The Neskowin Coastal Erosion Adaptation Plan June 2013

Tillamook County

Department of Community Development

1510 B Third Street, Tillamook, OR 97141

http://www.co.tillamook.or.us/gov/ComDev/

Development of this plan was supported through financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration.

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Preface

This report is the result of study and examination by the Neskowin Coastal Hazards Committee (NCHC). The NCHC is a Tillamook County *ad hoc* committee formed to respond to the present erosion threat from the ocean in the County and to the beach and community of Neskowin. Since its inception in Fall 2009, the committee has met monthly, with sub-committee meetings more frequently. There have been public meetings to garner feedback and many sessions with experts to gain input, all of which have contributed to this report.

The NCHC has been guided by its mission statement in its work, and the mission is evident throughout this document. The mission and objectives of the committee are as follows:

Mission: The mission of the Neskowin Coastal Hazards Committee is to—in priority order--plan ways to maintain the beach and protect the community through short term and long term strategies; recommend to state and county agencies and officials ways to maintain the beach and protect the community; and explore ways to plan for and adapt to the potential future changes in the Neskowin coastal area.

Objectives: 1) Become more knowledgeable about past and current dimensions of the situation and study expert projections for the future. 2) Provide information to alert Neskowin beach users to potential dangers of coastal hazards. 3) Investigate options (short and long term) for maintaining the beach and preserving the community. 4) Publish Committee findings and advocate actions likely to be most effective in fulfilling our mission. 5) Help garner support and resources necessary to implement agreed upon actions.

The next step in the development of this plan is for the Neskowin Citizens Planning Advisory Committee (CPAC) to solicit community input and support, and develop implementation steps, including public communication, education, and ultimately any necessary ordinance and community plan changes to be adopted by Tillamook County.

It should be noted that this plan is specific to Neskowin but is part of a much larger county and state planning effort. This plan was originally intended to be a "sub-plan" of the countywide adaptation plan that was developed concurrently. The Department of Land Conservation and Development may also use the product of this committee in other communities on the Oregon coast.

This report examines the land use recommendations and active protection measures separately, though knowing they are intricately intertwined. The NCHC continued to explore the active protection recommendations until they were fully developed and ready to be shared with the community. Options for implementing these recommendations were also developed and shared at that time. Land use recommendations listed in this report have been developed to the extent possible by this committee and were then reviewed and processed by the Neskowin CPAC.

Special thanks to Mark Labhart, Tillamook County Commissioner, who has been chairman of the committee and liaison to numerous federal and state agencies, and without whose leadership this plan would never have been developed. Credit for the development of this plan also goes to Bill Busch, Larry Glickman, Randall Koch, Dave Kraybill, Gale Ousele, Pete Owston, Guy Sievert, Alex Sifford, and Charlie Walker, all Neskowin residents; Pat Corcoran, an Oregon State University Sea Grant Extension Coastal Hazards Outreach Specialist, who organized and facilitated our meetings; Tony Stein, Coastal Land Use Coordinator at State of Oregon Parks and Recreation; Laren Woolley, Coastal Shores Specialist, and Matt Spangler, Senior Coastal Policy Analyst, State of Oregon Department of Land Conservation and Development; Valerie Sutton (Soilihi), past Tillamook County Community Development Director; and Dr. Jonathan Allan, Coastal Geomorphologist, Coastal Section Leader, State of Oregon Department of Geology and Mineral Industries, Coastal Field Office, who has shared his resources with the Committee.

A special thanks also to Mitch Rohse, who compiled the first draft of this document under a grant from the Oregon Department of Land Conservation & Development.

Preparation of this report was made possible by financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration.

1. Introduction

In January of 2009, the Coastal Management Program of the Oregon Department of Land Conservation and Development (DLCD) issued a report on the potential impacts of climate change on coastal communities (see "Climate Ready Communities" http://www.oregon.gov/ENERGY/GBLWRM/docs/climate_ready_communities.pdf). The document presented here was prepared by the Neskowin Coastal Hazards Committee (NCHC), representing its best analysis on how to respond to the coastal erosion hazard threats identified in the DLCD report; in this case, specifically for the unincorporated community of Neskowin, Oregon. It is intended for use by the residents and property owners in Neskowin to review and revise based on additional community input and to incorporate into the Neskowin Community Plan, which was last reviewed by Tillamook County in 2001. This document responds to the broader coastal hazards *Framework Plan* draft developed in 2011 for Tillamook County[1] in a way that is specific to the challenges that face the Neskowin community. Neskowin's Community Planning Advisory Committee (CPAC) oversaw the next review process for this plan. The final document will be submitted by the CPAC to the County Planning Commission for review and eventual approval by the County Board of Commissioners.

This plan was initially drafted for the NCHC with the support of a federal grant awarded by the Oregon Coastal Management Program (OCMP) of the DLCD. Laren Woolley, DLCD Coastal Shores Specialist, was project manager. Planning Consultant Mitch Rohse was the lead author of this document.

The current plan for Neskowin is a result of information, ideas, and comments provided by the NCHC, a Tillamook County *ad hoc* advisory committee chaired by County Commissioner Mark Labhart. From its inception in the Fall of 2009, this committee, consisting of state and county officials and local community members, with significant support from Oregon State University (OSU) researchers, has met monthly and spent countless hours learning more about coastal erosion hazards faced by Neskowin (Chapters 2 and 3) and exploring possible methods for dealing with them (Figure 1).

Two subcommittees of the NCHC were especially active in helping to prepare this plan. The Active Protection Subcommittee conducted extensive research and analysis of structural and engineered hazard-alleviation techniques (HATs) as well as non-structural HATs, such as beach nourishment, that might be used in Neskowin. The results of that effort are reflected in this draft plan's chapters on HATs (Chapter 4) and implementation strategies (Chapter 5). The Land Use Subcommittee of the NCHC researched and analyzed policy, planning, and land-use HATs for application within the community. That subcommittee's work is seen mainly in Chapter 5.

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[1] *Adapting to Coastal Erosion Hazards in Tillamook County: Framework Plan, Final Draft, June 10, 2011*. It will be cited throughout this document as the "Framework Plan." The draft Framework Plan is included as Appendix D only for the purpose of providing needed background scientific information and context for the Neskowin *Adaptation Plan*. The draft Framework Plan is currently not in force or effect in the County and will not be unless the County amends its comprehensive plan to specifically include and implement it. As such, no policies or provisions are operative as a result of its inclusion within Appendix D.

This process of recommending both engineered and land-use responses to the potential hazards of future climate change is meant to promote local community participation with an opportunity to customize future actions to community needs and wants.

Figure 1. Neskowin Coastal Hazards Committee meeting at the Neskowin Valley School, May 11, 2010.

The NCHC accepted the evidence that climate changes are affecting wave height, storm intensity, and sea level. The committee did not see any value in debating the causes of climate change. Rather, the committee used evidence of changes in the ocean and in storms over the last 30 years and projections of what the next 50 years may bring. These are projections based on the best available science, and the committee recognizes that this evidence may change as additional information is gathered in the future. Nevertheless, the committee believes that it is best to plan for the possibility of increased threats before they happen. Thus, this draft plan is, first and foremost, about preparedness. It is hoped that this plan is the first of a number of such plans to be developed by and for the communities that line Tillamook County's coast and face the prospect of erosion and related flooding from the Pacific Ocean.

Although some of the information that follows has some indirect applicability to tsunami preparedness, it is primarily a plan for dealing with year-in and year-out coastal erosion hazards rather than catastrophic events related to earthquakes and tsunamis. These latter issues are being dealt with by governmental emergency-management entities.

1.1 How Neskowin's Coastal Erosion Adaptation Plan Came About

During the early 1990s, as Neskowin's Community Plan was being written, coastal erosion was not a concern. The plan did note that, "Most of Neskowin is in the coastal lowlands, which are underlain by easily eroded sediments such as sand dunes."[2] But only a few properties in South Neskowin and The Point had or needed shorefront protective structures such as riprap to protect them from coastal erosion. The great majority of shorefront properties—the lots, cottages, condos and motels atop the main foredune—were protected by a broad expanse of beach. It seemed that the great buffer of sand would last forever. The plan concluded:

> Neskowin's beach is relatively stable, with no net loss or gain of sand on an annual basis. Summer waves generally replace sand lost in winter.[3]

The perception of the beach as "relatively stable," however, was changing even as those words were being written. By the turn of the 21st Century, rising sea level had come to be today's fact rather than tomorrow's theory. Winter-storm wave heights (a key factor in coastal erosion) were increasing dramatically. Geologists discovered solid evidence that Cascadia Subduction Zone earthquakes caused our coastal shores to suddenly drop several feet in the not-so-distant past and seem likely to do so again. The State's Department of Geology and Mineral Industries (DOGAMI) began monitoring erosion along the Oregon coast with new methods and instruments. Eventually, the monitoring revealed that portions of the beach at Neskowin had retreated by more than 50 meters (164 feet) during the decade from 1997 to 2008. During this period, several powerful winter storms caused dramatic narrowing of the beach and erosion of Neskowin's foredune.[4]

The most dramatic of the storms occurred in February and March of 1999. Offshore wave heights reached 13 meters (42 feet), waves overtopped Neskowin's foredune, and the dune escarpment in some places receded several feet per day, cutting deeply into yards of some shorefront properties.[5] In response, owners of shorefront properties in the main part of the village installed riprap. They did so largely under the provisions of a new set of administrative rules that were adopted in 1998, enabling property owners to obtain permits to install riprap when "property is in imminent peril of being destroyed or damaged by action of the Pacific Ocean or waters of a bay or river, landslide, or other natural disaster."[6]

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[2] *Neskowin Community Plan*, Appendix A, page A-1.

[3] *Neskowin Community Plan*, p. 37

[4] The forces and trends summarized here are described in detail in chapters 5 through 8 of Tillamook County's *Adapting to Coastal Erosion Hazards in Tillamook County: Framework Plan,* Final Draft, June 10, 2011.

[5] For a detailed account of these storms and the installation of shorefront protective structures in Neskowin during the late 1990s, see *The Effectiveness of the Emergency Rules of 1998, As Implemented during the Erosion Event in Neskowin Oregon, 1999, by* Amy Windrope, a graduate student in Marine Resource Management at Oregon State University. The unpublished thesis is available on-line at http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/7323/Windrope_Amy.pdf;jsessionid=246464BFB05DC9E3E17F5D1986749B46?sequence=1

[6] Oregon Administrative Rule 736-020-0050(1). The rules for emergency permits (OAR 736-020-0050 through -0070) enable the Oregon Parks and Recreation Department to issue an emergency permit quickly, before going through public review. Such review still must occur, but it can take place after the riprap or other shorefront protective structure has been installed. See http://arcweb.sos.state.or.us/rules/OARS_700/OAR_736/736_020.html

To provide technical data and conduct risk assessments for the county, the DLCD's Ocean and Coastal Management Program (OCMP) partnered with four other agencies:

- Oregon Department of Geology and Mineral Industries (DOGAMI)
- Oregon Parks and Recreation Department (OPRD)
- Oregon State University and OSU Sea Grant
- US Geological Survey (USGS)

In 2010, the DLCD awarded a grant to Tillamook County to develop a plan for identifying areas subject to coastal erosion and adapting to it – an "adaptation plan"—using information and ideas from the agencies listed above. The county contracted with planning consultant Mitch Rohse to write the plan. Throughout the project, the County's Department of Community Development worked closely with the agencies and consultant and helped manage the project.

At its outset, the project was expected to consist of a series of adaption plans, one for each community in Tillamook County threatened by coastal erosion. Neskowin was to be the first of those community adaptation plans. It soon became clear, however, that developing a series of stand-alone adaptation plans for as many as a dozen coastal communities in Tillamook County would cause redundancy and duplication as each community "reinvented the wheel" of adaptation planning. Thus, it was agreed that the project would be modified, to consist of two parts: a broad "framework plan" applicable to the county's entire coast, and a series of "sub-plans" dealing with the specific (and sometimes quite different) erosion hazards and needs of each individual coastal community (Figure 2). Neskowin would be the prototype, the first community to develop an adaptation sub-plan that rested on the foundation provided by the county framework plan.

A first draft of the county framework plan was completed and submitted to county officials in February 2011. It was reviewed and extensively revised in response to comments and new technical information and maps, to produce a revised draft of June 10, 2011. Unfortunately, due to budget and other constraints, the County has been unable to devote its attention to this revised version of the *Framework Plan.* Therefore, the NCHC has decided to move ahead with this adaptation plan independently. The draft *Framework Plan* has been included in this *Adaptation Plan* as Appendix D. It also will be posted on the website for Tillamook County's Community Development Department at http://www.co.tillamook.or.us/gov/ComDev/ when it is ready for public review.

The *Framework Plan* describes coastal erosion hazards in Tillamook County, and it explains the various factors and forces that cause and affect coastal erosion – rising sea level, for example. The *Framework Plan* also catalogs "hazard alleviation techniques" or HATs, measures and steps that can be taken to adapt to or prepare for coastal erosion.

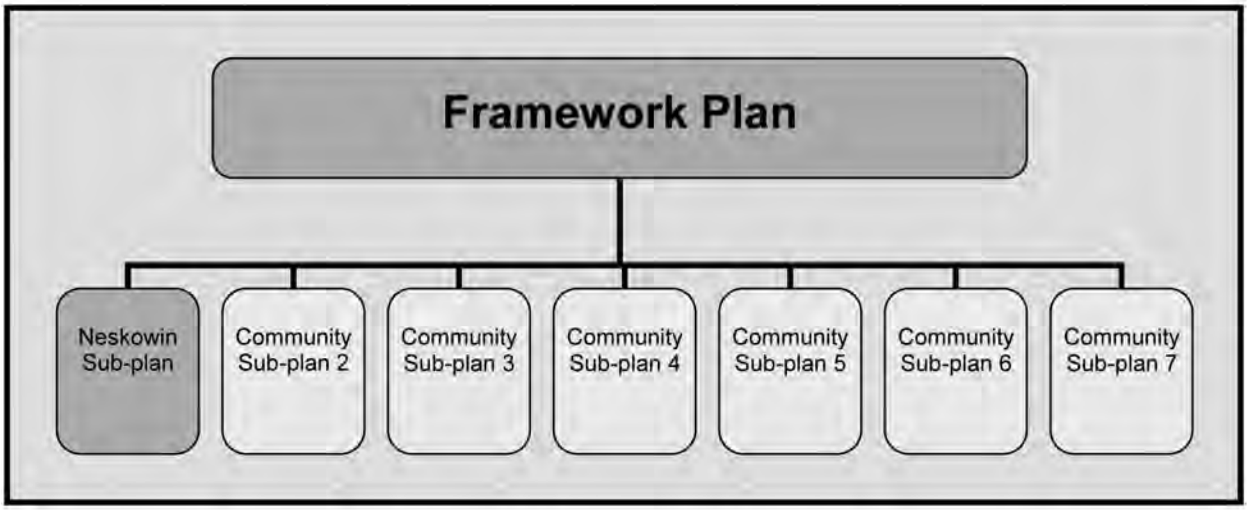


Figure 2. Tillamook County's erosion hazards adaptation plan was originally intended to have two "tiers": a broad framework plan, and a set of detailed sub-plans for the various coastal communities. Neskowin's "sub-plan" (now called the Neskowin *Adaptation Plan*) was to be the first in that series, and for now is a stand-alone plan, until the County adopts the *Framework Plan*.

Neskowin has a community plan that was adopted in 1999 (*Community Plan for the Unincorporated Community of Neskowin*).[7] It is one element of Tillamook County's much larger Comprehensive Plan.[8] This Neskowin *Adaptation Plan* is an extension of and complement to those documents. It does not repeal or replace any of their provisions.

