 | 2,329.53 |

TOTAL DUE (After Discount and Pre-payments) 2,259.64

↑ Tear Here PLEASE RETURN THIS PORTION WITH YOUR PAYMENT Tear Here ↑

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399456**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 2,259.64 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 1,521.96 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 776.51 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

MUNCH, MICHAEL T TRUSTEE
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-002930-225964

29100003994560000077651000015219600002259644

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399459

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00120 |
| ACRES: | 0.21 |
| SITUS: | 17420 PINE BEACH WAY COUNTY |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-17 |

17420 PINE BEACH WAY LLC
%MICHAEL T MUNCH
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 364,400 | 334,830 |
| STRUCTURES | 350,220 | 370,290 |
| TOTAL RMV | 714,620 | 705,120 |
| TOTAL ASSESSED VALUE | 545,010 | 561,360 |
| EXEMPTIONS | | |
| NET TAXABLE: | 545,010 | 561,360 |
| TOTAL PROPERTY TAX: | 5,102.49 | 5,249.30 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,526.23 |
| NW REGIONAL ESD | 86.34 |
| TILLAMOOK BAY CC | 147.97 |
| EDUCATION TOTAL: | 2,760.54 |
| TILLAMOOK COUNTY | 869.32 |
| COUNTY LIBRARY | 364.88 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 270.18 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 147.08 |
| 4H-EXTENSION SD | 38.73 |
| EMCD-911 | 105.70 |
| TILLA TRANSPORTATION | 112.27 |
| TILLA SOIL & WATER CONS | 33.68 |
| GENERAL GOVT TOTAL: | 1,953.84 |
| COUNTY LIBRARY | 27.17 |
| TILLA CNTY BONDS AFTER 2001 | 146.57 |
| SCHOOL 56 BONDS AFTER 2001 | 293.65 |
| TILLA BAY CC BONDS AFTER 2001 | 67.53 |
| BONDS - OTHER TOTAL: | 534.92 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,249.30

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,091.82 | 3,429.54 | 1,749.77 |
| 02/16/21 | | | 1,749.77 |
| 05/17/21 | | 1,749.77 | 1,749.76 |
| Total | 5,091.82 | 5,179.31 | 5,249.30 |

TOTAL DUE (After Discount and Pre-payments) 5,091.82

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PLEASE RETURN THIS PORTION WITH YOUR PAYMENT
2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399459**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,091.82 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,429.54 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,749.77 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

17420 PINE BEACH WAY LLC
%MICHAEL T MUNCH
5012 DOGWOOD DR
LAKE OSWEGO OR 97035

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-002859-509182

29100003994590000174977000034295400005091828

# REAL PROPERTY TAX STATEMENT

JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399462

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00121 |
| ACRES: | 0.20 |
| SITUS: | 17440 PINE BEACH WAY COUNTY |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-18 |

KLEIN, JEFFREY S & TERRY
12230 SW RIVERVIEW LN
WILSONVILLE OR 97070

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 364,400 | 334,830 |
| STRUCTURES | 326,640 | 345,810 |
| TOTAL RMV | 691,040 | 680,640 |
| TOTAL ASSESSED VALUE | 566,000 | 582,980 |
| EXEMPTIONS | | |
| NET TAXABLE: | 566,000 | 582,980 |
| TOTAL PROPERTY TAX: | 5,298.56 | 5,451.05 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,623.53 |
| NW REGIONAL ESD | 89.66 |
| TILLAMOOK BAY CC | 153.67 |
| EDUCATION TOTAL: | 2,866.86 |
| TILLAMOOK COUNTY | 902.80 |
| COUNTY LIBRARY | 378.94 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 280.59 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 152.74 |
| 4H-EXTENSION SD | 40.23 |
| EMCD-911 | 109.78 |
| TILLA TRANSPORTATION | 116.60 |
| TILLA SOIL & WATER CONS | 34.98 |
| GENERAL GOVT TOTAL: | 2,028.66 |
| COUNTY LIBRARY | 28.22 |
| TILLA CNTY BONDS AFTER 2001 | 152.22 |
| SCHOOL 56 BONDS AFTER 2001 | 304.96 |
| TILLA BAY CC BONDS AFTER 2001 | 70.13 |
| BONDS - OTHER TOTAL: | 555.53 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,451.05

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,287.52 | 3,561.35 | 1,817.02 |
| 02/16/21 | | | 1,817.02 |
| 05/17/21 | | 1,817.02 | 1,817.01 |
| Total | 5,287.52 | 5,378.37 | 5,451.05 |

TOTAL DUE (After Discount and Pre-payments) 5,287.52

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PLEASE RETURN THIS PORTION WITH YOUR PAYMENT

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399462**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,287.52 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,561.35 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,817.02 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

KLEIN, JEFFREY S & TERRY
12230 SW RIVERVIEW LN
WILSONVILLE OR 97070

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-003822-528752

29100003994620000181702000035613500005287521

# REAL PROPERTY TAX STATEMENT

JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399465

## PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00122 |
| ACRES: | 0.24 |
| SITUS: | 17460 PINE BEACH WAY COUNTY |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-19 |

HOLLAND, GLENNA M TRUSTEE &
HOLLAND, RACHAEL M TRUSTEE
3136 NE 45TH AVE
PORTLAND OR 97213

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 366,590 | 336,830 |
| STRUCTURES | 343,370 | 362,100 |
| TOTAL RMV | 709,960 | 698,930 |
| TOTAL ASSESSED VALUE | 537,990 | 554,120 |
| EXEMPTIONS | | |
| NET TAXABLE: | 537,990 | 554,120 |
| TOTAL PROPERTY TAX: | 5,036.91 | 5,181.77 |

## TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,493.65 |
| NW REGIONAL ESD | 85.22 |
| TILLAMOOK BAY CC | 146.07 |
| EDUCATION TOTAL: | 2,724.94 |
| TILLAMOOK COUNTY | 858.11 |
| COUNTY LIBRARY | 360.18 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 266.70 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 145.18 |
| 4H-EXTENSION SD | 38.23 |
| EMCD-911 | 104.34 |
| TILLA TRANSPORTATION | 110.82 |
| TILLA SOIL & WATER CONS | 33.25 |
| GENERAL GOVT TOTAL: | 1,928.81 |
| COUNTY LIBRARY | 26.82 |
| TILLA CNTY BONDS AFTER 2001 | 144.68 |
| SCHOOL 56 BONDS AFTER 2001 | 289.86 |
| TILLA BAY CC BONDS AFTER 2001 | 66.66 |
| BONDS - OTHER TOTAL: | 528.02 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,181.77

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,026.32 | 3,385.42 | 1,727.26 |
| 02/16/21 | | | 1,727.26 |
| 05/17/21 | | 1,727.26 | 1,727.25 |
| Total | 5,026.32 | 5,112.68 | 5,181.77 |

TOTAL DUE (After Discount and Pre-payments) 5,026.32

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## PLEASE RETURN THIS PORTION WITH YOUR PAYMENT

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399465**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,026.32 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,385.42 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,727.26 |

FORWARDING SERVICE REQUESTED

$ Enter Payment Amount

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

HOLLAND, GLENNA M TRUSTEE &
HOLLAND, RACHAEL M TRUSTEE
3136 NE 45TH AVE
PORTLAND OR 97213

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-015970-502632

29100003994650000172726000033854200005026328

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
399468

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DD00123 |
| ACRES: | 0.33 |
| SITUS: | 17480 PINE BEACH WAY ROCKAWAY BEACH |
| LEGAL: | PINE BEACH REPLAT UNIT 1 LOT-20 |

ELLIS, MICHAEL LEON TRUSTEE
2614 Q ST
VANCOUVER WA 98663

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 366,090 | 336,330 |
| STRUCTURES | 758,590 | 802,560 |
| TOTAL RMV | 1,124,680 | 1,138,890 |
| TOTAL ASSESSED VALUE | 790,600 | 814,310 |
| EXEMPTIONS | | |
| NET TAXABLE: | 790,600 | 814,310 |
| TOTAL PROPERTY TAX: | 7,396.36 | 7,609.27 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 3,664.56 |
| NW REGIONAL ESD | 125.24 |
| TILLAMOOK BAY CC | 214.65 |
| EDUCATION TOTAL: | 4,004.45 |
| TILLAMOOK COUNTY | 1,261.04 |
| COUNTY LIBRARY | 529.30 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 391.93 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 213.35 |
| 4H-EXTENSION SD | 56.19 |
| EMCD-911 | 153.33 |
| TILLA TRANSPORTATION | 162.86 |
| TILLA SOIL & WATER CONS | 48.86 |
| GENERAL GOVT TOTAL: | 2,828.86 |
| COUNTY LIBRARY | 39.41 |
| TILLA CNTY BONDS AFTER 2001 | 212.62 |
| SCHOOL 56 BONDS AFTER 2001 | 425.97 |
| TILLA BAY CC BONDS AFTER 2001 | 97.96 |
| BONDS - OTHER TOTAL: | 775.96 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 7,609.27

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 7,380.99 | 4,971.39 | 2,536.43 |
| 02/16/21 | | | 2,536.42 |
| 05/17/21 | | 2,536.42 | 2,536.42 |
| Total | 7,380.99 | 7,507.81 | 7,609.27 |

TOTAL DUE (After Discount and Pre-payments) 7,380.99

↑ Tear Here PLEASE RETURN THIS PORTION WITH YOUR PAYMENT Tear Here ↑

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 399468**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 7,380.99 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 4,971.39 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 2,536.43 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

ELLIS, MICHAEL LEON TRUSTEE
2614 Q ST
VANCOUVER WA 98663

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-020912-738099

29100003994680000253643000049713900007380991

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
62425

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DA03000 |
| ACRES: | 0.67 |
| SITUS: | 17560 OCEAN BLVD COUNTY |

DOWLING, DAVID A & ANGELA M
19690 WILDWOOD DR
WEST LINN OR 97068

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 368,780 | 338,830 |
| STRUCTURES | 327,820 | 351,300 |
| TOTAL RMV | 696,600 | 690,130 |
| TOTAL ASSESSED VALUE | 600,990 | 619,010 |
| EXEMPTIONS | | |
| NET TAXABLE: | 600,990 | 619,010 |
| TOTAL PROPERTY TAX: | 5,625.38 | 5,787.17 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,785.67 |
| NW REGIONAL ESD | 95.20 |
| TILLAMOOK BAY CC | 163.17 |
| EDUCATION TOTAL: | 3,044.04 |
| TILLAMOOK COUNTY | 958.60 |
| COUNTY LIBRARY | 402.36 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 297.93 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 162.18 |
| 4H-EXTENSION SD | 42.71 |
| EMCD-911 | 116.56 |
| TILLA TRANSPORTATION | 123.80 |
| TILLA SOIL & WATER CONS | 37.14 |
| GENERAL GOVT TOTAL: | 2,153.28 |
| COUNTY LIBRARY | 29.96 |
| TILLA CNTY BONDS AFTER 2001 | 161.62 |
| SCHOOL 56 BONDS AFTER 2001 | 323.80 |
| TILLA BAY CC BONDS AFTER 2001 | 74.47 |
| BONDS - OTHER TOTAL: | 589.85 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,787.17

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,613.55 | 3,780.95 | 1,929.06 |
| 02/16/21 | | | 1,929.06 |
| 05/17/21 | | 1,929.06 | 1,929.05 |
| Total | 5,613.55 | 5,710.01 | 5,787.17 |

TOTAL DUE (After Discount and Pre-payments) 5,613.55

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PLEASE RETURN THIS PORTION WITH YOUR PAYMENT
2020 - 2021 PROPERTY TAXES

Tear Here ↑

**ACCOUNT NO. 62425**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,613.55 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,780.95 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,929.06 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

DOWLING, DAVID A & ANGELA M
19690 WILDWOOD DR
WEST LINN OR 97068

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-003645-561355

2910000062425000019290600003780950000561355 8

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
62611

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DA03100 |
| ACRES: | 0.22 |
| SITUS: | 17490 OCEAN BLVD COUNTY |

DANNO, EVAN F TRUSTEE
144 HIGHLAND RIDGE RD
KALISPELL MT 59901

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 364,400 | 334,830 |
| STRUCTURES | 343,880 | 363,480 |
| TOTAL RMV | 708,280 | 698,310 |
| TOTAL ASSESSED VALUE | 562,770 | 579,650 |
| EXEMPTIONS | | |
| NET TAXABLE: | 562,770 | 579,650 |
| TOTAL PROPERTY TAX: | 5,268.40 | 5,419.97 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,608.54 |
| NW REGIONAL ESD | 89.15 |
| TILLAMOOK BAY CC | 152.80 |
| EDUCATION TOTAL: | 2,850.49 |
| TILLAMOOK COUNTY | 897.64 |
| COUNTY LIBRARY | 376.77 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 278.99 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 151.87 |
| 4H-EXTENSION SD | 40.00 |
| EMCD-911 | 109.15 |
| TILLA TRANSPORTATION | 115.93 |
| TILLA SOIL & WATER CONS | 34.78 |
| GENERAL GOVT TOTAL: | 2,017.13 |
| COUNTY LIBRARY | 28.06 |
| TILLA CNTY BONDS AFTER 2001 | 151.35 |
| SCHOOL 56 BONDS AFTER 2001 | 303.21 |
| TILLA BAY CC BONDS AFTER 2001 | 69.73 |
| BONDS - OTHER TOTAL: | 552.35 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,419.97

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,257.37 | 3,541.04 | 1,806.66 |
| 02/16/21 | | | 1,806.66 |
| 05/17/21 | | 1,806.66 | 1,806.65 |
| Total | 5,257.37 | 5,347.70 | 5,419.97 |

TOTAL DUE (After Discount and Pre-payments) 5,257.37

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PLEASE RETURN THIS PORTION WITH YOUR PAYMENT
2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 62611**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,257.37 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,541.04 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,806.66 |

FORWARDING SERVICE REQUESTED

$ Enter Payment Amount

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

DANNO, EVAN F TRUSTEE
144 HIGHLAND RIDGE RD
KALISPELL MT 59901

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-000343-525737

29100000626110000180666000035410400005257379

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
355715

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DA03104 |
| ACRES: | 0.17 |
| SITUS: | 17488 OCEAN BLVD COUNTY |

LOCKWOOD, MARY ANN CO-TRUSTEE &
KEMBALL, T. MARK CO-TRUSTEE
2355 SW SCENIC DR
PORTLAND OR 97225

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 364,400 | 334,830 |
| STRUCTURES | 284,490 | 301,390 |
| TOTAL RMV | 648,890 | 636,220 |
| TOTAL ASSESSED VALUE | 546,290 | 562,670 |
| EXEMPTIONS | | |
| NET TAXABLE: | 546,290 | 562,670 |
| TOTAL PROPERTY TAX: | 5,114.45 | 5,261.53 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 2,532.13 |
| NW REGIONAL ESD | 86.54 |
| TILLAMOOK BAY CC | 148.32 |
| EDUCATION TOTAL: | 2,766.99 |
| TILLAMOOK COUNTY | 871.35 |
| COUNTY LIBRARY | 365.74 |
| SOLID WASTE | 12.00 |
| GARIBALDI RFD | 270.81 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 147.42 |
| 4H-EXTENSION SD | 38.82 |
| EMCD-911 | 105.95 |
| TILLA TRANSPORTATION | 112.53 |
| TILLA SOIL & WATER CONS | 33.76 |
| GENERAL GOVT TOTAL: | 1,958.38 |
| COUNTY LIBRARY | 27.23 |
| TILLA CNTY BONDS AFTER 2001 | 146.91 |
| SCHOOL 56 BONDS AFTER 2001 | 294.33 |
| TILLA BAY CC BONDS AFTER 2001 | 67.69 |
| BONDS - OTHER TOTAL: | 536.16 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 5,261.53

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 5,103.68 | 3,437.54 | 1,753.85 |
| 02/16/21 | | | 1,753.84 |
| 05/17/21 | | 1,753.84 | 1,753.84 |
| Total | 5,103.68 | 5,191.38 | 5,261.53 |

TOTAL DUE (After Discount and Pre-payments) 5,103.68

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2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 355715**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 5,103.68 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 3,437.54 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 1,753.85 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

LOCKWOOD, MARY ANN CO-TRUSTEE &
KEMBALL, T. MARK CO-TRUSTEE
2355 SW SCENIC DR
PORTLAND OR 97225

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-017297-510368

29100003557150000175385000034375400005103685

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
62719

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DA03203 |
| ACRES: | 0.15 |

BERG, MEGAN
1734 W YAMPA ST
COLORADO SPRINGS CO 80904

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 341,740 | 312,720 |
| STRUCTURES | 0 | 0 |
| TOTAL RMV | 341,740 | 312,720 |
| TOTAL ASSESSED VALUE | 275,540 | 283,800 |
| EXEMPTIONS | | |
| NET TAXABLE: | 275,540 | 283,800 |
| TOTAL PROPERTY TAX: | 2,573.60 | 2,647.78 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 1,277.16 |
| NW REGIONAL ESD | 43.65 |
| TILLAMOOK BAY CC | 74.81 |
| EDUCATION TOTAL: | 1,395.62 |
| TILLAMOOK COUNTY | 439.49 |
| COUNTY LIBRARY | 184.47 |
| GARIBALDI RFD | 136.59 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 74.36 |
| 4H-EXTENSION SD | 19.58 |
| EMCD-911 | 53.44 |
| TILLA TRANSPORTATION | 56.76 |
| TILLA SOIL & WATER CONS | 17.03 |
| GENERAL GOVT TOTAL: | 981.72 |
| COUNTY LIBRARY | 13.74 |
| TILLA CNTY BONDS AFTER 2001 | 74.10 |
| SCHOOL 56 BONDS AFTER 2001 | 148.46 |
| TILLA BAY CC BONDS AFTER 2001 | 34.14 |
| BONDS - OTHER TOTAL: | 270.44 |

TAX STATEMENT INFORMATION WAS SENT TO:
FTC First Tech Credit Union

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 2,647.78

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 2,568.35 | 1,729.89 | 882.60 |
| 02/16/21 | | | 882.59 |
| 05/17/21 | | 882.59 | 882.59 |
| Total | 2,568.35 | 2,612.48 | 2,647.78 |

TOTAL DUE (After Discount and Pre-payments) 2,568.35

↑ Tear Here *COURTESY STATEMENT IF LENDER IS SCHEDULED TO PAY* Tear Here ↑

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 62719**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 2,568.35 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 1,729.89 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 882.60 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

BERG, MEGAN
1734 W YAMPA ST
COLORADO SPRINGS CO 80904

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-000873-256835

29100000627190000088260000017298900002568356

REAL PROPERTY TAX STATEMENT
JULY 1, 2020 TO JUNE 30, 2021
TILLAMOOK COUNTY, OREGON
201 LAUREL AVE
TILLAMOOK, OREGON 97141
(503) 842-3400

ACCOUNT NO
322822

PROPERTY DESCRIPTION

| | |
|---|---|
| CODE: | 5624 |
| MAP: | 1N1007DA03204 |
| ACRES: | 0.12 |

VON SEGGERN, HEATHER STECK
337 SOMERSET AVE
SARASOTA FL 34243

| VALUES: | LAST YEAR | THIS YEAR |
|---|---|---|
| REAL MARKET (RMV) | | |
| LAND | 341,740 | 312,720 |
| STRUCTURES | 0 | 0 |
| TOTAL RMV | 341,740 | 312,720 |
| TOTAL ASSESSED VALUE | 275,540 | 283,800 |
| EXEMPTIONS | | |
| NET TAXABLE: | 275,540 | 283,800 |
| TOTAL PROPERTY TAX: | 2,573.60 | 2,647.78 |

TAX BY DISTRICT

| | |
|---|---|
| SCHOOL 56 | 1,277.16 |
| NW REGIONAL ESD | 43.65 |
| TILLAMOOK BAY CC | 74.81 |
| EDUCATION TOTAL: | 1,395.62 |
| TILLAMOOK COUNTY | 439.49 |
| COUNTY LIBRARY | 184.47 |
| GARIBALDI RFD | 136.59 |
| TWIN ROCKS SANITARY DISTRICT | 0.00 |
| WATS-BARVIEW WD | 0.00 |
| PORT OF GARIBALDI | 74.36 |
| 4H-EXTENSION SD | 19.58 |
| EMCD-911 | 53.44 |
| TILLA TRANSPORTATION | 56.76 |
| TILLA SOIL & WATER CONS | 17.03 |
| GENERAL GOVT TOTAL: | 981.72 |
| COUNTY LIBRARY | 13.74 |
| TILLA CNTY BONDS AFTER 2001 | 74.10 |
| SCHOOL 56 BONDS AFTER 2001 | 148.46 |
| TILLA BAY CC BONDS AFTER 2001 | 34.14 |
| BONDS - OTHER TOTAL: | 270.44 |

Payments Online: www.co.tillamook.or.us
Payments by Phone: 1-844-784-9680

2020 - 2021 TAX ( Before Discount ) 2,647.78

PAYMENT OPTIONS

| Date Due | 3% Option | 2% Option | Trimester |
|---|---|---|---|
| 11/16/20 | 2,568.35 | 1,729.89 | 882.60 |
| 02/16/21 | | | 882.59 |
| 05/17/21 | | 882.59 | 882.59 |
| Total | 2,568.35 | 2,612.48 | 2,647.78 |

TOTAL DUE (After Discount and Pre-payments) 2,568.35

↑ Tear Here PLEASE RETURN THIS PORTION WITH YOUR PAYMENT Tear Here ↑

2020 - 2021 PROPERTY TAXES

**ACCOUNT NO. 322822**

TILLAMOOK COUNTY TAX COLLECTOR
201 LAUREL AVE
TILLAMOOK, OREGON 97141

| PAYMENT OPTIONS | Discount | Date Due | Amount |
|---|---|---|---|
| Full Payment Enclosed | 3% | 11/16/20 | 2,568.35 |
| or 2/3 Payment Enclosed | 2% | 11/16/20 | 1,729.89 |
| or 1/3 Payment Enclosed | 0% | 11/16/20 | 882.60 |

FORWARDING SERVICE REQUESTED

☐ Mailing address change on back

DISCOUNT IS LOST & INTEREST APPLIES AFTER DUE DATE

$ Enter Payment Amount

VON SEGGERN, HEATHER STECK
337 SOMERSET AVE
SARASOTA FL 34243

MAKE PAYMENT TO:

TILLAMOOK COUNTY TAX COLLECTOR

-000218-256835

291000032282200000882600000172989000025683544

**Allison Hinderer**

**From:** Sarah Mitchell <sm@klgpc.com>
**Sent:** Tuesday, July 27, 2021 4:20 PM
**To:** Sarah Absher; Allison Hinderer
**Cc:** Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
**Subject:** EXTERNAL: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Additional Evidence
**Attachments:** Exh 6 - West Consultants Fourth Supp Technical Memo 7.27.2021.pdf

**Importance:** High

Hi Sarah and Allison,

Please include the additional attached exhibit in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. Would you please confirm your receipt? Thank you.

Best,
Sarah

KELLINGTON
LAW GROUP

**Sarah C. Mitchell | Associate Attorney**
P.O. Box 159
Lake Oswego, OR 97034
(503) 636-0069 office
(503) 636-0102 fax
sm@klgpc.com
www.wkellington.com

# Technical Memorandum

WEST Consultants, Inc.
2601 25th St. SE
Suite 450
Salem, OR 97302-1286
(503) 485 5490
(503) 485-5491 Fax
www.westconsultants.com

67050PE
JULY 9, 2001
CHRIS D. BAHNER
EXPIRATION DATE: 12/31/21

**To:** Wendie Kellington, Kellington Law Group

**From:** Chris Bahner, P.E., D. WRE

**Date:** July 27, 2021

**Subject:** Fourth Supplemental Technical Memorandum

## 1. Introduction

This memorandum summarizes the changes to the dune classifications at the location of a proposed shoreline protection revetment for the oceanfront properties of the Pine Beach subdivision and all but one of the oceanfront lots in the George Shand Tracts (Ocean Boulevard Properties), together referred to as the "Subject Properties", in response to comments made at the July 15, 2021 Planning Commission hearing that the dune classifications of the Subject Properties have not changed. This is the fourth supplement to the design technical memorandum completed by WEST in March 2021 (WEST, 2021a).

The Subject Properties are located on the Oregon coast about 2 miles south of Rockaway Beach along the northwest coast of Oregon (Figure 1). These oceanfront landowners have been losing portions of their property due to coastal erosion and are experiencing coastal flooding as a result of high tides and wave run-up. Most recently, coastal flooding occurred during the King Tides in January of 2021, as well as in February of 2020. During these events, the maximum stillwater level reached the oceanfront homes, and went past the southernmost home for a distance of about 45 feet. There is a high level of risk for future damage to the Subject Properties' land, structures, and infrastructure without the proposed revetment. It is not accurate to state, as some commentors have, that the Subject Properties are not subject to wave overtopping or undercutting. They are subject to both.

WEST Consultants, Inc. (WEST) was contracted by Kellington Law Group to study and if appropriate to develop a rock riprap revetment design, which if constructed, is expected to prevent further erosion of the landowners' properties and to reduce the risk of coastal flooding. The revetment structure design and information required by Tillamook County was documented in a technical memorandum completed by WEST in March 2021 (WEST, 2021a). WEST also completed a three supplemental technical memorandum: (1) in May 2021 (WEST, 2021b); (2) in June 2021 (WEST, 2021c); and (3) on 21 July 2021 (WEST, 2021d).

**Figure 1. Location map**

## 2. Dune Classifications

The extents of beaches and dunes geomorphic classification and mapping was originally undertaken between 1972 and 1975 by the U.S. Department of Agriculture Soil Conservation Service and published in *Beaches and Dunes of the Oregon Coast* (USDA, 1975). Figure 2 shows the USDA 1975 beaches and dunes geomorphic classification at the proposed site. This figure shows that the oceanfront properties were located in the "younger stabilized dunes" with some inclusions of "open dune sand conditionally stable".

Changes to the beaches and dunes geomorphic characterization was noted in the dune hazard report of the Pine Beach Development completed by Handforth Larson & Barrett, Inc in 1994. This report indicates that coastal vegetation had grown within the area classified as "open dune sand conditionally stable" which tended to show that there was little to no ocean overtopping or undercutting, there were no "active foredunes" at the site, and development would be located on an area classified as "younger stabilized dune" which was not expected to be in danger of ocean flooding.

**Figure 2. Beach and dune geomorphic mapping classifications at Subject Project (USDA, 1975)**

Due to changes in coastal morphology from the significant erosion along the coastline, the Department of Geology and Mineral Industries (DOGAMI) completed a study in 2020 (DOGAMI, 2020). The 2020 DOGAMI study's updated dune classifications are consistent with the county plan's process for updated dune classifications where greater accuracy and detail are needed, given the dramatic changes that have occurred to the Tillamook coastline in the 45 years since USDA first mapped the county's dunes. Figure 3 shows the beaches and dunes geomorphic classification at the proposed site defined by the DOGAMI 2020 study. This figure shows that the residential development and residentially developable areas on the Subject Properties is near the interface of the "active foredune" and "recently stabilized foredune". Figure 4 shows the nomenclature used by the Oregon Department of Land Conservation and Development's (DLCD's) for beaches and dunes, and it shows that "recently stabilized foredune" is classified as "foredune, conditionally stable", which is subject to ocean undercutting and wave overtopping. The proposed beachfront protective structure (BPS) will be located within the "active foredune" classification area.

The following items summarizes the changes to the beaches and dunes classifications at the Subject Properties:

- Younger stabilized dune, with some inclusions of open dune sand conditionally stable defined from the USDA 1975 original classification. The area where residential development was established or authorized was not subject to ocean flooding (overtopping/undercutting).
- Coastal vegetation had filled in portions of property that were open dune sand conditionally stable (i.e. the Pine Beach subdivision's "common area") where no residential development was contemplated, and there was no active foredune on the Subject Properties. The residential development was on younger stabilized dune which was not expected to be subject to ocean flooding, as documented in the 1994 dune hazard report of the Pine Beach Development (Handforth Larson & Barrett, Inc, 1994).
- DOGAMI 2020 coastal morphology study indicates residential development on the Subject Properties – both existing and authorized – is now on a recently stabilized foredune, which DLCD refers to as a "conditionally stable foredune" that is now subject to ocean undercutting and wave overtopping. The proposed BPS in on an active foredune.

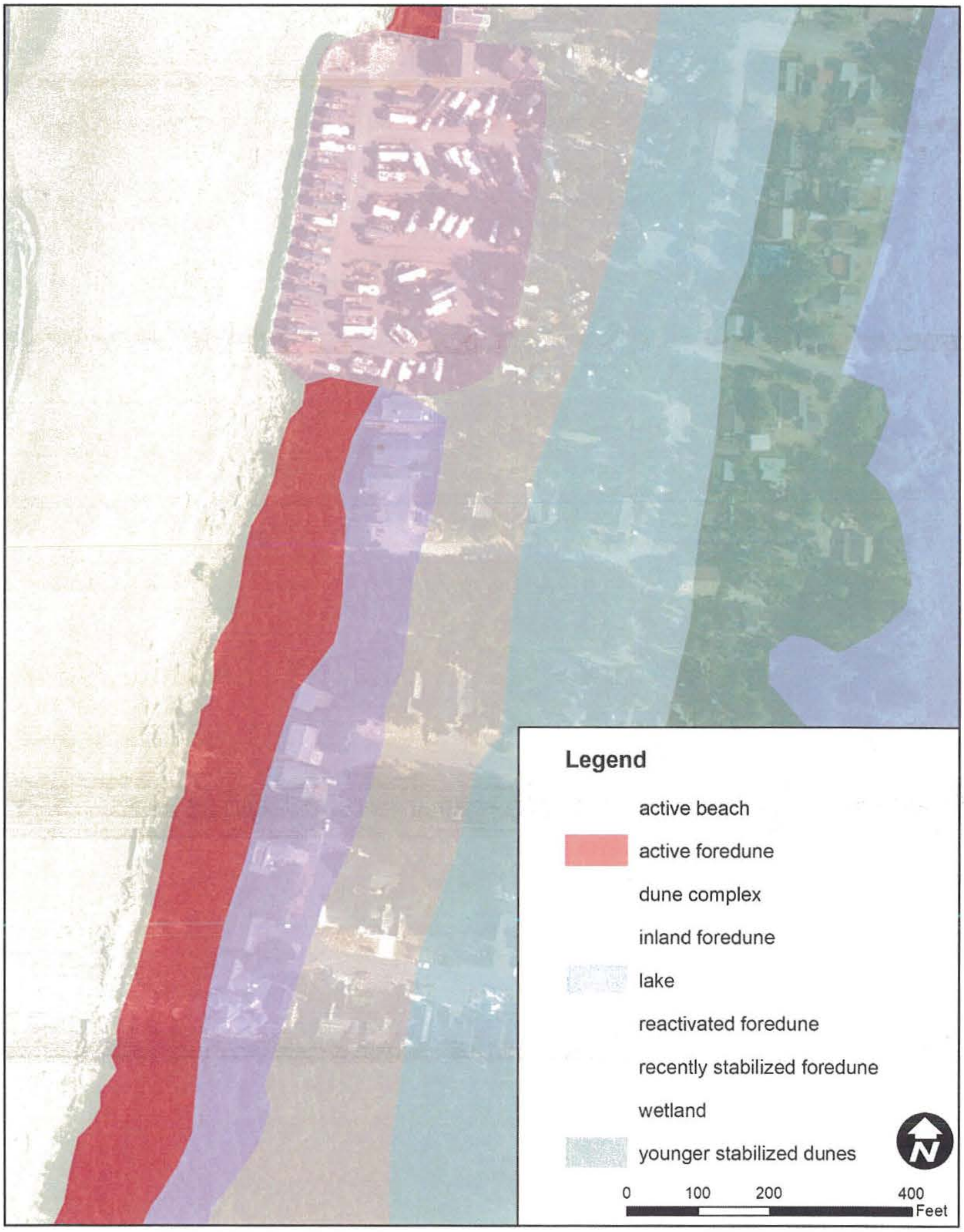

**Figure 3. Beach and dune geomorphic mapping classifications at Subject Project (DOGAMI, 2020)**

| Associated Dune Category | Inventory Classification | DLCD Classification | Mapping Unit |
|---|---|---|---|
| Active Beach and Foredune | beach | Beach | B |
| | active foredune | Foredune, Active | FDA |
| | active dune hummocks | Hummocks, Active | H |
| Recently Stabilized Dunes | recently stabilized foredune | Foredune, Conditionally Stable | FD |
| | inland foredune | | IFD |
| | dune complex | Dune Complex | DC |
| | younger stabilized dunes | Dune, Younger Stabilized | DS |
| Older Stabilized Dunes | older stabilized dunes | Dune, Older Stabilized | ODS |
| Inland Dunes | open dune sand | Dune, Active/Dune, Parabolic | OS |
| | open dune sand conditionally stable | Dune, Conditional Stable | OSC |
| | active inland dune | Dune, Active | AID |

**Figure 4. Beach and dune overlay zone nomenclature (after USDA, 1975) (DOGAMI, 2020)**

## 3. Conclusion

When mapped by USDA in 1975, the Subject Properties were on a "younger stabilized dune" with some inclusions of "open dune sand conditionally stable" and were not subject to ocean flooding (overtopping and undercutting). The dune hazard report performed in 1994 for the Pine Beach Subdivision found that since the properties were mapped in 1975, coastal vegetation had grown within the area classified as "open dune sand conditionally stable" which tended to show that ocean erosion was not occurring. That report noted that there were no "active foredunes" at the Subject Properties, and that residential development would be located on area classified as "younger stabilized dune". Further changes in the subject area are described in DOGAMI's 2020 report, which follows the county plan's Beaches and Dunes Element process for updated dune classification and now describes the area in which residential development exists or is contemplated as a conditionally stable foredune and the area in which the BPS is proposed as an active foredune. There is no dispute that the conditionally stable foredune is now subject to ocean undercutting and wave overtopping. Accordingly, the coastal morphology of the dunes upon which the Subject Properties are located have changed since they were originally mapped in 1975. The county's plan for beaches and dunes describes that the County will consult with the USDA SCS Soils Survey for coastal Tillamook County and will perform field inspections using criteria described in 1975 USDA report and in *A System of Classifying and Identifying Oregon's Beaches and Dunes*' (Oregon Coastal Zone Management Association, Inc, 1979). Notwithstanding that old County dune classifications of the area on which the Subject Properties are sited may not have been updated since 1975, the fact is that the dunes and their classifications have changed, and the dune classification should be adopted for the site since there are changes and classification system is consistent with the county's process for dune classification.