[7] See on-line at http://www.co.tillamook.or.us/gov/ComDev/documents/community/nesk_plan.pdf

[8] The county's plan and related documents are available on-line at https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/2866/Tillamook_County_Compplan.pdf?sequence=1

2. Coastal Erosion Hazards at Neskowin

The Neskowin (a.k.a. Nestucca) littoral cell extends from Pacific City and Cape Kiwanda on the north to Neskowin and Cascade Head on the south. It has become a prime example of a beach out of balance. That is, the normal cycle of winter erosion and summer restoration of sand, with no net long-term loss of sand in the cell, has been disrupted (see Chapter 5 of the *Framework Plan, Appendix D,* for more details about this cycle).

Since the late 1990s, the cell has experienced a net loss of sand (through June 2006) estimated to be between 1.3 million and 2.0 million cubic yards.[9] By any measure, the net loss of as much as 2.0 million cubic yards is a dramatic change. The greatest loss of sand in the cell has occurred in its southern part, at Neskowin. The northern part has experienced accretion, increasing the height of the dune along the Nestucca River spit. This build-up, however, is far exceeded by the net loss of sand over the entire littoral cell.

Since 1997, DOGAMI has been monitoring changes – erosion in many places, accretion in others – in Tillamook County's beaches. This monitoring is described at length in the *Framework Plan's* Chapter 6.

For the Neskowin littoral cell, DOGAMI has been monitoring 15 beach profiles (vertical cross sections of the beach) along the 7 miles from Proposal Rock at Neskowin, at the southern end of the cell, to Cape Kiwanda in the north. Detailed data from each of the 15 profiles in what is called the Neskowin Series can be seen on-line at http://nvs.nanoos.org/.

The profiles indicate a wide variety of conditions. Several profiles in the northern part of the cell, along the beach at Pacific City and Bob Straub State Park, show significant build-up of sand. In the southern part of the cell, the profiles tell a much different story – one of significant and increasing erosion over the 12 years of observation. Several of the Neskowin profiles show landward recession in excess of 100 feet.

The pattern of erosion and accretion in the Neskowin cell is shown graphically in Figure 3, a summary chart of DOGAMI's observations in recent years.

[9] Jonathan C. Allan and Roger Hart. *Assessing the temporal and spatial variability of coastal change in the Neskowin littoral cell: Developing a comprehensive monitoring program for Oregon beaches.* Portland, Oregon Department of Geology and Mineral Industries, 2007, p. 1.

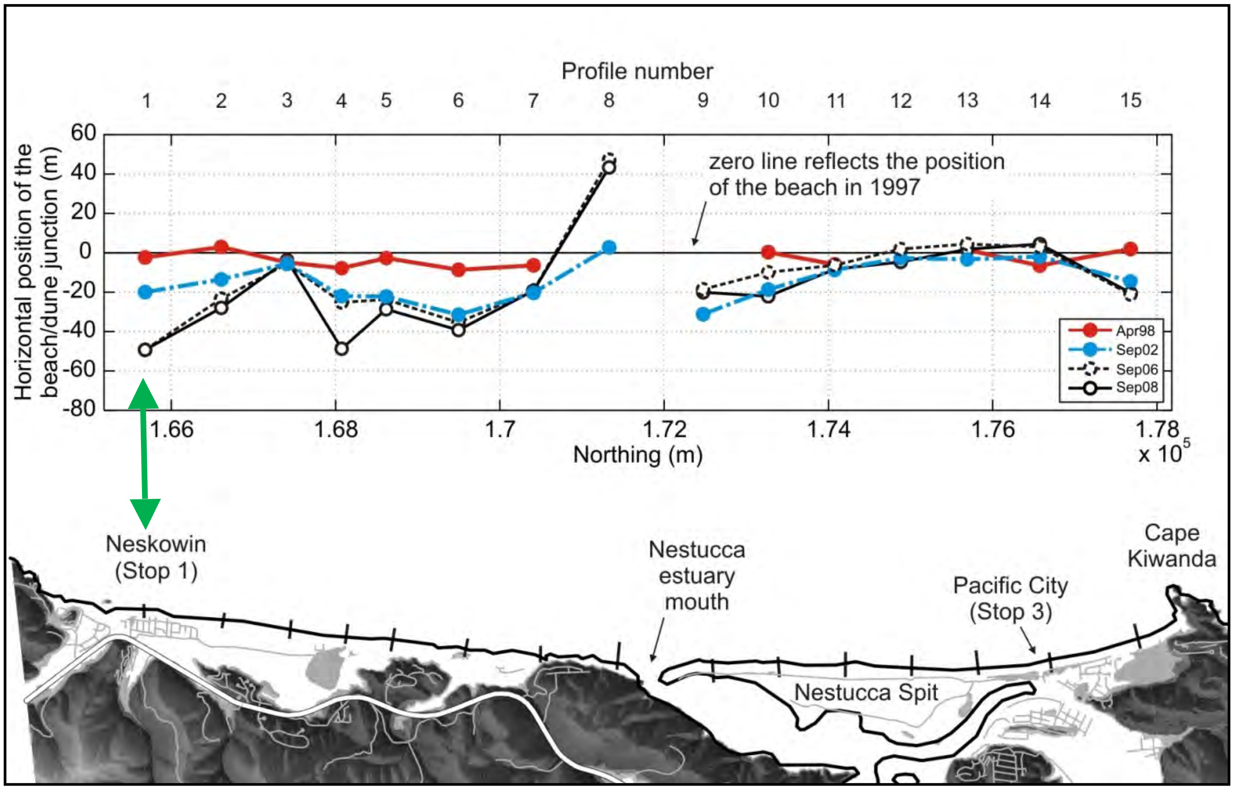


Figure 3. Beach Profiles from Neskowin to Cape Kiwanda, 1998 – 2008 (DOGAMI)

The upper part of the diagram in Figure 3 indicates the horizontal distance in meters that the beach has moved either landward or seaward from the beach's baseline position in 1997. The lower part is a map, with 15 vertical bars, each showing the location of a profile. Profile 1, for example, is shown on the map below as "Neskowin (Stop 1)."

Profile 1 lays near the western the end of McMinnville Avenue, in the central part of the village. Profile 2 is located about roughly 1,000 feet north of Corvallis Avenue. Profile 3 lies about 1,000 feet south of Neskowin North; Profile 4 is about 600 feet north of that subdivision. The remaining profiles are outside the village's community growth boundary.

For each profile, there is a dot showing the position of the beach as observed in the years 1998, 2002, 2006, and 2008. Where a dot appears above the zero line, the beach has moved seaward; i.e., the beach is growing. Among the 15 profiles in the Neskowin littoral cell, only number 8, just south of the Nestucca River mouth, shows any significant growth. Where a dot appears below the zero line, the beach is eroding and retreating landward. Note that in profiles 1, 2 and 4, at central Neskowin and Neskowin North, the beaches retreated as much as 50 meters (164 feet) during the decade of observations.

In 2007, DOGAMI published a detailed analysis of the first ten years of data from their observations at Neskowin.[10] It reported:

> "The beaches remain in a state of net deficit compared to their condition in 1997, with the estimated loss of sand as of June 2006 being on the order of 1 to 1.5 million m^3 (1.3 to 2.0 million yd^3) of sand. Whether the beach recovers fully and how long it takes remain important scientific and management questions, which will be answered as the beaches are monitored." (p. 1)
>
> "Much of the shore between Neskowin and the Nestucca estuary mouth will probably continue to be highly susceptible to major storm erosion events and will likely remain so until sand from the north end of the [littoral] cell has returned to the south." (p. 16)

2.1 Coping with Coastal Erosion

Rapid erosion of the beach and foredune in Neskowin during the late 1990s and early 2000s compelled many owners of shorefront properties to take fast action (Figure 4). For many, the best step – indeed the only step – to protect their property seemed to be installation of riprap revetments.

As a result, most shorefront properties in Neskowin now have been riprapped. Under Statewide Planning Goal 18, *Beaches and Dunes*, shorefront protective structures such as riprap generally are permitted only for properties that were developed (i.e., platted) as of January 1, 1977, or that have been granted an exception to Goal 18. Much of Neskowin's shoreline has been granted such an exception. The following three maps (Figures 5-7) show the properties eligible for riprap by virtue either of having been developed by 1977 or of having obtained an exception to Goal 18. The maps also indicate which areas have been riprapped.[11] The maps were developed from interactive mapping in the *Oregon Coastal Atlas*, at http://www.coastalatlas.net

A word of caution: the *Coastal Atlas* is updated periodically, but its maps are not sufficiently accurate to provide precise, up-to-date information for individual properties. Persons wanting to determine whether a specific lot or parcel is eligible for riprap should contact the Oregon Parks and Recreation Department (OPRD), which administers permits for riprap, at http://www.oregon.gov/OPRD/RULES/oceanshores.shtml#Background

[10] Allan, Jonathan C., and Roger Hart. *Assessing the temporal and spatial variability of coastal change in the Neskowin littoral cell: Developing a comprehensive monitoring program for Oregon beaches*. Portland, Oregon Department of Geology and Mineral Industries, 2007, 31 pp.

[11] In color prints or on-line, riprap appears as an irregular magenta line just seaward of the properties where it has been installed. On monochrome copies, it appears as a black line. The *Coastal Atlas* data are out of date: several properties shown on the maps as having no riprap do indeed have it now.

Figure 4. “High surf and the impact on the riprapped Neskowin shoreline on January 9, 2008.” This photo by Armand Thibault appeared in the *Oregonian* article “State monitoring shifting sands on coast,” March 1, 2009. The exposed area in the foreground was riprapped, but the revetment was damaged by storm waves and was undergoing repairs at the time the photo was taken.

Recently, the Oregon Parks and Recreation Department (OPRD) has developed a riprap construction timeline for the Neskowin shoreline (Table 1). The data were derived from analyzing Oregon Department Transportation (ODT) aerial photographs taken in 1967 and 1984 and from Lidar aerial photos taken in 2005. Some riprap may have been obscured or buried under sand when the photos were taken, making accurate identification and analysis difficult. One example is the tax lots immediately north of Mt. Angel Avenue, where buried riprap was exposed in 2010 after significant dune erosion. This riprap does not show up in the 1967 or 1984 aerial photos, and it was probably placed prior to the Beach Bill or was an unpermitted structure placed shortly thereafter.

Until 1999, the Parks Division of the Oregon Department of Transportation (ODOT) had joint jurisdiction over the ocean shore, and the Division of State Lands (DSL) issued all of the shoreline protection permits. OPRD now has jurisdiction from extreme low water to the Statutory Vegetation Line (SVL) or the line of vegetation, whichever is further inland. Overall, fifty–five (55) Ocean Shore Alteration Permits have been issued since 1967. In many cases, single permits were issued to multiple properties.

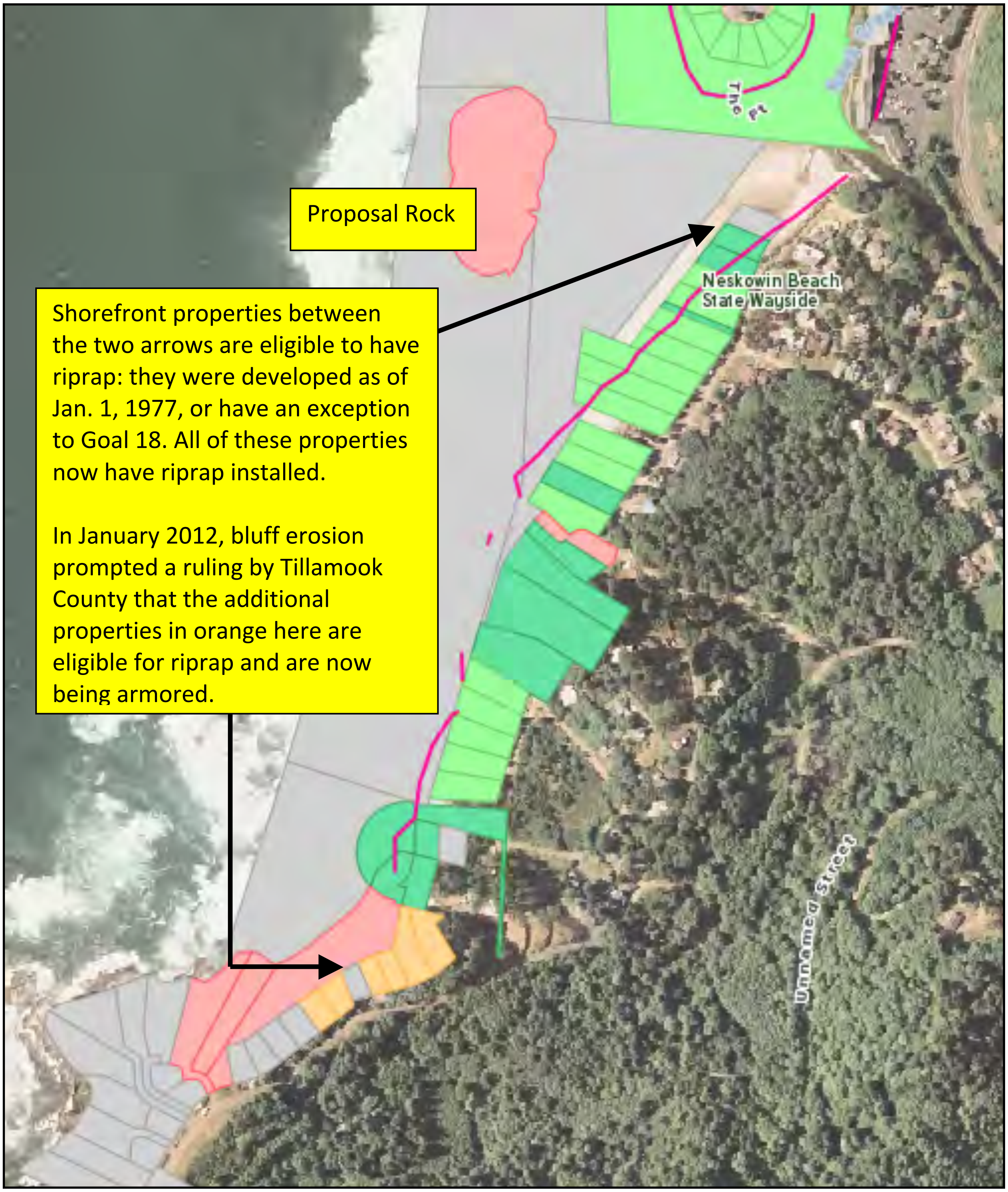


Figure 5. South Neskowin: Most of the shorefront parcels here are eligible to have riprap, and all eligible parcels have riprap. Existing riprap may be repaired, modified, or replaced, but the potential for additional properties to have riprap installed in this part of Neskowin is effectively zero.