## 4. References

Handforth Larson & Barrett, Inc, 1994 (June). *Dune Hazard Report and Modified Dune Hazard Report, Tax Lot 100, 101 & 102, 1N 10 7DD, Pine Beach Replat, Watseco, Oregon*, prepared for Mr. Dave Farr and Mr. Don Nessmeier

Oregon Coastal Zone Management Association, Inc., 1979. *A System of Classifying and Identifying Oregon's Coastal Beaches and Dunes*, by Christianna Stachelrodt Crook, Research Associate, OCZMA, Beaches and Dunes Study Team

State of Oregon Department of Geology and Mineral Industries, 2020. *Temporal and Spatial Changes in Coastal Morphology, Tillamook County, Oregon,* prepared by Jonathan C. Allan

U.S. Department of Agriculture Soil Conservation Service [USDA], 1975, *Beaches and Dunes of the Oregon Coast*: USDA Soil Conservation Service, 158 p

WEST, 2021a (March). *Technical Memorandum, Subject: Pine Beach Revetment Design*

WEST, 2021b (May). *Technical Memorandum, Subject: Supplement to the March 2021 Pine Beach Revetment Technical Memorandum*

WEST, 2021c (June). *Technical Memorandum, Subject: Second Supplement Memorandum*

WEST, 2021d (July 21). *Technical Memorandum, Subject: Third Supplement Memorandum*

## Allison Hinderer

**From:** Sarah Mitchell <sm@klgpc.com>
**Sent:** Tuesday, July 27, 2021 5:22 PM
**To:** Sarah Absher; Allison Hinderer
**Cc:** Wendie Kellington; Bill and Lynda Cogdall (jwcogdall@gmail.com); Bill and Lynda Cogdall (lcogdall@aol.com); Brett Butcher (brett@passion4people.org); Dave and Frieda Farr (dfarrwestproperties@gmail.com); David Dowling; David Hayes (tdavidh1 @comcast.net); Don and Barbara Roberts (donrobertsemail@gmail.com); Don and Barbara Roberts (robertsfm6@gmail.com); evandanno@hotmail.com; heather.vonseggern@img.education; Jeff and Terry Klein (jeffklein@wvmeat.com); Jon Creedon (jcc@pacifier.com); kemball@easystreet.net; meganberglaw@aol.com; Michael Munch (michaelmunch@comcast.net); Mike and Chris Rogers (mjr2153@aol.com); Mike Ellis (mikeellispdx@gmail.com); Rachael Holland (rachael@pacificopportunities.com); teriklein59@aol.com
**Subject:** EXTERNAL: 851-21-000086-PLNG & 851-21-000086-PLNG-01 Pine Beach BOCC Hearing Packet - Powerpoint Presentation to BOCC Part 1
**Attachments:** July 28 BOC Hearing PPT.pdf

**Importance:** High

[**NOTICE:** This message originated outside of Tillamook County -- **DO NOT CLICK** on **links** or open **attachments** unless you are sure the content is safe.]

Hi Sarah and Allison,

Please include the attached powerpoint presentation in the record of 851-21-000086-PLNG /851-21-000086-PLNG-01 and in the Board of Commissioners' packet for the July 28, 2021 hearing on these matters. Would you please confirm your receipt? Thank you.

Best,
Sarah

KELLINGTON
LAW GROUP

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# Pine Beach Combined Application for Shoreline Protection

## Tillamook County Board of Commissioners

July 28, 2021

Presented by:
Wendie L. Kellington, Kellington Law Group, PC
P.O. Box 159, Lake Oswego, Or 97034

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# Subject Properties/Proposal

- Avoiding a piecemeal approach, the owners of 15 properties working together seek approval of a critically needed beachfront protective structure.
- Application is for Goal 18 exception and County Development Permit
- Proposal is supported by the Pine Beach HOA.
- Proposal is supported by the County Planning Commission
- Pine Beach Loop (Pine Beach Subdivision – first platted 1932; replatted 1994) and Ocean Blvd. (George Shand tracts platted 1950).
- Acknowledged urban unincorporated community (Twin Rocks/Barview/Watseco), long planned and zoned for medium density urban residential use under an acknowledged urban planning program.

EXHIBIT R
Page 1 of 1

## Proposed Exception Area and Adjacent Lands Map

Image © 2021 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Imagery Date: 6/22/2017


Barview - Watseco - Twin Rocks Community Area
Location of Revetment
Barview - Watseco - Twin Rocks
Roads
1 inch equals 330.91 feet
0
430
860
1,720
2,580
3,440
Feet
®


Community Boundaries
Location of Revetment

EXHIBIT A
Page 1 of 1

## Subject Properties

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# Owners – personal responsibility
# Tillamook County is sole Decisionmaker

- The beachfront protective structure ("BPS") is not on beach.
- The BPS is entirely in the backyards of the properties it will protect.
- All other BPS proposals including Shorewood RV Park's was on the dry sand beach and County and OPRD had to approve.
- BPS here is entirely ***east*** of OPRD jurisdiction – east of established vegetation/SVL and east of the dry sand beach;
- Neither OPRD nor DLCD approval required – the Subject Properties are in an acknowledged urban unincorporated community that is part of an acknowledged and appropriate residential development program.
- △ Tillamook County is only the approval authority - local control.

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# Beachfront Protection is Urgently Needed

- 70-plus years of prograding; residential development approved on stable ground.
- Sudden onset retrograding beach: winter 1997-98 El Nino/1998-1999 El Nina.
- Aggressive erosion ever since.
- Now, King Tides in 2020 and 2021 reached Subject Properties + 45' beyond
- Continued significant threat of severe flooding.
- At risk are human lives, residential development, public water and sewer infrastructure.
- The proposal protects people; public and private investments; avoids significant environmental harm from destroyed homes; garaged vehicles; broken sewer and water infrastructure; broken electrical connections, gas connections; proposal protects coastal dune habitat.
- Water and sewer district costs of repair may be beyond district's capacity; at minimum would cause significant strain districts' resources.
- Torn out infrastructure risks dangerous service disruptions to the larger community.

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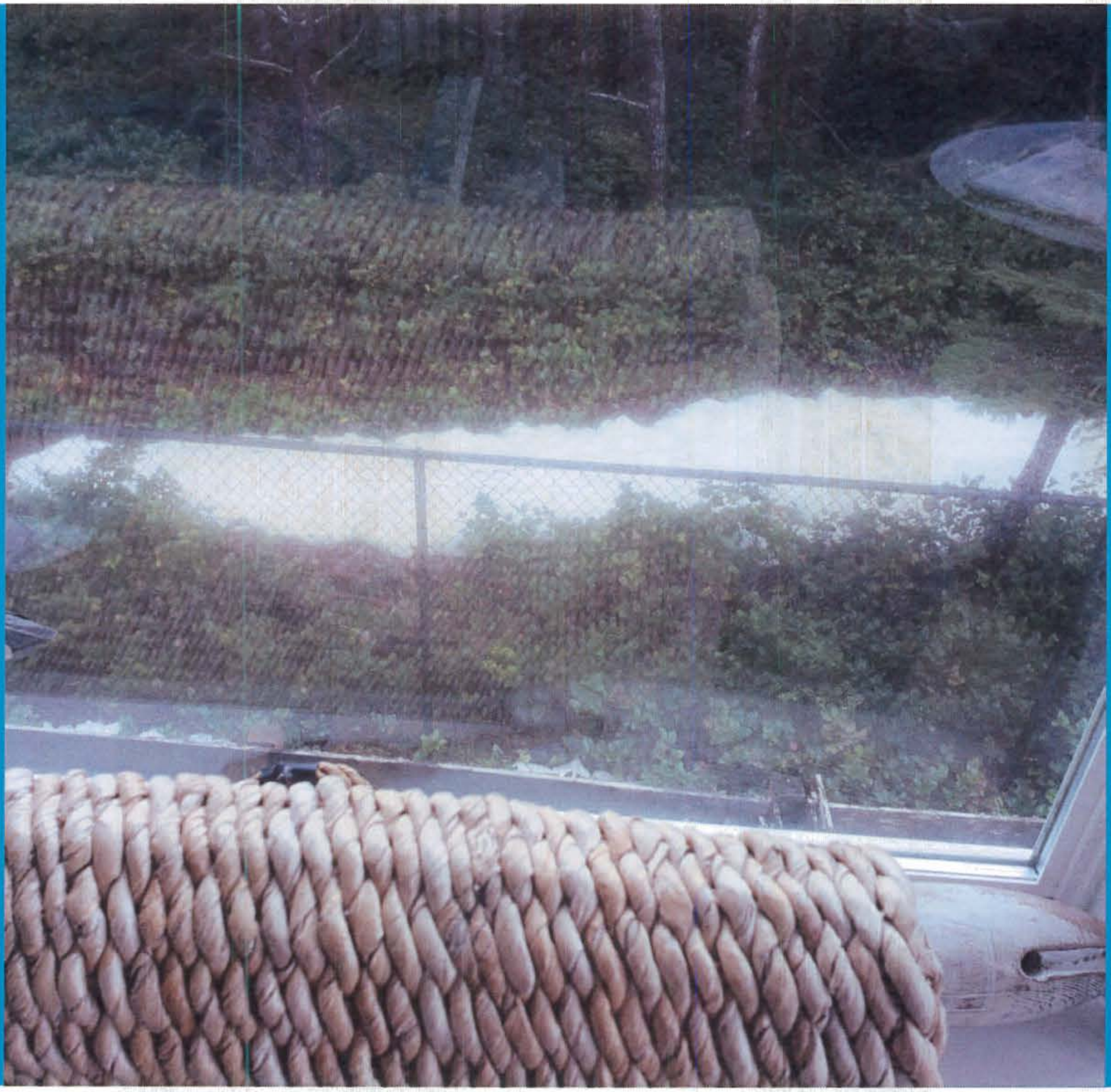

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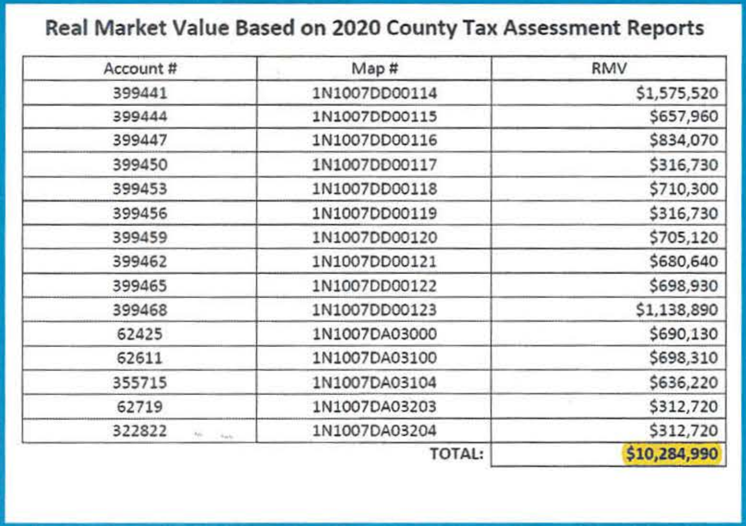
LAW GROUP, PC

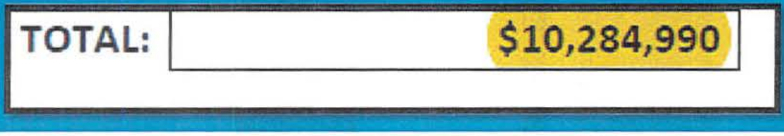
# Properties and infrastructure are now in imminent peril

- More than $10 million in property value at risk of being lost.
- In addition to infrastructure (public water and sewer, roads, utilities)



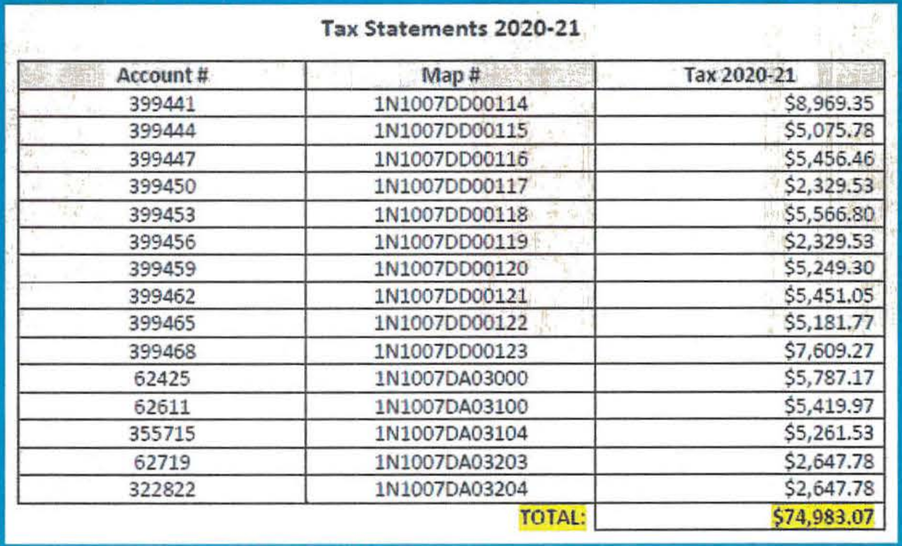
**Real Market Value Based on 2020 County Tax Assessment Reports**

| Account # | Map # | RMV |
|---|---|---|
| 399441 | 1N1007DD00114 | $1,575,520 |
| 399444 | 1N1007DD00115 | $657,960 |
| 399447 | 1N1007DD00116 | $834,070 |
| 399450 | 1N1007DD00117 | $316,730 |
| 399453 | 1N1007DD00118 | $710,300 |
| 399456 | 1N1007DD00119 | $316,730 |
| 399459 | 1N1007DD00120 | $705,120 |
| 399462 | 1N1007DD00121 | $680,640 |
| 399465 | 1N1007DD00122 | $698,930 |
| 399468 | 1N1007DD00123 | $1,138,890 |
| 62425 | 1N1007DA03000 | $690,130 |
| 62611 | 1N1007DA03100 | $698,310 |
| 355715 | 1N1007DA03104 | $636,220 |
| 62719 | 1N1007DA03203 | $312,720 |
| 322822 | 1N1007DA03204 | $312,720 |
|  | TOTAL: | $10,284,990 |



**TOTAL:** $10,284,990

# Property Owners Contribute $75,000/year to County in Taxes



**Tax Statements 2020-21**

| Account # | Map # | Tax 2020-21 |
|---|---|---|
| 399441 | 1N1007DD00114 | $8,969.35 |
| 399444 | 1N1007DD00115 | $5,075.78 |
| 399447 | 1N1007DD00116 | $5,456.46 |
| 399450 | 1N1007DD00117 | $2,329.53 |
| 399453 | 1N1007DD00118 | $5,566.80 |
| 399456 | 1N1007DD00119 | $2,329.53 |
| 399459 | 1N1007DD00120 | $5,249.30 |
| 399462 | 1N1007DD00121 | $5,451.05 |
| 399465 | 1N1007DD00122 | $5,181.77 |
| 399468 | 1N1007DD00123 | $7,609.27 |
| 62425 | 1N1007DA03000 | $5,787.17 |
| 62611 | 1N1007DA03100 | $5,419.97 |
| 355715 | 1N1007DA03104 | $5,261.53 |
| 62719 | 1N1007DA03203 | $2,647.78 |
| 322822 | 1N1007DA03204 | $2,647.78 |
|  | TOTAL: | $74,983.07 |

**TOTAL: $74,983.07**

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# Subject Properties are an Important Source of Property Taxes Supporting County Service Providers

- If Subject Properties are wiped out, $75,000 in annual tax revenues will be irrevocably lost.
    - Police
    - Fire
    - Schools
    - Education Service Districts

Catastrophic loss not only would cause lost property tax revenues, but also impose fiscal strain:

- Allowing Subject Properties to be wiped out: strain emergency providers and social services networks.
- Allowing Subject Properties to be wiped out: strain public facilities district equipage and resources.
- Approval is necessary so the Applicants can protect themselves and their homes.

# Application Legal Framework for Decision

- The Oregon land use planning system consists of state statutes, administrative rules, the Statewide Planning Goals and local plans and regulations.
- The legislature ensured local authority:
  - DLCD is responsible to "acknowledge" local plans and regulations to certify that local plans and regulations comply with all the state land use rules.
  - But local governments are vested with authority and responsibility to approve land use requests like the proposal.
  - This application is a local land use request that is exclusively within the control of the County Board of Commissioners.
- The legislature expressly authorizes cities and counties to adopt goal exceptions to retain flexibility in the land use system. ORS 197.732.
- DLCD rules echo the same: "The intent of the exceptions process is to permit necessary flexibility in the application of the Statewide Planning Goals." OAR 660-004-000(3).
- DLCD rules specifically say Goal 18 exceptions are permitted. OAR 660-004-0010(1)(g).
- Goal exceptions are site specific amendments to the County's Plan.
- It is simply mistaken that Goal 18 exceptions can never be granted to provide beachfront protection.
- The legal framework allows them in proper circumstances, such as those here.

# Goal Exceptions

- The legislature outlines three appropriate types of exceptions. ORS 197.732. All are relevant here.
- They are:
  - The land is "**physically developed** to the extent that it is no longer available for the uses allowed by the applicable goal."
  - The land is "**irrevocably committed** *** to uses not allowed by the applicable goal because adjacent uses and other relevant factors make the uses allowed by the applicable goal impractical."
    - Often referred to together as "built and committed" exceptions – this is how County plan refers to them.
  - "**Reasons** justify why the state policy" in a goal should not apply.
    - DLCD rules expressly allow two types of "reasons" exceptions. One is specific to Goal 18, and one is called the "catch all" that applies generally.

# County is Familiar with Goal Exceptions and has Adopted them Previously

- County has taken and DLCD has acknowledged as completely appropriate a “built and committed” Goal 17 Exception for the entire urban unincorporated community of Twin Rocks/Barview/Watseco (including where the proposed BPS will be located and beach beyond)– from County Plan:

- “8.2 ***"**Built and Committed" Rural Shorelands from Goal 17 Rural shoreland Use Requirements** 3e. Tillamook County finds that there are **shoreland areas** which are ***"**built and committed" to a type and degree of development which is not rural in nature**. These include the following communities *** **which are necessary, suitable or intended for urban use** (Netarts, Oceanside, Pacific City, Neskowin, Cloverdale, Neahkahnie and **Twin Rocks-Watseco-Barview**.)”

Community Boundaries

# Request is for a Limited Exception to Goal 18, Implementation Measures 2 and 5

*** Exception to Goal 18, Implementation Measure 2 ***

- Goal 18, Implementation Measure 2 says the County should not allow residential development on dunes subject to wave overtopping/undercutting.
    - No one thought Goal 18, Implementation Measure 2 would be triggered here.
    - When the County approved residential development on the Subject Properties, the beach had been in a 70+ year period of prograding; the approved residential development was east of a coastal forest, safe and exactly where Goal 18, IM 2 said it should be – nothing was proposed on a dune subject to overtopping/undercutting.
    - In fact, all residential development was approved far away from such dunes.
    - Residential development was established on Subject Properties in good faith based upon compliance with all rules.
    - Later, the dune dramatically changed; now, the Subject Properties are in significant danger.
    - Now, Subject Properties are residential development on a type of dune that Goal 18, IM 2 forbids.

- The requested limited Goal 18, IM 2 exception will do two things:
    - Allow the County to continue its long planned urban residential development program in Twin Rocks/Barview/Watseco.
    - Allow the County to protect urban residential development in that long-planned program so the County can comply with its obligations to protect people and property from destruction caused by natural or man-made hazards.
- Approval of requested limited Goal 18, IM 2 exception will mean Goal 18 allows the proposed beachfront protective structure.

# ***Limited Exception to Goal 18, Implementation Measure 5 ***

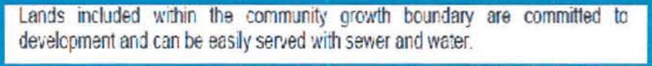
- Goal 18, Implementation Measure 5 says the County should prohibit beachfront protective structures for property that was not "developed" on Jan 1 1977.
- The limited Goal 18, IM 5 exception will *also* allow the protective structure, even though properties not "developed" by 1977.
- Request for exceptions to both Goal 18, Implementation Measures 2 and 5 is to provide the best insurance that the Subject Properties are protected.
- Either exception will allow the proposed beachfront protection system.
- But approving both Goal 18, Implementation Measure 2 and Implementation Measure 5 exceptions, maximizes any County approval decision being sustained if there are appeals.

# The Proposed BPS Meets Standards for Exceptions

## *** Physically developed/committed type ***

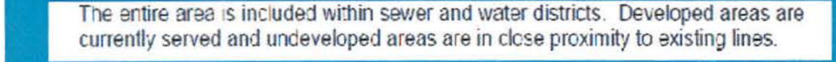
The Subject Properties are residentially developed/committed to residential development.

- All are in platted subdivisions;
- 11 are built with houses/garages; many occupied by full time residents;
- 4 do not yet have houses, but are developed with urban infrastructure (sewer, water, electricity, gas, telephone) and roads,
- All are in an acknowledged urban unincorporated community and zoned R-3 (med density residential). County Plan reinforces Twin Rocks-Barview-Watseco commitment to residential development:

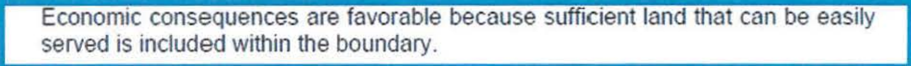


Lands included within the community growth boundary are committed to development and can be easily served with sewer and water.

Environmental consequences are beneficial because committed areas are used for development.

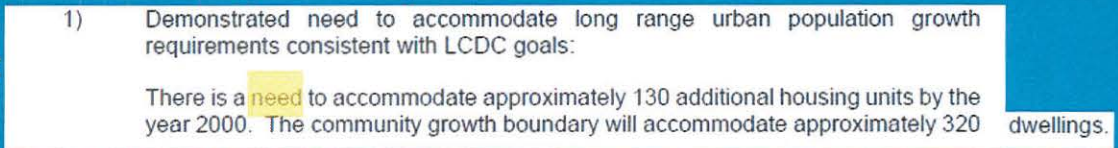


The entire area is included within sewer and water districts. Developed areas are currently served and undeveloped areas are in close proximity to existing lines.



Economic consequences are favorable because sufficient land that can be easily served is included within the boundary.

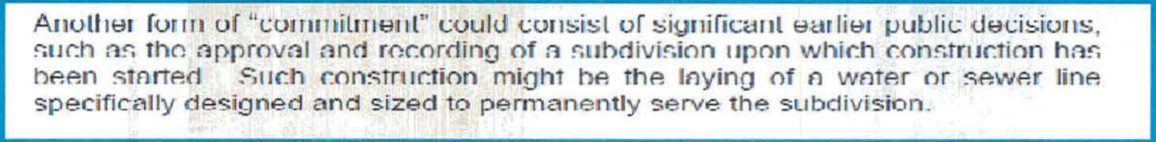
- (5) County Plan states the County "needs" the Subject Properties and the rest of Twin Rocks-Barview-Watseco to maintain housing:



1) Demonstrated need to accommodate long range urban population growth requirements consistent with LCDC goals:

There is a need to accommodate approximately 130 additional housing units by the year 2000. The community growth boundary will accommodate approximately 320 dwellings.

- In fact, the acknowledged County Comprehensive Plan defines facts here to meet "committed" exception type



Another form of "commitment" could consist of significant earlier public decisions, such as the approval and recording of a subdivision upon which construction has been started  Such construction might be the laying of a water or sewer line specifically designed and sized to permanently serve the subdivision.

# Proposed BPS Also Meets "Reasons" Exception Standards

- Demonstrated need for the County to amend its Plan to meet state Goal 7 obligations to protect persons and property from natural / man-made hazards.
- Demonstrated need for the County to comply with its acknowledged Goal 10 (housing) obligations to provide urban residential development on the Subject Properties.
- Demonstrated Goal 14 need to provide for the livability of the County designated urban unincorporated communities of Twin Rocks/Barview/Watseco.
- Demonstrated Goal 18 need to "reduce the hazard to human life and property from natural or man-made actions" in beach and dune areas.
- Denial would put County at risk of not complying with these state Goal obligations.

# “Reasons” Exception Standards

- "Areas that do not require a new exception cannot reasonably accommodate the use".
  - **NOTE**: This is not an alternative *methods* issue, but an alternative *areas* issue.
  - Regardless, the evidence shows that there is no other area for the proposed BPS or other method that can protect the human lives and properties at severe risk.
- “The long-term environmental, economic, social and energy consequences resulting from the use at the proposed site with measures designed to reduce adverse impacts are not significantly more adverse than would typically result from the same proposal being located in areas requiring a goal exception other than the proposed site.”
- "The proposed uses are compatible with other adjacent uses or will be so rendered through measures designed to reduce adverse impacts.”
- **NOTE**: Rule defines meaning of “compatible”: “‘Compatible’ is not intended as an absolute term meaning no interference or adverse impacts of any type with adjacent uses.”
- Evidence demonstrates only that the proposal is compatible with other adjacent uses.

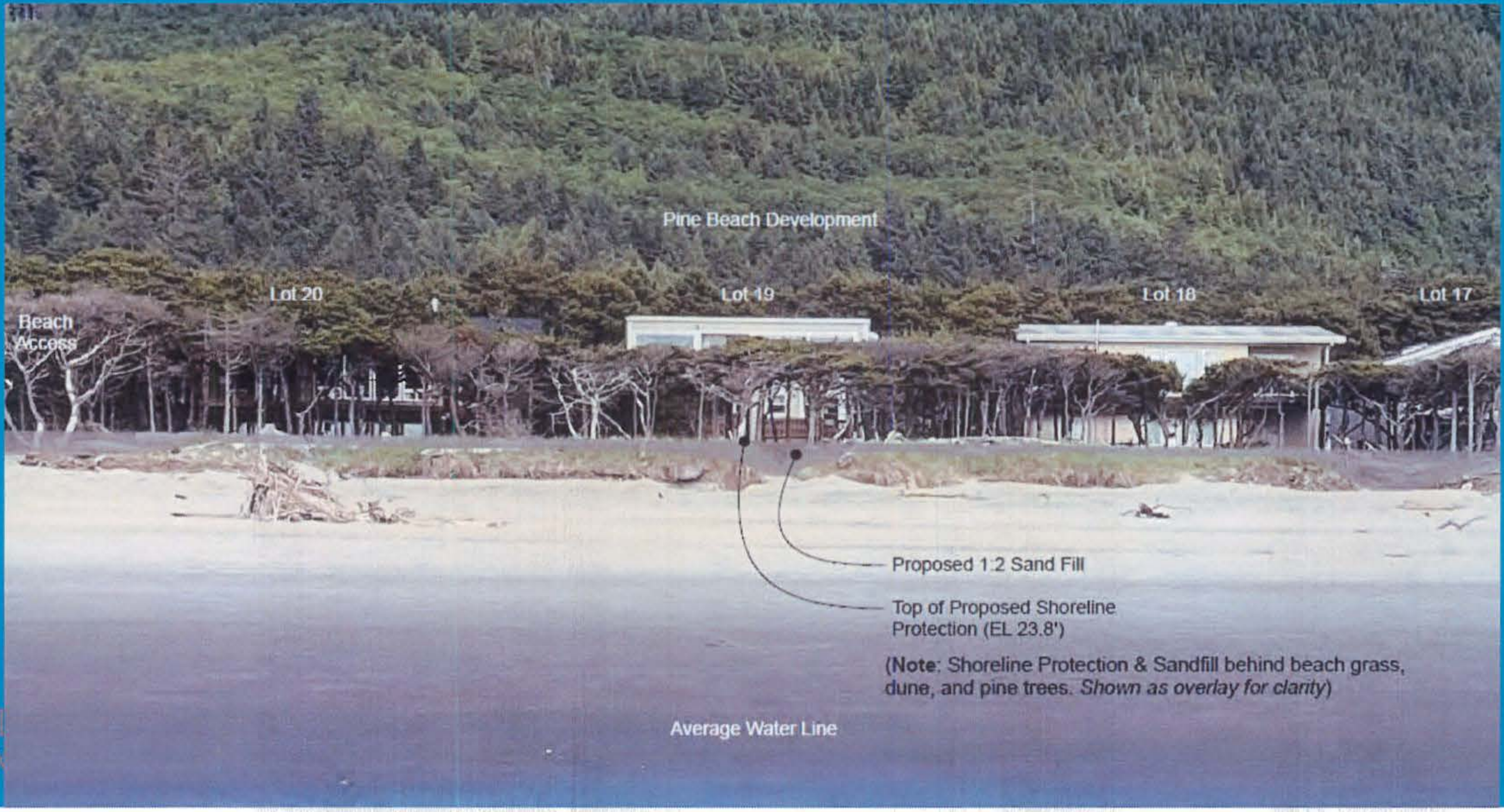
# Goal 18 Specific "Reasons" Exception Standards

- "Goal 18 — Foredune Development: An exception may be taken to the foredune use prohibition in Goal 18 'Beaches and Dunes', Implementation Requirement. Reasons that justify why this state policy embodied in Goal 18 should not apply shall demonstrate that:
- "(a) The use will be adequately protected from any geologic hazards, wind erosion, undercutting ocean flooding and storm waves, or the use is of minimal value;
- "(b) The use is designed to minimize adverse environmental effects."
- (c) meets other previously listed reasons exception standards.
- The evidence, opinions of experts, County Planning Commission and legal analyses show that all "reasons" exception standards are met.