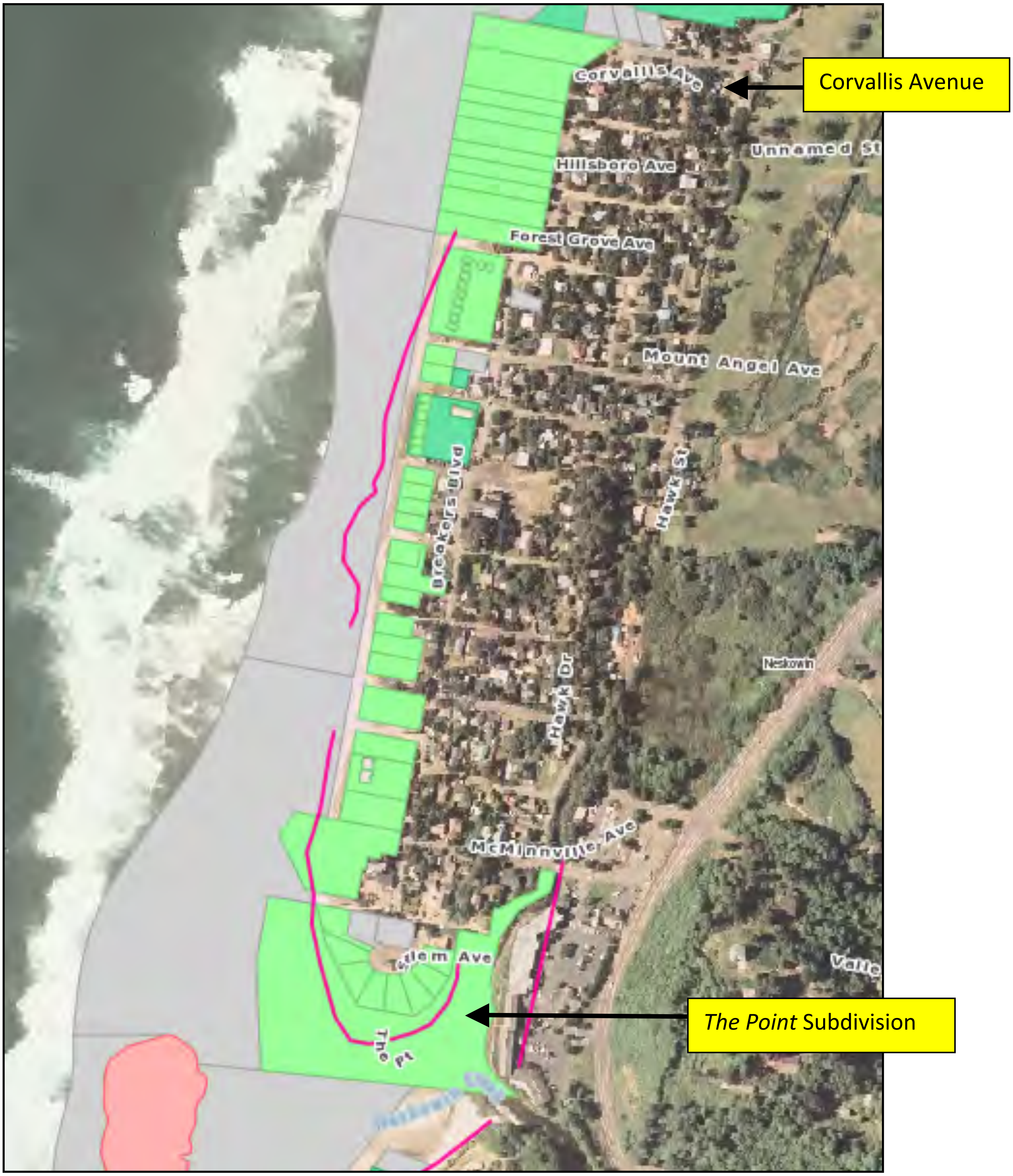


Figure 6. Central Neskowin: All the shorefront properties from The Point (at the bottom of the photo) to Corvallis Avenue at the top are eligible for riprap by virtue of an exception to Goal 18. All have been riprapped.

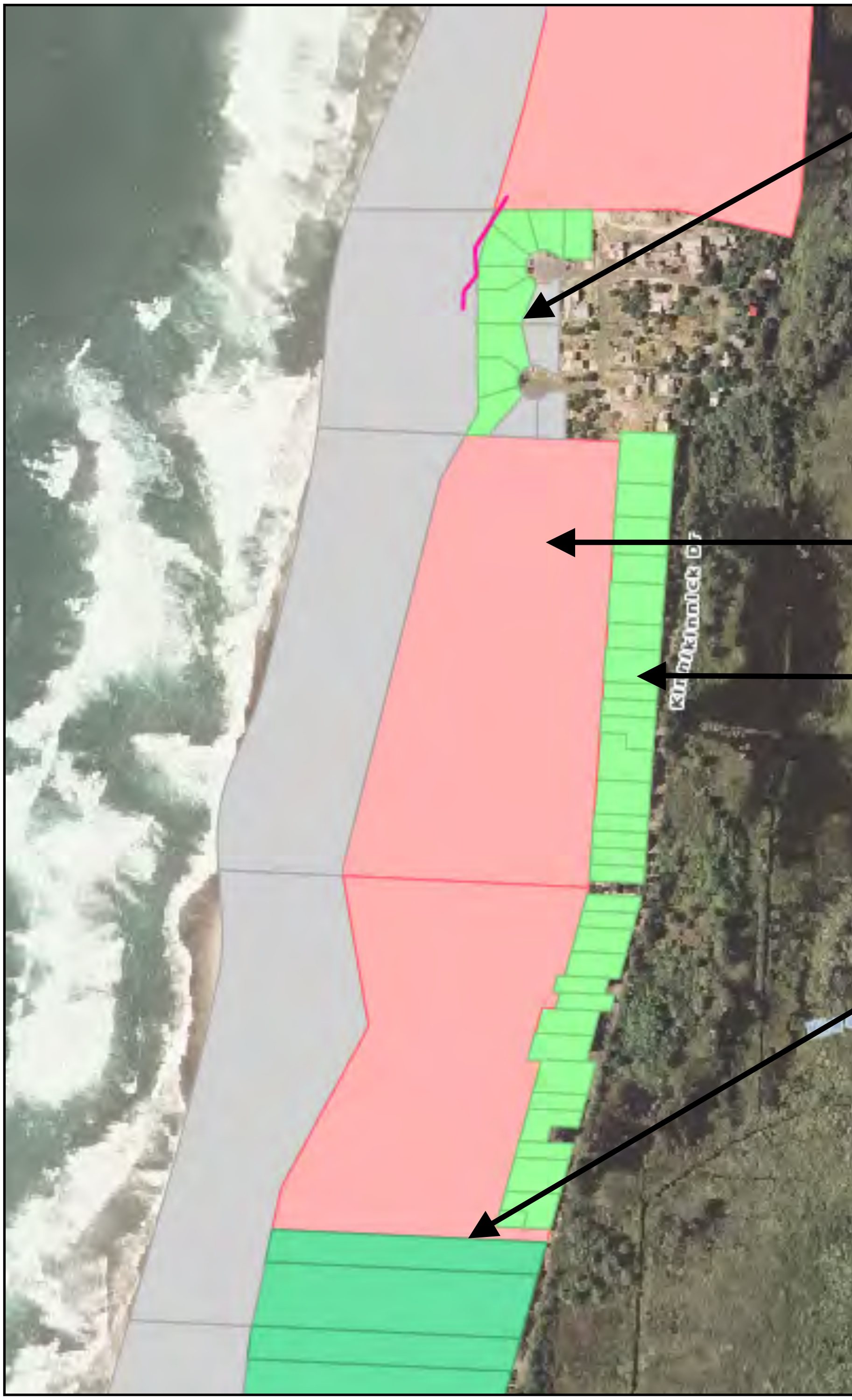


Figure 7. Neskowin North: The shorefront properties in Neskowin North Subdivision are eligible for riprap by virtue of an exception to Goal 18. All have been riprapped. Properties to the north are not eligible.

Two large, undeveloped properties to the south are owned by Tillamook County. They are not eligible for riprap and are not riprapped.

The 31 private residential parcels between the county property and Kinnikinnick Drive are eligible for riprap (per a Goal 18 exception) but have not been riprapped.

Fifteen residential parcels south of the county property and north of Corvallis Avenue (not all shown on this map) with long east-west boundaries were developed as of Jan. 1, 1977, thus are eligible for riprap. None is currently riprapped. The dwellings on these parcels are sited on their east side, adjoining the road.

Table 1. Neskowin Shoreline Protection Timeline				
Time Period	**Location and Total Length of Shoreline**	**(feet)**	**Riprap Constructed (Est.) (feet)**	**(% of shoreline)**
1967	Cascade Head to Neskowin Creek	2,700	900	
	Neskowin Creek to Corvallis Avenue	3,600	150	
	Neskowin North	800	0	
	Total	**7,100**	**1,050**	**15%**
1968 to 1998	Cascade Head to Neskowin Creek	2,700	0	
	Neskowin Creek to Corvallis Avenue	3,600	0	
	Neskowin North	800	0	
	Total	**7,100**	**0**	**0%**
1999 to present	Cascade Head to Neskowin Creek	2,700	1,800	
	Neskowin Creek to Corvallis Avenue	3,600	3,450	
	Neskowin North	800	800	
	Total	**7,100**	**6,050**	**85%**

As the maps and data reveal, the great majority of shorefront properties in Neskowin now have riprap in place. Most of it was installed fairly recently and is in good or fair condition. It should not be assumed, however, that the revetments have solved the problem. They are neither a complete nor long-term solution to coastal erosion hazards, for three reasons:

First, revetments such as riprap have a narrow purpose: to protect shoreline property from erosion. They do not prevent erosion of the beach, and in some cases they may locally increase or accelerate it. It is likely, however, that the shoreline riprap of the foredune provides some protection for adjacent and lower-lying properties in the village area of Neskowin. But, as will be described more fully in Section 2.3, the village area is also vulnerable to intrusion of ocean waters flooding Hawk Creek during periods of storm surges and high tides. Thus, coastal erosion and related hazards such as flooding from the ocean would remain a problem for the community even if its foredune were armored to the maximum extent possible.

Second, riprap is not as durable as its massive appearance might suggest. A typical stone revetment has a design life of 20-25 years and requires continual maintenance. See *Framework Plan*, Section 7.1, p. D-38-D-40. Many sections of the revetments at Neskowin have already been replaced or undergone extensive repair.

Third, some wave overtopping of the riprap has occurred, damaging some buildings behind the revetment and resulting in currently-minor intrusion of ocean water into lower-lying areas behind the riprap. The frequency and severity of such overtopping will likely increase, for reasons discussed in Chapter 8 of the *Framework Plan*: “Climatic and Geologic Forces Affecting Erosion.”

In January 2012, during a strong winter storm with high rainfall, bluff erosion occurred at the south end of Neskowin, and the affected properties undertook a very large, collective riprap project (Figure 5) under a temporary emergency permit issued by OPRD. The riprap partially failed during the November 2012 storms, a permanent permit has not been issued, and the problem has still not been solved as of this writing.

2.2 Active Protection Measures

As noted in the previous section, the problem of coastal erosion at Neskowin (as well as many other coastal communities) is neither confined to the front line of shorefront properties nor solved by armoring the shore to protect them. Severe and continuing erosion is likely to have significant effects on the entire community. That is not to say that every property will be damaged by severe erosion or flooding. But hazards that directly damage only some properties also are likely to damage streets, sewers, water lines and other infrastructure, impose significant public costs, impair local businesses, and harm natural resources – effects that would be felt throughout the community.

Neskowin's search for the most effective shoreline protective structures continues. NCHC's Active Protection Subcommittee conducted extensive research on this. The NCHC tasked the subcommittee to review short-term solutions for better design of shoreline protective structures. It further requested the subcommittee to review and investigate alterations to these structures or even other innovative options that might provide similar or better protection. The subcommittee was also interested in seeing whether better shoreline protective structure design or other innovative options might better preserve the beach and not just focus on protecting beachfront development (and the community in general).

NCHC's overall charge is to attempt to balance these two concepts, of preserving the beach and protecting property. The group collected a great deal of information in working with DOGAMI, OPRD, OSU and others to move forward. It reached a point, however, where it was deemed prudent to contract with a qualified coastal engineering firm to review the Active Protection Subcommittee's options and explore other options in an effort to identify the most viable engineering ideas and concepts and their likely costs. Thanks to generous contributions from the Neskowin community and additional support from DLCD, the NCHC, through the County, contracted with a well-qualified firm to study the situation at Neskowin and make recommendations for erosion mitigation options based on their professional judgment and community-determined viability. The contractor, ESA PWA, with headquarters in San Francisco, CA, issued its final report, Neskowin Shoreline Assessment: Coastal Engineering Analysis of Existing and Proposed Shoreline Protective Structures, in March 2013.The Project Manager was David Revell, PhD, who has considerable experience on the Oregon Coast. Five of the firm's other engineers and PhDs contributed to the effort. The full ESA PWA report and an executive summary prepared by NCHC has been included in Appendix B and has been posted on the NCA Web site. Relevant findings by ESA PWA and the NCHC recommendations concerning them are also found in Appendix B.

2.3 Flooding From the Ocean and Vulnerability of the Hawk Creek Bridge

Coastal hazards in Neskowin are not limited to erosion. Strong storm surges, combined with high tides and heavy rainfall can and have resulted in flooding of Hawk Creek in the Village and Sutton Creek in South Beach. The flooding of Hawk Creek along with resultant influx of heavy woody debris from the ocean and beach have, in the past, created the potential for damage to the bridge over Hawk Creek at Salem Avenue and the utility lines that are located under the bridge's roadway. In addition to the utility lines, this bridge is the only public vehicle access to Highway 101 from most of the Village as well as from Neskowin North.

Figures 8 and 9 illustrate that flooding the Village is not a new problem. Part of the flooding in 1964 was from intrusion of ocean water. The 1998-1999 flooding was primarily from intrusion of ocean water combined with high tides and heavy rainfall. Figures 10 and 11 show a 2010 situation where large woody debris was washed in from the ocean and against the Hawk Creek Bridge, threatening it and the utility lines that run underneath its roadbed. The County removed the debris in December 2010. If storms increase in intensity in the future as predicted, the potential for damage to the bridge as well as problems on private property from flooding will increase. This would be especially true if a huge storm with heavy rain as well as a strong storm surge from the ocean coincided with an extremely high tide. If sea level continues to rise as predicted, the problem will be exacerbated in future years.

Figure 8. Flooding in Neskowin in 1964 looking west, up Salem Ave.

Figure 9. Flooding of Hawk Creek, with water over the bridge, during the La Nina winter of 1998-1999. Also note damage to the deck of the Hawk Creek Café. (Courtesy of Monte J. Fuller and Fuller Films.)

Figure 10. View from bridge, April 2010, showing debris in Hawk Creek, just downstream from the bridge, with the beach in the background.

Figure 11. Massive pieces of wood, some weighing several tons, being loaded onto a large truck by county road crews.

3. Neskowin's Vulnerability to Coastal Erosion Hazards

How vulnerable is Neskowin to coastal erosion and related hazards, such as ocean flooding? That depends, of course, on what is meant by *vulnerability*. Scientists use the word not only to describe the extent to which a community or place may experience a hazardous event but also that place's ability to withstand or quickly recover from the event. Vulnerability thus is defined to be a combination of three essential factors: *exposure*, *sensitivity*, and *resilience*.[12]

Exposure means the amount of a community's assets – population, buildings, resources, and infrastructure – that lie within a hazard-prone area. Exposure is an absolute term typically expressed in units such as people, dollars, or acres. For example, we might say that a community has high exposure because a large number of properties would suffer damage from erosion hazards in a specified period of time.

Sensitivity is a relative term to describe the degree to which a community's assets are exposed to the risk. It is usually expressed as a percentage. For instance, a small community with, say, half of its properties likely to suffer damage from a defined hazard is considered quite sensitive; not because the numbers of properties is large but because such a large portion of the community might suffer damage.

Finally, *resilience* means the capacity of a community to withstand, adapt to, and recover from a hazard event, such as a severe winter storm accompanied by major erosion, landslides, and ocean flooding. Having an adaptation plan such as this and implementing it is one way a community can increase its resilience.

To evaluate the three variables that make up a community's vulnerability to a hazard, we must define what we mean by "hazard." In the case of coastal erosion, the hazard is defined in terms of the total water level (TWL) at that critical point where the beach meets the adjoining dune or bluff. The potential for erosion is greater with higher TWL.

As explained in greater detail in the *Framework Plan, Appendix D,* (page D-29), the total height of the ocean water level at a given beach is the sum of several "wave height factors," such as wave run-up, tide, and storm surge. One can create various scenarios by assuming certain combinations of these variables. For example, the "worst-case scenario" that can reasonably be expected would be a huge storm occurring at high tide after sea level has risen substantially. DOGAMI's scientists have created a variety of scenarios and used them to delineate areas at Neskowin subject to high, moderate or low risk.

To estimate water levels, DOGAMI focused on two scenarios: the 50-year storm (a storm of a magnitude that would be expected to occur once in 50-years) and the 100-year storm. The

[12] These concepts and terms are described much more fully in the *Framework Plan's* Chapter 9, "Assessing Risk and Vulnerability."

former, of course, is the storm more likely to occur. The 100-year storm, although less likely, would do greater damage and affect a larger area. Tables 2 and 3 show the factors used to define the two events.

Table 2. Water Level Calculation: Water Height in Feet at Toe of Dune or Riprap

Wave Factor	50-Year Storm	100-Year Storm
Mean high tide	7.55	7.55
Monthly mean water level	1.31	1.31
Storm surge	3.28	5.58
Sea level rise	0	1.31
Wave run-up*	14.34	17.72
Total Water Level	**26.48 feet**	**33.47 feet**

*Wave run-up is estimated using the assumptions shown in the Table 3.

Table 3. Factors for Computing Wave Run-up

Factor	50-Year Storm	100-Year Storm
Beach slope	4 percent	4 percent
Deep-water significant wave height	47.6 feet	52.5 feet
Wave period	17 seconds	20 seconds
Deep-water wave length	1,481 feet	2,050 feet

The calculations in Tables 2 and 3 were performed by NCHC members, based upon data provided to the NCHC by DOGAMI's Jonathan Allan, for the committee meeting of April 29, 2010.

3.1 DOGAMI Maps

Using scenarios for "design events" such as the storms described above, DOGAMI has defined and mapped coastal erosion hazard zones along the two main types of beaches found in Tillamook County, dune-backed and bluff-backed.[13] Dune-backed beaches typically erode more rapidly, in direct proportion to severity of storms and wave run-up. In contrast, erosion of bluff-backed beaches is most directly related to geological make-up of the bluff. The four types of hazard zones are summarized in Table 4. Subsequent land-use recommendations in this

[13] DOGAMI's analysis for the Tillamook County coast is published as DOGAMI Open File Report (OFR) 0-01-03, *Evaluation of Coastal Erosion Hazard Zones Along Dune and Bluff Backed Shorelines in Tillamook, Oregon: Cascade Head to Cape Falcon*, by J.C. Allan and G.R. Priest, 2001.

Table 4. Beach Erosion Hazard Zones in Tillamook County[14]			
Dune-Backed Beaches			
Zone	**General Location of Zone**	**Zone Width**	**Design Event**
Active Hazard	Sandy beach and foredune face	Width of beach plus dune face*	Significant erosion or accretion occurring now
High Risk	250-280 ft landward of dune-beach junction	250-280 ft	**Large storm:** Wave heights to 47.6 ft; above-average high tide; storm surge 3.3 ft
Moderate Risk	Next 415-460 ft landward of high-risk zone	415-460 ft	**Severe Storm:** Wave heights to 52.5 ft plus sea level rise of 1.3 ft
Low Risk	Next 460-510 ft landward of moderate-risk zone	460-510 ft	**Extreme Event**: Severe storm plus 3.3 ft subsidence from CSZ earthquake
Bluff-Backed Beaches			
Zone	**General Location of Zone**	**Zone Width**	**Design Event**
Active Hazard	Sandy beach; bluff toe; bluff face to top edge	Width of beach plus bluff face*	Significant erosion or accretion occurring now
High Risk	First 20-30 ft landward of bluff top edge	20-30 ft**	Gradual erosion at low mean rate over 60 yr period; bluff talus at ideal angle of repose
Moderate Risk	Next 40 to 250 ft land-ward of high-risk zone	40-250 ft**	Block failures, retreat to angle of repose; erosion over 60-100 yr period
Low Risk	Next 60-490 ft landward of moderate-risk zone	60-490 ft**	Erosion over 60-100 yr period; maximum slope failure; erosion to ideal angle of repose
* The active hazard zone is typically west of the beach/dune interface except in those areas without riprap.			
** Width of zone varies widely with composition of material in bluff			
This table summarizes information from Jonathan C. Allan and George R. Priest's *Evaluation of coastal erosion hazard zones along dune and bluff backed shorelines in Tillamook County, Oregon: Technical report to Tillamook County*, Portland, Oregon Department of Geology and Mineral Industries, 2001. 93 pp.			

document combine the "Active Hazard," "High Risk," and "Moderate Risk" zones shown in Table 4 into one "regulatory trigger" zone. The land-use recommendations (detailed later in Section 5.2) do not pertain to the "Low Risk" zone. DOGAMI's maps of all four coastal erosion hazard zones in the Neskowin area are shown in Appendix A, Attachment 10. The regulatory trigger zone used by the NCHC in making its land use recommendations is shown in Figure 12.

Figure 12. DOGAMI Maps (2) of Coastal Erosion Hazard Zones in Neskowin as modified by the NCHC.[15]

The following two pages are modified DOGAMI maps of hazard zones in the Neskowin area, from "Neskowin," Appendix E, page 91, DOGAMI Open File Report (OFR) 0-01-03, *Evaluation of Coastal Erosion Hazard Zones Along Dune and Bluff-Backed Shorelines in Tillamook, Oregon: Cascade Head to Cape Falcon*, by J.C. Allan and G.R. Priest, 2001.

The modification to the maps consists of combining the Active Hazard, High Risk, and Moderate Risk zones identified in OFR 0-01-03 into one Hazard Zone, colored blue for dune-backed beaches and purple for bluff-backed beaches.

The first map starts about 1,200 feet north of Neskowin North and ends just south of Mt. Angel Avenue. The second map starts about 1,000 feet north of Corvallis Avenue and extends south to just beyond the historic beach area.


Coastal Erosion Hazard Zones
Moderate-HighDune Erosion Hazard
Bluff Erosion Hazard
N
W
E
S
500 250 0 500 1,000 Feet
Coastal Erosion Hazard Zones obtained from DOGAMI Open File Report O-01-03
Evaluation of Coastal Erosion Hazard Zones Along the Dune and Bluff Backed
Shorelines in Tillamook County, Oregon, Cascade Head to Cape Falcon
by Jonathan C. Allan and George R. Priest, 2001


Coastal Erosion Hazard Zones
Moderate-HighDune Erosion Hazard
Bluff Erosion Hazard
N
W
E
S
500
250
0
500
1,000 Feet
Coastal Erosion Hazard Zones obtained from DOGAMI Open File Report O-01-03
Evaluation of Coastal Erosion Hazard Zones Along the Dune and Bluff Backed
Shorelines in Tillamook County, Oregon, Cascade Head to Cape Falcon
by Jonathan C. Allan and George R. Priest, 2001

For the Neskowin area, Oregon State University has also expanded on the DOGAMI maps to incorporate estimates of probabilities that various types of coastal hazards may occur. This work by OSU is described in Appendix A, Attachment 11. **The OSU maps constitute a pilot project, done especially for the Neskowin area**, not the entire county. The OSU project deals only with dune-backed beaches and assumes that the riprap is not present. The recently completed OSU maps have been peer reviewed or officially adopted by any agency. They are, however, valuable in helping the County and the community better estimate the risk faced by various areas in Neskowin.

Appendix A, Attachment 11 describes the OSU work in detail. The OSU maps and analysis suggest the following:

- The "design event" is a total water level with a one-percent probability. This is a severe event that, like the "100-year flood," has a one-in-a-hundred chance of occurring in a specified time period (the present to 2050 for purposes of this plan).
- If such an event occurs in the next few decades (i.e., by 2050), areas along the village's shoreline have the "highest risk for erosion." There is a 98 percent confidence level (near certainty) that hazardous erosion would occur here. These are shown in the golden-brown band on maps in Attachment 11.
- Areas immediately east (landward) of that high-risk area also might experience hazardous erosion. Properties in much of Neskowin face some risk, ranging from just under 98 percent odds of erosion to as little as 2 percent. The farther west (seaward) its location, the closer the odds of a property's erosion come to the 98 percent confidence level.

To reiterate, while the OSU project yields useful insights, only official DOGAMI maps and related data and analysis are used in this plan to estimate which areas of Neskowin are at significant risk from erosion hazards.

3.2 Estimating Vulnerability to Coastal Erosion Hazards

Researchers from DOGAMI and OSU have used erosion maps and data to determine the *exposure* and *sensitivity* of coastal communities in Oregon to coastal erosion.[16] Tables 13 and 14 cover the communities from the northern border to the south as far as Yachats. The chart on the left, showing the number of residents living in the active, high, or moderate erosion zones, is one measure of a community's exposure to erosion hazards. The chart on the right, showing the percentage of a community's residents living in the active, high, or moderate erosion zones, indicates a community's sensitivity to coastal erosion.

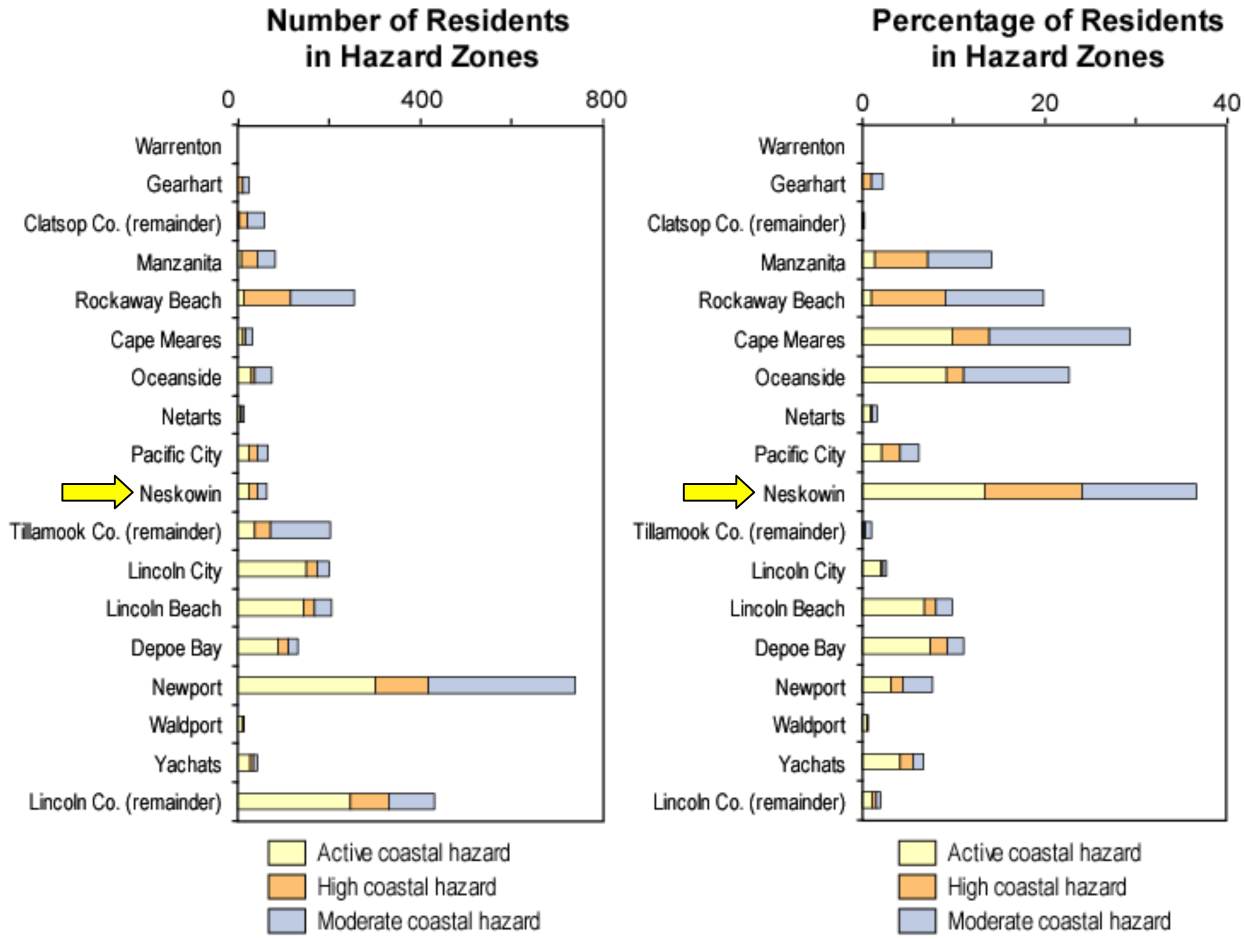


Figure 13. *Exposure* and *sensitivity* of coastal communities in Oregon to coastal erosion.

Note that Neskowin has much in common with the other Tillamook County communities of Manzanita, Rockaway Beach, Cape Meares, and Oceanside. All are small communities that do not have large numbers of people living in the three most hazardous erosion zones. By that measure, then, they may be considered to have only moderate exposure to erosion hazards. But, because a large *percentage* of their residents reside in the three erosion zones, the communities do have a high sensitivity to such hazards – and Neskowin is the most sensitive of all.

Another way to assess such vulnerability is to consider the extent of a community's developed land that lies within the erosion zones (Figure 14). The data show that the same five Tillamook County communities are quite vulnerable to erosion hazards. They also reveal that rural areas of the county have significant amounts of developed land in erosion-prone areas.

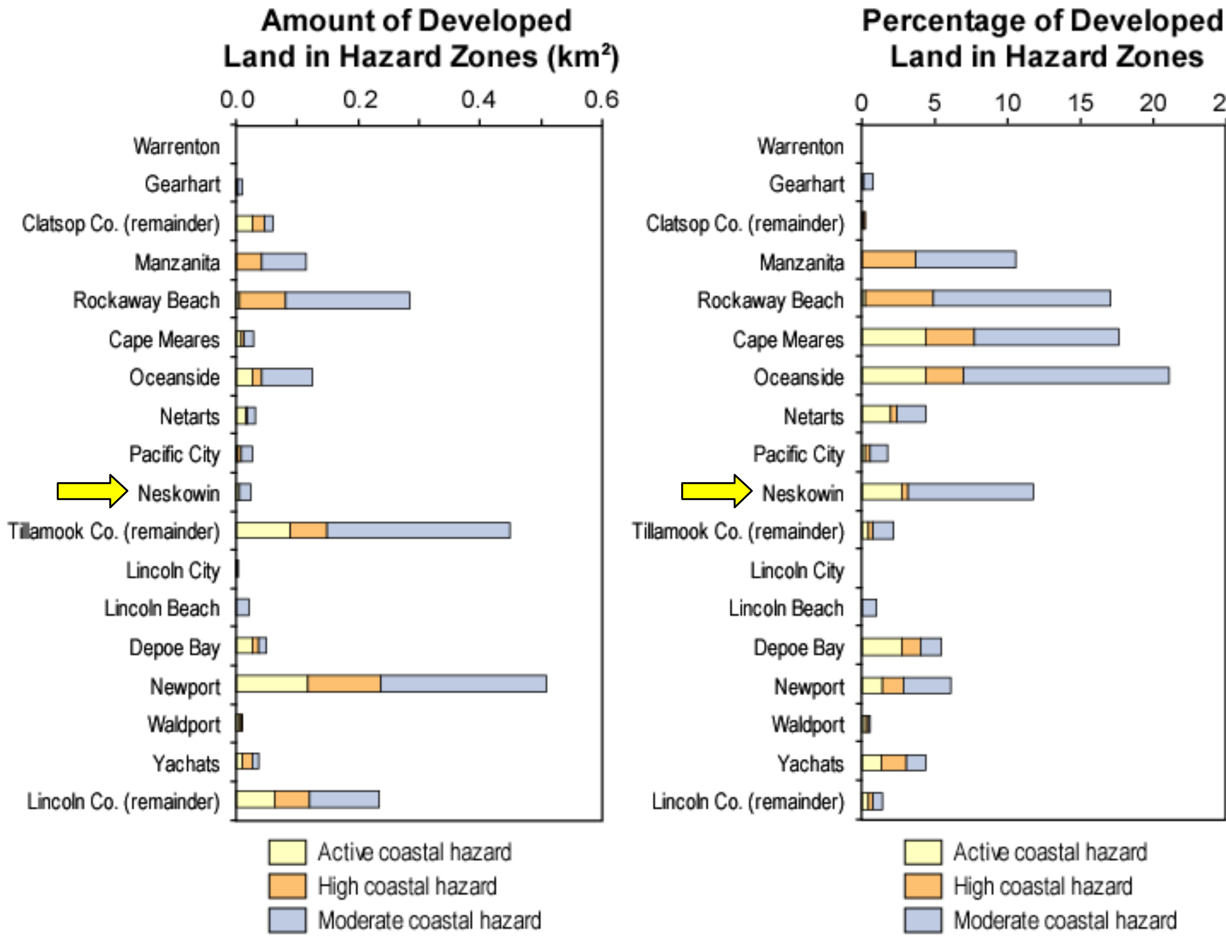


Figure 14. Amount and percentage of developed land on the Oregon coast that is in hazard zones.