# Expert Analysis Establishes that Approval Furthers State and County Land Use Programs and Policies

- Planning Commission reviewed and agreed that approval is appropriate.
- Expert analysis backed by authoritative papers (DOGAMI and others) proves that all standards are met .
- Expert analysis proves that the proposed beachfront protection is compatible, minimizes adverse environmental effects, is properly designed and will not cause ocean flanking, accelerated wave runup, or any other harm.
- Evidence demonstrates that the proposal does not cause adverse impacts to persons on the beach walking north/south; no adverse impact on east/west private access points to the beach.
- Proposed protection cannot be easily seen by beachgoers.

# Pine Beach's BPS will blend into the natural coastal landscape

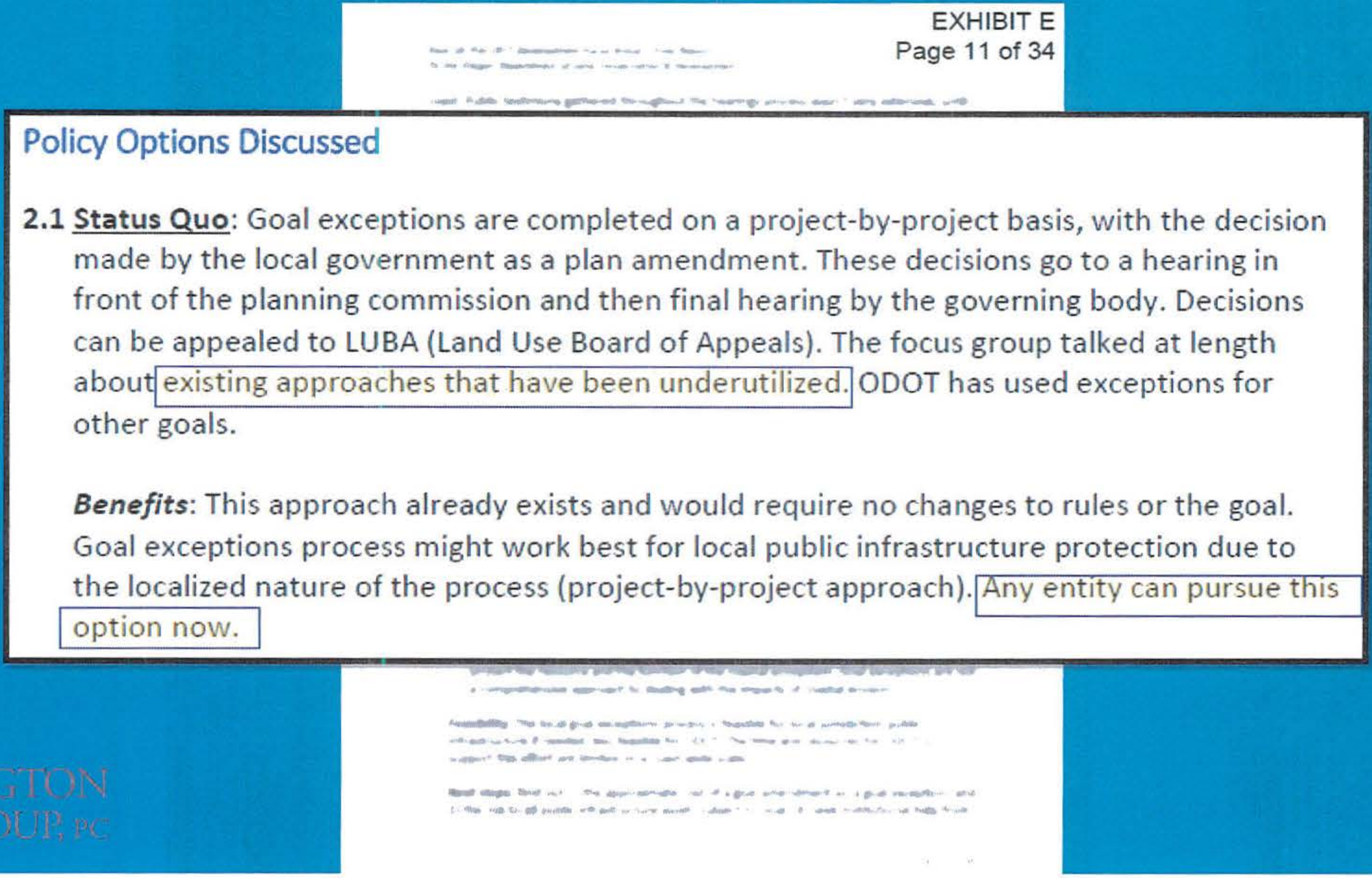


Proposed 1:2 Sand Fill

Top of Proposed Shoreline Protection (EL 23.8')

(**Note**: Shoreline Protection & Sandfill behind beach grass, dune, and pine trees. *Shown as overlay for clarity*)

# • Approval is Consistent with DLCD's "Goal 18 Focus Group" Expectations – the Exception Process is Appropriate



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### Policy Options Discussed

**2.1 Status Quo**: Goal exceptions are completed on a project-by-project basis, with the decision made by the local government as a plan amendment. These decisions go to a hearing in front of the planning commission and then final hearing by the governing body. Decisions can be appealed to LUBA (Land Use Board of Appeals). The focus group talked at length about existing approaches that have been underutilized. ODOT has used exceptions for other goals.

***Benefits***: This approach already exists and would require no changes to rules or the goal. Goal exceptions process might work best for local public infrastructure protection due to the localized nature of the process (project-by-project approach). Any entity can pursue this option now.

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# Claims that there is no severe, imminent flooding risk, are mistaken

- Between 1994-2021, the shoreline has receded 142 feet.

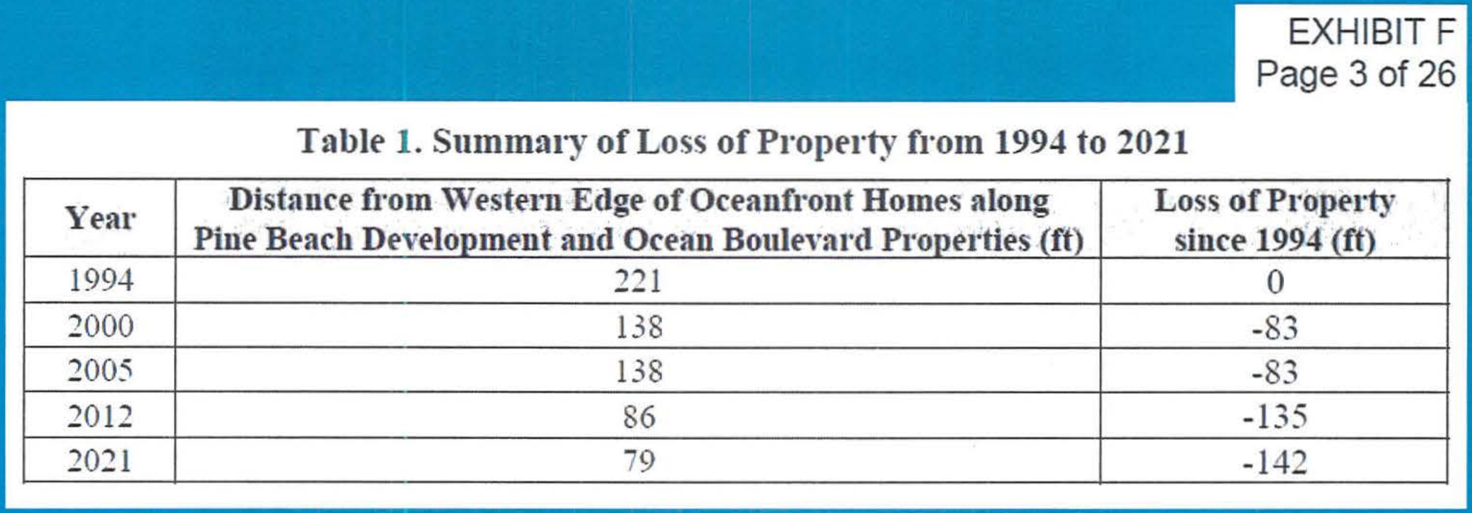

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Table 1. Summary of Loss of Property from 1994 to 2021

| Year | Distance from Western Edge of Oceanfront Homes along Pine Beach Development and Ocean Boulevard Properties (ft) | Loss of Property since 1994 (ft) |
|---|---|---|
| 1994 | 221 | 0 |
| 2000 | 138 | -83 |
| 2005 | 138 | -83 |
| 2012 | 86 | -135 |
| 2021 | 79 | -142 |

The problem explained in graphics

Figure 2. Top of shoreline for the period between 1994 and 2021

# 1994

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**Beach Erosion History – Google Earth**

1994

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# 2000

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2000

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# 8/2005

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August 2005

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# 2011

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2011

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# 2014

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2014

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# 2016

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2016

# 2017

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2017

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# 2020

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2020

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# Dune Changes - 1975-2020

1975 (USDA):

- Younger stabilized dune
- Open dune sand conditionally stable

1994 (Pine Beach Dune Hazard Report):

- 70-year history of ocean prograding
- Coastal forest had grown on open dune sand
- Homes to be sited on younger stabilized dune
- No active foredunes
- No risk of wave overtopping undercutting

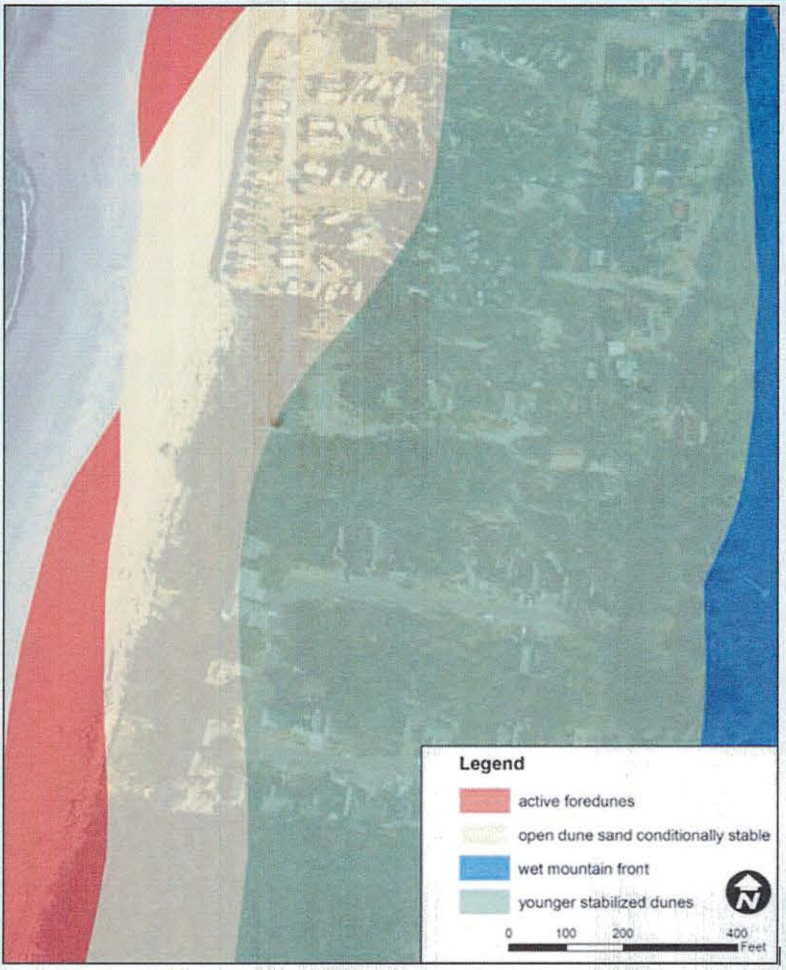

**Figure 2. Beach and dune geomorphic mapping classifications at Subject Project (USDA, 1975)**

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# Dune Changes 1975-2020

## 2020 (DOGAMI):

- Subject Properties are now on "recently stabilized foredune" (DLCD classification: "conditionally stable foredune").
- That dune is now subject to ocean undercutting / wave overtopping
- BPS will be on active foredune.

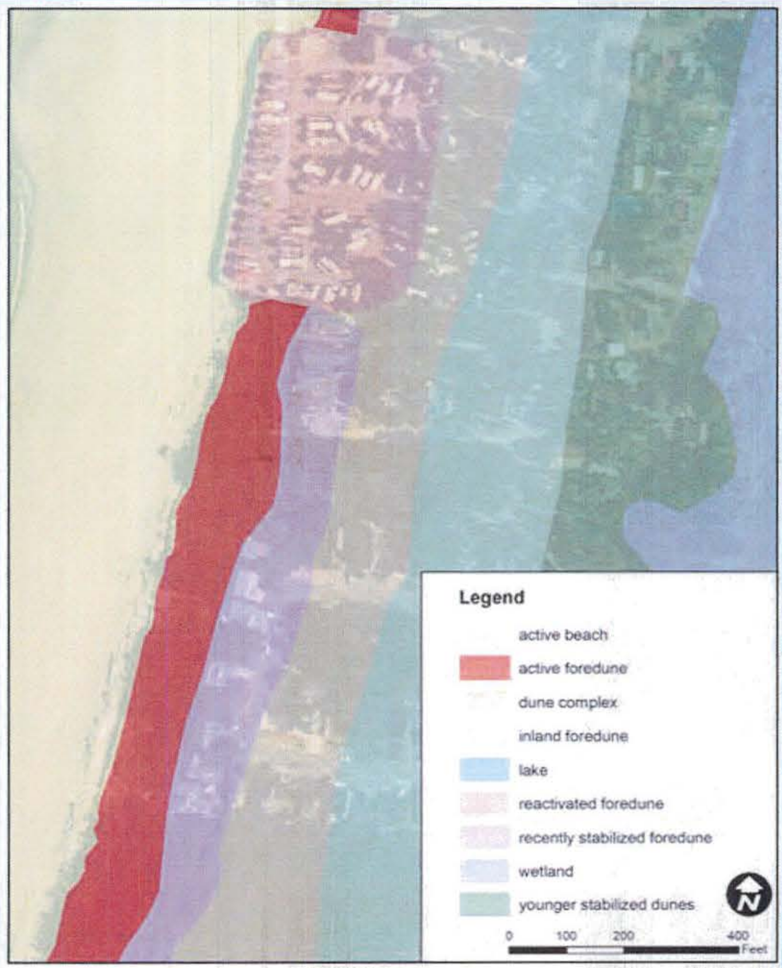

Figure 3. Beach and dune geomorphic mapping classifications at Subject Project (DOGAMI, 2020)

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# Changes in 1975-2020

- Summary:
  - When the residential development on the Subject Properties was approved, the development was where Goal 18 said it should be --on a "younger stabilized dune" that was not subject to ocean undercutting or wave overtopping.
  - Now, the residential development on the Subject Properties is on a "conditionally stable foredune" that is subject to ocean undercutting and wave overtopping, where Goal 18, IM 2 forbids residential development without a goal exception.
  - Hence the requested exception to Goal 18, IM 2.

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- Applicants respectfully request that the County Board follow the recommendation of its planning commission and approve the requested exceptions because the law and evidence supports doing so
- Applicants are willing and enthusiastic to work with County to help draft findings as desired.

# Alternative Request

- The Applicants request the County also make alternative findings that the existing built/committed exceptions to Goals 3, 4 and 17 that allow the approved residential development to be exactly where it is, is also a built and committed exception that allows the approved residential development to continue to exist where it is even when the dune changed and became subject to wave overtopping/undercutting.
- Recall that Goal 18, Implementation Measure 2, prohibits residential development on a dune subject to wave overtopping/undercutting without an exception that allows the residential development to be there.
- The Goal 3, 4 and 17 exceptions were approved on the basis that the Subject Properties and Twin Rocks-Barview-Watseco was committed to residential use.
- They allow the Subject Properties residential development to be where it is.
- Which is now on an eroding dune. Therefore, the existing exceptions allow residential development on an eroding dune.

# The Policy Underpinnings for Existing Exceptions Demonstrates Approved Residential Development may Remain in Place and, as such, Goal 18 Requires they be Protected from Harm

- It is true that exceptions to one goal do not "ensure compliance with any other applicable goal" (OAR 660-004-0010(3)).
- However, it is also the case that the existing exceptions that cover the Subject Properties, together with the acknowledged applicable urban planning program, commit the Subject Properties to residential development.
- Goal 18 states that its purpose is "To reduce the hazard to human life and property from natural or man-induced actions associated with these areas."
- Accordingly, it furthers the policy of Goal 18 to protect life and property from hazards, to interpret the existing committed exceptions that allow residential development on the Subject Properties, to be exceptions to Goal 18, Implementation Measure 2 such that Goal 18 allows Beachfront Protective Structures, without a new exception.

# Requested Board of Commissioners Decision:

1. The Subject Properties meet standards for a "committed" and a "built" exception to Goal 18, Implementation Measure 2 that otherwise prohibits residential development on a dune subject to wave overtopping/undercutting.
2. The Subject Properties meet standards for a "committed" and a "built" exception to Goal 18, Implementation Measure 5 that otherwise prohibits beachfront protection for property not "developed" on January 1, 1977.
3. The Subject Properties meet the standards for a Goal 18 specific "reasons" exception to Goal 18, Implementation Measure 2.
4. The Subject Properties qualify for the "catch all" reasons exception to Goal 18, Implementation Measure 2 and 5. (DLCD prefers).

IN THE ALTERNATIVE ONLY, the existing exceptions that cover the Subject Properties allow residential development on a dune that is now eroding and so they are in fact an exception to Goal 18, Implementation Measure 2. Which means Goal 18 allows the proposed BPS.

# The Request is Unique – not reproducible elsewhere

- When the Pine Beach subdivision was replatted (1994-1996); when the George Shand tracts were initially platted (1950); when water and sewer was extended to the subdivisions and when most houses were built, the ocean had been PROGRADING for 70-years– depositing sand, not taking it away.
- The professional reports of the time, stated residential development would be more than 237 feet away from the surveyed statutory vegetation line and further still from the ocean.
- A coastal forest separated residential development from the beach.
- The Subject Properties' residential development was approved in good faith in complete compliance with all state and County standards. No reason to punish good faith landowners.
- Coastal processes substantially influenced by two man-made jetties on either end of the Rockaway littoral subregion.
- No other known littoral cell or littoral subregion on Oregon Coast is bounded by jetties in such close proximity to one another.
- The unusual placement of the man-made jetties in the Rockaway subregion has caused extreme erosion in the subregion where the Subject Properties are located, yet sand is still being deposited the rest of the littoral cell. The problem is unique to the Rockaway subregion.
- Subject Properties are in an acknowledged and vibrant urban unincorporated community.
- Goal 3, 4 and 17 exceptions already.
- 90% of the properties in the Rockaway subregion either have or are entitled to have rip rap per DLCD's own "Atlas." This was the compelling reason that DLCD and others used to approve BPS in Lincoln County. No reason this justification does not also apply here.

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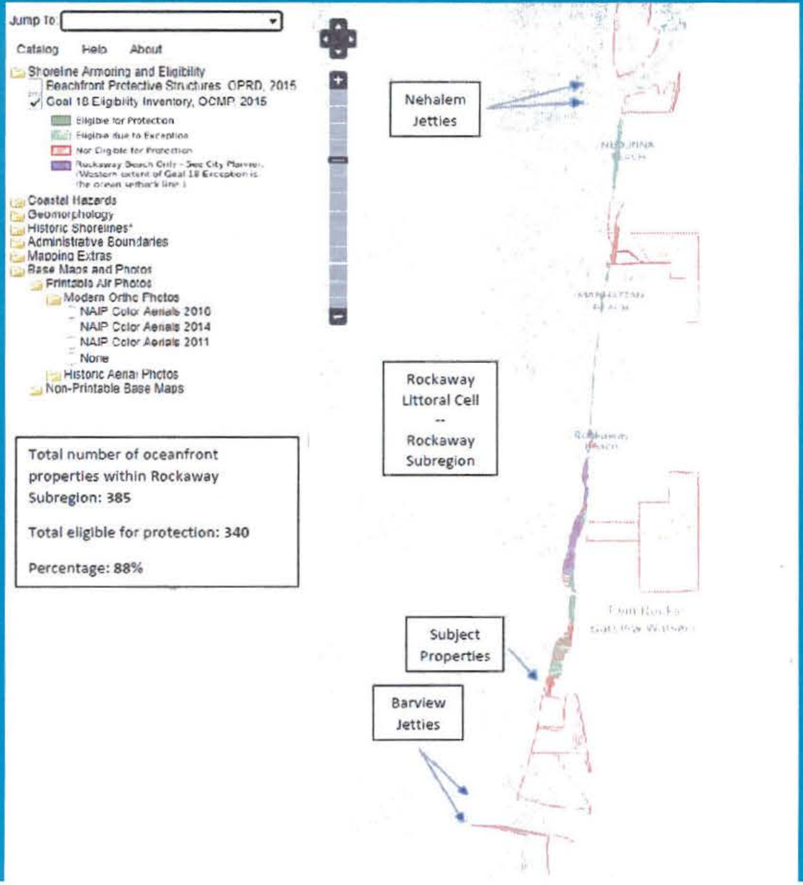
# Nearly 90% of Properties in Rockaway Subregion are Eligible for BPS

- 90% of the residential properties with development are identified as eligible for protection on DLCD's "Coastal Atlas".
- Non-eligible properties are the Subject Properties and properties that are generally zoned RM and Open Space w/little to no development.



Total number of oceanfront properties within Rockaway Subregion: 385

Total eligible for protection: 340

Percentage: 88%

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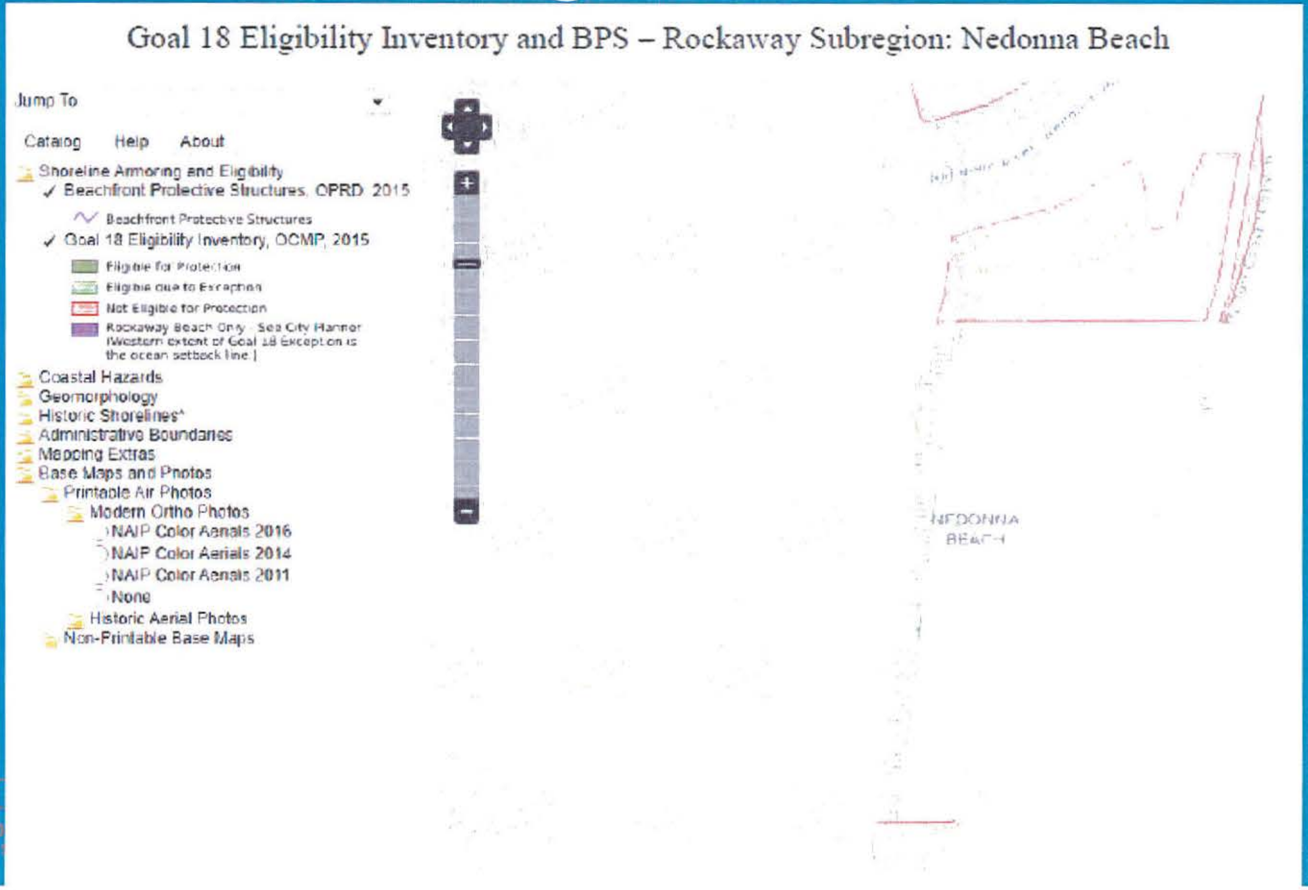
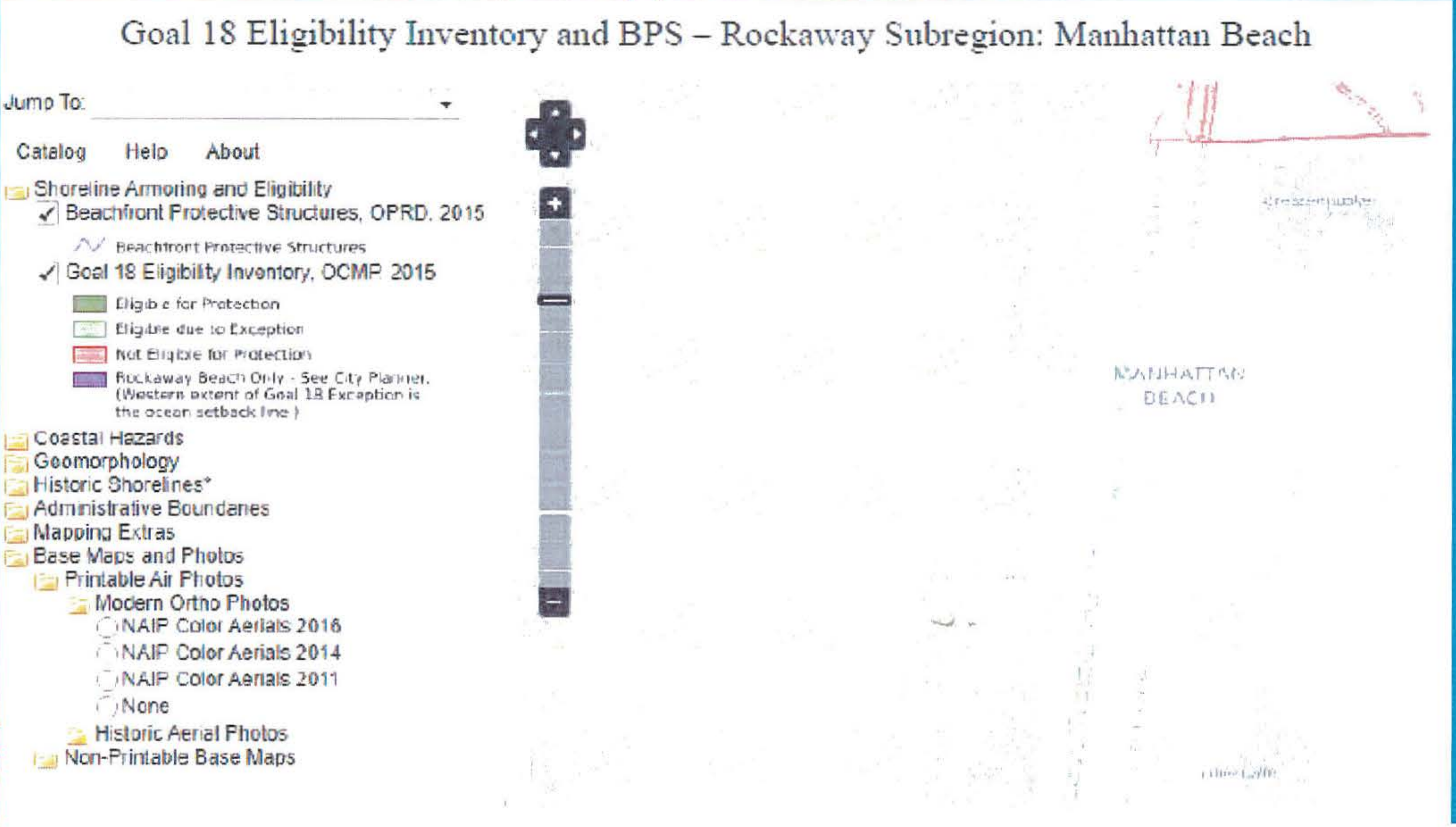
# Nearly 90% of Properties in Rockaway Subregion are Eligible for BPS



Goal 18 Eligibility Inventory and BPS – Rockaway Subregion: Nedonna Beach

# Nearly 90% of Properties in Rockaway Subregion are Eligible for BPS



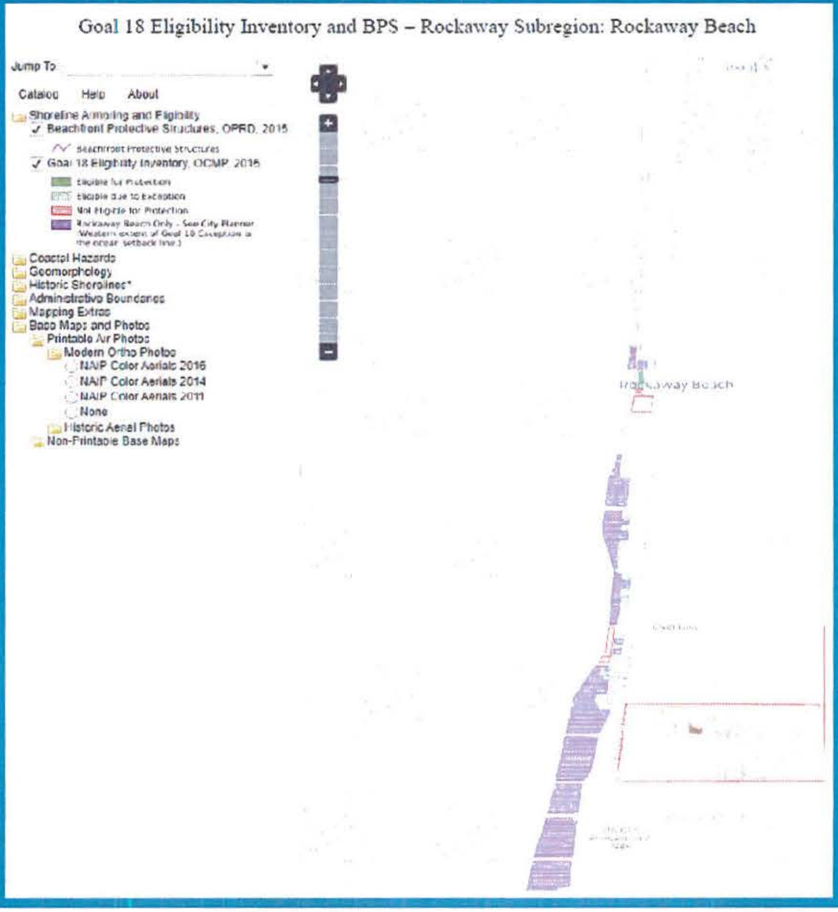
Goal 18 Eligibility Inventory and BPS – Rockaway Subregion: Manhattan Beach

Jump To:

Shoreline Armoring and Eligibility
- ☑ Beachfront Protective Structures, OPRD. 2015
  - Beachfront Protective Structures
- ☑ Goal 18 Eligibility Inventory, OCMP 2015
  - 🟩 Eligible for Protection
  - ▭ Eligible due to Exception
  - 🟥 Not Eligible for Protection
  - 🟪 Rockaway Beach Only - See City Planner. (Western extent of Goal 18 Exception is the ocean setback line.)

Coastal Hazards
Geomorphology
Historic Shorelines*
Administrative Boundaries
Mapping Extras
Base Maps and Photos
- Printable Air Photos
  - Modern Ortho Photos
    - ○ NAIP Color Aerials 2016
    - ○ NAIP Color Aerials 2014
    - ○ NAIP Color Aerials 2011
    - ○ None
  - Historic Aerial Photos
- Non-Printable Base Maps

# Nearly 90% of Properties in Rockaway Subregion are Eligible for BPS



Goal 18 Eligibility Inventory and BPS – Rockaway Subregion: Rockaway Beach

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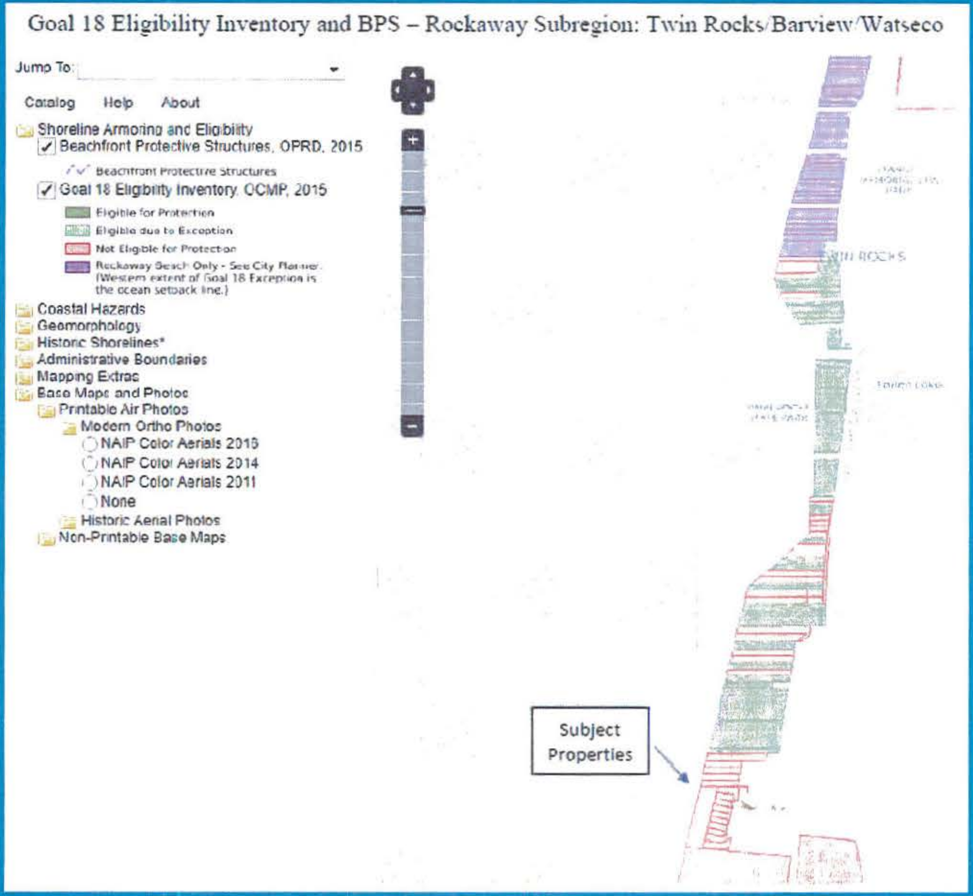
# Nearly 90% of Properties in Rockaway Subregion are Eligible for BPS



Goal 18 Eligibility Inventory and BPS – Rockaway Subregion: Twin Rocks/Barview/Watseco

Jump To:

Catalog Help About

- Shoreline Armoring and Eligibility
  - ☑ Beachfront Protective Structures, OPRD, 2015
    - Beachfront Protective Structures
  - ☑ Goal 18 Eligibility Inventory, OCMP, 2015
    - 🟩 Eligible for Protection
    - ▨ Eligible due to Exception
    - 🟥 Not Eligible for Protection
    - 🟪 Rockaway Beach Only - See City Planner. (Western extent of Goal 18 Exception is the ocean setback line.)
- Coastal Hazards
- Geomorphology
- Historic Shorelines*
- Administrative Boundaries
- Mapping Extras
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    - Modern Ortho Photos
      - ○ NAIP Color Aerials 2016
      - ○ NAIP Color Aerials 2014
      - ○ NAIP Color Aerials 2011
      - ○ None
    - Historic Aerial Photos
  - Non-Printable Base Maps

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# Revetment Details

- Harms no one per engineering analysis in the record
- Best chance of reestablishing natural vegetation
- Maintains existing beach accesses
- Approx. size: 6’ thick 30’ wide rock revetment; maximum height 3’ above ground level
- Covered in excavated sand, replanted with native beach grasses
- Some confusion about the existing beach accesses. Whatever they are they will remain and not be blocked or impeded in any way.

# Comment/Answer

- This section addresses comments made by people who objected to the proposal before the planning commission.

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# Comment/Answer

- *"Site conditions and environmental factors that impact development are beyond the County's control. At what point does the County's responsibility to protect private properties developed in coastal high hazard areas end?"*
- The existing residential development on the Subject Properties was never in a mapped "coastal high hazard area."
- The Subject Properties became subject to ocean undercutting/wave overtopping due to the unusual effect of too closely placed man-made jetties influenced by successive El Nino and El Nina events causing unexpected erosion in the Rockaway subregion that reversed the 70+-year period of prograding that had been occurring when residential development was approved on the Subject Properties.
- County obligations under Goal 7: "Protect people and property from natural hazards." Goal 18: "Reduce the hazard to human life and property from natural or man-induced actions associated with [coastal beach and dune] areas."

# Comment/Answer

- *"Goal 18 recognizes importance of natural function of the beach. Actions should not contribute to loss of a natural resource. Rip rap always contribute to loss of natural function of the beach"*
- The proposed BPS will not contribute to loss of the beach. The BPS will not be sited on the beach; it will be sited entirely in the Applicants' backyards which are still vegetated.
- Proposed BPS is "Type II" in Weggel's classification system = structure w/minimal impacts on coastal processes within littoral cell system.
- There are types of BPS that cause harm, but the proposed BPS is not one of them – it has been carefully designed and per the well-known classification system, the proposal has minimal impact.

# Comment/Answer

- *"Goal 18 protects public access to the beach and citizen rights to enjoy the beach. Construction of a BPS will restrict access to the beach."*
- As explained throughout the record, the BPS will not restrict access to *<u>or along</u>* the beach any more than is already occurring.
- Shorewood RV Resort's BPS restricts access along the beach during high tides.
- Proposed BPS will be located further inland than Shorewood RV Resort's BPS.
- High tides already restrict N-S access along the beach in front of Subject Properties (water comes right up to homes). BPS will not further restrict N-S access.

# Comment/Answer

- *"The beach is the natural resource and protecting the resource is greater than the right to protect private property from erosion and ocean flooding."*
- Goal 18 places two overarching goal obligations on the County: (1) To conserve, protect, where appropriate develop, and where appropriate restore the resources and benefits of coastal beach and dune areas; and (2) To reduce the hazard to human life and property from natural or man-induced actions associated with these areas.
- The acknowledged planning program for the Subject Properties is under Goal 18's "appropriate development" prong.
- County is obligated under Goal 18 to protect human life and property from the hazards of coastal erosion and flooding.

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# Comment/Answer

- *"Concern of negative impacts to neighboring properties if BPS is constructed. Shorewood RV Park and other properties in the County were identified to support these concerns."*
- BPS will have no negative impacts to adjacent properties.
- Property to north is entitled to BPS (built before 1977), hence not part of this application. And can get BPS anytime they want it without going through a Goal exception process.
- Shorewood RV Park BPS does not harm neighboring properties. Erosion on adjacent properties caused by same forces that are eroding the Subject properties.

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# Comment/Answer

- *"Lack of demonstration and justification to grant exception through Reasons criteria."*
- The Applicants have thoroughly demonstrated that the proposal complies with the requirements for a Goal 18-specific "reasons necessary" standard under OAR 660-004-0022(11) and the requirements for a "catch-all" reasons exception under OAR 660-004-0020(1).
- Respectfully, it appears likely that many commentors have not read the Applicants' submittals.

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# Comment/Answer

- *"Blanket exceptions should not be granted. The taking of one exception does not alone constitute or satisfy criteria for granting additional exceptions."*
- This is no "blanket exception." Authoritative papers encourage property owners to work together as here to avoid the "sawtooth effect."
- Subject Properties' existing exceptions not sole basis for granting the requested exceptions, but factor into "reasons why" calculus of why the requested exception should be approved.
- Existing exceptions are only directly used in the Applicants' requested ALTERNATIVE decision that the existing exceptions already allow residential development on the eroding dune and so are an exception to the prohibition in Goal 18, Implementation Measure 2, that residential development be prohibited on an eroding dune.

# Comment/Answer

- *"This decision is precedent setting, as DOGAMI projections indicate conditions are going to get worse, what obligation will the County be under in the future should this exception request be approved?"*
- DOGAMI and other professional projections indicate only Rockaway littoral subregion is experiencing significant continued erosion.
- 90% of all properties in Rockaway subregion are already entitled to BPS, so will not require a Goal 18 exception when they need BPS.
- Other 10% are mostly large tracts in public ownership or large tracts with no development that would require a BPS.
- Neskowin is also experiencing significant erosion but they also already have a Goal 18 exception that allows the BPS.
- Other Goal 18 exceptions requests will have to be evaluated on a case-by-case basis.
- No reasonable basis to conclude this is precedent setting because no other known part of the County or the state has the unique circumstances that are causing severe erosion here.

# Thank you

- Questions?

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**Allison Hinderer**

| | |
|---|---|
| **From:** | Teryn Yazdani <teryn@crag.org> |
| **Sent:** | Tuesday, July 27, 2021 8:48 PM |
| **To:** | Public Comments; Sarah Absher; Allison Hinderer; Melissa Jenck |
| **Cc:** | Anuradha Sawkar; phillip@oregonshores.org; orshores@teleport.com |
| **Subject:** | EXTERNAL: Or. Shores Comment for BOCC Pub. Hearing, Tillamook County File No(s) 851-21-000086-PLNG-01/851-21-000086-PLNG |
| **Attachments:** | 2021.07.27_FINAL Or. Shores Tillamook G18 BOCC Comment.pdf |

Dear Sarah,

As you know, this office represents the Oregon Shores Conservation Coalition. Please find attached Oregon Shores' written testimony and materials for the aforementioned files. Please confirm receipt of this email and attached documents.

Sincerely,
Teryn Yazdani

--

**Teryn Yazdani**
Legal Fellow
Crag Law Center
3141 E Burnside Street
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Tel: (503) 234-0788
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*She/Her/Hers*

*Protecting and Sustaining the Pacific Northwest's Natural Legacy*

OREGON SHORES
CONSERVATION COALITION

July 28, 2021

Tillamook Board of County Commissioners
c/o Sarah Absher, Director
Tillamook County Courthouse
201 Laurel Avenue
Tillamook, OR 97141

*Via Email to:* publiccomments@co.tillamook.or.us, sabsher@co.tillamook.or.us, ahindere@co.tillamook.or.us, mjenck@co.tillamook.or.us

**Re: Tillamook County File No(s) 851-21-000086-PLNG-01/851-21-000086-PLNG Land Use Applications for Goal Exception, Flood Plain Development Permit Comments of Oregon Shores Conservation Coalition.**

Dear Chair Bell, Vice-Chair Yamamoto, and Commissioner Skaar,

Please accept these comments from the Oregon Shores Conservation Coalition and its members (collectively, "Oregon Shores") to be included in the evidentiary record for the Board of County Commissioner's ("BOCC" or "Board") hearing on 851-21-000086-PLNG-01/851-21-000086-PLNG Land Use Applications for Goal Exception, Flood Plain Development Permit. Oregon Shores is a non-profit organization dedicated to protecting the Oregon coast's natural communities, ecosystems, and landscapes while preserving the public's access to these priceless treasures in an ecologically responsible manner. Our mission includes assisting local residents in land use matters and other regulatory processes affecting their coastal communities, as well as engaging Oregonians and visitors alike in a wide range of advocacy efforts and stewardship activities that serve to protect our state's celebrated public coastal heritage. For nearly half a century, Oregon Shores has been a public interest participant in legal processes and policy decisions related to land use, shoreline, and estuarine management in the State of Oregon.

Oregon Shores previously submitted comments and supplementary evidence materials for inclusion within the record for this matter before the Planning Commission on May 27, 2021, June 3, 2021 Comment, and June 10, 2021. In addition, we submitted a letter on June 24, 2021 objecting to certain materials submitted by the Applicants in contravention of Planning Commission requirements originally provided at the May 27, 2021 public hearing. We hereby adopt in full and incorporate by reference our previous comments and materials in the record.

Please continue to notify us of any further decisions, reports, or notices issued as well as meetings or hearings held in relation to these Land Use Applications ("Applications"). Pursuant to ORS 197.763(4) and (6), Oregon Shores respectfully requests that the BOCC continue the hearing in order to allow for an opportunity to present additional evidence, arguments, and testimony regarding these Applications. Additionally, Oregon Shores requests that the BOCC leave the record open following the public hearing to allow for submission of additional information and rebuttal of information presented for at least seven days.[1] Oregon Shores will provide further comments as appropriate and allowed.

At its July 15, 2021 public hearing, the Planning Commission passed a motion to recommend approval of Development Permit request #851-21-000086-PLNG to the Board of County Commissioners.[2] Additionally, the Planning Commission recommended that the Board "work with staff on development of Conditions of Approval [incorporated into Development Permit #851-21-000086-PLNG] for construction of the BPS with required inspections during the construction phase to ensure the BPS is constructed as proposed and in accordance with the development standards outlined in the Beach and Dune Overlay Zone."[3]

Our comment supports the view that the Planning Commission erred in its application of the requisite criteria, and misconstrued or otherwise failed to make adequate and substantiated findings regarding its recommendation to approve the Applicants' requests. Oregon Shores argues that the Applications have not demonstrated compliance with the applicable approval criteria set forth in the Statewide Planning Goals ("Goals"), the requisite criteria for a Goal Exception within the Oregon Administrative Rules ("OAR"), the Oregon Revised Statutes ("ORS"), the Tillamook County Comprehensive Plan ("TCCP"), and the Tillamook County Land Use Ordinance ("TCLUO"). On the basis of the present record, a recommendation for denial is the most supported conclusion. Oregon Shores respectfully requests that this Board reject the recommendation of the Planning Commission and deny approval of the Applications for the following reasons.

### A. The Applications Do Not Meet the Mandatory Requirements for Granting a Reasons Exception under OAR 660-004-0020 and OAR 660-004-0022.

In DLCD's May 19, 2021 Letter, the Department determined that "the proper administrative rule provisions are those of OAR 660-004-0022(1) . . . because the houses that exist in this area were lawfully developed under the County's regulations at the time of

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[1] ORS §§ 197.763(4), (6); TCLUO SECTION 10.080(5).

[2] Board of County Commissioners Hearing Packet at 1. At the time of writing this comment, Oregon Shores was unable to locate an official draft of the Planning Commissions' findings and recommendation to the Board on the County website. Thus, Oregon Shores references the Planning Commission decision as stated in the Board of County Commissioners Hearing Packet.

[3] *Id.* at 2.

development."[4] DLCD also stated that it was the Department's "position that a 'reasons' exception to Goal 18 is necessary in this case[]" and that because the Applications do not establish that adjacent uses are the basis for this exception request—a requirement for a "committed" exception under OAR 660-004-0028—they do not qualify for or need a "committed" exception.[5] The Department found "[o]nly a general 'reasons' exception to Goal 18, Implementation Requirement #5 is needed in this case."[6] DLCD ultimately recommended "that the County deny [this] goal exception request" due to the Applications' "problematic and missing analysis."[7]

Oregon Shores agrees with DLCD's assessment that the "demonstrated need" pathway or a reasons exception is the only available avenue for a goal exception in this instance. As noted previously and within this comment, the Applicants and Applications do not demonstrate that the proposal is consistent with the criteria for a reasons exception under OAR 660-004-0022(1)'s catch-all provision. Oregon Shores also agrees with DLCD that the County should deny the Applicants this goal exception request due to missing, problematic analysis and failure to meet the mandatory criteria. Oregon Shores incorporates by reference our previous analysis regarding OAR 660-004-0022 and OAR 660-004-0020 in our May 27, 2021 Comment, our June 3, 2021 Comment, and our June 10, 2021 Comment on this matter. Further, Oregon Shores incorporates by reference our previous analysis regarding ORS 197.732 in our May 27. 2021 Comment and our June 3, 2021 Comment.

As previously stated in detail in our June 10, 2021 Comment, which Oregon Shores incorporates by reference, the Applications also fail to meet the necessary, mandatory criteria for "built" and "committed" exceptions under Goal 2, Part II, ORS 197.732(2)(a)–(b), OAR 660-004-0025, and OAR 660-004-0028. However, even if the Applications met the mandatory criteria for these two exception pathways—which they do not—"built" and "committed" exceptions are neither necessary nor applicable in the current circumstance. As highlighted in DLCD's June 10, 2021 Letter:

> [T]he application does not warrant either a "built" exception or a "committed" exception . . . There is no [beachfront protective structure or BPS] at the proposed location yet, so it is not "built." Likewise, there is only one BPS in the immediate area (the Shorewood RV Resort) which the applicants argue has not impacted the properties. Therefore, other BPS in the adjacent area have not "committed" this beach and dunes resource area to a non-resource use necessitating BPS here as well.[8]

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[4] May 19, 2021 DLCD Letter to the Tillamook County Planning Department at 2.

[5] *Id.*

[6] *Id.*; *see also* June 10, 2021 DLCD Letter to the Tillamook County Planning Department at 3 ("Since there is not a specific section in OAR 660-004-0022 pertaining to reasons for an exception to allow [beachfront protective structures] for an ineligible development, a general 'reasons' exception is the appropriate pathway for the applicants.").

[7] *Id.* at 5.

[8] June 10, 2021 DLCD Letter to the Tillamook County Planning Department at 3.

The Applications have still failed to demonstrate otherwise that the current circumstances necessitate "built" or "committed" exceptions. Because they fail to meet the relevant goal exception requirements of ORS and OAR, the Board of County Commissioners should deny the Applications.

### B. The Applications Do Not Meet the Mandatory Local Criteria Under the Tillamook County Land Use Ordinances ("TCLUO") and the Tillamook County Comprehensive Plan ("TCCP").

#### i. Applicable TCLUO Provisions

The Applications fail to meaningfully address the local criteria as required in the TCLUO regarding the Flood Hazard Overlay Zone, the Beach and Dune Overlay Zone, the TCLUO's Comprehensive Plan Text Amendment Criteria under Article 9, and the TCLUO's Article 10 Administrative Provisions. Each local land use ordinance and the Applications' noncompliance will be discussed in further detail below.

##### *a. TCLUO Section 3.510: Flood Hazard Overlay ("FH") Zone*

i. 3.510(1): Purpose

The stated purpose of the FH zone is to:

> [P]romote the public health, safety and general welfare and to minimize public and private losses or damages due to flood conditions in specific areas of unincorporated Tillamook County by provisions designed to:
>
> (a) Protect human life and health;
>
> (b) Minimize expenditure of public money for costly flood control projects;
>
> (c) minimize the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the public;
>
> * * *
>
> (e) Minimize damage to public facilities and utilities such as water and gas mains, electric, telephone and sewer lines, streets and bridges located in areas of special flood hazards; "
>
> (f) Help maintain a stable tax base by providing f or the sound use and development of areas of special flood hazard so as to minimize future flood blight areas;
>
> * * *
>
> (h) Ensure that those who occupy the areas of special flood hazard assume responsibility for their actions.

The proposed project area is within an active eroding foredune east of the line of established vegetation in the Coastal High Hazard (VE) zone as well as within an Area of Special Flood Hazard within the Flood Hazard Overlay Zone (TCLUO Section 3.510). The subject fifteen tax lots are Lots 11-20 of the Pine Beach Replat Unit #1, designated as Tax Lots 114 through 123,[9] of Section 7DD, between 17300 to 17480 Pine Beach Loop in Rockaway Beach [Pine Beach Properties]. Additionally, the subject properties also include Tax Lots 3000, 3100,

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3104, 3203, and 3204[10] (north to south) of Section 7DA [Ocean Boulevard Properties]. All properties are in Township 1 North, Range 10 West of the Willamette Meridian, Tillamook County, Oregon.

The Applications' analysis entirely overlooks the negative impacts that the proliferation of BSP will have on the shoreline and how adding riprap to a mostly untouched portion of the beach[11] will impact the public's safety and access. Additionally, as our colleague Surfrider noted in its June 3, 2021 comment, this proposal would likely have detrimental impacts on adjacent properties based on the well-known impacts of riprap on adjacent structures. "Property owners have . . . commented on the detrimental effect they witness on rip rap adjacent properties. Water gets refracted off of the hard structure and creates more erosion to the adjacent properties than if the structure was not there. It can funnel and focus wave energy to create destruction."[12] The Applications lack any analysis regarding the potential harms that this proposal will have on adjacent properties and infrastructure in relation to protecting human life and health and impacts to adjacent public facilities and utilities. Because this proposal will likely have many significant impacts on more than just the Applicants' privately owned homes and properties, more is needed in order for this proposal to accomplish the FZ zone's stated purpose.

### ii. 3.510(10): Specific Standards for Coastal High Hazard Areas (V, VE, or V1–V30 Zones)

TCLUO Section 3.510(10) states that "[l]ocated within areas of special flood hazard established in Section 3.510(2) are Coastal High Hazard Areas. These areas have special flood hazards associated with high velocity waters from tidal surges" and must meet a number of mandatory standards. Because the Applicants' proposed site is located within a VE flood zone, the standards in this section apply. TCLUO Section 3.510(10)(h) requires that development in Coastal High Hazard Areas "[p]rohibit man-made alteration of sand dunes, including vegetation removal, which would increase potential flood damage." The Applications, in response to this requirement, state that the purpose of the beachfront protection structure is to "decrease potential flood damage and "in order to accomplish this purpose, the man-made alteration of sand dunes, including vegetation removal . . . is required[.]"[13] Although the Applications attempt to explain away removal of vegetation and area disturbance as "temporary," "minimal," and necessary for the long-term protection of the dune and its vegetation, their analysis is inconsistent and contrary to the plain language of the TCLUO. The Applications cannot justify TCLUO Section 3.510(10) by acting in conflict with TCLUO Section 3.510(10)—especially given the harmful, long-term impacts that increased proliferation of riprap and alteration of sand dunes will have on the public's beach and surrounding properties.

### iii. 3.510(14)(b): Development Permit Review Criteria

Although much of the development review criteria apply to fill and is thus not applicable to this proposal, the Applications have not adequately analyzed 3.510(14)(b)(5)'s development

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[11] *See* Attachment A (showing the pristine nature of the Pine Beach Area).
[12] Surfrider Foundation's June 3, 2021 Comment at 2.
[13] Combined Application at 84.

permit review criteria requiring that "no feasible alternative upland locations exist on the property." While the proposal states the BPS "is placed at the most landward point possible on the subject properties," it is worth noting that in general, the Applications failed to look into adequate alternatives for preventing beach-front erosion outside of installing BSP. The Applications have provided no analysis regarding realistic, non-structural solutions to the issues the properties face. To satisfy this criterion, Oregon Shores argues that more complete examination of non-structural alternatives to BPS is needed.

### b. *TCLUO Section 3.530: Beach and Dune Overlay Zone*

The stated purpose of the Beach and Dune Overlay Zone is to "regulate development and other activities in a manner that conserves, protects and, where appropriate, restores the natural resources, benefits, and values of coastal beach and dune areas, and reduces the hazard to human life and property from natural events or human-induced actions associated with these areas." This zone applies "to dune areas identified in the Goal 18 . . . Element of the Comprehensive Plan and indicated on the Tillamook County Zoning Map." TCLUO Section 3.530(4)(A) lays out specific permitted uses, including strict requirements under Section 3.530(4)(A)(4)(b) requiring beachfront protective structures on properties developed after January 1, 1977 to receive an exception to Statewide Planning Goal 18, IR 5.

The Applications fail to meaningfully address a number of required criteria under Section 3.530(4)(A)(4). For example, Section 3.530(4)(A)(2) requires a showing that "[n]on-structural solutions cannot provide adequate protection" to justify the placement of beachfront protective structures on the properties. The Applications merely state that "the instillation of the proposed beachfront protective structure is the only viable solution to stop rapid erosion, the loss of shoreline vegetation, and the threat of damage to property, dwellings and infrastructure"[14] in the proposal area. As stated above and in the record, this assertion is overly conclusory and fails to address how shoreline hardening will impact and increase future erosion rates on the site. The Applications have not explored other options to address the issues the properties face, including actions that would only impact the homeowners such as implementing better setbacks of structural changes to the homes themselves rather than to the public's beach.

Another example of failure to meet the mandatory criteria relates to Section 3.530(4)(A)(6). This provision requires that "existing public access is preserved" when placing beachfront protective structures. In addressing this criterion, the Applications conclusively state that "[t]he proposed beachfront protective [structure] is designed such that these [existing public] accesses will be maintained," therefore asserting that the proposal is consistent with this requirement. The Applications fail to meaningfully address the impacts to public access that the proliferation of riprap will have on this site and on the public's beach, falling short of ensuring that public access is preserved. Thus, the Applications fail to meet vital criteria under TCLUO Section 3.530 and their proposal should be denied by the Board of County Commissioners.

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### c. *TCLUO Section 9.030(3) – Text Amendment Criteria*

The applicable criteria for amendments to the Tillamook County Comprehensive Plan under TCLUO Section 9.030(3) are:

> (a) If the proposal involves an amendment to the Comprehensive Plan, the amendment must be consistent with the Statewide Planning Goals and relevant Oregon Administrative Rules;
> (b) The proposal must be consistent with the Comprehensive Plan. (The Comprehensive Plan may be amended concurrently with proposed changes in zoning);
> (c) The Board must find the proposal to be in the public interest with regard to community conditions; the proposal either responds to changes in the community, or it corrects a mistake or inconsistency in the subject plan or ordinance; and
> (d) The amendment must conform to Section 9.040 Transportations Planning Rule Compliance.

As explained elsewhere in this and related comments, the Applications fail to demonstrate consistency with Goals and OARs. Therefore, the Applications fail to meet the requirement of TCLUO Section 9.030(3)(a). The Applications' consistency with the Tillamook County Comprehensive Plan as required by Section 9.030(3)(b)[15] and the proposed amendment's conformity with Section 9.030(3)(d) will be discussed in more detail below.

The Applications state the proposal is consistent with subsection (c) of this criterion because "[i]t is in the public interest to protect this subdivision [at issue], which is part of a larger urban residential area . . . as well as to protect the water and sewer public facilities that serve[] that greater community and supporting street system."[16] The Applications also state that this criterion is satisfied because the "proposal responds to natural changes in the community that were contrary to the 70-year trend of shoreline prograding that existed at the time of residential development."[17] The Applications fail to meaningfully address this criterion and fail to show that this proposal is truly within the "public interest" regarding community conditions. As previously noted in Oregon Shores' prior comments and throughout the record, approval of this proposal will impose more coastal harm and negatively impact the public interest—particularly with impeding future and sustained public access to the beach. While the proposal's purpose is to prevent damage to private properties, the beachfront protection structures are going on land that belongs to Oregonians as a whole. The Applications fail to satisfy this criterion and thus are not in compliance with TCLUO Section 9.030(c)'s mandatory text amendment criteria.

The Applications also conclusively state that the proposed construction of the beachfront protective structure complies with TCLUO Section 9.040 because it "will not generate any additional traffic other than during construction, when traffic will be minimal." While compliance with this criterion is only relevant to the proposal within the context of meeting the text amendment requirements in TCLUO Section 9.030(3)(d), the Applications still fail to

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[15] *Infra* Section B(ii).
[16] Pine Beach & Ocean Boulevard Combined Application for Shoreline Protection ("Combined Application") at 95.
[17] *Id.*

meaningfully address it. Further, the Applications failed to meaningfully analyze or consider the temporary impacts of the construction.

Even if the Board finds that the Applications have meaningfully addressed compliance with TCLUO 9.040, that ultimately is inconsequential because the Applications fail to satisfy or address the mandatory criteria of TCLUO 9.030(3)(a)–(c) and thus fail to show that the proposal meets the text amendment criteria.

#### *d. TCLUO Article 10 Administrative Provisions*

While TCLUO Article 10 contains purely procedural steps, the most relevant portion of that mandatory criteria states, under TCLUO Section 10.010(3), that "[t]he processing of applications . . . under this Ordinance shall be consistent with the Oregon Revised Statutes (ORS)" As noted in Oregon Shores' Prior Comments, throughout the record, and above, the Applications fail to show that this proposal is consistent with the Oregon Revised Statutes—namely, they fail to show that this proposal is compliant with and reasons exception under ORS 197.732. For that reason, the Applications fail to meet the mandatory criteria under TCLUO Article 10.

### ii. The Applications Do Not Comply with the Applicable Statewide Planning Goals, the Applicable Tillamook County Comprehensive Plan Provisions.

The Applicants assert in both their Combined Application and Final Argument that the proposal satisfies a number of Statewide Planning Goals, and TCCP Goals, or Elements. However, the Applications fail to provide the necessary and adequate reasoning for such conclusory assertions and fail to demonstrate the proposal's compliance with the relevant Statewide Planning Goals or the TCCP Goals. As previously noted by DLCD, an exception to one goal or goal requirement does not ensure compliance with any other applicable goals or goal requirements for the proposed uses at the exception site. Post-acknowledgement plan amendments ("PAPAs"), such as the proposal at issue, must comply with Oregon's Statewide Planning Goals under ORS 197.175(2)(a). The Applicant bears the burden of proof in showing that its proposal complies with all applicable criteria and standards. Tillamook County's decision to approve the proposed PAPA must either explain why the rezoning is consistent with the Goals or adopt findings explaining why the Goal is not applicable. Each relevant Goal and its parallel (i.e., implementing) TCCP Goal Element is discussed in further detail below.

#### *a. Goal 5 Natural Resources, Scenic and Historic Areas, and Open Spaces; TCCP Goal 5, TCCP Goal 17*

The Applications fail to demonstrate compliance with Goal 5. The purpose of Goal 5 is to "protect natural resources and conserve scenic and historic areas and open spaces." To be consistent with Goal 5, Tillamook County is required to inventory and adopt a program to protect and/or conserve several types of resources, findings, and related policies. The Combined Application asserts that because "[t]here are no identified Goal 5 resources on the subject property or on immediately surrounding properties," the proposal "does not implicate and is consistent with Goal 5."[18] The Final Argument concludes that because "there are no Goal 5 resources on the Subject Properties . . . the proposal cannot be inconsistent with Goal 5."[19] However, the Applicants fail to provide sufficient information or analysis to support these assertions. In fact, publicly available evidence suggests the opposite conclusion may be true. There are known inventoried Goal 5 resources, including significant wildlife habitat areas (Hidden Lake, Smith Lake, and Camp Magruder) which could be impacted by the Applicants' proposal.[20] As noted previously, the Applications fail to meaningfully address impacts of the proposed BPS to Camp Magruder or other adjacent properties and therefore fail to meaningfully address the proposal's consistency with Goal 5. Absent further analysis, the Applications fail to establish consistency with Goal 5.

### *b. Goal 6 Air, Water, and Land Resources Quality; TCCP Goal 6*

The Applications fail to demonstrate compliance with Goal 6. The purpose of Goal 6 is to "maintain and improve the quality of the air, water[,] and land resources of the state." Here, the Applications claim that the proposal's approval "maintains ocean and sand resources so that they may be enjoyed by the public rather than risking the serious damage that would occur if the proposed BPS is not approved."[21] There is no evidence to meaningfully support this conclusion, and as noted previously, publicly available scientific evidence suggests the opposite to be true. Namely, the proposed riprap structure will deplete sand resources, drown the public's beach, and take the public's beach in order to protect private property. As noted by DLCD "[t]he impacts of additional shoreline armoring on the beach, beach access, and surrounding properties are not adequately addressed in the [Applications]."