Again, the small communities of Manzanita, Rockaway Beach, Cape Meares, Oceanside, and Neskowin are revealed to have only moderate *exposure* to coastal erosion in terms of the absolute number of acres of developed land in the active, high, or moderate erosion zones. But because they all have a high percentage of developed land in erosion-prone areas, they are *sensitive* to the hazard – and thus should be considered vulnerable.

3.3 Lifelines

Neskowin is especially vulnerable to coastal erosion and related hazards, such as flooding from the ocean and tsunamis, because of its severe lack of “lifelines.” Lifelines, as described on pages 98-99 of the *Framework Plan*, are linear utility or infrastructure networks or segments thereof that are essential to public health and safety during and after a hazard event. The most critical lifelines for Neskowin and other coastal communities are east-west collector streets from the beach to Highway 101. During hazardous events, these collectors – *if* they are not flooded or otherwise damaged — enable vehicles and pedestrians to escape to safer areas.
Neskowin’s lifelines are few in number and highly vulnerable. For most of the village and all of Neskowin North, the only public vehicular escape route from vulnerable areas along the beach is along Salem Avenue, across the Hawk Creek Bridge, to Highway 101. For *all* of the South

Neskowin, the key escape route is South Beach Drive, across the gated bridge over Neskowin Creek, to Highway 101.

Both of these lifelines are narrow two-lane streets. Both pass through low-lying areas vulnerable to flooding. Both have critical “pinch-points” where damage to or destruction of a bridge would restrict or eliminate the lifeline. A private road exists between the golf course and the State Wayside, and the property owner has stated that this could be used for emergency evacuation. But it is currently impassible by vehicles because of vegetative growth and is liable to be seriously flooded in any serious event that knocks out the Hawk Creek Bridge.

While Salem Avenue is the only lifeline route available to vehicles leaving the central and northern parts of Neskowin, pedestrians may have another option: a “Tsunami Trail” that extends east from Hawk Street across the southern end of the Neskowin Marsh Unit of the Nestucca Bay National Wildlife Refuge toward Highway 101 and higher ground (Appendix A, Attachment 6). A tsunami evacuation sign on the shoulder of Hawk Street designates the western end of the trail. The US Fish and Wildlife Service (USFWS), the management agency for the Refuge, says that they plan to continue maintaining the trail for public access (Appendix A, Attachment 4, letter of April 28, 2011, from Rob Lowe, USFWS, to Tillamook County). Unfortunately, the trail’s potential as an effective lifeline is highly questionable. Much of the area it crosses is a wetland that is often inundated. The trail thus is likely to be underwater at the very time it is needed most.

4. Hazard Alleviation Techniques (HATs)

Neskowin's vulnerability to coastal erosion hazards raises an obvious question: What measures can we take to reduce or eliminate impacts of hazardous events like beach erosion or flooding? Such measures are referred to as *hazard alleviation techniques* or HATs. Think of them as the tools that make up our toolkit for adapting to coastal hazards.

An extensive array of such tools is available. They are described in Chapter 11 of the County's *Framework Plan* (Appendix D). But, as with any toolbox, not all tools in the box are equally useful for any given situation. Some HATs that might be useful on, for example, a sheltered bay or barrier island in the southeastern United States are not suitable for use in Neskowin, which is exposed to direct attack from the powerful waves of the northeastern Pacific Ocean. We observe the same variability when comparing one property to another: riprap may be appropriate for a particular dune-backed beachfront lot but of little value for a bluff-backed lot only a few hundred feet away. We thus cannot prescribe one or even several HATs that will work in all situations. Rather, we must eliminate HATs that seem generally unsuitable for Neskowin, evaluate the remainder, and focus on those most likely to be of value.

The information in Table 5 starts us on that course. It lists all the tools generally known to have been of use in adapting to coastal erosion hazards in the United States and in several other countries. It then designates those that seem suitable, unsuitable, and possibilities for future use in Neskowin.

Of the 40 HATs shown in the Table 5 were readily found to be "Not Suitable" for Neskowin. In some cases, these rejected HATS are simply are the wrong tool. They would not alleviate erosion damage in an active wave environment. In other cases, the HAT in question is inappropriate because it is too costly, State law may also prohibit its use on the Oregon coast, or it would significantly reduce or eliminate public access to beaches. It should be noted that the HATs analysis was done prior to contracting with ESA PWA.

Table 5. General Suitability of Main Hazard Alleviation Techniques (HATs)

S = Suitable for at least some sites or areas
N = Not likely to be suitable for any sites or areas
M = May be useful or necessary in the future

1. Hard (Structural) HATs		
Revetment (Riprap)	**S**	Riprap revetments are widely used in Neskowin
Bulkhead	**N**	Minimal use in Neskowin; effective only for a few special situations
Seawall	**N**	Minimal use in Neskowin; more costly than riprap
Sand bypass	**N**	Not applicable; mainly useful on types of beaches found on US east coast
Sill (for "perched beach")	**N**	Not applicable; mainly useful on types of beaches found on US east coast
Groin	**N**	May have regulatory problems; expensive; major barrier to public access
Jetty	**N**	Not applicable to Neskowin; used only at mouths of navigable waterways
Artificial reef	**N**	Not suitable: very high costs; doubtful effectiveness
Breakwater	**N**	Probably not suitable: very high costs; doubtful effectiveness
Reef breakwater	**N**	Probably not suitable: very high costs; doubtful effectiveness
2. Soft (Nonstructural) HATs		
Beach nourishment	**M**	Not yet used in Neskowin, but could prove effective; costly; source of sand uncertain
Dune management	**M**	Difficult to use with a depleted sand base; requires Dune Management Plan
Dune stabilization	**M**	Some potential in northern part of village, along with dune management
Buffer dune	**N**	Probably not feasible in Neskowin's active wave environment
Dynamic riprap	**N**	Used at Cape Lookout, but not feasible at Neskowin; would eliminate sandy beach
3. Development HATs		
Abandon structure	**S**	May be only alternative for certain properties at extreme risk
Elevate structure	**S**	Feasible for some existing structures; could be required of some new structures
Make structure movable	**S**	Feasible for some existing structures; could be required of some new structures
Relocate structure	**S**	Feasible for some existing structures at extreme risk
Relocate community	**M**	Contingency plan could be developed for extreme events or unforeseen changes
Relocate infrastructure	**S**	Feasible (and perhaps necessary) in some at-risk areas
Control runoff and drainage	**S**	Low-cost, practical HAT for most bluff-backed sites and some other sites
Modify structure	**S**	On some sites, structural reinforcement or modification may alleviate erosion hazard
4. Policy and Planning HATs		
Compensatory mitigation	**M**	Potential source of revenue for erosion-control measures; not now used in Oregon
Conservation easement	**M**	Could be applied to at-risk sites or areas, in conjunction with other measures
Floor elevation COD (*Condition of Development*)	**S**	Now done through FEMA; higher standards could be adopted for sites or areas at risk from ocean flooding
Require geologic reconnaissance (COD)	**N**	Proposed by some as an alternative to full-fledged geotech reports; geologists have expressed doubts about effectiveness and propriety of superficial geological evaluations
Require geotech report (COD)	**S**	Important HAT for reducing erosion and flooding risks for future development; already required for development of some types in Tillamook County
Indemnification (COD)	**S**	Important HAT for reducing public's liability for private risk-taking
Land div. standards (COD)	**S**	Current land division standards could be increased for at-risk sites and areas
Liability waiver (COD)	**S**	Important HAT for reducing public's liability for private risk-taking
Safe-site requirement (COD)	**S**	Useful land-division requirement to ensure proper site selection of future development
Floodplain management	**S**	Now done through FEMA; higher standards could be adopted for at-risk areas
Hazard-area overlay zone	**S**	Important HAT for reducing erosion and flooding risks for future development
Prohibition of development	**S**	Development of some sites at high risk from coastal hazards could be barred.
Public notice and review	**S**	Essential part of any community or county action; can be time-consuming and costly
Public education	**S**	Important part of any community or county action; can be time-consuming and costly
Purchase of development rights	**M**	Used to establish conservation easements; costly
Setback	**S**	Setbacks from dune or bluff scarps could be required of future development
Transfer of development rights	**M**	Could be useful with abandonment or relocation HATs; require changes in state law

One must be careful, however, not to imply greater precision in Table 5 than actually exists. A thorough analysis and comparison of all these HATs and their suitability for Neskowin would require detailed studies from engineers, geologists, planners, and other specialists. Such detailed analysis is far beyond the scope of both this plan and the ESA PWA engineering analysis. The entries in the table therefore should not be considered definitive solutions. Rather, they summarize ideas and opinions of community members, County officials, and planners who gleaned information from a variety of sources:

- three years of readings and research;
- discussions with experts from key state agencies such as DOGAMI;
- advice from officials at agencies such as the U. S. Army Corps of Engineers;[17]
- three well-attended public workshops in Neskowin;
- monthly meetings of the NCHC;
- periodic meetings of special subcommittees formed by the NCHC.

Thus, the information in Table 5 is a preliminary guide, not a prescription. The same can be said for the recommendations resulting from the ESA PWA Report that are described in Appendix B. The task of using such preliminary information to make informed policy choices is also explained in the next chapter.

The most notable (and disappointing) characteristic of the HATs in Table 5 is a lack of immediate benefits. Only a few of the suitable or potentially suitable HATs can be put into place and begin reducing risk within a year. Most are planning and policy measures that will apply mainly to new development and thus reduce risk quite gradually, over several decades. If Neskowin had a large amount of vacant, buildable land on its shorefront, the likely effects of new planning and policy measures would be more significant. But even a casual glance at the hazard maps shows few vacant lots in the at-risk areas. With such little potential for new development in these crucial areas, new hazard alleviation ordinance provisions will affect only a small fraction of the properties.

In short, there is no single solution to the coastal erosion hazards facing Neskowin. Instead, the hazards must be managed with a combination of measures, most of which will bring results slowly and incrementally.

5. Implementation Strategies

The preceding chapter outlines the universe of possibilities, presenting a brief description of all the HATs that could conceivably be used to mitigate or adapt to coastal erosion hazards. It then winnows those that clearly seem inappropriate or inapplicable for Neskowin. But that initial winnowing is only a first step. The next step is the essence of planning: to compare and evaluate likely options and then decide which ones would likely be most effective.

To consider such policy choices, the NCHC divided the labor between two groups: the *Active Protection Subcommittee* and the *Land-Use Subcommittee*. A third group, the *Implementation Subcommittee*, worked on developing ways to carry out the policy choices proposed by the two other subcommittees. The subcommittees have regularly reported their findings at the monthly NCHC meetings, and the full committee has carefully reviewed these reports.

5.1 The Active Protection Subcommittee's Recommendations

The active protection group analyzed the "hard" (structural) and "soft" (non-structural) HATs summarized in Sections 1 and 2 of the "HATs table" (Table 5). In 2011, the subcommittee presented its research during a public meeting in Neskowin on the Spring Break weekend and a public workshop on the Memorial Day weekend. During the Memorial Day session, the subcommittee surveyed the attendees to ask their opinion of the active protection measures. The results are summarized in Table 6 and Figure 15. Note the strong vote favoring protection for the Hawk Creek Bridge.

The Active Protection Subcommittee then used its research and the public input to prioritize various HATs for use in Neskowin. It placed a high priority on these three "short-term" measures:

- Continue maintenance of riprap revetments;
- Increase the height and uniformity of riprap revetments;
- Find ways to increase protection for Hawk Creek Bridge.

To clarify, the Active Protection Subcommittee looked at measures that might be taken in the short term, including tasks that would have long-term impacts.

The subcommittee concluded that the remaining active-protection measures – beach nourishment; seawalls and bulkheads; breakwaters; and groins – probably would not be effective or feasible for Neskowin. The group agreed, however, that it would be useful for the community to continue investigating other active-protection options, innovative structures, and inshore wave-energy conversion devices. See Appendix A, Attachment 9 for a summary of the group's findings made prior to receiving the coastal engineering report.

Table 6. Results of Public Survey of May 29, 2011: Preferences Regarding Active Protection Measures

Short-Term Options	(1) First Choice	(2) Medium priority	(3) Lower Priority	(4) Total (unweighted)
Continue to maintain riprap revetment	14	20	8	**42**
Increase height and uniformity of riprap revetment	11	14	12	**37**
Protect Hawk Creek Bridge	47	15	10	**72**
Long-Term Options				
Beach nourishment	2	4	6	**12**
Seawalls and bulkheads (standalone)	0	0	0	**0**
Breakwaters, continuous or intermittent (offshore barriers parallel to shore)	3	1	1	**5**
Groins (barriers perpendicular to shore)	1	1	2	**4**
Continued investigation of options, innovative structures, and inshore wave-energy conversion devices	2	19	23	**44**
"None of the above"	0	4	13	**17**
TOTALS	**80**	**78**	**75**	**233**

As mentioned previously in Section 2.2, a contractor, ESA PWA, with headquarters in San Francisco, CA, was hired to further research for active protection measures in Neskowin. ESA PWA issued its final report, *Neskowin Shoreline Assessment: Coastal Engineering Analysis of Existing and Proposed Shoreline Protective Structures*, in March 2013. The full ESA PWA report plus an executive summary prepared by NCHC has been included in Appendix B and has been posted on the NCA Web site. Relevant findings by ESA PWA and the NCHC recommendations concerning them can also be found in Appendix B.

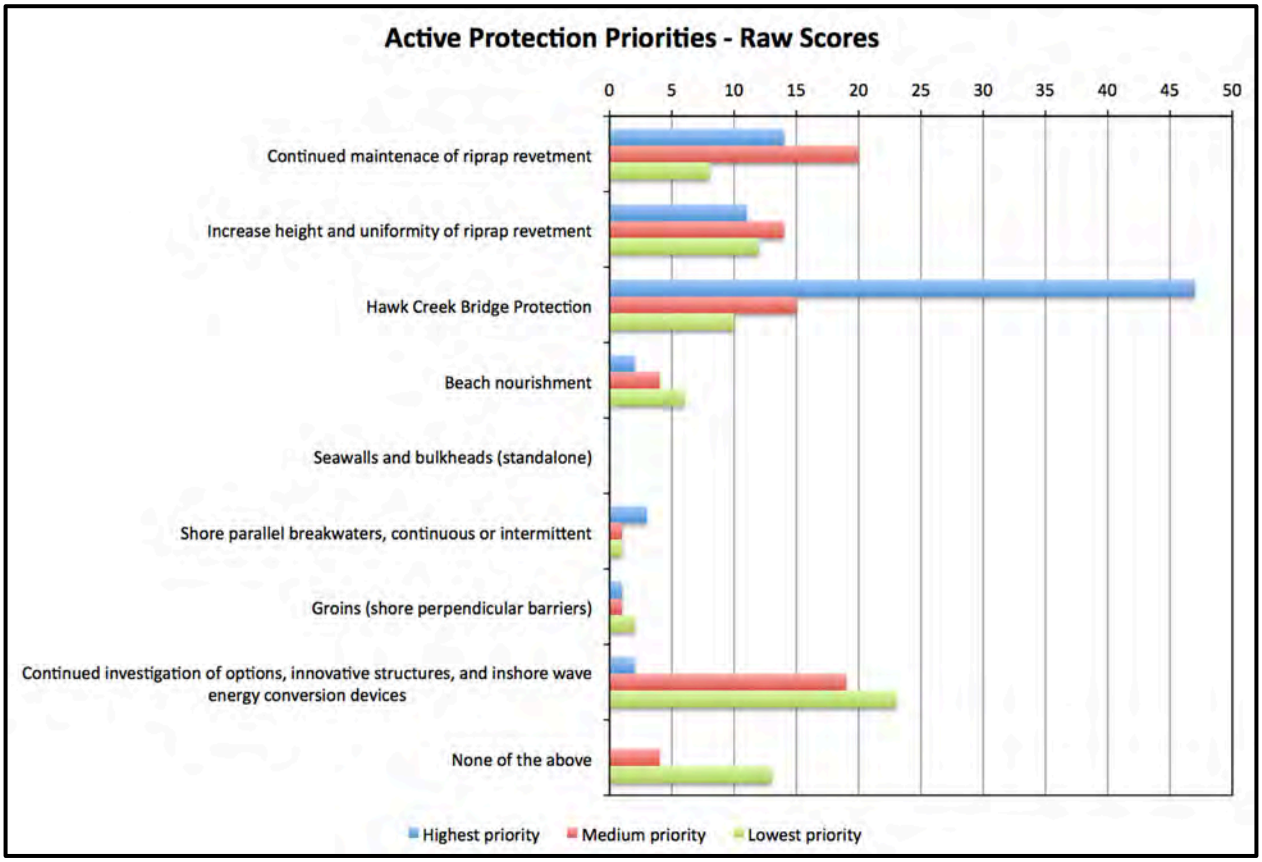


Figure 15. Graph showing results of public survey of May 29, 2011, for active protection measures.