The Applications also state that the "proposed BPS protects water delivery systems" relied upon by the public and that the public "would suffer catastrophic damage if the proposal is not approved and the ocean rips out the homes and the water infrastructures serving them." Again, there is no meaningful evidence to support the claim that the BPS would protect water delivery systems, or that it is a preferred way to do so in the case that such water systems are in fact threatened. Further, the Applications fail to explain how this is relevant to address compliance with Goal 6 (i.e., whether the proposal does in fact "maintain and improve the quality of air, water, and land resources of the state").

Finally, in the TCCP, Goal 6 only specifically addresses requirements, findings, and policies on air quality, water quality, solid waste disposal, and noise control—none of which are specifically addressed by the Applications. The Applications focus only on the damages to the private properties and fail to meaningfully analyze the harmful impacts that the BPS would have on the land resources and the overall long-term health and safety of the beach. Absent such analysis, the Board of County Commissioners cannot conclude that this proposal is consistent with Goal 6.

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[18] Combined Application at 52.
[19] Applicants' Final Argument ("Final Argument") at 28–29; Combined Applications at 52.
[20] TCCP Goal 17, Sec. 3.2b; TCCP Goal 5 Sec. 1.3c.
[21] Combined Application at 53.

### c. *Goal 7 Areas Subject to Natural Hazards; TCCP Goal 7*

The Applications fail to demonstrate compliance with Goal 7. The purpose of Goal 7 is "[t]o protect people and property from natural hazards." Under Goal 7(A)(2), "coastal erosion" is one of the hazards the County should protect against. The Applicants correctly state that Goal 7 requires that appropriate safeguards be applied when planning for development in areas identified as a natural hazard. However, the Applications' assertion that "approving the proposed BPS is the only way to ensure that the county can reasonably comply with Goal 7 at this location"[22] is not meaningfully supported by the record and provided analysis. While the beach at the proposed site has changed since the time of the subdivision's approval and since construction of the residential dwellings, the current threats endangering the Applicants will only worsen with increased shoreline hardening. The Applicants ask for a solution to what are asserted as "immediate threats"[23] to the properties; however, the addition of riprap to the coastline will, in the long run, only exacerbate and escalate the coastal erosion and natural hazards the properties face. The Applications provide no meaningful discussion of the long-term hazard impacts to the beach and public safety within the context of Goal 7. Absent such analysis, the Board of County Commissioners cannot conclude that the proposed plan amendment and Goal 18 IR 5 exception is consistent with Goal 7 based on the current record.

Under Section 1.1(b)(4) of the TCCP Goal 7, implementation guidelines specify that "possible creation of new natural hazards by proposed developments should be considered, evaluated, and provided for." The Applications have yet to meaningfully evaluate or provide solutions for the increase harm and hazards that the proliferation of riprap will have on the natural environment, neighboring properties, overall safety of the beach. They only focus their analysis on the hazards and impacts to the private property owners will face if hardening is denied. As stated throughout the record, increased shoreline hardening—especially riprap—on the coast increases the rate and amount of erosion, degrades the long-term stability of and access to the beaches, and results in the need for more shoreline to compensate for damage. The Applications failure to meaningfully address this aspect demonstrates noncompliance with TCCP Goal 7.

### d. *Goal 8 Recreational Needs; TCCP Goal 8*

The Applications also fail to establish compliance with Goal 8. The purpose of Goal 8 is "[t]o satisfy the recreational needs of the citizens of the state and visitors, and where appropriate, to provide for the siting of necessary recreational facilities including destination resorts." In their Combined Application, the Applicants highlight that there are two beach accesses in the exception area that connect Pine Beach Loop and Ocean Boulevard to a long stretch of dry sandy beach.[24] The Applications then conclusively state that "[t]he proposed structure will improve the

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[22] Combined Application at 53.

[23] Oregon Shores agrees with DLCD that there does not appear to be a clear "specificity of a unique need" in this case, and strongly argues that the Applicants should address less impactful alternatives to their preferred method of mitigation of shoreline erosion. It should also be noted that four of the subject properties are currently undeveloped. Per Oregon Shores' review, the Applications omit a discussion of need for the proposal for these properties, and fail to address compliance with Goal 7.

[24] *See* Combined Application at 54 ("There are two beach accesses in the exception area. One beach access

northern beach access[,]" "allows improved access to the beach[,]" and does not interfere with the southern beach access."[25] The Applications further state that approval of the proposed riprap would "protect[] those public recreation interests from the harm that would occur to the ocean and beaches[.]"[26] These assertions are not only unsupported but also inaccurate. The Applications fail to address the harms and negative impacts to recreation that increased riprap will have on the public's access to the beach. As stated in Oregon Shores' prior comments and throughout the record, the addition of shoreline hardening to these sites—particularly the addition of riprap—would destroy recreational opportunities and greatly disturb the public's access. Riprap not only reduces the walkability of a beach by making public walking and recreation spaces narrower and less safe but also continues beach erosion and causes beaches to disappear entirely over time.[27] The Applications provide no meaningful discussion of how the purpose of Goal 8 will be fulfilled. Absent such analysis, the Planning Commission cannot on the basis of the current record conclude that the proposed plan amendment is consistent with Goal 8.

#### *e. Goal 9 Economic Development; TCCP Goal 9*

The Applications also fail to demonstrate compliance with Goal 9. The purpose of Goal 9 is "[t]o provide adequate opportunities throughout the state for a variety of economic activities vital to the health, welfare, and prosperity of Oregon's citizens." The Applications conclusively state that the proposal "does not implicate" yet is still "consistent with Goal 9."[28] This assertion is overly conclusive and if the Applicants claim compliance with Goal 9, they must assert a more robust analysis. Absent such analysis, the Board of Commissioners cannot on the basis of the current record conclude that the proposal is consistent with Goal 9.

#### *f. Goal 10 Housing; TCCP Goal 10*

The Applications also fail demonstrate compliance with Goal 10. The purpose of Goal 10 is "to provide for the housing needs of the citizens of the state." It imposes an affirmative duty on local governments to ensure opportunities for the provision of adequate numbers of needed housing units at prices and rents that are affordable to Oregonians. *See* OAR 660-008-0000(1) (describing the purpose of Goal 10).

As noted in our prior June 10, 2021 Comment, the TCCP Goal 10 element satisfies the County's planning obligation under Goal 10. The Applications conclusively assert that the "County's acknowledged Goal 10 Buildable Lands Inventory relies greatly upon its urban unincorporated communities, to include the Twin Rocks-Watseco-Barview urban unincorporated community that includes the subject properties, to provide medium density residential uses to the

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runs between Tax Lots 123 and 3204 to the beach. See Exhibit Q, p. 2. The other access runs from Pine Beach Loop between Tax Lots 11 3 and 114, and then along the southern boundary of Tax Lot 114 to the beach. Those beach accesses connect Pine Beach Loop and Ocean Boulevard to a tong stretch of dry sandy beach. See Exhibit Q, p. 2; Exhibit F, Attachment 1, field photos.").

[25] *Id,*

[26] *Id.*

[27] *The True Cost of Armoring the Beach*, SURFRIDER (July 6, 2020) https://sandiego.surfrider.org/the-true-cost-of-armoring-the-beach/ (last visited June 7, 2020).

[28] Combined Application at 54.

County." However, even assuming this to be true, the Applications' materials themselves acknowledge that this "need has largely been met, with a few more vacant lots available in the identified area." The Applications fail to demonstrate that the existing structures are needed housing within the meaning of Goal 10, or that said existing upland structures and vacant lots are somehow necessary to meet the County's identified need under Goal 10. The Applicants' materials also fail to establish that there are *any* requirements or obligations on the County under Goal 10 that would necessitate the proposed exception to Goal 18 to allow the Applications' preferred shoreline erosion mitigation use (i.e., hardened SPS). The Applications' assertion that "[p]rotecting the existing lots planned, zoned and mostly developed with residences complies with the County's buildable lands inventory and meets the County's demonstrated housing needs under Goal 10" does not constitute an express obligation under Goal 10 that would require the County to take the proposed exception to Goal 18 allowing hardened SPS for otherwise ineligible properties. Because the Applicants' materials fail to establish requirements or obligations on the County related to Goal 10, the Board of County Commissioners cannot conclude that the proposal is consistent with the demonstrated need rule on the basis of Goal 10 itself sufficient to justify an exception to Goal 18.

### *g. Goal 11 Public Facilities; TCCP Goal 11*

The Applications also fail to demonstrate compliance with Goal 11. The purpose of Goal 11 is to "plan and develop a timely, orderly and efficient arrangement of public facilities and services to serve as a framework for urban and rural development." The Applications assert that the proposal is consistent with Goal 11 without providing any reasoning other than the assertion that "[o]ne purpose of the proposed revetment is to protect . . . public facility investments from potential future beachfront erosion."[29] The Applications fail to provide meaningful evidence to support this claim and fail to demonstrate how the preferred method of shoreline erosion mitigation (i.e., a hardened SPS) is consistent with Goal 11. Absent further analysis and evidence, the Board of Commissioners cannot on the basis of the current record conclude that the proposal is consistent with Goal 11.

As noted in Oregon Shores' June 6, 2021 Comment, the Goal 11 element of the TCCP fulfills the County's planning obligations with respect to and directs development in accordance with Goal 11 (including the Watseco-Barview Water District and the Twin Rocks Water District). The Applicants' materials do not establish that there are requirements or obligations on the County related to Goal 11 that necessitate either the proposed SPS or the proposed exception to Goal 18 to allow the SPS at the Pine Beach or Ocean Shore Boulevard properties.

### *h. Goal 14 Urbanization; TCCP Goal 14*

The Applications also fail show compliance with Goal 14. The purpose of Goal 14 is to "provide for an orderly and efficient transition from rural to urban land use to accommodate urban population and urban employment inside urban growth boundaries, to ensure efficient use of land, and to provide for livable communities." The Applications state that the subject properties are "subject to an acknowledged goal exception that designates them to provide urban

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[29] *Id.* at 56.

levels of residential use and are served with urban public facilities and services[,]"[30] thus making them consistent with Goal 14. The Applications also state that the "proposed structure is consistent with the level of that development and will protect that development."[31] However, the Applications fail to explain how the fact that the existing structures on the subject properties may have been subject to a previous Goal exception for residential development is relevant to the inquiry of whether the proposed SPS is compliant with Goal 14 for the purposes of taking an exception to Goal 18. As noted by DLCD:

> [T]he *homes* that exist in the application area were built in conformance with the provisions of Goal 18, Implementation Requirement (JR) 2. The *houses* were not built in an active foredune or in a dune area subject to ocean flooding, which means they did not need an exception to Goal 18, IR2. The other goal exceptions (to Goals 3, 4, 11, and 14) that allow for the Barview/Twin Rocks/Watseco community to be residentially developed, do not specify the exact location of development on each parcel in this unincorporated community...The *houses* were built in the eastern portions of their respective parcels to comply with the prohibition areas of Goal 18 for residential development. [DLCD] understands the applicants to argue that the other goal exceptions allowed the development to be placed in a foredune and therefore, they have an exception to Goal 18, IR2. That is not reflected in the Tillamook County Comprehensive Plan. To reiterate, a goal exception is an affirmative act that is required to be incorporated into a comprehensive plan.

In other words, the proposed BPS requires an exception to Goal 18, and is not simply consistent with Goal 14 because the upland structures may be subject to an exception to said Goal.

Further, Goal 14 focuses mostly on managing urban growth using the urban growth boundary; this Goal—and its implementation in the TCCP—are about criteria to manage and control the phasing of development within an urban growth boundary.[32] The addition of riprap and BPS on the coast is not consistent with the overall purpose and requirements of Goal 14 which dictate urbanization. The fact that the BPS may "protect" the development that has taken place on the subject properties is not enough to make this specific proposal consistent with Goal 14. The Applicants reliance on this Goal and the prior Goal exception is misplaced. Even if the Board determines that this proposal is consistent with Goal 14 and takes the Applications' assertions as truth, the proposal's consistency with this Statewide Planning Goal should not be determinative of the proposal's compliance with the applicable Goals criteria as a whole.

### *i. Goal 17 Coastal Shorelands; TCCP Goal 17*

The Applications also fail to satisfy obligations under Goal 17. The purpose of Goal 17 is to "conserve, protect, *where appropriate*, develop and *where appropriate* restore the resources and benefits of all coastal shorelands, recognizing their value for protection and maintenance of water quality, fish and wildlife habitat, water-dependent uses, economic resources and

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[30] *Id.* at 56.
[31] *Id.*
[32] *See* TCCP Goal 1, 2.5: Purpose of the Urbanization Goal, Goal 14.

recreation and aesthetics."[33] In other words, local governments must first conserve and protect "the resources and benefits of all coastal shorelands, recognizing their value for protection and maintenance of water quality, fish and wildlife habitat, water-dependent uses, economic resources and recreation and aesthetics." If development is consistent with Goal 17's mandate to conserve and protect (i.e., "where appropriate"), only then can it be allowed to proceed. The Goal's objective is also "[t]o reduce the hazard to human life and property, and the adverse effects upon water quality and fish and wildlife habitat, *resulting from* the use and enjoyment of Oregon's coastal shorelands."[34]

In their Combined Application, the Applicants state that Goal 17 does not apply to the subject properties because the properties were "planned for residential use and the findings for the Pine Beach Subdivision approval in 1994 noted that an exception to Goal 17 was taken for the area."[35] As noted above, the fact that the subject properties may have an exception for the development of the subdivision or structures on the eastern portions of their relevant parcels (consistent with Goal 18's prohibitions) does not automatically mean that the subject properties have an exception for the proposed BPS. DLCD has previously noted that the subject properties are, in fact, subject to both Goal 17 and Goal 18 as resource lands; therefore, the Applications err by claiming Goal 17 does not apply to this proposal. The Applicants should address compliance with Goal 17.

The Applications also state that the proposed BPS will not interfere with recreational uses in violation of Goal 17 because "the BPS is located on vegetative property, not on the beach" and therefore there is "no way" the BPS nor the location of the BPS will interfere with public access or recreational uses.[36] This assertion is overly conclusive and fails to recognize the erosive nature of riprap and the impacts BPS has on beaches. The Applications fail to meaningfully address the harmful impacts this proposal will have on the public's beach and long-term beach access by limiting the scope of this proposal's impact to private property interests. Without a more in-depth analysis of how this proposal will impact this coastal shorelands area, the Board should not determine the Applications are in compliance with Goal 17.

### *j. Goal 18 Beaches and Dunes; TCCP Goal 18*

The purpose of Goal 18 is to "conserve, protect, where appropriate develop, and where appropriate restore the resources and benefits of coastal beach and dune area[]" and to "To reduce the hazard to human life and property from natural or man-induced actions associated with these areas." As discussed previously, because the properties were not developed as of January 1, 1977, Goal 18 prohibits the Applicants' from constructing their preferred method of shoreline erosion mitigation (i.e., hardened SPS) in order to protect the public's beach. Hence, to lawfully develop the proposed SPS, the Applicants bear the burden of demonstrating that an exception to Goal 18 is justified.

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[33] Goal 17, (emphasis added).
[34] Goal 17, (emphasis added).
[35] Combined Application at 57.
[36] *See* Final Argument at 30.

As stated in Oregon Shores' prior comments and throughout the record, the Applicants' proposal for riprap proliferation is antithetical to beach conservation, and increases erosion to adjacent properties as well as creating a public safety hazard (through narrowing of the beach). For these reasons, the legislative declaration in ORS 390 and policy underlying Goal 18 effectively placed a cap on the amount of ocean shore in Oregon that may be armored to limit the cumulative impacts of such hardening. Specifically, Goal 18 prohibits permits for SPS where development exists after January 1, 1977. Oregon Shores incorporates by reference our previous robust analysis regarding the proposal's inconsistency with Statewide Planning Goal 18 in our June 3, 2021 Comment and our June 10, 2021 Comment on this matter. Oregon Shores strongly argues that the Applications fall well short of the high bar required by the general reason set forth at OAR 660-004-0022(1). As such, the Board of County Commissioners should recommend denial of the Applications.

Finally, as noted by DLCD, future uses of the four vacant oceanfront lots within the proposed goal exception location "would have to comply with the provisions of Goal 18, including to reduce hazards to human life and property." As discussed above, the Applications fail to provide specific analysis regarding these vacant lots, including addressing compliance with Goal 18. The Applicants should address compliance with Goal 18 with respect to these lots prior to any final decision in this matter.

As highlighted in our June 3, 2021 Comment, incorporated by reference, Tillamook County has identified and adopted specific exception areas for Goal 18, Implementation Requirement #2 in the County's Comprehensive Plan (Part 6 of the Beaches and Dunes Element). As noted in the Staff Report:

> Section 6 of the Goal 18 element of the [TCCP] inventories those built and committed areas where a Goal 18 exception has been taken. These are areas within unincorporated Tillamook County identified as built and committed areas located on foredunes which are conditionally stable and that are subject to ocean undercutting or wave overtopping, and on interdune areas (deflation plains) that are subject to ocean flooding. These built and committed areas are Cape Meares, Tierra Del Mar, Pacific City and Neskowin.

The areas specified in the Applications are not within these three adopted Goal 18, IR 2 exception areas, as set forth in the TCCP (TCCP Goal 18, §§6.1a–d).

### *k. Catch-all Analysis for Goals 1, 3, 4, 12, and 13*

For the sake of issue preservation, Oregon Shores notes that the Applications conclusively state compliance with Goals 1, 3, 4, 12, and 13. While it is true that Goals 3 and 4 are not implicated in this matter, the Applications cannot simply state that the project is consistent with the Goals without a more analysis. The Applications also state that the proposal is consistent with Goal 1 because the application is processed in accordance with the county's acknowledged land use regulations and procedures. Because the local criteria, as detailed above, are not satisfied, the proposal is not consistent with Goal 1 or Goal 2.

The purpose of Goal 12 is to "provide and encourage a safe, convenient and economic transportation system." The Applications conclusively state that the proposal is consistent with Goal 12 without providing any reasoning other than the assertion that the traffic generated from structure construction will not have any significant impacts necessary to address under Goal 12. Absent such analysis, the Board of Commissioners cannot on the basis of the current record conclude that the proposal is consistent with Goal 12. Even the Board determines that this overly conclusive assertion means that the proposal is consistent with Goal 12, the proposal's consistency with this Statewide Planning Goal should not be determinative of the proposal's compliance with the applicable Goals criteria as a whole. The purpose of Goal 13 is to "conserve energy." The Applications conclusively state that the proposal "does not directly implicate" yet is still "consistent with Goal 13."[37] This assertion is overly conclusive and if the Applications claim compliance with Goal 13, they must assert a more robust analysis. Absent such analysis, the Board of Commissioners cannot on the basis of the current record conclude that the proposal is consistent with Goal 13.

### iii. The Applications Do Not Comply with the Applicable Tillamook County Comprehensive Plan Policies Contained in TCCP Goal 7, TCCP Goal 16, TCCP Goal 17, and TCCP Goal 18.

#### *a. TCCP Goal 7, Policy 2.4(a)*

In addressing erosion Policy 2.4(a) in their Combined Application, the Applications only focused on the riprap's immediate stabilization of the shoreline and failed to address how this beachfront protection structure impacts the stability of its surrounding area over time, the implications that this structure will have on public safety, and how this proposal may ultimately result in the proliferation of more shoreline hardening.[38] TCCP Goal 7, Section 2.4(a) does not require the County to use hardened SPS to prevent erosion much less approve an exception to Goal 7 and the TCCP's Goal 7 element to allow private entities to do so, and the Applicants' materials fail to argue otherwise. The Applications' assertion that failure to approve the proposed exception for the Applicants' preferred shoreline mitigation measure (i.e., hardened riprap) measure would mean the County would fail to comply with the TCCP implementation measure to fulfill its planning obligation under Goal 7, is unsupported and contrary to the case law governing OAR 660-004-0022(1)(a). Further, given that the proposed SPS will increase erosion and the need for remedial measures, the suggestion that it is needed is contrary to sound management of natural hazards on the shoreline. The Applications assert, absent any meaningful evidence and analysis, that "critical public infrastructure is at risk." Even assuming this is true, again, there is no obligation identified by the Applications that require the County to uses riprap as a preventative or remedial measure in this case.

#### *b. TCCP Goal 7, Policy 2.5(d)*

The Applications failed to specifically discuss compliance with TCCP Goal 7 Policy 2.5(d) for Flooding, which states that "permanent structures shall not be placed in channels

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[37] Combined Application at 55–56.
[38] Combined Application at 63.

subject to flash flooding." The BPS the Applicants are proposing is a permanent shoreline hardening structure in an area that is subject to tidal flooding. The Applications fail to acknowledge this policy that seemingly opposes this proposal and fail to offer an analysis of ow this proposal is still in compliance with this policy.

### c. *TCCP Goal 16, Policy 7.5(2)*

The Applications state that that the "shoreline stabilization proposed here is the highest option left" as vegetated riprap. Goal 16 Policy 7.5(2) does state that the general priories for shoreline stabilization within estuarine waters, intertidal areas, tidal wetlands, and along WDD shoreland zones and other shoreland areas are, from highest to lowest, proper maintenance of existing riparian vegetation; planting of riparian vegetation; vegetated riprap; non-vegetated riprap; groins, bulkheads and other structural methods. However, the Applications fail to discuss any other preferred alternatives to shoreline stabilization and insist that "vegetated riprap" is the only means of addressing the private homeowners' issues. The Applications' conclusive analysis fails to demonstrate compliance with this TCCP policy.

### d. *TCCP Goal 16, Policy 7.5(4)*

Goal 16. Policy 7.5(4) states that structural shoreline stabilization methods shall be permitted *only if*:

a. flooding or erosion is threatening a structure or an established use or there is a demonstrated need (i.e., a substantial public benefit) and the use or alteration does not unreasonably interfere with public trust rights; and
b. land use management practices or non-structural solutions are inappropriate because of high erosion rates or the use of the site; and
c. adverse impacts on water currents, erosion and accretion patterns and aquatic life and habitat are avoided or minimized.

The Applications conclusively state that each of the above-mentioned Policy 7.5(4) subsections are met; however, the Applications fail to meaningfully discuss each in detail . Even if the Board finds that the Applications are consistent with this TCCP Policy, that consistency should not be determinative of the Applications overall consistency with the TCCP.

### e. *TCCP Goal 16, Policy 7.5(5)–(6)*

While these policies only apply to Estuary Natural/Estuary Conservation Aquaculture zones and Estuary Conservation 1/Estuary Conservation 2 zones respectively and may not specifically apply to these Applications, the Applicants state in their Combined Application that the proposal is consistent with both policies because the BOS will "protect existing dwellings and publics water and sewer facilities" as well as "not adversely affect long term use of the beach resource and not cause alteration of the beachfront other than at the protected location."[39] As stated throughout this record and in Oregon Shore's previous comments, the Applications have only conclusively stated that the proposed BPS will "not adversely" impact the surrounding

---

[39] Combined Application at 67.

and adjacent beaches and not impact public beach access. The proposal fails to offer any discussion addressing the harmful nature of riprap and thus, the Applications fail to meaningfully demonstrate compliance with these TCCP Policies.

### *f. TCCP Goal 17, Policy 4.2*

To the extent that Goal 17, Policy 4.2 applies, the Applications have failed to meaningfully address compliance. This policy for shoreline development states:

> New shoreland development, expansion, maintenance or restoration of existing development; or restoration of historic waterfront areas shall be sited, designed, constructed and maintained to minimize adverse impacts on riparian vegetation, water quality and aquatic life and habitat in adjacent aquatic areas, and to be consistent with existing hazards to life and property posed by eroding areas and flood hazard areas.
>
> To accomplish this:
> a. The requirements of the National Flood Insurance Program shall be used to regulate development in flood hazard areas within coastal shorelands:
> b. Shoreland setbacks shall be established to protect riparian vegetation and to recognize eroding areas (See Section 9, of this element):
> c. Priority shall be given to nonstructural rather than structural solution to problems of erosion or flooding:
> d. Existing state and federal authorities referenced in the Water Quality policies shall be utilized for maintaining water quality and minimizing Goal 17 Coastal Shorelands Complete 62 man-induced sedimentation in aquatic areas.

The Applications have failed to meaningfully discuss how the proposed riprap will minimize adverse impacts and how it is consistent with existing hazards to life and property in these areas—especially related to safety of beach access and the hazardous impacts of riprap. As stated above, this policy gives priority to "nonstructural" solutions rather than structural solutions to address the problems of shoreline erosion or flooding. The Applications fail to offer solutions more in line with the TCCP's shoreline development policy and thus fail to demonstrate compliance.

### *g. TCCP Goal 17, Policy 4.3*

The Applications fail to meaningfully discuss compliance with Goal 17, Policy 4.3 related to scenic views and public access. The policy states:

> New shoreland development, expansion, maintenance or restoration of existing development and restoration of historic waterfront areas shall be designed to promote visual attractiveness and scenic views and provide, where appropriate, visitor facilities, public viewpoints and public access to the water. Existing public access to publicly owned shorelands shall be maintained. Existing public ownerships, right-of-way and similar public easements in coastal shorelands which provide access to, or along coastal waters shall be retained or replaced if sold,

> exchanged or transferred. Rights-of-way may be vacated to permit redevelopment or shoreland areas provided public access across the affected site is retained.

This TCCP policy highlights the importance of the public's access to the County's shorelands—something implementation of this proposal threatens. The Applications fail to mention this policy and how the proposed BPS will comply with the County's policy to maintain existing public ownership and access to the coastal shorelands.

### *h. TCCP Goal 18, Policy 2.4a and 4.4e*

The Applications failed to discuss compliance with Goal 18, Policy 2.4a which states, in relevant part:

> All decisions on land use actions in beach and dune areas other than older stabilized dunes shall be based on the following specific findings unless they have been made in the comprehensive plan:
>
> (a) The type of use proposed and the adverse effects it might have on the site and adjacent areas;
>
> * * *
>
> (c) Methods for protecting the surrounding area from any adverse effects of the development; and
>
> (d) Hazards to life, public and private property, and the natural environment which may be caused by the proposed use.

Goal 18, Policy 4.4e confirms that this policy "shall apply to beachfront protective structures"

As noted throughout the record and this comment, the Applications fail to fully address the hazardous impacts of BPS on access to the public's beach and on the long-term negative effects of riprap on erosion on the site and surrounding beach as a whole.

### *i. TCCP Goal 18, Policy 2.4b*

As noted above in Section B(i)(a) analyzing Flood Hazard Overlay Zone compliance, the Applications have not demonstrated total compliance with certain FH zone criteria. Because of this, the Applications fail to demonstrate compliance with Goal 18, Policy 2.4b which requires that "[d]evelopment in beach and dune areas shall comply with the requirements of the Flood Hazard Overlay zone."

### *j. TCCP Goal 18, Policy 4.4c*

This policy implements Goal 18, IR 5, stating that "[b]eachfront protective structures . . . are permitted only where development existed on January 1, 1977 or where buildings are authorized by Section 5." This is the main crux of the Applicants' request and because the Applications failed to justify an exception under Goal 18, IR 5, they cannot show compliance with this TCCP policy.

*k. TCCP Goal 18, Policy 4.4f*

This policy states that "[s]horeline protection measures shall not restrict existing public access." The Applications conclusively argue throughout the record that there will be no issues with existing public access because "[t]he proposed structure will improve the northern beach access with a gravel path and ramp that foes over the rock revetment and allows improved [beach] access" and because "the proposal does not interfere with the southern beach access." However, this argument fails to analyze the known impacts of riprap on the public's beach and the sustained impacts that the proliferation of shoreline hardening will have on the beach and future adjacent sites. The Applications fail to meaningfully analyze address this in and fail to show compliance with this TCCP policy. As a whole, this proposal is not consistent with the TCCP and thus the Board should deny the Applications.

### C. Conclusion

Allowing installation of hardened structures along the shore, which can deprive the beach of a sand source that may help to mitigate the progressive loss of sand from Oregon's bluff-backed shorelines due to increasing erosion, does not protect the public's interest in the beach as the County is required to do. Given the increases in storm surge and wave height we are already experiencing on the Oregon coast, and given what we know of further predicted changes resulting from long-term climate change and cyclical climatic events such as El Niño, these requests for protective structures permits are likely to increase. Further, allowing the installation of protective structures exacerbates the risks to public health and safety as well as to shorefront properties by encouraging investment in shorefront protection rather than incentivizing movement away from shoreline areas and coastal hazards. The result is prioritizing the protection of private property in the short-term to the detriment of the public's long-term interest in preserving the beach, inconsistent with the Oregon Beach Bill and Goal 18. In the long run, armoring the ocean shore will prove futile against sea level rise and erosion. In the meantime, significant practical and policy questions arise in light of the effects of rising sea level on the ocean shore.

Oregon Shores strongly believes that the Board of County Commissioners needs to get in front of this crisis and make decisions on the basis of present and increasing risks, consistent with the principles of Goal 18 and ORS 390.610. The Applications fail to demonstrate reasons justifying an exception to Goal 18 and fails to satisfy the mandatory local criteria. On the basis of the present record and Oregon Shores' previous comments, incorporated by reference, the Board of County Commissioners should deny these applications.

Sincerely,

Phillip Johnson
Executive Director
Oregon Shores Conservation Coalition
P.O. Box 33
Seal Rock, OR 97376
(503) 754-9303
phillip@oregonshores.org

# Attachment A

# Aerial Photos of the Pine Beach Area

## Allison Hinderer

**From:** Sarah Absher
**Sent:** Wednesday, July 28, 2021 9:18 AM
**To:** Allison Hinderer
**Subject:** ORCA Testimony, Pine Beach Goal 18 Exception (#851-21-000086)
**Attachments:** ORCA to Tillamook BOC re Pine Beach Goal 18 Exception July 2021.pdf; 1915, C-0129-Watseco Plat.pdf; 1932, C-0071- Plat of Pine Beach.PDF; 1950, A-0444- George Shand Tracts.pdf; 1986, B-1218, Patten Survey (Shows Lots W. of Ocean Blvd. in Pine Beach).pdf; 1996, C-0466- Pine Beach Replat, Unit 1.pdf; Pine Beach Area Survey Chronology May 2021.pdf

**From:** Cameron La Follette <cameron@oregoncoastalliance.org>
**Sent:** Wednesday, July 28, 2021 8:55 AM
**To:** Melissa Jenck <mjenck@co.tillamook.or.us>; Sarah Absher <sabsher@co.tillamook.or.us>
**Cc:** Sean Malone <seanmalone8@hotmail.com>
**Subject:** EXTERNAL: ORCA Testimony, Pine Beach Goal 18 Exception (#851-21-000086)

Dear Ms. Absher and Ms. Jenck,

Attached please find the testimony of Oregon Coast Alliance before the Tillamook County Board of Commissioners on the matter of the Pine Beach Goal 18 Exception request. There are also six additional attachments, for a total of **seven** documents attached to this email. Please respond that you have received this email, and opened and placed all seven documents in the record for this matter.

Thank you,

Cameron
—

Cameron La Follette
Executive Director
Oregon Coast Alliance
P.O. Box 857
Astoria, OR 97103
(503) 391-0210
cameron@oregoncoastalliance.org
www.oregoncoastalliance.org

# Sean T. Malone

## Attorney at Law

259 E. Fifth Ave.,
Suite 200-C
Eugene, OR 97401

Tel. (303) 859-0403
Fax (650) 471-7366
seanmalone8@hotmail.com

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July 28, 2021

Via Email

Tillamook County Board of Commissioners
c/o Melissa Jenck
Tillamook County Department of Community Development
1510-B Third Street
Tillamook, OR 97141
mjenck@co.tillamook.or.us

Re: Oregon Coast Alliance testimony for a request for an Exception to Goal 18, and Development Permit Request for Construction of a Beachfront Protective Structure, #851-21-000086

Dear Board of Commissioners,

On behalf of Oregon Coast Alliance, please accept this testimony for the requested goal exception to Goal 18 for the installation of a beachfront protective structure (riprap revetment along roughly 880 feet) within an active eroding foredune east of the line of established vegetation in the Coastal High Hazard (VE) zone, an Area of Special Flood Hazard within the Flood Hazard Overlay Zone. The subject properties are Lots 11-20 of the Pine Beach Replat Unit #1, designated as Tax Lots 114 through 123, of Section 7DD, and Tax Lots 3000, 3100, 3104, 3203, and 3204 of Section 7DA all in Township 1 North, Range 10 West of the Willamette Meridian, Tillamook County, Oregon. The applicant has presented a moving target, with alternative requests. In essence, the applicant requests exceptions to Goal 18, implementation measure 2 and to Goal 18, implementation measure 5. Moreover, as the applicants do not already hold a Goal 18 exception, and no alternative request should be approved.

Goal 18 intends "to conserve, protect, where appropriate develop, and appropriate restore the resources and benefits of the coastal beach and dune areas." Goal 18 places a limitation on permits for beachfront protective structures when the development exists after a date-certain:

> "Permits for beachfront protective structures shall be issued only where development existed on January 1, 1977. Local comprehensive plans shall identify areas where development existed on January 1, 1977. For the purposes of this requirement and

> Implementation Requirement 7 'development' means houses, commercial and industrial buildings, and vacant subdivision lots which are physically improved through construction of streets and provision of utilities to the lot and includes areas where an exception to (2) above has been approved."

Goal 18, Implementation Requirement 5. The subdivision at issue was first platted *after* 1977 and no development occurred prior to 1977, with the exception of an undisputedly vacated subdivision that did not include any development, as the term is defined in the rule.

The history of the platted area in and around Pine Beach is complex. Attached to this testimony is a chronological timeline of the platted areas, as well as copies of the original plats and surveys. To briefly recap, there was a 1915 survey of Watseco plat, but a subsequent plat vacation in 1931. Neither of these created or concerned any platting activity west of Ocean Boulevard. The 1932 plat of Pine Beach, to the south of Watseco Plat, also shows Ocean Boulevard as the westernmost platted land. Survey A-0444 of 1950, the George Shand Tracts, was the first time lots were platted west of Ocean Boulevard; a resurvey took place in 1967, and a partial resurvey in 1980. No houses were built on the George Shand tracts. It was not until 1986 that land was even platted west of Ocean Boulevard to the *west* of the Pine Beach plat. Partition plats of 1994, 1995, 1996 and 1999 divided land west of Ocean Boulevard in Pine Beach and George Shand tracts. The first houses on the Pine Beach lots were built in 1997 and 1998, with others added later. The first house on the Shand Tract lots was built in 1989. This history makes it clear that no development, as defined by the rules, took place in the Pine Beach area where a Goal 18 is now requested until 1997 in Pine Beach. Merely surveying and platting is not "development."

ORCA agrees that "development did not exist[] … on January 1, 1977[.]" Planning Commission Staff Report at 4.[1] Furthermore, the definition of "development" has not been satisfied. Because of this, an exception is necessary to place any beachfront protective structures, and, as demonstrated below, the applicants do not already possess an exception. As the area at issue in this application is not part of an exception area to Goal 18, a goal exception is necessary. Because a "committed" exception is focused on adjacent uses, and the applicant does not rely on adjacent uses, a "committed" exception is not applicable. Therefore, a reasons exception process is the applicant's only path forward, even though an approval is foreclosed on that basis as well.

---

[1] No development was in existence on January 1, 1977. Evidence from the agencies and records identified above confirms *development* as defined above and which requires more than simply the creation of the lots/parcels occurred after January 1, 1977." Staff Report, Page 4.

[2] "The four standards in Goal 2 Part II(c) required to be addressed when taking an exception to a goal are described in subsections (a) through (d) of this section, including general requirements applicable to each of the factors:

> (a) "Reasons justify why the state policy embodied in the applicable goals should not

Any request for an exception faces a high bar. The criteria for a "reasons" exception are found at OAR 660-004-0020(2).[2]

---

[2] "The four standards in Goal 2 Part II(c) required to be addressed when taking an exception to a goal are described in subsections (a) through (d) of this section, including general requirements applicable to each of the factors:

> (a) "Reasons justify why the state policy embodied in the applicable goals should not apply." The exception shall set forth the facts and assumptions used as the basis for determining that a state policy embodied in a goal should not apply to specific properties or situations, including the amount of land for the use being planned and why the use requires a location on resource land;
>
> (b) "Areas that do not require a new exception cannot reasonably accommodate the use". The exception must meet the following requirements:
>
> > (A) The exception shall indicate on a map or otherwise describe the location of possible alternative areas considered for the use that do not require a new exception. The area for which the exception is taken shall be identified;
> >
> > (B) To show why the particular site is justified, it is necessary to discuss why other areas that do not require a new exception cannot reasonably accommodate the proposed use. Economic factors may be considered along with other relevant factors in determining that the use cannot reasonably be accommodated in other areas. Under this test the following questions shall be addressed:
> >
> > > (i) Can the proposed use be reasonably accommodated on nonresource land that would not require an exception, including increasing the density of uses on nonresource land? If not, why not?
> > >
> > > (ii) Can the proposed use be reasonably accommodated on resource land that is already irrevocably committed to nonresource uses not allowed by the applicable Goal, including resource land in existing unincorporated communities, or by increasing the density of uses on committed lands? If not, why not?
> > >
> > > (iii) Can the proposed use be reasonably accommodated inside an urban growth boundary? If not, why not?
> > >
> > > (iv) Can the proposed use be reasonably accommodated without the provision of a proposed public facility or service? If not, why not?
> >
> > (C) The "alternative areas" standard in paragraph B may be met by a broad review of similar types of areas rather than a review of specific alternative sites. Initially, a local government adopting an exception need assess only whether those similar

The applicant alleges that the public water and sewer systems that provide serve to the properties would be threatened, as well as the integrity of the systems themselves. This obviously proves too much. If ever these were threatened, they could be shut off or even removed. There is no evidence that the beach would be contaminated prior to some remedial action. This is a basic failure to provide substantial evidence. The application can be denied on this issue alone.

---

> types of areas in the vicinity could not reasonably accommodate the proposed use. Site specific comparisons are not required of a local government taking an exception unless another party to the local proceeding describes specific sites that can more reasonably accommodate the proposed use. A detailed evaluation of specific alternative sites is thus not required unless such sites are specifically described, with facts to support the assertion that the sites are more reasonable, by another party during the local exceptions proceeding.

(c) "The long-term environmental, economic, social and energy consequences resulting from the use at the proposed site with measures designed to reduce adverse impacts are not significantly more adverse than would typically result from the same proposal being located in areas requiring a goal exception other than the proposed site." The exception shall describe: the characteristics of each alternative area considered by the jurisdiction in which an exception might be taken, the typical advantages and disadvantages of using the area for a use not allowed by the Goal, and the typical positive and negative consequences resulting from the use at the proposed site with measures designed to reduce adverse impacts. A detailed evaluation of specific alternative sites is not required unless such sites are specifically described with facts to support the assertion that the sites have significantly fewer adverse impacts during the local exceptions proceeding. The exception shall include the reasons why the consequences of the use at the chosen site are not significantly more adverse than would typically result from the same proposal being located in areas requiring a goal exception other than the proposed site. Such reasons shall include but are not limited to a description of: the facts used to determine which resource land is least productive, the ability to sustain resource uses near the proposed use, and the long-term economic impact on the general area caused by irreversible removal of the land from the resource base. Other possible impacts to be addressed include the effects of the proposed use on the water table, on the costs of improving roads and on the costs to special service districts;

(d) "The proposed uses are compatible with other adjacent uses or will be so rendered through measures designed to reduce adverse impacts." The exception shall describe how the proposed use will be rendered compatible with adjacent land uses. The exception shall demonstrate that the proposed use is situated in such a manner as to be compatible with surrounding natural resources and resource management or production practices. "Compatible" is not intended as an absolute term meaning no interference or adverse impacts of any type with adjacent uses.

The applicants' focus on the particular design at issue here is irrelevant. Rather, it is the broader issue – whether a protective structure is allowed at all. The siting and design of the protective structure is another matter entirely that does not come into play at this stage.

The applicant has not sufficiently presented alternatives that would not require a goal exception. Only through an analysis of alternatives can the applicant demonstrate that a goal exception is necessary. This is principle is well established in caselaw. The applicant has also not demonstrated a particularly unique need for the proposed exception. Eroding shores are common throughout Oregon and the general area; that the Pine Beach houses were built on what was at the time a stabilized dune is likewise irrelevant. This is a high hazard area on the coast, and fluctuations in sand movement in such areas are recognized, common and continuous coastwide. If all eroding shorelands are eligible for a protective structure, then Goal 18 has simply become superfluous and nothing about this property is unique. This is not a situation where, as in Lincoln County at Gleneden Beach, the area is dominated by riprap. The applicant must demonstrate that this area is somehow different than other areas where shoreline armoring is not permitted. Moreover, the applicants must demonstrate alternatives to the use of a protective structure, which has not occurred.

Consistent with the purpose of Goal 18 the applicant must address the impacts of additional shoreline armoring on the beach, access to the beach, and adjacent or nearby properties. These are "relevant factors," and the application obviously fails to address these impacts. For example, the use of riprap would affect other, non-armored areas of the cell. The applicant has not presented an analysis of these impacts, and, instead, presents a narrow view, one where "[t]he only 'relevant factors' to consider in this 'reasons' exception are the specific exception area as defined, and the above-cited specific characteristics of a beachfront protective structure that require its shoreline location on the subject properties." The applicants have failed to consider the effect of the exception on surrounding properties.

The applicant is wrong to allege that no resource land is being used for the proposed shoreline protection. The properties are subject to Goal 17 and 18, and, therefore, the proposed protective structure is resource land. The applicant must consider other alternatives that would not require an exception on the subject property i.e., on resource land.

The proposed ESEE analysis remains deficient. For the environmental considerations, the applicants allege that the structure was "designed to reduce adverse impacts" but never explains the expected impacts. Even if it is assumed that the allegation is correct, some degree of impacts is conceded, yet unexplained and unanalyzed. It is incumbent upon the applicant and local government to address those impacts. The applicant essentially threatens the possibility of loss of homes and detritus after years of erosion with the certainty of riprap. The ESEE analysis must present a straightforward analysis of the impacts, not a skewed version.

The economic analysis continues to be deficient. It fails to acknowledge the economic impacts to other properties as a result of placing riprap. The applicant focuses almost exclusively on the value of the existing homes and the possibility of damage to water and sewer facilities. Moreover, the notion that remedial action would not occur for such facilities is far-fetched. The applicant has not provided a serious attempt at an economic analysis.

The applicant also includes four vacant oceanfront lots within the proposed exception area. The applicant has not demonstrated adequate reasons for the inclusion of these properties, as the alleged threats are not present on vacant land. As with other issues, the applicant has not presented a rational reason or even substantial evidence to include these properties

Finally, there is no alternative basis to approve an exception based on the allegation that an exception already exists. The applicants are simply wrong and the argument is half-hearted. The applicant would not have originally requested an exception if an exception already existed. Moreover, there is no dispute that no exception to what the applicant seeks here has ever been allowed. Exceptions are specific, not general. The applicants simply fail to present a cogent argument on this issue.

Tillamook County does not have a responsibility to protect private properties with residences built in high hazard zones; but it does have a responsibility to ensure that applications for a Goal 18 exception meet the requirements of state law, and to uphold state policies on protection of beach resources, both for public enjoyment and to limit rather than exacerbate the coastal erosion that follows placement of riprap and other shoreline armoring.

For the above reasons, ORCA respectfully requests that the Board of Commissioners deny the application for a Goal 18 exception.

Sincerely,

Sean Malone

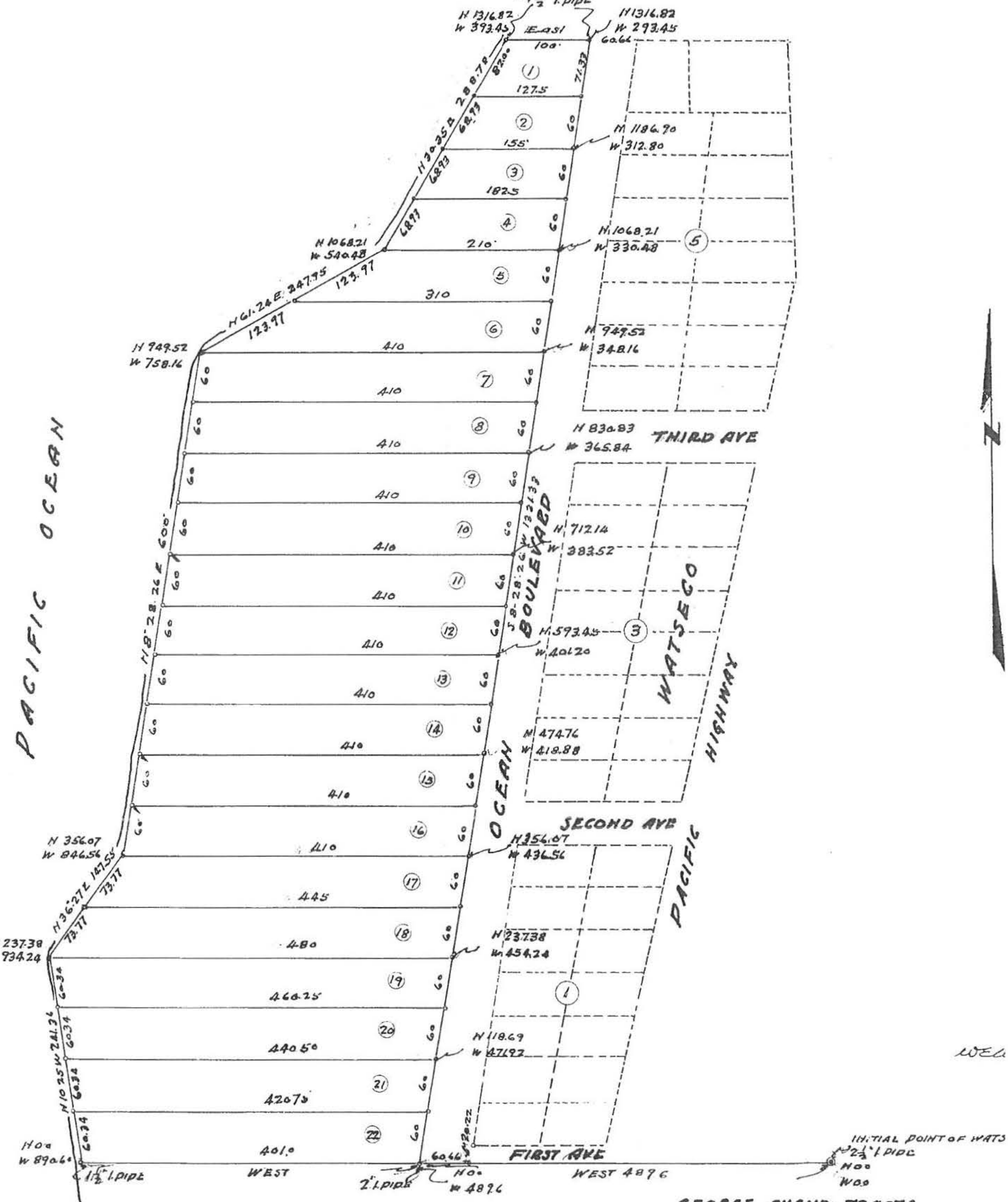
Sean T. Malone
Attorney for Oregon Coast Alliance

Cc:
Client

## SURVEYOR'S CERTIFICATE

I. W. E. Anderson County Surveyor of Tillamook Oregon do hereby certify that this map was made from notes taken during an actual survey made by me in Oct. 1959. and that it correctly represents the property, herein shown

County Surv WEA



GEORGE SHAND TRACTS
LOCATED
IN SEC 7 T.WP 1.N.R 10.W.W.M
TILLAMOOK ORE
SCALE 1"=100'
W.E. ANDERSON

A/444

# 851-21-000086-PLNG-Application, Tillamook County
## Plat & Survey Chronology May 2021

| | |
|---|---|
| **1914** | Tillamook, N. Jetty Constructed |
| **1915** | Survey C-0129, Watseco Plat, Ocean Blvd. is western most platted land |
| **1916** | Nehalem, S. Jetty Constructed |
| **1918** | Nehalem, N. Jetty Constructed |
| **1931** | Tillamook N. Jetty Reconstructed and Extended to full length |
| **1931** | Survey C-0111, Vacation Plat of a Portion of Watseco Plat, Ocean Blvd. western most platted land. |
| **1932** | Survey C-0071, Plat of Pine Beach **(land to the south of Watseco Plat)**, Ocean Blvd. is western most platted land. Note reference to Watseco Blks. to the north. |
| **1950** | Survey A-0444, George Shand Tracts**, first time Lots are platted west of Ocean Blvd., west of Watseco Plat** |
| **1967** | Survey A-1502, Resurvey/Monument of George Shand Tracts |
| **1969** | Tillamook S. Jetty Construction Began and final segment completed in 1979 |
| **1980** | Survey B-1033, Resurvey of a portion of George Shand Tracts |
| **1986** | Survey B-1218, George Patten Bdy. Survey, **first time land is platted west of Ocean Blvd., west of Pine Beach Plat** |
| **1994** | Partition Plat 1994-3, divided land west of Ocean Blvd. in B-1218 into three parcels. |
| **1995** | Partition Plat 1995-33, partition in George Shand Tracts. |
| **1996** | **Survey C-0466,** Pine Beach Replat, Unit 1- Note location of Ocean Blvd. relative to Pine Beach Subdivision Lots 11-20 where revetment is proposed. |
| **1999** | **Survey C- 0494,** Pine Beach Replat, Unit 2 |

**South to North**
1N10WS7DD, Pine Beach Lots:
TL114-House Built 2004
TL115-House Built 1997
TL116-House Built 1998
TL117-No House
TL118- House Built 1997
TL119- No House
TL 120- House Built 1997
TL121- House Built 1999
TL122- House Built 1997
TL123- House Built 2016

1N10WS7DA, Shand Tract Lots:
TL3204-No House
TL3203-No House
TL3104-House Built 1997
TL3100-House Built 1997
TL3000- House Built 1989

Rockaway Littoral Cell; Cape Meares to Cape Falcon.

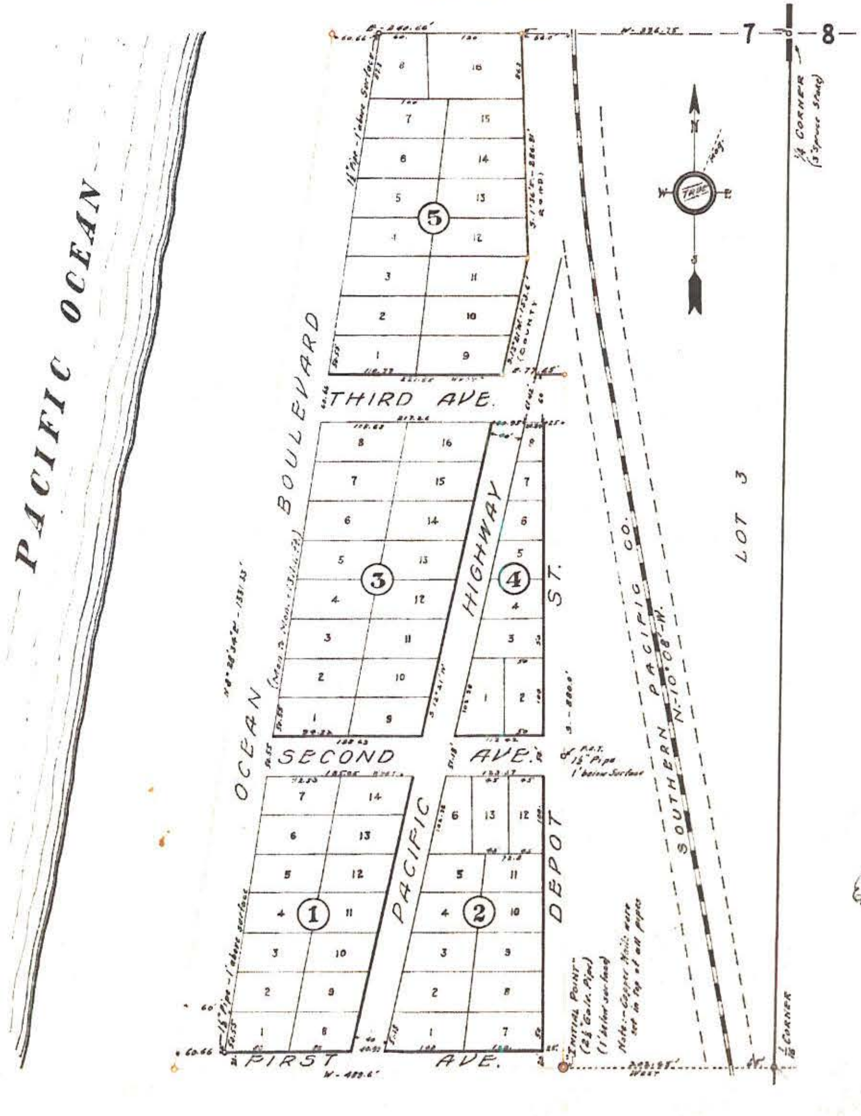
MAP OF

# WATSECO.

SITUATED IN

SECTION 7, T.1N.-R.10W.-W.M.

Scale:- 1 in.= 100 ft.



## DEDICATION

Know all men by these presents: that we, ROBERT WATT and LOIS WATT, his wife, and GEORGE WATT and HELEN S. WATT, his wife, have caused to be surveyed and subdivided into streets, avenues, boulevards, highways, blocks and lots; part of LOT-3 - SECTION 7, T.1 N. - R.10 W.- W.M., as appears in the following description to wit:- Beginning at the "INITIAL POINT", a point marked by a Copper Nail, set in cement, in the top of a GALVANIZED IRON PIPE, 2½ inches in diameter and 4 feet long, driven 1 foot below surface and located 1316.75 ft. SOUTH and 283.95 ft. WEST of the "QUARTER SECTION CORNER" between SECTIONS 7 and 8, - T.1 N. - R.10 W. - W.M.:- thence WEST, 489.6 ft.; thence N. 8°28'34"E., 1331.33 ft.; thence EAST, 240.66 ft.; thence S.1°36'E., 286.81 ft.; thence S.12°21'W., 153.60 ft.; thence EAST, 77.65 ft.; thence SOUTH, 880 ft., to "INITIAL POINT".

That we do hereby dedicate to the public, the perpetual use of the streets, avenues, boulevards and highways, as delineated and set forth on the map of WATSECO as hereon shown

Witnessed:- John a Bozorth
L.F. Brode

Signed:- Robert Watt
Lois Watt
George Watt
Helen S. Watt

## ACKNOWLEDGEMENT

State of OREGON
County of TILLAMOOK } ss

This is to certify that on this, the 8th day of JULY 1915 before me, the undersigned, a NOTARY PUBLIC, in and for the COUNTY and STATE aforesaid, personally appeared the abovenamed ROBERT WATT and LOIS WATT, his wife, and GEORGE WATT and HELEN S. WATT, his wife, who are known to me to be the identical persons described in, and who executed the foregoing instrument and severally acknowledged that they executed the same freely and volintarily for the use and purposes therein mentioned

In testimony whereof, I have set my hand and Official Seal, the day and year last above mentioned.

L.F. Brode Notary Public for OREGON.
Residing at BAY. CITY, ORE.
My Commission expires October 8th 1916

## SURVEYOR'S CERTIFICATE.

State of OREGON
County of TILLAMOOK } ss

I, GEO. S. BEATTY, being first duly sworn, depose and say that I have correctly surveyed the land embraced in the plat of WATSECO:- that the survey thereof is accurately delineated on the map hereon shown: that proper monuments have been placed and that a Copper Nail set in the top of a Galvanized Iron Pipe, 2½ inches in diameter and 4 feet long, driven 1 foot below surface, marks the Initial Point of such survey

Geo. S. Beatty SURVEYOR

Subscribed and sworn to before me, the 12th day of JULY 1915.

R. E. Jackson Notary Public for OREGON
Residing at BARVIEW, ORE.
My Commission expires Sept. 16 1915

All back taxes and assessments on the property described on the attached plat have been paid; dated this 22 day of JULY 1915.

Attest:- J. C. Holden COUNTY CLERK.

H. Crenshaw SHERIFF.
By W.L. Campbell Dep.

APPROVED:- JULY 22, 1915.

Ross Shreve COUNTY SURVEYOR.

APPROVED:- JULY 22, 1915.

C. A. Johnson ASSESSOR.

APPROVED:- August 5th 1915.

A. M. Hare COUNTY JUDGE.
Geo. R. McKinney COUNTY COMMISSIONER.
Frank L. Owens COUNTY COMMISSIONER.

C-129

C-129

## NARRATIVE

THE PURPOSE OF THIS SURVEY IS TO LOCATE IN THE FIELD THE FOUR PARCELS OF LAND WHICH COMPRISE THE PLAT OF PINE BEACH UNDER ONE OWNERSHIP. THE VACATED STREETS OF THE SOUTH 1/2 OF FIRST AVE; THIRD AVE.; FOURTH AVE. AND LAKE SIDE DRIVE HAVE BEEN INCORPORATED INTO THESE PARCELS AND ARE NOT SHOWN SPECIFICALLY.

FOR THE BASIS OF BEARINGS SEE THE NOTE AT THE LOWER RIGHT HAND CORNER OF THIS DRAWING.

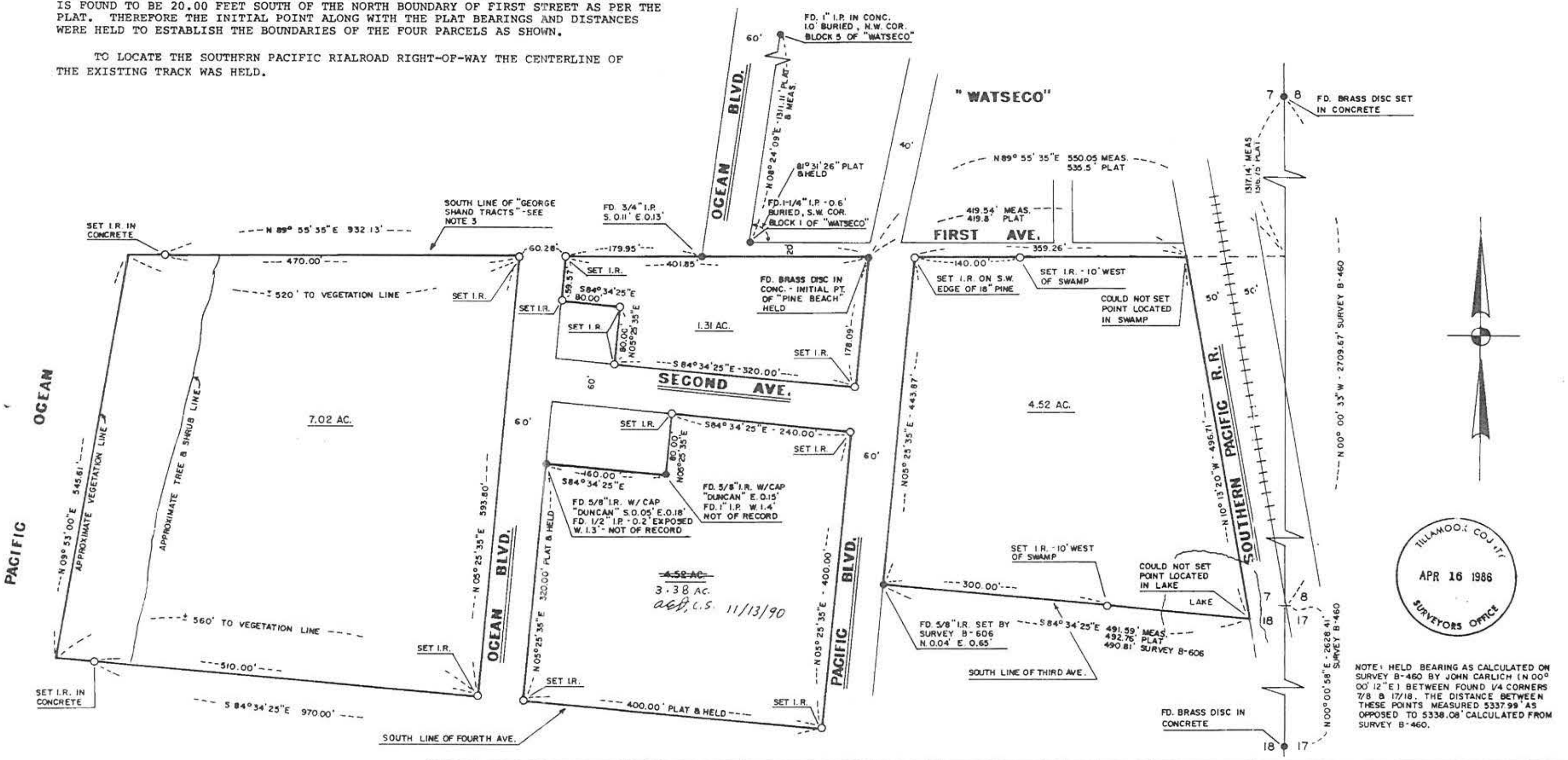
THE ONLY MONUMENT SET ON THE PINE BEACH PLAT IS THE INITIAL POINT AND SINCE "PINE BEACH'S" NORTH BOUNDARY IS EQUAL TO THE SOUTH BOUNDARY OF "WATSECO", THE TWO IRON PIPES FOUND ON THE EAST SIDE OF OCEAN BLVD, IN THE PLAT OF "WATSECO" WERE HELD TO ESTABLISH THE BEARINGS FOR THE PLAT OF PINE BEACH.

WHEN THE PLAT ANGLE OF 81°31'26" IS TURNED FROM THE EAST BOUNDARY OF OCEAN BLVD. TO THE NORTH BOUNDARY OF FIRST AVE., THE INITIAL POINT OF PINE BEACH IS FOUND TO BE 20.00 FEET SOUTH OF THE NORTH BOUNDARY OF FIRST STREET AS PER THE PLAT. THEREFORE THE INITIAL POINT ALONG WITH THE PLAT BEARINGS AND DISTANCES WERE HELD TO ESTABLISH THE BOUNDARIES OF THE FOUR PARCELS AS SHOWN.

TO LOCATE THE SOUTHERN PACIFIC RIALROAD RIGHT-OF-WAY THE CENTERLINE OF THE EXISTING TRACK WAS HELD.

## NOTES:

1. ● DENOTES MONUMENT FOUND.
2. ○ DENOTES 5/8" IRON ROD SET WITH A YELLOW PLASTIC CAP STAMPED "ZAROSINSKI-TATONE L.S. 1349".
3. THE SOUTH LINE OF THE "GEORGE SHAND TRACTS" AS SURVEYED BY SURVEY A-444 HAS PROJECTED THE SOUTH BOUNDARY OF "WATSECO" WESTERLY ACROSS AN ACCRETED OCEAN FRONT AREA APPROXIMATELY 500 FEET. THIS PROCEDURE DOES NOT AGREE WITH THE COMMON LAW PRACTICE OF ESTABLISHING PROPERTY LINES ACROSS ACCRETED LANDS AT RIGHT ANGLES TO THE SHORELINE.



NOTE: HELD BEARING AS CALCULATED ON SURVEY B-460 BY JOHN CARLICH (N 00° 00' 12"E) BETWEEN FOUND 1/4 CORNERS 7/8 & 17/18. THE DISTANCE BETWEEN THESE POINTS MEASURED 5337.99' AS OPPOSED TO 5338.08' CALCULATED FROM SURVEY B-460.