5.2 The Land Use Subcommittee's Recommendations

While the Active Protection Subcommittee focused on engineering measures, the Land Use Subcommittee directed its attention to other long-term measures. These are the HATs summarized in Sections 3 and 4 of Table 5. Most of them involve new or amended plan and code provisions that would affect future development. For example, suppose the County development code was amended to increase the distance buildings must be set back from the shoreline. Code amendments would apply only to new construction and thus would increase community resilience to coastal hazards only gradually, over a period of many years. During the 2011 Memorial Day meeting, the committee surveyed the attendees to ask their opinion of the land use options. The results are summarized in Table 7.

After many meetings and considerable research, the Land Use Subcommittee proposed the strategies and actions set forth below. They focus on which of the long-term hazard alleviation techniques (HATs) should be used for Neskowin and on how they should be implemented.

Table 7. Results of Public Survey of May 29, 2011: Preferences Regarding Land Use Options				
	(1) First Choice	(2) Medium priority	(3) Lower Priority	(4) Total (unweighted)
Strengthen Floor Elevations/Floodplain Rules	4	3	2	**9**
Strengthen Geotechnical Report Standards	3	5	0	**8**
Special Building Techniques	5	6	1	**12**
Indemnification/Liability Waiver	0	3	1	**4**
Setback from High Hazard	4	4	8	**16**
Safest Site Requirements	3	1	2	**6**
Land Division Standards	3	8	12	**23**
Hazard Area Overlay Zone	2	1	6	**9**
Prohibition of Development	29	9	3	**41**
Strengthen Public Notice/Review	0	7	6	**13**
Strengthen Public Education	2	3	3	**8**
Conservation Easements	1	3	2	**6**
Control Runoff and Drainage	8	10	7	**25**
Elevate Existing Structures	0	1	3	**4**
Make Structures Movable	1	2	1	**4**
Relocate Structure	3	3	1	**7**
"None of the above"	6	5	7	**18**
TOTALS	**74**	**74**	**65**	**213**

1. Hazard Area Overlay Zone

DOGAMI has developed Coastal Erosion Hazard Zone (CEHZ) maps for Tillamook County. Following are subcommittee recommendations related to this hazard information:

a. The County should adopt the DOGAMI Hazard Risk Zone Maps, modified to a single "regulatory trigger" hazard zone that combines DOGAMI's active hazard, high risk, and moderate risk zones and disregards the low risk zone as an initial step in developing appropriate zoning regulations in areas of significant risk from coastal erosion hazards.

b. The Neskowin Community Sub-Plan should include the modified Neskowin area CEHZ maps shown in Figure 12. The County should restructure the County hazard regulations to incorporate and reference these maps. The key sections of the County's zoning provisions, as currently constituted, are Section 3.085 and Section 4.070.

The County should consider specific regulations related to these hazard zones. Many of the hazard alleviation techniques discussed within this section (Section 5.2) could utilize this hazard map information.

2. Public Notification, Geologic Reports, and Regulatory Review

a. The subcommittee recommends that the County review its hazard requirement procedures to clarify what is required and make sure procedures and processes are clearly outlined in the applicable land use code provisions.
b. The subcommittee recommends that the County utilize additional requirements for coastal development (e.g., Coastal Processes and Hazards Working Group, or CPHWG, requirements for new development on oceanfront properties). These requirements are found in Appendix A, Attachment 12. They include additional requirements for geologic reports done in ocean front locations to insure that reports are adequate for these areas.

3. Special Building Techniques

a. The subcommittee reviewed a variety of special building techniques most of which are already being utilized by the County. Special building techniques addressing coastal hazards currently implemented in Tillamook County include:
    - Tillamook County, through the Oregon Structural Specialty Code requires construction techniques to protect against strong winds events (or wind loading); most coastal sites require the highest code standards (110 mph, Exposure D).
    - Tillamook County through Oregon Structural Specialty Code requires Seismic Design Category D2 standards, which are the highest design standards for seismic safety applicable in Oregon.
    - Velocity Flood Zone ("V-Zone") standards (contained in both County code and state building code), are applicable to structures in designated coastal flood hazard areas. These standards require that the elevation of the lowest floor be at least three feet above the base flood elevation, that open piling or column-type foundations be used, and that the structure be engineered to withstand predicted hydraulic loading (wave impacts) from the base flood event.

    Note that the County has limited ability to modify these requirements, which are established by the State of Oregon.
b. There are no current standards or requirements addressing moveable building design. The County may wish to explore this concept in certain designated hazard zones; standards may address both building design (e.g. wood-frame construction only; no

slab-on-grade foundations) and building site access. For example, the County could require houses in a high-risk area to be built on a stem wall foundation, which would allow a house mover to relocate the structure if coastal erosion threatened to destroy it. The County might also require a road access large enough to move the structure out of harm's way. The full NCHC has not made any recommendations at this time for moveable building design.

4. Safe-Site Requirement/Land Division Standards (also Prohibition of Development)

These potential hazard alleviation techniques (HATs) all include various concepts related to directing new development away from higher-risk hazard areas. Currently the County does not have any substantive requirements related to safest-site location or limiting land divisions within hazard areas. The subcommittee recommends that the County look into these issues as indicated below.

a. **Safest Site requirement:** The County should consider adding a "safest site" standard to both Section 3.085 (Beaches and Dune Overlay Zone) and Section 4.070 (Development Requirements for Geologic Hazard Areas). This standard would specify that proposed development on parcels within hazard areas must be located within an area most suitable for development as determined by a qualified professional as part of a geologic report. It would also be subject to standards within Section 4.070 of the County zoning ordinance.
b. **Land Division Standards**: The County should consider adding standards within its land division ordinance that:
    - Limits creation of parcels to those which include a building site located outside the hazard risk zone; and
    - Prohibits adding to the number of existing housing units (including ADUs) on a developed parcel that is within the hazard zone, and
    - Prohibits the creation of additional multifamily dwelling units (including ADUs) within the hazard zone, and
    - Requires location of all new infrastructure (e.g., roads, water and sewer lines) to be landward of the hazard zone, whenever possible.

5. Setback Requirements

Currently the County administers an oceanfront setback line (OSL) as directed by Section 3.085 (4)(A)(1)c of the County zoning ordinance. A significant reason for the OSL is to protect views by establishing a fairly uniform line that development would need to stay behind. The County could more fully consider other things besides view protection within the OSL regulations in order to establish a safer setback from hazards. The County could consider the following:

a. The County could integrate FEMA velocity flooding information into development of a revised oceanfront setback area.[18] One example might be that the County could direct that no development be authorized in a velocity flooding area, or if the entire property is located in a velocity flooding area the house must be located as far inland as possible;

b. The County should clarify within existing zoning code provisions the existing restrictions to additional seaward development on developed parcels within foredune/deflation plain areas. Statewide Planning Goal 18 and related County policy prohibits development on beaches, active foredunes, other foredunes subject to ocean undercutting and wave overtopping and deflation plain areas subject to ocean flooding. Additional development seaward of existing development is not authorized in these areas.
c. The County could review other options related to amending the OSL, including potentially utilizing the new FEMA V-Zone analysis in some way.
d. The County could also consider, for bluff-backed shorelines, a standard setback to bluff edges for new construction. On approach could be based on a 50+ annual erosion rate (plus buffer distance). This option would require a geologist to identify an annual erosion rate. The annual erosion rate would then be multiplied by the number of years (e.g., 50) to get a minimum setback. The County could also include a "buffer" distance beyond this potential minimum erosion distance to be used in the setback calculation. This approach could include a minimum setback and should apply a larger setback if recommended by the associated geologic hazard report.

6. Runoff and Drainage Controls

It is clear that improper drainage and runoff from development can contribute significantly to coastal erosion. The County's current zoning code addresses runoff and drainage but only in a cursory way. Substantive requirements, if any, would come via a required geologic report in a case-by-case manner. We recommend that the County:

a. Develop a comprehensive set of standards designed to reduce runoff and drainage that contribute to coastal erosion.
b. Include within these standards a requirement that conformance with those standards be considered by the qualified professional who prepares the site-specific geologic report.
c. In developing these standards, the County should consider recently developed standards in other coastal communities.

7. Relocation of Structures within Existing Lots or Parcels

a. The committee recommends that the County implement zoning code standards to provide incentives for the relocation of structures from higher to lower risk areas. Such incentives would include relaxation of normal setbacks, lot coverage or similar dimensional standards.
b. The County should also explore the use of a threshold for "substantial improvements" and/or "substantial damage" to existing structures in high-hazard areas. Such a threshold would act as a trigger requiring the relocation of structures in high-risk hazard areas to a safer part of the parcel when such structures are substantially expanded and/or restored. County flooding provisions have similar requirements in some circumstances in place currently. For example, if the threshold was 50% and a structure was damaged to a point greater than 50 % of its value, or a property owner proposed

improvements to the structure greater than 50% of its value, then the structure would need to be relocated to a safer part of the parcel before improvements could be made. This standard could be incorporated into the “safe site” provision discussed above, if adopted.

8. Indemnification and Liability Waivers

a. Indemnification involves a requirement for permit applicants in designated hazard areas to indemnify and defend the County in any action for damages related to hazard area development brought by a third party. Indemnification has been proposed in some jurisdictions, but significant questions have been raised regarding the legal effectiveness of such a requirement. The subcommittee does not recommend that the County develop indemnification requirements.
b. A liability waiver requires a permit applicant to hold the County harmless in the event permitted development is damaged by natural hazards. This requirement has been implemented in some jurisdictions, and the County may wish to explore applicable examples and research the relevant experience of jurisdictions using it. The subcommittee recommends that the County explore this HAT.
c. Neither indemnification nor liability waivers actually reduce risk of damage from natural hazards, but they can serve to reduce the risk of the public incurring costs associated with this damage. They also may provide some disincentives to proposing development in higher-risk areas of a site.

9. Public Education

We believe that citizens who educate themselves regarding existing and potentially increasing coastal hazards will make better choices regarding proposed development near those hazards. Although “public education” is not generally thought of as a regulatory function of local government, we suggest that the County consider the following concepts:

a. Develop a comprehensive plan policy or policies indicating that increasing coastal hazards will affect citizens more and more in the future and that public education on these hazards is critical to help protect citizens of the County. Further, these policies should indicate that County officials should prepare and provide materials and develop opportunities to notify and inform key audiences.
b. Within the County’s zoning code, develop a disclosure standard which would require, as part of any development permit within applicable hazard zones, a disclosure form to be filed with the County (potentially within the deed record for the parcel) to indicate such things as potential hazard risk zone(s) on the subject parcel, known geologic reports for the parcel, and other known geologic risks on the parcel.

10. Conservation Easements

State law (ORS 271.725) authorizes the County to acquire conservation easements by purchase or donation. Generally, such easements limit the permissible use and development of the land subject to the easement. An easement in an area subject to coastal hazards could prohibit high-risk or other inappropriate development. Conservation easements could provide an alternative, voluntary mechanism to limit or prohibit development in high-risk hazard areas. Given the low likelihood that the County could devote any significant funding to the acquisition of conservation easements, action on this HAT should be limited to a general plan policy supporting the voluntary use of conservation easements in areas subject to coastal hazards. The County also could promote tax incentives currently available to owners who place easements on their property. In addition, the zoning code could provide development incentives for allowing a portion of a property to be placed within a conservation easement. These development incentives could include things such as relaxation of normal setbacks, increased density on the remaining portion of parcels, and greater allowable building heights.

11. Federal Emergency management Agency (FEMA) Floodplain Provisions

a. The County currently has a significant set of requirements to address flooding. For example, the County currently regulates floor elevation, or the elevation that the first habitable floor must be above, well above the State minimum 1 foot above the base flood elevation (BFE) and requires floor elevation to be 3 feet above BFE. The base flood elevation (BFE) is the extent or level of flooding that the FEMA analysis indicates would occur based on a one (1) percent change of occurring in any given year. It is also called a "100 year flood" and it is a significant flooding event. The subcommittee does not recommend modifications at this time.
b. FEMA remapping of flood hazards will occur within the next two years and the County will be required by FEMA to adopt the new analysis and associated Flood Insurance Rate Maps (FIRMs).
c. Related to elevation of structures as indicated above, the subcommittee indicates that, given the existing building height requirements and the potential for increasing BFE's, restrictions on building heights may seriously limit future building.

The subcommittee does not recommend modifications to the FEMA Floodplain provisions at this time.

These recommendations of the Land Use Subcommittee and the NCHC were passed on to the Neskowin CPAC in August 2012. Over the next nine months, the Neskowin CPAC further developed these recommendations, and also developed ordinance language that could be used to implement them. The revised recommendations and proposed ordinance language can be found in Appendix C. [IMPORTANT NOTE: THESE RECOMMENDATIONS AND PROVISIONS WILL BE ADOPTED BY TILLAMOOK COUNTY IN THE APPROPRIATE LOCATIONS WITHIN THE TILLAMOOK COUNTY COMPREHENSIVE PLAN AND IMPLEMENTING ORDINANCES. THEIR REFERENCE IN THIS DOCUMENT AND IN APPENDIX C PROVIDES DOCUMENTATION AND HISTORICAL PERSPECTIVE ONLY AND THEY ARE NOT NECESSARILY THE PROVISIONS IN EFFECT.]

5.3 Strategies for HATs That May Prove Suitable or Necessary ("Contingency HATs")

The six HATs discussed below are measures that *could* prove to be useful or necessary someday in the event of sudden, extreme or unexpected changes in conditions related to coastal erosion. The NCHC describes them as "contingency HATs" because we do not recommend employing any of them under current conditions but recognize that one or more of them might come to be considered feasible in the future. For example, an unexpectedly rapid increase in relative sea level and in the height of deep-water storm wave heights might cause such severe erosion that some parts of the community would need to be relocated. This is not something we expect, but it is a contingency for which we should be prepared. Toward that end, we recommend steps to explore these options further. NCHC recommendations for each are shown in italics at the end of each section below.

1. Purchase of development rights (PDR)

Purchase of development rights may be a suitable hazard alleviation technique for certain at-risk properties in Neskowin. With this HAT, a public agency or non-governmental organization would buy the rights to develop private properties that are at great risk or that enhance the community's resilience by remaining undeveloped. With PDR, the purchasing agency or non-profit entity pays the private landowner to establish a conservation easement, which bars future development of the property. The easement runs with the land, and thus carries on in perpetuity, even as the land is transferred from one owner to another. The best-known example of PDR is the worldwide program run by The Nature Conservancy.

Purchase of development rights has proved to be quite an effective method of protecting natural and cultural resources. As might be expected, the chief limitation of this HAT is its cost: the price of development rights for a shorefront property typically is quite high.

The implementation strategy here, then, is threefold:

- *Identify undeveloped properties in Neskowin where PDR would be an effective means of reducing risk from coastal erosion hazards;*
- *Encourage key agencies and NGOs to purchase the rights to develop such properties; and*
- *Negotiate with landowners and buyers to establish effective conservation easements using the PDR process.*

2. Transfer of development rights (TDR)

Transfer of development rights is a complex process in which the owner of a "receiving property" may buy development rights from a "sending property." The owner of the sending property thus gets reimbursed for a lost right to develop, while the owner of the receiving property gains a right to develop more intensively on his or her property. For example, a local government or the state might prohibit the owner of a vacant high-risk beachfront parcel from building there but compensate the owner by awarding him or her rights to develop an upland parcel (perhaps farm or forest land) more intensively than otherwise would be allowed under current zoning.

Transfer of development rights is perhaps best known for its use in implementing the Tahoe regional plan in California and Nevada. In Oregon, it has been used to implement a regional plan in southern Deschutes County, in the La Pine area. Transfer of development rights has not been used much elsewhere in Oregon, but that may change, with the passage in 2009 of two new laws intended to encourage its use. Senate Bill 763 enables local governments to develop and adopt TDR programs, while House Bill 2228 established a pilot program to employ TDR as one method of protecting farm and forest lands.[19] The new laws are ambiguous on the extent to which they enable TDR to be used for land *not* zoned for farming or forestry. We have raised this issue with the Department of Land Conservation and Development and explained how TDR might be appropriate for some of Neskowin's at-risk residential lands. We also have requested that the agency initiate rule making if that is necessary to enable such use of TDR. If, however, the new laws do indeed prohibit use of TDR for residentially zoned lands, only the legislature could change that: the state agency (LCDC) cannot use its rule-making authority to amend a statute.

An implementation strategy for TDR thus would consist of three main steps:

- *Determine whether TDR would be an effective risk-management technique for any at-risk properties in Neskowin.*
- *Either clarify that use of TDR is permissible for "sending areas" in residential zones, or pursue rule making or legislation to authorize such use of TDR.*
- *Identify noncoastal lands in Tillamook County that would be appropriate as TDR "receiving areas."*

3. Abandonment of buildings

To abandon a structure that has been damaged or destroyed or that is in imminent danger from coastal hazards is, of course, a last resort — an action taken only when all other measures have failed. It is a HAT only in the sense that risk to human life may be reduced by having a building's occupants leave it to seek a safer place. It is not an option the community wants to pursue. It does, however, have two significant policy implications that should be considered if there is any likelihood that buildings might have to be abandoned.

The first is simply the question of where the former occupants of abandoned buildings might go. This should not be confused with the matter of where persons *temporarily* displaced by a natural hazard may seek shelter. It is, instead, the longer-term issue of where and how persons or businesses permanently displaced by a storm or flooding may find a new place to live or work. The state or community could ease such transitions by providing relocation assistance.

The second policy issue revolves around hazards (and perhaps legal issues) resulting from abandoned structures. For example, if a beachfront home is badly damaged by ocean flooding, leaving hazardous debris on a public beach and a dilapidated structure in danger of collapse, who bears responsibility for removing those hazards? Further, if the property has a riprap structure, who assumes responsibility for maintaining it, because the failure of riprap on one property endangers other properties on either side and behind?

To determine whether such issues might become significant in Neskowin, the community may follow a two-step strategy:

- *Determine the number of owner-occupied dwellings and businesses in areas of greatest risk from coastal erosion hazards.*
- *Determine what public programs or resources are available to facilitate relocation of such structures and to reduce or eliminate hazards to the public from such structures.*

One concept that may be of use here is that of a "de-commissioning plan." Such plans often are required for certain large industrial and energy-generation facilities. The plans specify how a facility and its site will be managed in the event of a plant closure. Typically, the plan specifies that the facility's owner is responsible to restore the site and eliminate any hazardous conditions. Often the builder or owner of such a plant is required to maintain a performance bond in the amount necessary to cover de-commissioning costs. Such plans offer two main benefits: they ensure that (a) plant closure is an orderly process that addresses all significant issues and (b) the public does not get left "holding the bag" for costs incurred when the plant owner abandons the facility. Using this same idea, a coastal community might require a similar sort of agreement from anyone who proposes to build in a high-risk area where natural hazards might someday force the building to be abandoned.

4. Relocation of infrastructure

In adaptation planning, public attention often is focused most intently on protection of private property, especially dwellings. But a community's vulnerability is by no means determined solely by the extent to which private structures are exposed to or protected from coastal hazards. Vulnerability also is very much a function of how public infrastructure such as roads, bridges, sewers, and water lines are designed and placed. By relocating or reinforcing key infrastructure, a community can greatly increase its capacity to withstand hazardous events.

This is especially significant for Neskowin because many of its utilities are concentrated in one highly vulnerable place: the Hawk Creek Bridge. Major water and sewer lines are suspended under the bridge. Damage to or destruction of the bridge thus would not only eliminate vehicle and pedestrian access to much of the village but also would leave many buildings without sewer or water services.

An implementation strategy for Neskowin to deal with infrastructure relocation would consist of two main steps:

- *Identify key service systems or facilities that are vulnerable to coastal erosion hazards.*
- *Work with system and facility managers to determine how such infrastructure can be made less vulnerable by relocating those parts of it most exposed to hazardous events and conditions.*

5. Compensatory mitigation

One of the most critical questions regarding any hazard alleviation technique is "How will this be paid for?" The main methods of funding – federal grants, state assistance, local improvement districts, etc. – are summarized in Chapter 12 of the *Framework Plan* (Appendix D)*.* Often, availability of federal or state funding determines which HATs can – or cannot – be employed. Thus, a small community may have little choice in determining which HATs to use or how to use them.

One funding technique that may give small communities more choice and greater control is the use of a compensatory mitigation fee. This is a charge leveed on property owners to compensate for certain impacts of their development on the community. It does not appear to have been used in Oregon. We find it mentioned in the state of Hawaii's *Coastal Erosion Management Plan* with no explanation of its use or effectiveness. In that state, where the armoring of many miles of coastline has caused massive erosion of beaches, the revenue from the fee is to be used for the expensive and continuing process of "beach nourishment" (replenishment of sand). Hawaii's *Coastal Erosion Management Plan* describes the fee thus:

> **Compensatory Mitigation.** If environmental impacts cannot be minimized, the concept of compensatory mitigation can be employed where the landowner contributes to the state or county an amount related to the costs to develop or replenish similar beach resources elsewhere.[20]

Using such fees, a community could build a "hazard alleviation fund." This would be similar to the reserves created by private homeowners' associations, which collect monthly fees from members, and then use the money for structural maintenance — to replace roofing and siding, for example. Money from the hazard alleviation fund could then be used to for whatever HAT seems most appropriate.

Whether compensatory mitigation can be used in Oregon and how effective it might be are questions that remain unanswered. *If Neskowin or Tillamook County proposes to use such a funding method, the first step toward implementation would be to conduct a feasibility study to answer questions such as these:*

- *Is compensatory mitigation funding authorized under Oregon law?*
- *Are there successful examples of such funding that could be emulated?*
- *Is such a system likely to generate enough revenue to be an effective source of funding?*

6. Relocation of community

The county should explore the feasibility of and methods for relocating the entire community or substantial portions of it. Among the questions that need to be answered are these:

a. What conditions or hazard events should be regarded as sufficient to trigger a relocation effort? Should the threshold for action be *prospective*, triggered by conditions such as a rapid and unforeseen increase in sea level, or *reactive,* undertaken only in response to a hazard event such as catastrophic erosion and flooding associated with a subduction-zone earthquake?

b. Since Neskowin is primarily a community of second homes, where the majority of dwellings are not occupied by year-round residents and where proximity to the beach is the primary attribute for which many such homes are bought and used, is relocation to an upland area some distance from the beach either feasible or desirable?
c. What nearby upland areas, such as state-owned or federal lands, might be suitable for relocation?
d. To what extent can TDR and PDR be used to establish such an alternate location?
e. What are the likely costs to relocate all or most of the community, and are such costs proportional to the expected benefits?
f. What state or federal programs or agencies might be available to provide funding or technical assistance for relocation?

5.4 Further Work To Be Done

The strategies proposed in this chapter are preliminary. The NCHC anticipates that further work will be done on them to provide greater detail and to more precisely identify steps necessary to accomplish the concepts outlined above. This process probably will entail amendments to this plan that could be implemented by the County and could provide the detail needed for the implementation chapter of this plan. It is anticipated that County staff will work with the citizens of Neskowin in presenting such proposed amendments for review by citizen committees and hearing bodies, ultimately bringing about adoption by the Tillamook County's Board of Commissioners.

6. Conclusion

This plan does not mark the end of Neskowin's efforts to prepare for and adapt to the hazards associated with coastal erosion. Quite the contrary: this plan is a blueprint for the future. It describes (in Section 5 and Appendices B and C) actions and activities to be taken that will help make Neskowin less vulnerable to such hazards. Some of those actions and activities have been initiated, but much remains to be done.

Although much work lies ahead, Neskowin and Tillamook County have already taken significant steps toward hazard adaptation. In the nearly 4-year process of developing this *Adaptation Plan*, much was accomplished, thereby making Neskowin a more resilient community:

- Public awareness of the hazards has been greatly increased. Three well-attended public meetings, several mailings to community members, and internet postings of the monthly NCHC meetings all have worked to increase the amount of hazard information available to residents and businesses in Neskowin. The NCHC also prepared and distributed a suggested reading list of works on coastal erosion and posted information on the community association's Web site. It can safely be said that most people who live and work in Neskowin are now much better informed about the hazards associated with coastal erosion and thus are better able to adapt to them.
- With Tillamook County's preparation of the *Framework Plan*, the community now has a concise, objective source of information about forces and factors that influence erosion hazards on our coast and on a variety of techniques for alleviating those hazards.
- The nature and extent of coastal erosion in the community are being scientifically and systematically measured. The resulting data have enabled DOGAMI and OSU to prepare maps that identify hazardous areas with much greater precision than was available even a decade ago.
- Both the county and the community have formed strong alliances with key state and federal agencies such as DOGAMI, OPRD, DLCD, OSU and USGS. The community knows where and how to get technical assistance, funding and emergency services for dealing with hazard events in the future.
- The community has a successful network of well-informed volunteers that continue to work with Tillamook County and key agencies to reduce Neskowin's vulnerability to coastal hazards.
- Neskowin worked with OPRD to conduct a community-wide survey of riprap revetments. The survey provided a lot-by-lot summary of the condition and extent of these rock structures, identifying places where repairs are or soon will be needed.
- The NCHC, through the County, and thanks to contributions from the community and DLCD, contracted with a coastal engineering firm to study the situation at Neskowin and make recommendations for erosion mitigation options based on their professional judgment and community-determined viability. The consultants submitted their report in October 2012, and the NCHC has reported its response to their findings in this plan.
- Tillamook County and Neskowin have worked together closely to develop a set of strategies, expressed in this plan, for alleviating or adapting to coastal erosion hazards.

7. Glossary

NOTE: This is the start of a glossary to define/explain terms thought to be unfamiliar to general readers. It is based partly on Voight, Brian. 1998. Glossary of coastal terminology. Washington Department of Ecology. Updated April 26, 2006. http://www.ecy.wa.gov/programs/sea/swces/products/glossary.htm

Angle of repose: Related to slope stability, it is the maximum degree of slope at which a section of hillside is stable.

Littoral cell: A section of ocean shoreline that lies between two headlands or capes.

Mean high tide: The average or mean level of the high tide, taken over a period of time. The variability of the height of the tide is caused by a variety of astronomical, atmospheric, and oceanographic forces.

Ocean flooding: Intrusion of ocean water into low-lying shoreline areas that are normally dry.

Riprap: A revetment (facing for protection of an embankment) of rocks to protect embankments exposed to wave action from erosion, scour, or sloughing and, thus, protect structures behind them.

Storm surge: An increase in the water surface level caused by strong onshore winds and low atmospheric pressures associated with a significant storm event.

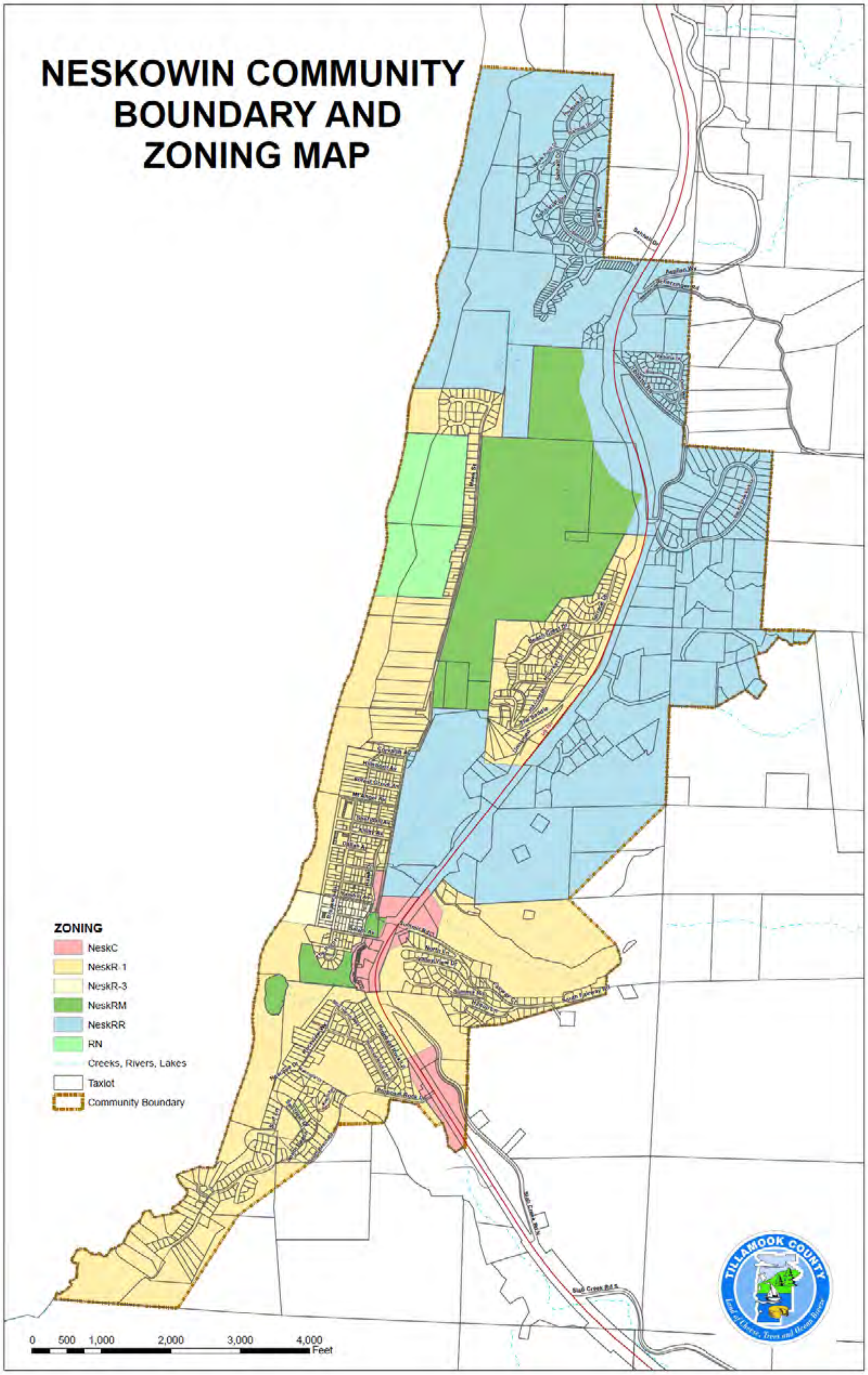
Sea level rise: An increase in mean sea level that is expected to occur over time. It is usually considered a consequence of climate change.

Wave run-up: The rush of water up a beach or structure (such as riprap) on the breaking of a wave. The amount of run-up is the vertical height above still-water level that the rush of water reaches. The height of the wave run-up is determined by the slope of the beach or structure, the wave height in deep water, the wave period (time between waves), and deep water wave length (the distance between waves in deep water).