TILLAMOOK COUNTY
APR 16 1986
SURVEYORS OFFICE

**ZAROSINSKI-TATONE ENGINEERS, INC.**
**3737 S.E. EIGHTH AVE. PORTLAND, ORE.**

LOCATED IN SECTION 7, T.1N., R.10W.,
WILLAMETTE MERIDIAN
TILLAMOOK COUNTY, OREGON

DRAWN: C.C.F.
CHECKED:
SCALE: 1" = 100'
DATE: 3-18-86

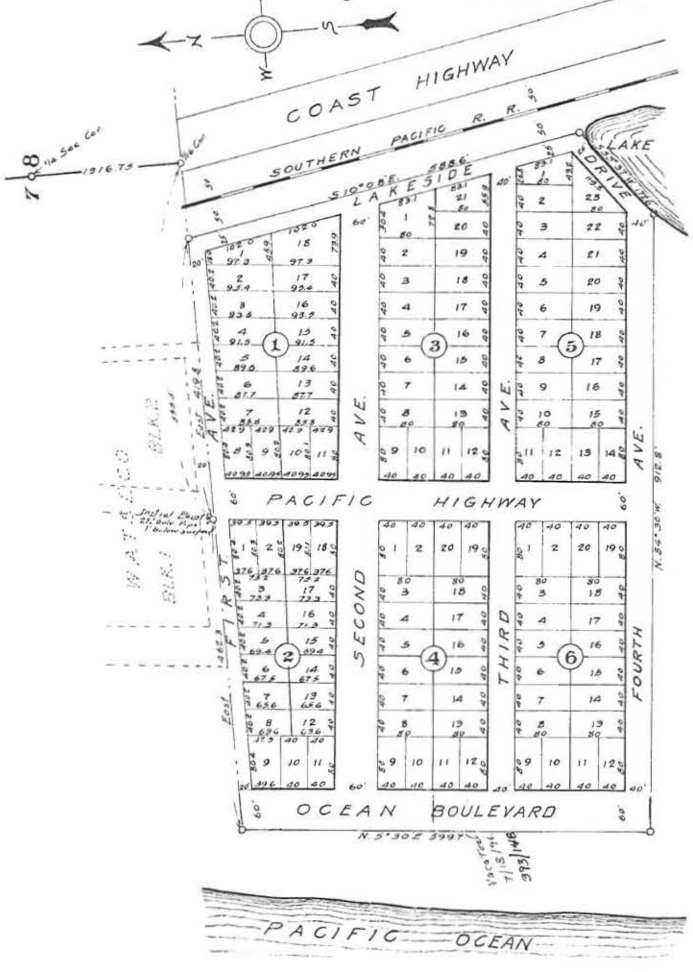
GEORGE PATTEN

1269-1

**BOUNDARY SURVEY**

B-1218

# PLAT OF
# PINE BEACH
## SITUATED IN
LOT 4, SECTION 7, T. 1 N., R. 10 W.
SCALE: 1 INCH = 100 FEET.



## DEDICATION

Know all men by these presents that we R. E. Jackson and Elizabeth L. Jackson, his wife, are the owners of Lot 4, Section 7, T. 1 N. R. 10 W. W. M. that we have caused such portion of the same to be surveyed and subdivided into streets, avenues, boulevards, lots and blocks as appear in the following description, to wit:

Beginning at the Initial Point marked by a copper nail set in cement, on the top of a galvanized iron pipe, 2½ inches in diameter and 3 feet long, driven one foot below the surface and located 1316.75 feet South and 535.5 West of the quarter section corner between Section 7 and 8 T. 1 N. R. 10 W. W.M. thence East 419.8 feet; thence S 10°08'E. 588.6 feet thence S. 53°37'W. 112.6 feet; thence N. 84°30'W. 912.8 feet thence N 5°30'E. 599.7 feet; thence East 462.3 feet to the initial Point.

We caused said lots, blocks, streets and avenues to be laid out as hereon marked and dedicated and we hereby dedicate the same said map and plat and the same said streets and avenues as hereon marked out on said map and plat and named as streets and avenues to be used as and for public highways forever.

R. E. Jackson
Elizabeth L. Jackson

## ACKNOWLEDGMENT

State of Oregon
County of Multnomah

This certifies that on this 21st day of June, 1932 before me the undersigned, a Notary Public in and for said County and State, personally appeared the within named R. E. Jackson and Elizabeth L. Jackson, his wife, who are known to me to be the identical individuals described in and who executed the within instrument and acknowledged to me that they executed the same as their free act and deed for the uses and purposes therein expressed.

In testimony whereof I have hereunto set my hand and notarial seal the day and year last above written.

Vivian Browning
Notary Public for Oregon
My Commission expires Jan 22, 1934

SEAL

## SURVEYOR'S CERTIFICATE

State of Oregon
County of Multnomah

I, R. E. Jackson, a Registered Professional Engineer of the State of Oregon, being first duly sworn, depose and say that I have correctly surveyed the land embraced in the plat of Pine Beach; that the survey thereof is accurately delineated on the map hereon shown; that proper monuments have been placed and that a copper nail set in the top of a galvanized iron pipe 2½ inches in diameter and three feet long, driven one foot below the surface, marks the initial point of survey.

R. E. Jackson - Registered Professional Engineer 412

Subscribed and sworn to before me this 21st day of June 1932

Vivian Browning
Notary Public for Oregon
My Commission expires Jan 22-1934

SEAL

Approved and accepted by the County Court of Tillamook County this 6th day of July 1932.

H. B. Beltz ... County Judge
E. H. Lindsay ... County Commissioner
F. L. Owens ... County Commissioner

Approved: W. C. Anderson County Surveyor
Approved: J. C. Holden ... County Sheriff
Approved: A. M. Hare County Assessor
Attest: H. S. Brimhall County Clerk

C-71

C-466

# PINE BEACH REPLAT
# UNIT 1

SHEET 1 of 3

## SE 1/4 SECTION 7, T1N, R10W, W.M.
## COUNTY

JUNE 24, 1996

### DECLARATION:

KNOW ALL PEOPLE BY THESE PRESENTS THAT PINE BEACH DEVELOPMENT L.L.C., AN OREGON LIMITED LIABILITY COMPANY AND CENTENNIAL BANK, BEING THE OWNERS OF THE LAND HEREIN DESCRIBED, DO HEREBY MAKE, ESTABLISH, AND DECLARE THE ANNEXED MAP OF "PINE BEACH REPLAT UNIT 1", AS DESCRIBED IN THE ACCOMPANYING SURVEYOR'S CERTIFICATE, TO BE A TRUE AND CORRECT MAP AND PLAT THEREOF, ALL LOTS BEING OF THE DIMENSIONS SHOWN ON SAID MAP. AREA 'A' IS A COMMON AREA. WE DO HEREBY DEDICATE FOREVER, THE EAST 10.00 FEET OF THAT PORTION OF PARCEL 3, PARTITION PLAT NO. 1994-003, THAT LIES WEST OF OLD PACIFIC HIGHWAY AS A PUBLIC WAY, WITHOUT RESERVATION. EASEMENTS E-1 THROUGH E-4 AS SHOWN HEREON ARE HEREBY GRANTED AS NON-EXCLUSIVE EASEMENTS FOR THE PURPOSES STATED HEREIN. ALL STREETS WITHIN THIS PLAT ARE PRIVATE.

PINE BEACH DEVELOPMENT L.L.C.
BY DONALD K. NUSSMEIER,
ITS MANAGING MEMBER

PINE BEACH DEVELOPMENT L.L.C.
BY DAVID L. FARR, ITS MANAGING MEMBER

Jeffery P. Tainer
CENTENNIAL BANK
BY JEFFERY P. TAINER,
ITS ASSISTANT VICE-PRESIDENT

### ACKNOWLEDGEMENT:

STATE OF OREGON >
> S.S.
COUNTY OF WASHINGTON >

THIS INSTRUMENT WAS ACKNOWLEDGED BEFORE ME ON July 30th, 1996, BY DONALD K. NUSSMEIER, AND DAVID L. FARR, AS MANAGING MEMBERS OF PINE BEACH DEVELOPMENT L.L.C., ON BEHALF OF THE COMPANY AND JEFFERY P. TAINER, AS ASSISTANT VICE-PRESIDENT OF CENTENNIAL BANK, ON BEHALF OF CENTENNIAL BANK.

Alice M. Dewees
NOTARY PUBLIC

MY COMMISSION EXPIRES: 7/30/98

OFFICIAL SEAL
ALICE M DEWEES
NOTARY PUBLIC - OREGON
COMMISSION NO. 036436
MY COMMISSION EXPIRES JUL 30, 1998

### MONUMENT NOTES:

(1) FOUND OSHD ALUMINUM CAP ON A 5/8" IRON ROD STAMPED "WAT 1975", TOP 0.3' BELOW GROUND, 3.5' NORTHEAST OF METAL WITNESS STAKE, AT SOUTHWEST QUADRANT OF OLD PACIFIC HIGHWAY AND HIGHWAY 101. USED FOR NGS TIE. SET BY OSHD AS BEACH ZONE LINE CONTROL.

(2) FOUND OSHD ALUMINUM CAP ON A 5/8" IRON ROD STAMPED "AQU 1975", TOP FLUSH WITH GROUND, 1.0' WEST OF BROKEN METAL WITNESS STAKE, 10.3' EAST OF EAST EDGE OF PAVEMENT OF HIGHWAY 101. USED FOR NGS TIE. SET BY OSHD AS BEACH ZONE LINE CONTROL.

(257) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "ZAROSINSKI TATONE LS 1349", TOP 0.1' ABOVE SURFACE, 2.5' SOUTH OF CENTERLINE OF A FOOT PATH. NORTH 0.04' AND WEST 0.07' OF CALCULATED POSITION FOR THE NORTHEAST CORNER OF PARCEL 1, PARTITION PLAT NO. 1994-003. SEE MAP B-1218.

(258) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB INC", TOP FLUSH WITH SURFACE AND IN CENTERLINE OF A FOOT PATH. S 89°55'35" W 85.14' AND N 00°04'25" W 0.08' OF SET MONUMENT FOR THE MOST NORTHERLY NORTHEAST CORNER OF THE EXTERIOR BOUNDARY FOR PINE BEACH REPLAT. SEE MAP B-1760.

(262) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB INC", TOP 0.5' BELOW SURFACE. SOUTH 0.06' AND WEST 0.03' OF CALCULATED POSITION. PULLED THIS MONUMENT. SEE PARTITION PLAT NO. 1994-003.

(265) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB INC", TOP 0.6' BELOW SURFACE. SOUTH 0.07' AND EAST 0.19' OF CALCULATED POSITION. PULLED THIS MONUMENT. SEE PARTITION PLAT NO. 1994-003.

(268) FOUND COUNTY SURVEYOR'S BRASS CAP SET IN CONCRETE, INITIAL POINT FOR PINE BEACH, TOP FLUSH WITH SURFACE. HELD FOR BASIS OF BEARINGS. SEE REWITNESS BIN #30

(269) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "ZAROSINSKI TATONE LS 1349", TOP FLUSH WITH SURFACE. HELD FOR BASIS OF BEARINGS. SEE MAP B-1218.

(272) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "ZAROSINSKI TATONE LS 1349", TOP FLUSH WITH SURFACE. BEARS N 84°34'25" W 8.74' FROM SOUTHEAST CORNER OF LOT 9. SEE MAP B-1218.

(286) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "A DUNCAN LS 795", TOP FLUSH WITH SURFACE. SOUTH 0.14' AND EAST 0.06' OF CALCULATED POSITION FOR THE SOUTHWEST CORNER OF LOT 10, BLOCK 4, PLAT OF PINE BEACH. SEE MAP A-5178.

### APPROVALS:

STATE OF OREGON >
> S.S.
COUNTY OF TILLAMOOK >

EXAMINED AND APPROVED BY THE FOLLOWING:

Allan E. Duncan 8-13-96
COUNTY SURVEYOR DATE

Ken Burdick 8-20-96
COUNTY COMMISSIONER DATE

Tim Lutz 8-19-96
COUNTY ASSESSOR DATE

COUNTY COMMISSIONER DATE

Josephine Veltri by Susan Holmes deputy 9-11-96
COUNTY CLERK DATE

Jerry A. Rose 8/19/96
COUNTY COMMISSIONER DATE

TAXES ARE PAID IN FULL TO JUNE 30, 1997.

Debi K. Pointer 9-10-96
COUNTY TAX COLLECTOR DATE

Vice 9-11-96
CHAIRMAN DATE
TILLAMOOK COUNTY PLANNING COMMISSION

### MONUMENT NOTES:

(287) FOUND 1/2" IRON PIPE WITH PLUG AND TACK, TOP 0.2' ABOVE SURFACE. SOUTH 0.38' AND WEST 1.45' OF CALCULATED POSITION FOR THE SOUTHWEST CORNER OF LOT 10, BLOCK 4, PLAT OF PINE BEACH. NO RECORD.

(289) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "A DUNCAN LS 795", TOP 0.2' ABOVE SURFACE. SOUTH 0.08' AND EAST 0.06' OF CALCULATED POSITION FOR THE SOUTHEAST CORNER OF LOT 7, BLOCK 4, PLAT OF PINE BEACH. SEE MAP A-5178.

(293) FOUND 5/8" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB INC", TOP FLUSH WITH SURFACE. S 89°55'35" W 190.41' AND N 00°04'25" W 0.14' OF SET MONUMENT FOR THE MOST NORTHERLY NORTHEAST CORNER OF THE EXTERIOR BOUNDARY FOR PINE BEACH REPLAT. SEE MAP B-1760.

### SHEET INDEX:

SHEET 1
DECLARATION
ACKNOWLEDGEMENT
TAX STATEMENT
APPROVALS
MONUMENT NOTES
EASEMENTS
SHEET INDEX
SURVEYOR'S CERTIFICATE
LEGEND
CONDITIONS AND RESTRICTIONS

SHEET 2
BOUNDARY SURVEY MAP
BASIS OF BEARINGS
NOTES

SHEET 3
NARRATIVE
CERTIFICATE OF COUNTY CLERK
COPY STATEMENT
DETAILS A,B,C,D
CURVE TABLE DATA
LINE TABLE DATA

### LEGEND:

| | |
|---|---|
| ○ | INDICATES 5/8" X 40" REBAR SET WITH YELLOW PLASTIC CAP MARKED "HLB ASSOC. INC." |
| ◉ | INDICATES MONUMENT FOUND AS NOTED HEREON USED FOR CONTROL. |
| ● | INDICATES MONUMENT FOUND AS NOTED HEREON. |
| $( )^1$ | INDICATES RECORD VALUE PER PARTITION PLAT NO. 1994-003. |
| | NO ( ) INDICATES MEASURED VALUE. |
| S.F. | INDICATES SQUARE FEET. |
| (G & N) | INDICATES GROSS AND NET AREA |
| (G) | INDICATES GROSS AREA |
| (N) | INDICATES NET AREA |

TILLAMOOK COUNTY SURVEYORS OFFICE
SEP 11 1996

REGISTERED
PROFESSIONAL
LAND SURVEYOR
Ronald G. Larson
OREGON
July 13, 1984
2102
RONALD G. LARSON

### EASEMENTS OF RECORD:

RIGHTS AS CONTAINED IN PATENT FROM UNITED STATES OF AMERICA, TO LLOYD C. SMITH, HIS HEIRS AND ASSIGNS, AS DISCLOSED BY INSTRUMENT RECORDED SEPTEMBER 22, 1880, IN BOOK 1, PAGE 321, TILLAMOOK COUNTY DEED RECORDS.

### EASEMENTS:

E-1: A 15.00' WIDE NON-EXCLUSIVE EASEMENT FOR SEWER SYSTEM IMPROVEMENTS, INGRESS AND EGRESS TO TWIN ROCKS SANITARY DISTRICT.

E-2: A NON-EXCLUSIVE EASEMENT FOR SEWER SYSTEM IMPROVEMENTS, INGRESS AND EGRESS TO TWIN ROCKS SANITARY DISTRICT.

E-3: A 8.00' WIDE NON-EXCLUSIVE EASEMENT FOR UTILITIES TO TILLAMOOK PEOPLE'S UTILITY DISTRICT.

E-4: A 8.00' WIDE NON-EXCLUSIVE EASEMENT FOR ELECTRICAL UTILITIES TO TILLAMOOK PEOPLE'S UTILITY DISTRICT.

### CONDITIONS & RESTRICTIONS:

SEE BOOK 381, PAGE 172 TILLAMOOK COUNTY DEED RECORDS FOR DECLARATIONS, COVENANTS, RESTRICTIONS AND RESERVATIONS.

### SURVEYOR'S CERTIFICATE:

STATE OF OREGON >
>S.S.
COUNTY OF TILLAMOOK >

I, RONALD G. LARSON, CERTIFY THAT:

I HAVE CORRECTLY SURVEYED AND MARKED WITH PROPER MONUMENTS THE TRACT OF LAND REPRESENTED ON THE ANNEXED MAP, THE EXTERIOR BOUNDARY OF "PINE BEACH REPLAT UNIT1" BEING DESCRIBED AS FOLLOWS:

BEGINNING AT A POINT ON THE WEST RIGHT-OF-WAY LINE OF PACIFIC HIGHWAY WHICH POINT IS SOUTH 89°55'35" WEST 10.05 FEET AND SOUTH 05°25'35" WEST 357.13 FEET FROM THE INITIAL POINT OF PINE BEACH, RECORDED AS MAP C-71, PLAT RECORDS OF TILLAMOOK COUNTY, LOCATED IN SECTION 7, TOWNSHIP 1 NORTH, RANGE 10 WEST OF THE WILLAMETTE MERIDIAN, TILLAMOOK COUNTY, OREGON, SAID POINT BEING THE INITIAL POINT OF THIS SUBDIVISION PLAT AND MARKED BY A 5/8" X 40" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB ASSOC. INC. ";

THENCE NORTH 84°34'25" WEST 230.00 FEET TO A 5/8" X 40" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB ASSOC. INC. ";

THENCE NORTH 05°25'35" EAST 40.00 FEET TO THE SOUTHEAST CORNER OF LOT 7, BLOCK 4, PINE BEACH;

THENCE NORTH 84°34'25" WEST ALONG THE SOUTH LINE OF LOTS 7,8 AND 10, BLOCK 4, PINE BEACH AND THE WESTERLY EXTENSION THEREOF 220.00 FEET TO THE WEST RIGHT-OF-WAY LINE OF OCEAN BOULEVARD;

THENCE NORTH 05°25'35" EAST ALONG SAID WEST RIGHT-OF-WAY LINE 220.00 FEET TO THE INTERSECTION WITH THE WESTERLY EXTENSION OF THE NORTH LINE OF LOT 10, BLOCK 2, PINE BEACH;

THENCE SOUTH 84°34'25" EAST ALONG SAID WESTERLY EXTENSION 5.00 FEET TO A 5/8" X 40" REBAR WITH YELLOW PLASTIC CAP STAMPED "HLB ASSOC. INC. ";

THENCE NORTH 05°25'35" EAST 54.28 FEET TO THE EASTERLY EXTENSION OF THE NORTH LINE OF PARCEL 1, PARTITION PLAT NO. 1994-003, RECORDS OF TILLAMOOK COUNTY;

THENCE NORTH 89°55'35" WEST 520 FEET, MORE OR LESS, TO THE MEAN HIGH WATER LINE OF THE PACIFIC OCEAN;

THENCE SOUTHERLY ALONG SAID MEAN HIGH WATER LINE 550 FEET, MORE OR LESS, TO SOUTH LINE OF PARCEL 3, PARTITION PLAT NO. 1994-003, THAT LIES WEST OF OLD PACIFIC HIGHWAY;

THENCE SOUTH 84°34'25" EAST ALONG SAID SOUTH LINE 1048 FEET, MORE OR LESS, TO THE WEST RIGHT-OF-WAY LINE OF PACIFIC HIGHWAY;

THENCE NORTH 05°25'35" EAST ALONG SAID WEST RIGHT-OF-WAY LINE 638.09 FEET TO THE SOUTH RIGHT-OF-WAY LINE OF FIRST AVENUE;

THENCE SOUTH 89°55'35" WEST ALONG SAID SOUTH RIGHT-OF-WAY LINE 10.05 FEET TO A POINT WHICH IS 10.00 FEET WESTERLY AS MEASURED PERPENDICULAR TO THE WEST RIGHT-OF-WAY LINE OF PACIFIC HIGHWAY;

THENCE SOUTH 05°25'35" WEST PARALLEL WITH SAID WEST RIGHT-OF-WAY LINE 357.13 FEET TO THE INITIAL POINT.

**HLB & ASSOC., INC.**
HANDFORTH LARSON & BARRETT
SURVEYING • ENGINEERING • PLANNING

TILLAMOOK COUNTY
180 LANEDA AVE.
MANZANITA, OR 97130
(503) 368-5394
FAX: (503) 368-5847

CLATSOP COUNTY
4253A HWY 101 N.
GEARHART, OR 97138
(503) 738-3425
FAX: (503) 738-7455

12771601.DWG

C-466

C-466

SHEET 2 of 3

# PINE BEACH REPLAT
# UNIT 1

## SE 1/4 SECTION 7, T1N, R10W, W.M.
## TILLAMOOK COUNTY

JUNE 24, 1996

BASIS OF BEARINGS:

THE LINE BETWEEN THE FOUND MONUMENTS (269) AND (268) AS SHOWN HEREON, BEARS NORTH 05°25'35" EAST, THE RECORD VALUE FROM PARTITION PLAT NO. 1994-003.

REGISTERED
PROFESSIONAL
LAND SURVEYOR
Ronald G. Larson
OREGON
July 13, 1984
2102
RONALD G. LARSON
RENEWAL DATE DECEMBER 31, 1996

TILLAMOOK COUNTY
SEP 11 1996
SURVEYORS OFFICE

"FARR3" 28
12771602.DWG

**HLB & ASSOC., INC.**
HANDFORTH LARSON & BARRETT
SURVEYING • ENGINEERING • PLANNING

TILLAMOOK COUNTY
180 LANEDA AVE.
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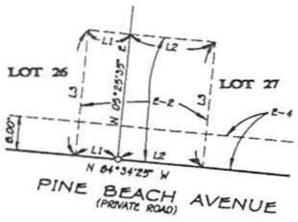
CLATSOP COUNTY
4253A HWY 101 N.
GEARHART, OR 97138
(503) 738-3425
FAX: (503) 738-7455

C-466

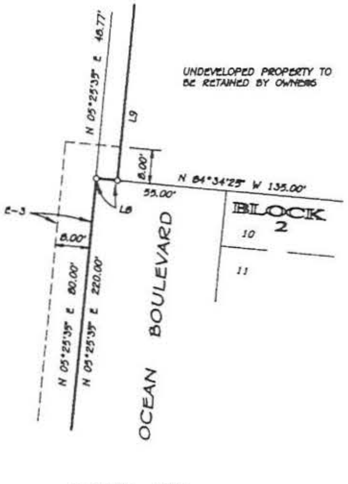
C-466

# PINE BEACH REPLAT
# UNIT 1
## SE 1/4 SECTION 7, T1N, R10W, W.M.
## TILLAMOOK COUNTY
JUNE 24, 1996

SHEET 3 of 3

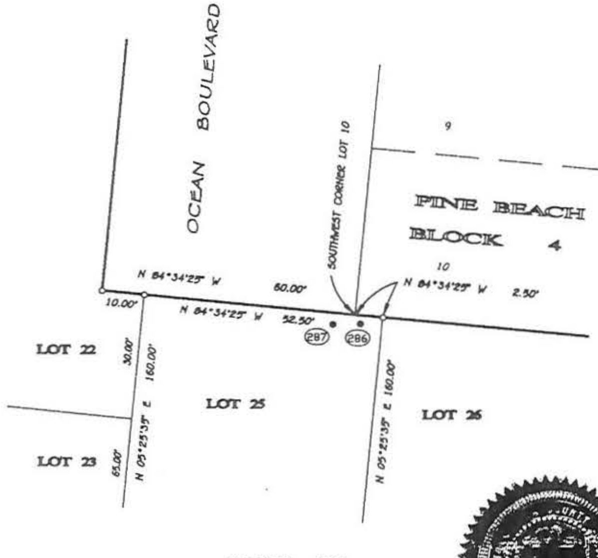


DETAIL 'A'
NOT TO SCALE

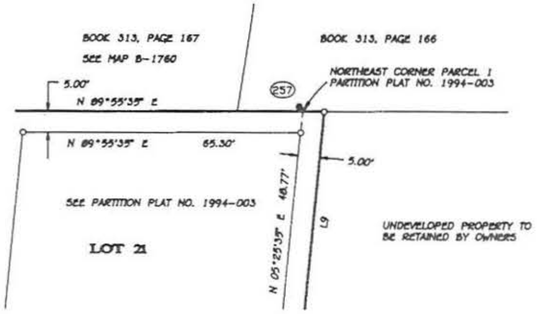


DETAIL 'B'
NOT TO SCALE

SCALE:
NO SCALE



DETAIL 'D'
NOT TO SCALE



DETAIL 'C'
NOT TO SCALE

## NARRATIVE:

THIS SURVEY WAS CONDUCTED AS A DEPENDENT RESURVEY OF THE SUBJECT PROPERTY DESCRIBED AS PARCELS 1, 2 AND 3, PARTITION PLAT NO. 1994-003, RECORDED FEBRUARY 2, 1994, IN PLAT CABINET B, SLIDE 248, TILLAMOOK COUNTY RECORDS, EXCEPTING THEREFROM THAT PORTION OF SAID PARCEL 3 THAT LIES EAST OF OLD PACIFIC HIGHWAY AND WEST OF THE SOUTHERN PACIFIC RAILROAD RIGHT OF WAY. THE PURPOSE OF THIS SURVEY IS TO SUBDIVIDE THE SUBJECT PROPERTY INTO THIRTY-TWO LOTS AND A COMMON AREA. THE NORTH AND SOUTH 5.00 FEET OF SAID COMMON AREA ARE PRIVATE WALKWAYS FOR ACCESS TO THE BEACH.

HELD THE INITIAL POINT OF PINE BEACH AND MONUMENT (269) FOR BASIS OF BEARINGS. HELD RECORD ANGLES FROM PARTITION PLAT NO. 1994-003 TO ESTABLISH THE NORTH AND SOUTH LINES OF PLAT BOUNDARY.

PORTIONS OF OCEAN BOULEVARD ARE BEING VACATED WITH THE FILING OF THIS PLAT AND FILED AS ROAD VACATION PETITION #481. THE WEST RIGHT-OF-WAY LINE OF PACIFIC HIGHWAY IS BEING MONUMENTED THIS SURVEY TO INCLUDE THE 10.00 FOOT WIDE PUBLIC DEDICATION.

### CURVE TABLE DATA

| CURVE | RADIUS | LENGTH | CHORD | BEARING | DELTA |
|---|---|---|---|---|---|
| C1 | 20.00' | 34.11' | 30.12' | N 35°42'52" W | 97°43'05" |
| C2 | 45.00' | 76.75' | 67.78' | N 35°42'52" W | 97°43'05" |
| C3 | 70.00' | 119.39' | 105.43' | N 35°42'52" W | 97°43'05" |
| C4 | 70.00' | 14.90' | 14.87' | N 07°02'51" E | 12°11'39" |
| C5 | 70.00' | 30.20' | 29.97' | N 11°24'40" W | 24°43'22" |
| C6 | 70.00' | 26.86' | 26.69' | N 34°45'52" W | 21°59'05" |
| C7 | 70.00' | 25.74' | 25.60' | N 56°17'27" W | 21°04'07" |
| C8 | 70.00' | 5.00' | 5.00' | N 68°52'21" W | 04°05'36" |
| C9 | 70.00' | 16.68' | 16.64' | N 77°44'46" W | 13°39'18" |
| C10 | 70.00' | 100.53' | 92.11' | N 54°17'08" E | 82°16'55" |
| C11 | 45.00' | 64.62' | 59.21' | N 54°17'08" E | 82°16'55" |
| C12 | 20.00' | 28.72' | 26.32' | N 54°17'08" E | 82°16'55" |
| C13 | 70.00' | 27.14' | 26.97' | N 24°15'04" E | 22°12'48" |
| C14 | 70.00' | 26.28' | 26.13' | N 46°06'47" E | 21°30'37" |
| C15 | 70.00' | 30.10' | 29.87' | N 69°11'10" E | 24°38'10" |
| C16 | 70.00' | 17.01' | 16.97' | N 88°27'56" E | 13°55'20" |

### LINE TABLE DATA

| LINE | DIRECTION | DISTANCE |
|---|---|---|
| L1 | N 84°34'25" W | 10.00' |
| L2 | N 84°34'25" W | 20.00' |
| L3 | S 05°25'35" W | 30.00' |
| L4 | S 84°34'25" E | 48.16' |
| L5 | S 84°34'25" E | 48.84' |
| L6 | N 84°34'25" W | 49.51' |
| L7 | S 53°45'37" E | 44.65' |
| L8 | N 84°34'25" W | 5.00' |
| L9 | S 05°25'35" W | 54.28' |
| L10 | N 84°34'25" W | 10.00' |
| L11 | N 87°31'04" W | 23.33' |
| L12 | N 67°07'39" E | 54.52' |

STATE OF OREGON >
> S.S.
COUNTY OF TILLAMOOK >

I HEREBY CERTIFY THAT THIS PLAT WAS RECEIVED FOR RECORD ON THE 11th DAY OF SEPTEMBER 1996 AT 2:41P O'CLOCK AND RECORDED IN PLAT CABINET B-493-0 TILLAMOOK COUNTY RECORDS, AS INSTRUMENT NO. 96353590.
JOSEPHINE VELTRI, COUNTY CLERK.

BY: Josephine Veltri, by Susan Holmes, deputy

## CERTIFICATE OF COUNTY CLERK:

STATE OF OREGON >
> S.S.
COUNTY OF TILLAMOOK >

I, JOSEPHINE VELTRI, DO HEREBY CERTIFY THAT I AM THE QUALIFIED CLERK OF TILLAMOOK COUNTY, OREGON AND THAT THIS COPY IS THE FULL, COMPLETE AND TRUE COPY OF THE ORIGINAL PLAT OF SAME, AS RECORDED IN PLAT CABINET B-493-0 OF PLAT RECORDS OF TILLAMOOK COUNTY, OREGON, RECORDED SEPTEMBER 11, 1996 AT 2:41P O'CLOCK, AS INSTRUMENT NO. 96353590.

Josephine Veltri, by Susan Holmes, deputy
JOSEPHINE VELTRI

I, RONALD G. LARSON, DO HEREBY CERTIFY THAT THIS IS A FULL, COMPLETE AND TRUE COPY OF THE ORIGINAL PLAT AS REFERENCED ABOVE.

Ronald G. Larson
RONALD G. LARSON, PLS 2102

TILLAMOOK COUNTY
SEP 11 1996
SURVEYORS OFFICE

REGISTERED
PROFESSIONAL
LAND SURVEYOR
Ronald G. Larson
OREGON
July 13, 1984
2102
RONALD G. LARSON
RENEWAL DATE: DECEMBER 31, 1996

12771603.DWG

**HLB & ASSOC., INC.**
HANDFORTH LARSON & BARRETT
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TILLAMOOK COUNTY
180 LANEDA AVE.
MANZANITA, OR 97130
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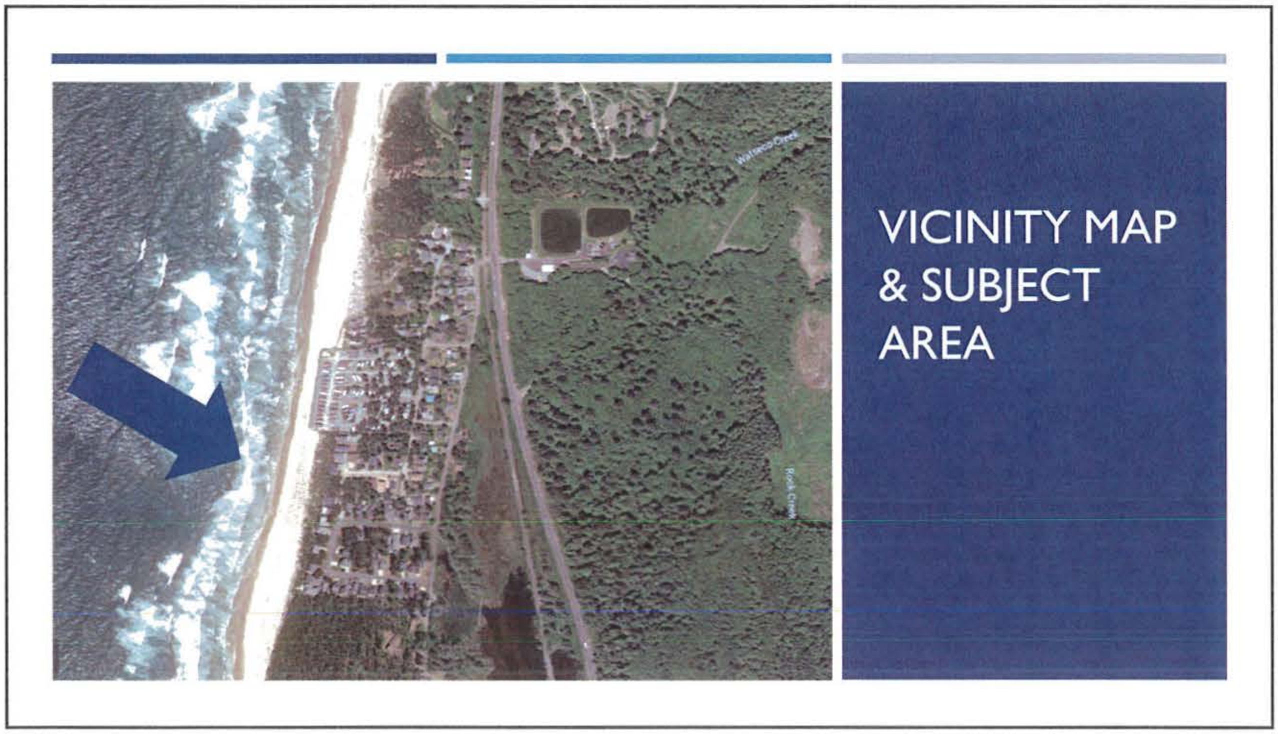
FAX: (503) 368-5847

CLATSOP COUNTY
4253A HWY 101 N.
GEARHART, OR 97138
(503) 738-3425
FAX: (503) 738-7455

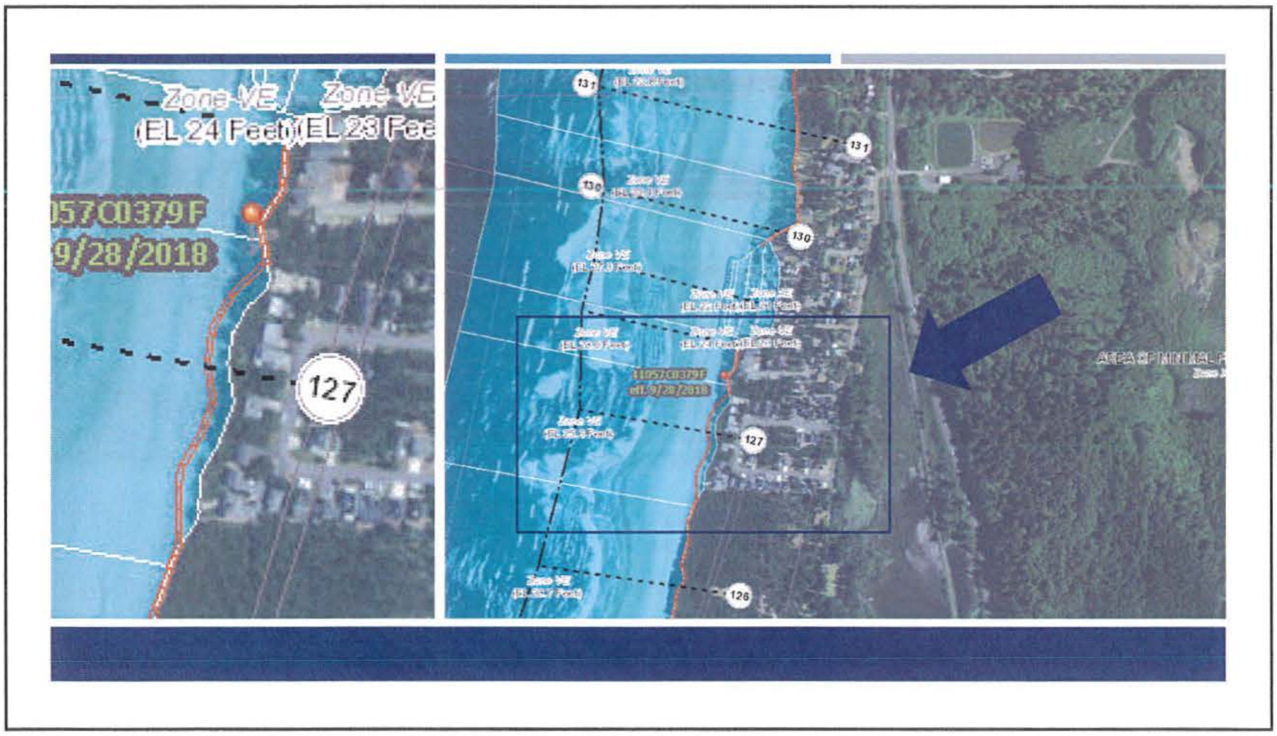
# #851-21-000086-PLNG-01: GOAL 18 EXCEPTION REQUEST #851-21-000086-PLNG: FLOODPLAIN DEVELOPMENT PERMIT

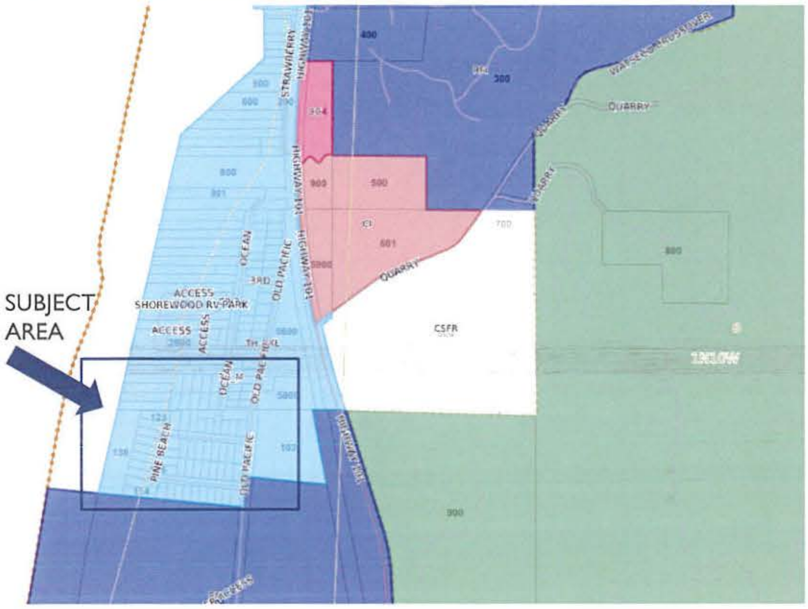
SARAH ABSHER, CFM, DIRECTOR

TILLAMOOK COUNTY DEPARTMENT OF COMMUNITY DEVELOPMENT



# VICINITY MAP & SUBJECT AREA





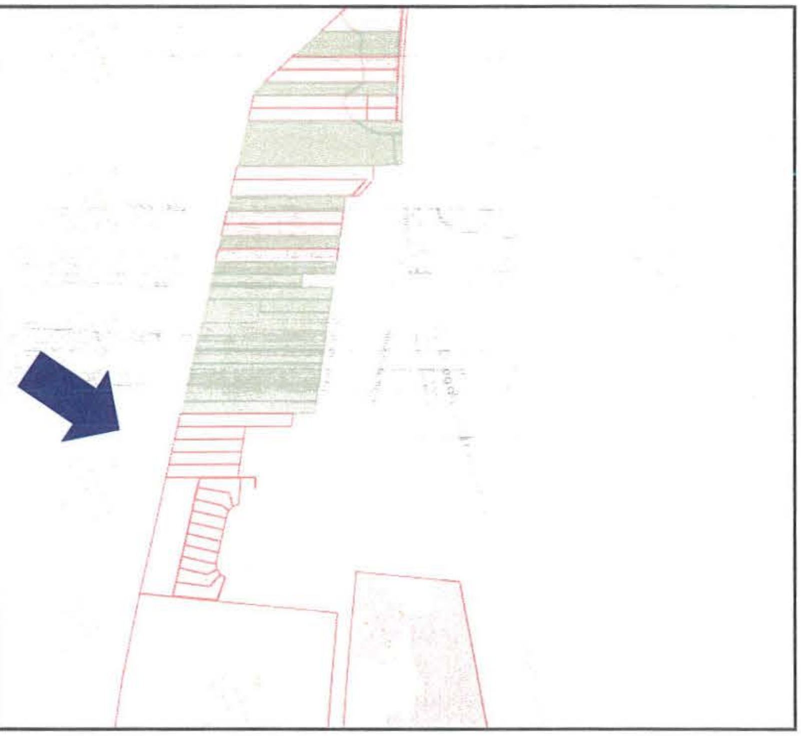
## ZONING MAP

horeline Armoring and Eligibility

☐ Beachfront Protective Structures, OPRD, 2

☑ Goal 18 Eligibility Inventory, OCMP, 2015

- 🟩 Eligible for Protection
- 🟩 Eligible due to Exception
- 🟥 Not Eligible for Protection
- 🟪 Rockaway Beach Only - See City Planner. (Western extent of Goal 18 Exception is the ocean setback line.)



HTTPS://WWW.COASTALATLAS.NET/OCEANSHORES/

- Coastal Atlas, Goal 18 Eligibility Inventory, OCMP, 2015

DUNE LEGEND

| | |
|---|---|
| AID | Active inland dune |
| B | Beach |
| CT | Coastal terrace |
| DC | Dune complex of OS, OSC, |
| DS | Younger stabilized dunes |
| FD | Recently stabilized foredune: |
| FDA | Active foredune |
| H | Active dune hummocks |
| M | Mountain scarp |
| ODS | Older stabilized dunes |
| OS | Open dune sand |
| (OS) | Designates items of secondar |
| OSC | Open dune sand conditionall |
| W | Wet interdune |
| WDP | Wet deflation plain |
| WFP | Wet flood plain |
| WMF | Wet mountain front |
| WSP | Wet surge plain |

# APPLICATIONS UNDER REVIEW

- Goal Exception request for approval of an exception to Statewide Planning Goal 18, Implementation Measure (IM) 5; approval of a comprehensive plan amendment for a "committed" exception and/or a "reasons" exception to Goal 18, Implementation Measure 5 for the construction of shoreline stabilization along the westerly lots of the Pine Beach Subdivision and five oceanfront lots to the north located within the Barview/Twin Rocks/Watseco Unincorporated Community Boundary .
- Development Permit Request for the installation of a beachfront protective structure (rip rap revetment) within an active eroding foredune east of the line of established vegetation in the Coastal High Hazard (VE) zone, an Area of Special Flood Hazard within the Flood Hazard Overlay Zone.
  - Beach & Dune Hazard Overlay Zone provisions are also made part of this permit review process.

# CONSIDERATION FOR ACTION
# 2 SEPARATE APPLICATIONS & DECISIONS

## #851-21-000086-PLNG-01

- EXCEPTION TO GOAL 18 IMPLEMENTATION MEASURE 5 TO ALLOW THE CONSTRUCTION OF A BEACHFRONT PROTECTIVE STRUCTURE (BPS)

## #851-21-000086-PLNG

- DEVELOPMENT PERMIT FOR CONSTRUCTION OF BPS (BEACH & DUNE OVERLAY ZONE) & DEVELOPMENT WITHIN AREA OF SPECIAL FLOOD HAZARD

# GOAL 18 IMPLEMENTATION MEASURES #2 & #5

- Statewide Planning Goal 18 Implementation Measure #2 requires prohibition of residential, commercial and industrial development on beaches, active foredunes and other foredunes which are conditionally stable and that are subject to ocean undercutting or wave overtopping, and on interdune areas (deflation plains) that are subject to ocean flooding.
- These are areas within unincorporated Tillamook County identified as built and committed areas located on foredunes which are conditionally stable and that are subject to ocean undercutting or wave overtopping, and on interdune areas (deflation plains) that are subject to ocean flooding. **These built and committed areas are Cape Meares, Tierra Del Mar, Pacific City and Neskowin.**
- Implementation Measure #5 of Statewide Planning Goal 18 only allows beachfront protective structures where development existed on **January 1, 1977.** *Development is defined as houses, commercial and industrial buildings, and vacant subdivision lots which are physically improved through construction of streets and provision of utilities to the lot and includes areas where an exception to (2) above has been approved.*
- Criteria that must be met for the construction of beachfront protective structures is included in Implementation Measure #5 and require evidence that visual impacts are minimized, access to the beach is maintained, negative impacts to adjacent properties are minimized, and long-term or recurring costs to the public are avoided.

## APPLICABLE PROVISIONS

- Oregon Statewide Planning Goals
- Oregon Revised Statutes
  - ORS 197.732
- Oregon Administrative Rules, Exception Requirements
  - OAR 660-004-0020-0022 Goal 2, Part II(c), Exception Requirements, (11) Goal 18 Foredune Development Reasons Exception Requirements
- Tillamook County Comprehensive Plan
- TCLUO Section 3.510: Flood Hazard Overlay Zone
- TCLUO Section 3.530: Beach & Dune Overlay Zone
- TCLUO Section 9.030: Text Amendment Procedure and Criteria
- TCLUO Article 10: Administrative Provisions

## DEFINITION OF "DEVELOPMENT" STATEWIDE PLANNING GOAL 18

- **1977**
- **Develop**
- To make a physical change in the use or appearance of land, to divide land into parcels, or to create or terminate rights of access.
- **Development**
- The act, process, or result of developing.

- **1984**
- Houses and vacant subdivision lots which are physically improved through construction of streets and provision of utilities to the lot.

## DISCUSSION & CONSIDERATION

- DEFINITION OF DEVELOPMENT
  - 1977- IS EXCEPTION REQUIRED IF DEVELOPMENT MET DEFINITION?
    - 1941 SUBDIVISION PLAT VACATION OF PINE BEACH
  - 1984- EXCEPTION WOULD BE REQURIED IF DEVELOPMENT DOES NOT MEET 1984 DEFINITION OF DEVELOPMENT
- WHAT TYPE OF EXCEPTION IS APPROPRIATE FOR CONSIDERATION? APPLICANT EXPLORES ALL THREE. TESTIMONY RECEIVED BY DLCD & OTHERS ARGUE THAT A REASONS EXCEPTION IS THE ONLY PATH FORWARD FOR A GOAL 18 IM5 EXCEPTION
- DEVELOPMENT LAWFULLY PERMITTED. GOAL 18 IM2/IM5 EXCEPTIONS WERE NOT REQUIRED TO BE TAKEN ON THE YOUNGER STABILIZED DUNE. THREAT OF EROSION & OCEAN FLOODING WAS NOT PRESENT AT THE TIME OF DEVELOPMENT BUT ARE PRESENT NOW.

**THE BEACH IS THE RESOURCE- PURPOSE OF GOAL 18 IS TO PRESERVE & PROTECT THE BEACH RESOURCE**

- PROTECTION PRIORITY: DEVELOPMENT OR THE BEACH?
  - POLICIES OF GOAL 18 ITSELF- PROTECT BEACH RESOURCE- WHAT IMPACT, IF ANY, DOES THE BPS HAVE ON THE RESOURCE NOW AND IN THE FUTURE, AND ULTIMATELY WILL THE BPS RESULT IN FURTHER DEGREDATION OF THE RESOURCE?
- WHILE SITE CONDITIONS MAY CHANGE DUE TO CONTINUED EROSION, THE CONSTRUCTION OF THE PROPOSED BPS IS LOCATED WHOLLY WITHIN PRIVATE PROPERTY BOUNDARIES OF THE SUBJECT PROPERTIES
  - FUNCTION OF BPS- ONLY WHEN THREAT OF EROSION EXISTS AT THE LOCATION OF THE BPS. UNTIL THEN, WHAT IS THE PURPOSE AND FUNCTION OF THE BPS?
- ENSURING PUBLIC ACCESS ALONG THE BEACH, NOT NECESSARILY ACCESS TO THE BEACH FROM THE PRIVATE/PUBLIC ROAD SYSTEM
- LINCOLN COUNTY APPLICATION VS TILLAMOOK COUNTY FROM DLCD STANDPOINT- SITE CONDITION CONSIDERATION

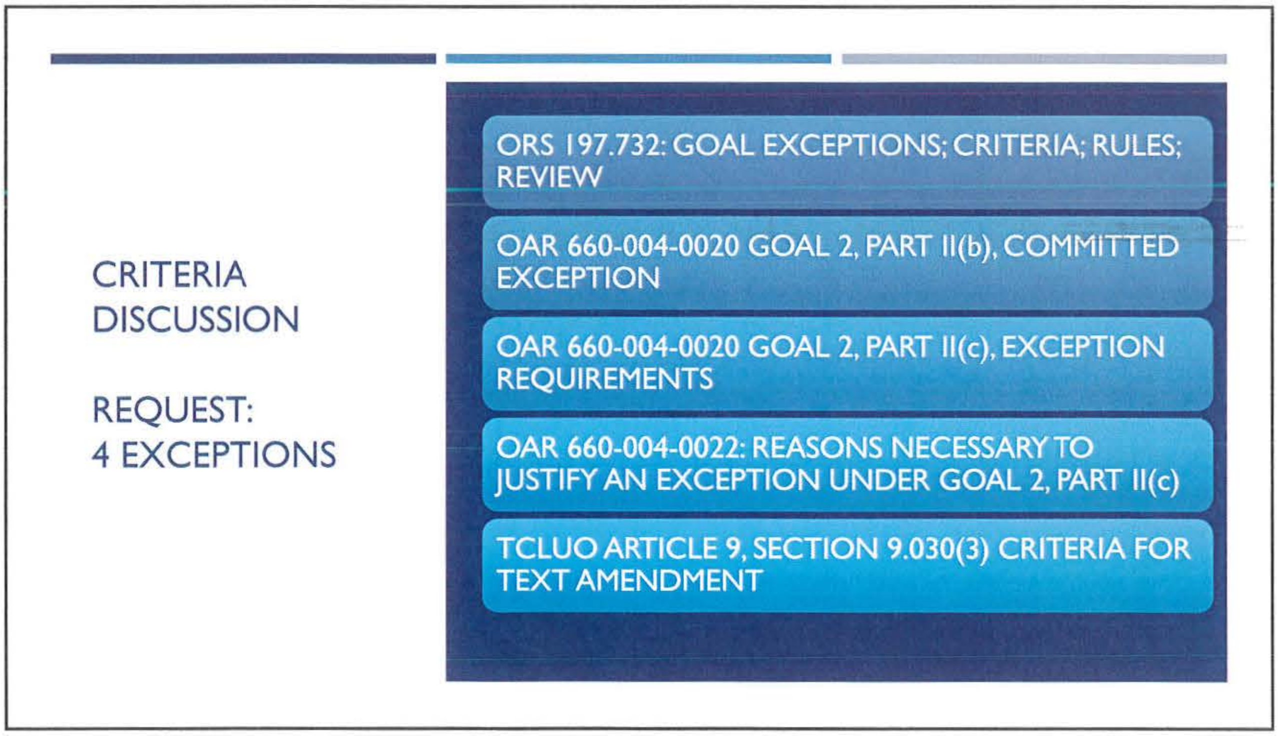
**RELATIONSHIP WITH OTHER POLICIES & GOALS**

- GOAL 7, NATURAL HAZARDS- COUNTY'S OBLIGATION TO UPHOLD OTHER POLICIES OF STWP & COMPREHENSIVE PLAN- BPS PROPOSAL AND GOAL EXCEPTION REQUEST IS CONSISTENT WITH GOAL 7 POLICIES?
- GOAL 10 HOUSING ELEMENT- POLICY TO PROMOTE DIVERSE HOUSING STOCK & HOUSING CRISIS?
- SHORELAND GOAL 17 ELEMENT- HAS EXCEPTION BEEN TAKEN? PRIORITY OF NON-STRUCTURAL VS STRUCTURAL SOLUTIONS? SHOULD AN ALTERNATIVE ANALYSIS BE DONE TO PROVE WHY NON-STRUCTURAL SOLUTIONS CANNOT BE CONSIDERED?

## DISCUSSION & CONSIDERATION CONTINUED

## RELEVANT GOALS & GOAL ELEMENTS

- Goal 1- Planning Process & Citizen Involvement
- Goal 2- Land Use Plan & Exception Process (Reasons/Committed Exception Request)
- Goal 7- Hazards
- Goal 11- Public Facilities
- Goal 14- Urbanization
- Goal 17- Shorelands
- Goal 18- Beaches & Dunes
  - Goal 18 IM #2
  - Goal 18 IM #5



## CRITERIA DISCUSSION

REQUEST:
4 EXCEPTIONS

- ORS 197.732: GOAL EXCEPTIONS; CRITERIA; RULES; REVIEW
- OAR 660-004-0020 GOAL 2, PART II(b), COMMITTED EXCEPTION
- OAR 660-004-0020 GOAL 2, PART II(c), EXCEPTION REQUIREMENTS
- OAR 660-004-0022: REASONS NECESSARY TO JUSTIFY AN EXCEPTION UNDER GOAL 2, PART II(c)
- TCLUO ARTICLE 9, SECTION 9.030(3) CRITERIA FOR TEXT AMENDMENT

## SUMMARY OF FINDINGS MADE BY APPLICANT TO JUSTIFY WHY EXCEPTIONS SHOULD BE GRANTED

- DEVELOPMENT was lawfully permitted by Tillamook County
  - Some if not all properties meet definition of "DEVELOPMENT" as originally defined in Goal 18
    - Determination and identification of properties that meet definition of "development"
  - Subject area is an irrevocably committed area intended for urban residential use
- REQUEST IS CONSISTENT WITH GOAL 18 (AND GOAL 7) POLICIES TO REDUCE HAZARD TO HUMAN LIFE & PROPERTY FROM NATURAL ACTIONS ASSOCIATED WITH COASTAL BEACH & DUNE AREAS
- Visual impacts are minimized and existing beach access is maintained.
- BPS IS DESIGNED TO MINIMIZE IMPACTS ON ADJACENT PROPERTIES AND WILL NOT INCREASE RISK OF HAZARDS (WAVE RUN-UP, INCREASED WAVE HEIGHT, INCREASED FLOOD RISK OR DIVERSION OF FLOOD WATER)
- BPS IS DESIGNED TO MEET GOAL 18 REQUIREMENTS & BEACH & DUNE HAZARD OVERLAY ZONE STANDARDS
    - (a) The use will be adequately protected from any geologic hazards, wind erosion, undercutting ocean flooding and storm waves, or the use is of minimal value;
    - (b) The use is designed to minimize adverse environmental effects; and
    - (c) The exceptions requirements of OAR 660-004-0020 are met.

## SUMMARY CONTINUED

- The project design protects surrounding properties from the adverse impacts of development, including protection from direction of additional water to surrounding properties, increase in wave heights or wave runup, or impact to the natural littoral drift of sediment along the coast.
- As stated in the Technical Memorandum provided by West Consultants, the proposed revetment structure will reduce the risk of damage to life, property and the natural environment from beach erosion and coastal flooding resulting from large waves occurring during high tides.
- West Consultants Technical Memorandum explains that the structure is designed to address ocean flooding and storm waves and that its design will not cause an increase to FEMA total water levels near the structure.
- The proposed beachfront protective structure will protect the natural environment from beach erosion and adverse impacts from coastal flooding.
- Applicants state the design of the proposed beachfront protective structure is consistent with Goal 18, IM 3 and will provide protective measures where natural protective measures have failed including protection (not the destruction) of desirable vegetation.
- Applicants state the proposed beachfront protective structure does not use or affect groundwater as the structure does not reach down to the water table and will not lead to loss of water quality or the intrusion of salt water into water supplies.
- Foredune breaching is not part of the proposed development.
- Applicants state that while grading and sand movement will occur for the development of the proposed beachfront protective structure, these construction activities are not for the purposes of maintaining views or preventing sand inundation (Exhibit B). The proposal to construct a beachfront protective structure will protect the foredune.
- BPS will be constructed and maintained (including vegetation maintenance requirements) by the property owners.

## ENVIRONMENTAL, ECONOMIC, SOCIAL & ENERGY CONSEQUENCE ANALYSIS SUMMARY

- Applicants state the ESEE demonstrates consequences that would result from the construction of a beachfront protective structure at the subject location are not significantly more adverse than what would typically result from the same proposal being located in a different area that would or would not require a Goal 18, IM 5 exception. Applicants add that there are only two differences between the proposed exception area and the other sites:
  - The proposed exception area is much larger than individual property elsewhere and while the adverse environmental impact of building a beachfront protective structure at the subject location is greater than for a single property, the impact will be temporary given the impact area will be re-covered with sand, replanted and monitored.
  - An environmental benefit will result from this proposal for a larger area as a greater area of the foredune (not just an area within a single lot) will be restored and protected with beach grasses, shrubs and trees.
  - Locating the beachfront protective structure at any other location would not protect the subject properties and related public infrastructure, hence the reason for the exception request.

## TCLUO SECTION 9.030(CRITERIA)

- (a) If the proposal involves an amendment to the Comprehensive Plan, the amendment must be consistent with the Statewide Planning Goals and relevant Oregon Administrative Rules;
- (b) The proposal must be consistent with the Comprehensive Plan. (The Comprehensive Plan may be amended concurrently with proposed changes in zoning);
- (c) The Board must find the proposal to be in the public interest with regard to community conditions; the proposal either responds to changes in the community, or it corrects a mistake or inconsistency in the subject plan or ordinance; and
- (d) The amendment must conform to Section 9.040 Transportations Planning Rule Compliance.

## PUBLIC & AGENCY COMMENTS

- LACK OF EVIDENCE THAT EXCEPTION SHOULD BE GRANTED
- ALTERNATIVES ANALYSIS DOES NOT MEET JUSTIFICATION FOR EXCPETION
- THREAT OF EROSION TO ADJACENT PROPERTIES
- INCREASED THREAT OF FLOOD RISK TO ADJACENT PROPERTIES
- PROTECTION OF EXISTING DEVELOPMENT DOES NOT JUSTIFY NEED TO GRANT EXCEPTION
- EXCEPTION SHOULD NOT BE GRANTED SIMPLY BECAUSE EXCEPTIONS IN THIS AREA HAVE ALREADY BEEN TAKEN
- THREAT OF BEACH ACCESSIBILITY ON STRETCH OF BEACH ADJACENT TO THE SUBJECT PROPERTIES

## DEVELOPMENT PERMIT DISCUSSION
## BEACH & DUNE OVERLAY ZONE, TCLUO SECTION 3.530

- **PERMITTED CONSTRUCTION OF A BPS REQUIRES GOAL EXCEPTION**
- *For the purposes of this requirement, "development" means houses, commercial and industrial buildings, and vacant subdivision lots which are physically improved through the construction of streets and provision of utilities to the lot. Lots or parcels where development existed as of January 1, 1977, are identified on the 1978 Oregon State Highway Ocean Shores aerial photographs on file in Tillamook County.*
- **SITE DEVELOPMENT REQUIREMENTS & DETAILED SITE INVESTIGATION REQUIRED**
- *The report of a Detailed Site Investigation shall recommend development standards to assure that proposed alterations and structures are properly designed so as to avoid or recognize hazards described in the preliminary report or as a result of separate investigations. The report shall include standards for:*
    - *a. Development density and design;*
    - *b. Location and design of roads and driveways;*
    - *c. Special foundation design (for example spread footings with post and piers), if required;*
    - *d. Management of storm water runoff during and after construction.*
- *Summary Findings and Conclusions. The Preliminary and Detailed Site Reports shall include the following summary findings and conclusion:*
    - *1. The proposed use and the hazards it might cause to life, property, and the natural environment;*
    - *2. The proposed use is reasonably protected from the described hazards for the lifetime of the structure.*
    - *3. Measures necessary to protect the surrounding area from any hazards that are a result of the proposed development;*
    - *4. Periodic monitoring necessary to ensure recommended development standards are implemented or that are necessary for the long-term success of the development.*
- **BPS WILL NOT EXCEED 3-FOOT HEIGHT MAXIMUM**

## DEVELOPMENT PERMIT DISCUSSION
## FLOOD HAZARD OVERLAY ZONE, TCLUO SECTION 3.510

- GENERAL STANDARDS
  - ANCHORING
  - CONSTRUCTION MATERIALS & METHODS
  - UTILITIES
- SPECIFIC STANDARDS FOR COASTAL HIGH HAZARD AREAS
  - ELEVATION & PILING CONSTRUCTION (NOT APPLICABLE)
  - MUST BE ENGINEERED DESIGN
  - MUST BE LOCATED LANDWARD OF THE REACH OF MEAN HIGH TIDE
  - PROHIBIT MAN-MADE ALTERATION OF SAND DUNES, INCLUDING VEGETATION REMOVAL, WHICH WOULD INCREASE POTENTIAL FLOOD DAMAGE

## DEVELOPMENT PERMIT DISCUSSION
## FLOOD HAZARD OVERLAY ZONE CRITERIA, TCLUO SECTION 3.150

*Development Permit Review Criteria*

- *(1) The fill is not within a floodway, Coastal High Hazard Area, wetland, riparian area or other sensitive area regulated by the Tillamook County Land Use Ordinance.*
- *(2) The fill is necessary for an approved use on the property.*
- *(3) The fill is the minimum amount necessary to achieve the approved use.*
- *(4) No feasible alternative upland locations exist on the property.*
- *(5) The fill does not impede or alter drainage or the flow of floodwaters.*

- *BPS is not a new or modified Flood Refuge Platform*

## CONCLUSIONS

**ARE THE CIRCUMSTANCES UNIQUE AND EXCEPTIONAL TO JUSTIFY GRANTING AN EXCEPTION?**

**GOAL 18 CRITEIRA FOR BPS MET?**

**BEACH AND DUNE DEVELOPENT STANDARDS FOR BPS MET?**

**FLOOD HAZARD OVELRAY ZONE STANDARDS FOR DEVELOPMENT WITHIN THE SFHA-CRITERIA MET?**

## FINDINGS IN SUPPORT OF APPROVING THE GOAL 18 EXCEPTION REQUEST BY THE PLANNING COMMISSION

- Unique and exceptional circumstances apply to these properties. The subdivision and subsequent development of the lots was done through appropriate land use and permitting processes and were done in good faith.
- Zoning allows for residential development of these properties within the Unincorporated Community of Barview/Twin Rocks/Watseco, an urbanized area committed to urban development through previously taken Goal Exceptions (3,4, 11 and 14).
- Because this area has historically been categorized as a stabilized dune, no Goal 18 Exceptions were needed to be considered or taken for this area at the time of adoption of the Tillamook County Comprehensive Plan.
- Request for Goal 18 Exception is not a self-created issue. At the time of permitting and land use review, development was sited on a stabilized dune. Site conditions that exist today did not exist at the time of development- specifically erosion and ocean flooding.
- In relation to adjacent lots not part of this exception request, granting a Goal 18 Exception does not prevent those who already have a right to rip rap or develop from pursuing same option in the future. It is not right to deny a property owner the same opportunities to protect their property that others are afforded due to grandfathered rights that allow them to take action for protection of their property. (Properties where "development" existed on January 1, 1977.)
- The development standards and criteria of the Flood Hazard Overlay Zone have been met through design and location of the proposed BPS.
- The development standards and criteria of the Beach and Dune Overlay Zone have been met through design and location of the proposed BPS.

## ADDITIONAL FINDINGS BY THE PLANNING COMMISSION:

- Site conditions and environmental factors that impact development are beyond the County's control. At what point does the County's responsibility to protect private properties developed in coastal high hazard areas end?
- Is it the County's responsibility to protect private property?
- Goal 18 recognizes importance of natural function of the beach. Actions should not contribute to loss of a natural resource.
- Goal 18 protects public access to the beach and citizen rights to enjoy the beach. Construction of a BPS will ultimately restrict access to the beach.
- The beach is the natural resource and protecting the resource is greater than the right to protect private property from erosion and ocean flooding.
- Concern of negative impacts to neighboring properties if BPS is constructed. Shorewood RV Park and other properties in the County were identified to support these concerns.
- Lack of demonstration and justification to grant exception through Reasons criteria.
- Blanket exceptions should not be granted. The taking of one exception does not alone constitute or satisfy criteria for granting additional exceptions.
- This decision is precedent setting, as DOGAMI projections indicate conditions are going to get worse, what obligation will the County be under in the future should this exception request be approved?