APPENDIX A: ATTACHMENTS

NOTE: The maps included as attachments require further work. Specifically, some need legend information and all lack adequate references. They have been provided as further information and are for illustration only.

Attachment 1: Neskowin Community Plan Map



Attachment 2: Map of Neskowin Community Growth Boundary and Tax Lots

Attachment 3: Letter to Neskowin Landowners Describing the Erosion Hazard and Formation of the NCHC, and Inviting "Feedback and Ideas"

To: Residents of Neskowin
From: Neskowin Coastal Hazards Committee
Date: December 14, 2009

We write this letter to you on behalf of your state, county and some of your community citizens to bring attention to a potentially serious situation in the Neskowin area. It is important that you are all aware of the threat from coastal erosion, flooding, and inundation hazards. These forces could impact the beach, oceanfront properties, and the village behind it.

Neskowin has experienced significant erosion of its beaches in recent years. Ongoing research by the Oregon Department of Geology and Mineral Industries suggests that Neskowin could experience even more negative impacts in the future. Jonathan Allan with the Department, presented research recently that indicates:

1. Ocean winter wave heights have increased significantly during the past decade, and are the highest they have been in the past three decades.
2. Significantly stronger wave events are happening earlier in the Fall/Winter and not subsiding until later in the Winter/Spring, effectively lengthening the period of winter erosion.
3. The Neskowin beach/dune continues to erode and is currently not replenishing itself.
4. Because the volume of sand contained in the beaches and dune is much lower than was present in the mid-1990s (for example the dune face north of Proposal Rock has eroded landward ~150 ft. since 1997). Should Neskowin experience storms today with intensities comparable to those of the late 1990s, combined with high tides, there is a strong probability that the community could experience significant damage to its shorefront.

There have been several community meetings in Neskowin to discuss available facts on what has been happening and to consider both short and long term solutions. County Commissioner Mark Labhart is now chairing a committee of local citizens and county and state government representatives to address this issue.
The mission of the Neskowin Coastal Hazards Committee is to: Recommend to state and county agencies and officials ways to maintain the beach and protect the village through short term and long term strategies; and explore ways to plan for and adapt to the potential future changes in the Neskowin coastal area.

Neskowin Coastal Hazards Committee

The objectives of the Committee are to:

1. Become more knowledgeable about past and current dimensions of the situation and study expert projections for the future.
2. Provide information to alert Neskowin beach users to potential dangers of coastal hazards.
3. Investigate options (short and long term) for maintaining the beach and preserving the village.

4. Publish Committee findings and advocate actions likely to be most effective in fulfilling our mission.
5. Help garner support and resources necessary to implement agreed upon actions.

The Committee will keep the community informed as we learn more information and make plans to move forward on recommendations. Any actions to protect and preserve Neskowin will need community support and will not happen without it.

In the meantime, the Committee encourages residents to stay informed about potentially threatening events by monitoring official sources of weather forecasts and warnings. The National Weather Service (NWS) provides forecasts and warnings for extreme weather and high surf. This information is found at the NWS website (http://www.wrh.noaa.gov/pqr/) and is broadcast on NOAA weather radios. Private companies, such as The Weather Channel, also provide phone based on NWS warnings for extreme weather.

The Committee welcomes feedback and ideas as we develop options for consideration by the community. If there are residents or property owners interested in, or have questions for, the Committee please contact Commissioner Mark Labhart or a local Committee member.

Sincerely yours,
Neskowin Coastal Hazards Committee

Community members: Leslie Gordon, Gale Ousele, Pete Owston, Alex Sifford, Guy Sievert, Charlie Walker, Jeff Walton

Tillamook County members: Mark Labhart (Commissioner), Gerald Parker (Planning Director)

State agency members: Jonathan Allan (DOGAMI), Laren Wooley (DLCD) Tony Stein (Oregon State Parks), Patrick Corcoran (Oregon Sea Grant)

Attachment 4: Correspondence between Tillamook County, USACE and USFWS Regarding Hawk Creek Bridge and the Tsunami Escape Trail

Tillamook County

Tillamook County Commissioners
201 Laurel Avenue
Tillamook, Oregon 97141
Charles Hurliman, Tim Josi, Mark Labhart
Phone 503-842-3403
Fax 503-842-1384
TTY Oregon Relay Service

Land of Cheese, Trees and Ocean Breeze

April 22, 2011

Kevin Moynahan
Chief, Regulatory Branch
333 SW First Ave.
Portland, OR 97204

Roy Lowe
USF&W Service
2127 SE Marine Science Drive
Newport OR 97365

Dear Mr. Moynahan & Mr. Lowe:

The purpose of this letter from the Tillamook County Board of Commissioners is to respectively ask for Corps technical and planning assistance regarding the Hawk Creek Bridge in the unincorporated community of Neskowin.

While you may not be the exact Corps person to consider this matter, you were able to sit in on the meeting the Neskowin Coastal Hazards Committee (NCHC) had with representatives of the Corps several months ago in Portland. You were the highest ranking Corps official in the room. Thus, this letter to you. We would appreciate it if would please forward this letter onto whomever would be the appropriate person.

Attached in the email document to you is a letter the Tillamook County Board of Commissioners received from representatives of the Neskowin Coastal Hazards Committee. The Committee is made up of Neskowin residents, representatives from State Parks, Dept. of Land Conservation & Development, Tillamook County and the Nestucca Fire Dist. The Committee was formed by the Tillamook County Board of Commissioners about a year ago with the mission to explore ways to maintain the beach and protect the community through short and long term strategies. It is also to recommend to state and county agencies ways to maintain the beach and protect the community. The group is also exploring ways to plan for and adapt to the potential future long-term changes in the Neskowin area.

In the attached letter from the NCHC, they have requested the Board of Commissioners ask the Corps for technical & planning assistance regarding the situation with the county's Hawk Creek Bridge in Neskowin. The Board agreed & also asks that the Corps and USF&W work with the NCHC to additionally explore a Tsunami alternate evacuation route through USF&W property north of the county's Hawk Creek Bridge.

In the way of background and as discussed with you and other representatives from the Corps at our Portland meeting, the Hawk Creek Bridge is a small two lane county bridge that is the only access into and out of the main residential area of Neskowin. The bridge also has water and sewer lines hanging on it. The bridge is not built to current earthquake standards. It has on numerous occasions been overtopped by ocean wave action. It most recently and in years past been struck by large ocean debris including root wads and beach logs. The County most recently removed several large root wads from in front of the bridge and adjacent to the Hawk Creek Café. It is our belief that the bridge will not withstand a subduction zone earthquake and subsequent Tsunami which could trap several hundred people on the wrong side of the creek. Evacuation across the creek on foot would be difficult at best during an event. Neskowin has a large elderly population. The bridge is also at risk of wave action every winter.

AN EQUAL OPPORTUNITY EMPLOYER

We would ask if the Corps has staff that they could designate to help this small unincorporated community with options as to what to do about this bridge as we believe you have significant expertise in this area. In addition with this letter we are asking Roy Lowe with the USF&W to work with the NCHC and the Corps to explore a second evacuation route using the "old road" across USF&W property to be used for a Tsunami evacuation route in order to help residents evacuate the Tsunami inundation zone.

The county has very little financial contribution it can make to this effort as we are currently reducing staffing in our road dept, not doing any paving this year and trying to find dollars just to fill potholes throughout the county.

We know that the Corps is also financially strapped given the current state of the federal budget but we believe given the current situation in Japan, we as a community of government need to take steps to address what we believe is a very serious situation to the community of Neskowin.
We look forward to your reply.

Very truly yours,

Tim Josi
Vice-Chair

Mark Labhart
Commissioner

Liane Welch, Tillamook Co. Public Works
NCHC

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Oregon Coast National Wildlife Refuge Complex
2127 SE Marine Science Drive
Newport, OR 97365

April 28, 2011

Mr. Mark Labhart, Commissiner
Tillamook County Board of Commissoners
201 Laurel Avenue
Tillamook, Oregon 97141

Dear Commissioner Labhart:

Thank you for your letter of April 22, 2011, signed by you and Commissioner Josi regarding the Neskowin Coastal Hazards Committee (NCHC) and their current planning process to protect lives and property within the Neskowin community. We would be glad to work with the NCHC on a Tsunami escape route that would involve refuge lands. Prior to your April 22nd letter we had not been requested to do so. I attended the Neskowin Community meeting on March 26, 2011, which I thought was a very good overview of the situation, natural processes at work and the direction of the NCHC.

We acquired the former Snell property that contains the "old road" across Neskowin Marsh in February 2002. We have allowed use of this trail to continue although we have not advertised it for public use. At some point in the past an unknown individual or agency posted a Tsunami Escape Route sign at the west end of the trail without seeking permission or notifying us. To my knowledge this is not an official designation.

We realize this trail would serve as a vital escape route in the advent of a nearby subduction zone earthquake and resultant tsunami. We are currently preparing a Comprehensive Conservation Plan (CCP) for Nestucca Bay National Wildlife Refuge (NWR). Neskowin Marsh is a unit of Nestucca Bay NWR. On November 30, 2010, we held a public Open House Scoping meeting in Pacific City to initiate the CCP process. During the presentation portion of that meeting I acknowledged the importance of the Tsunami Escape Trail and our intent to keep this route open. We will host another public meeting next fall to discuss the draft alternatives for the CCP, but I can tell you now that the continued existence of the Tsunami Escape Trail is in all of the alternatives we are working on. Our CCP for Nestucca Bay NWR and two other refuges on the Oregon Coast will be completed in 2012.

We have concerns that the old roadbed may impede natural hydrologic flows out of the marsh and into Meadow Creek. We hope to study this in the future and correct the situation if it is determined to be impacting the marsh. Any potential alteration of the roadbed/trail would take into consideration the need for an escape route.

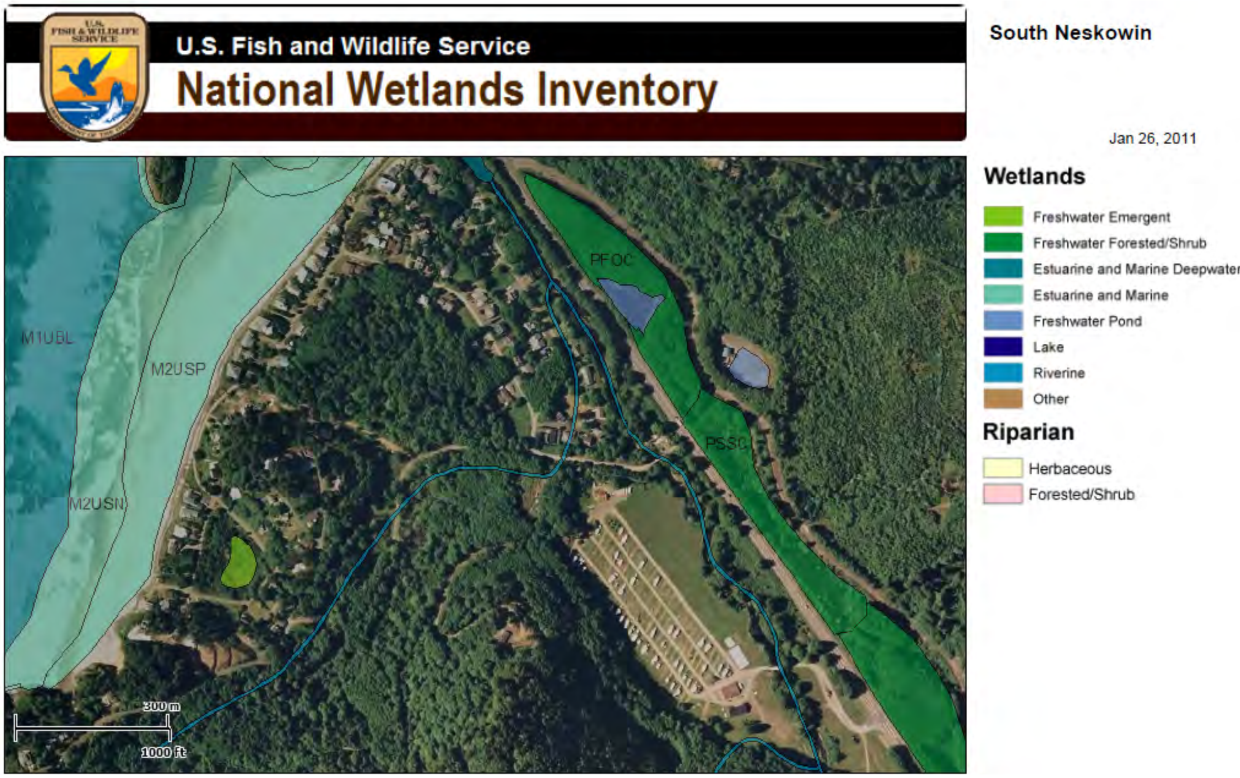
TAKE PRIDE® IN AMERICA

Thank you again for your letter and your concern.

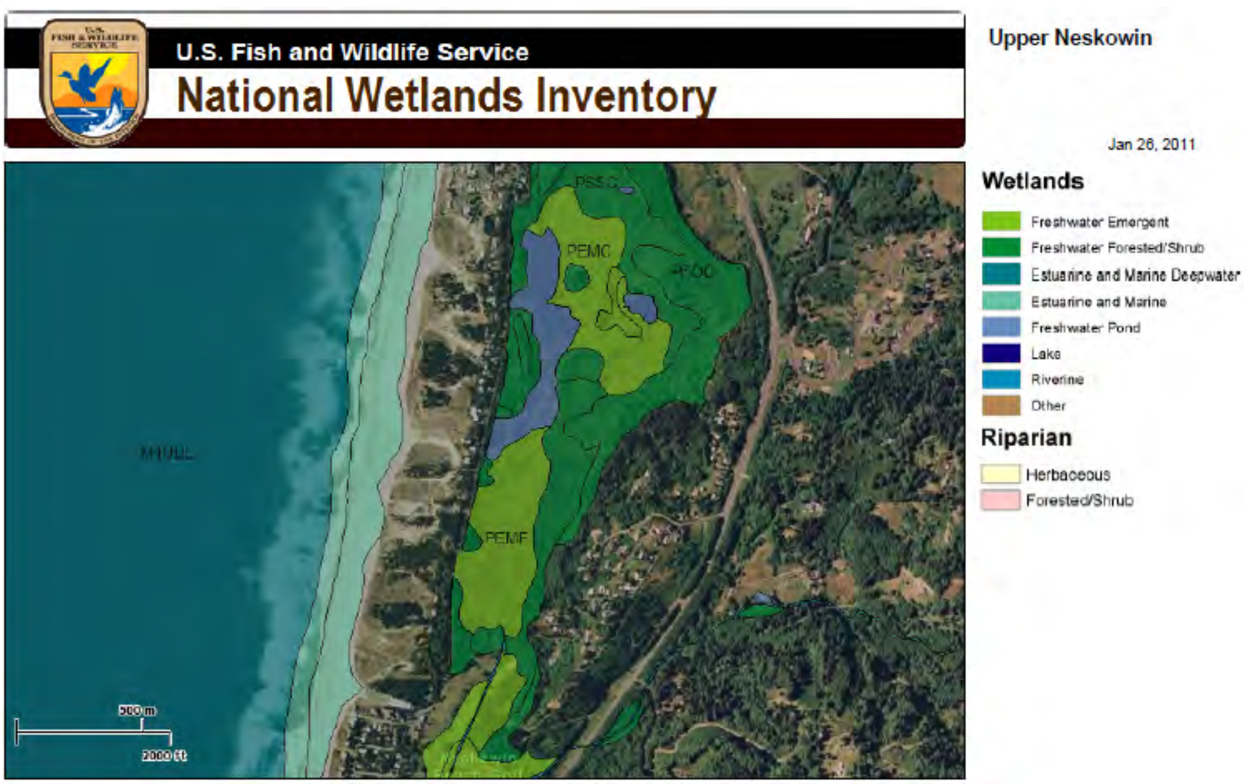
Sincerely,

Roy W. Lowe
Project Leader

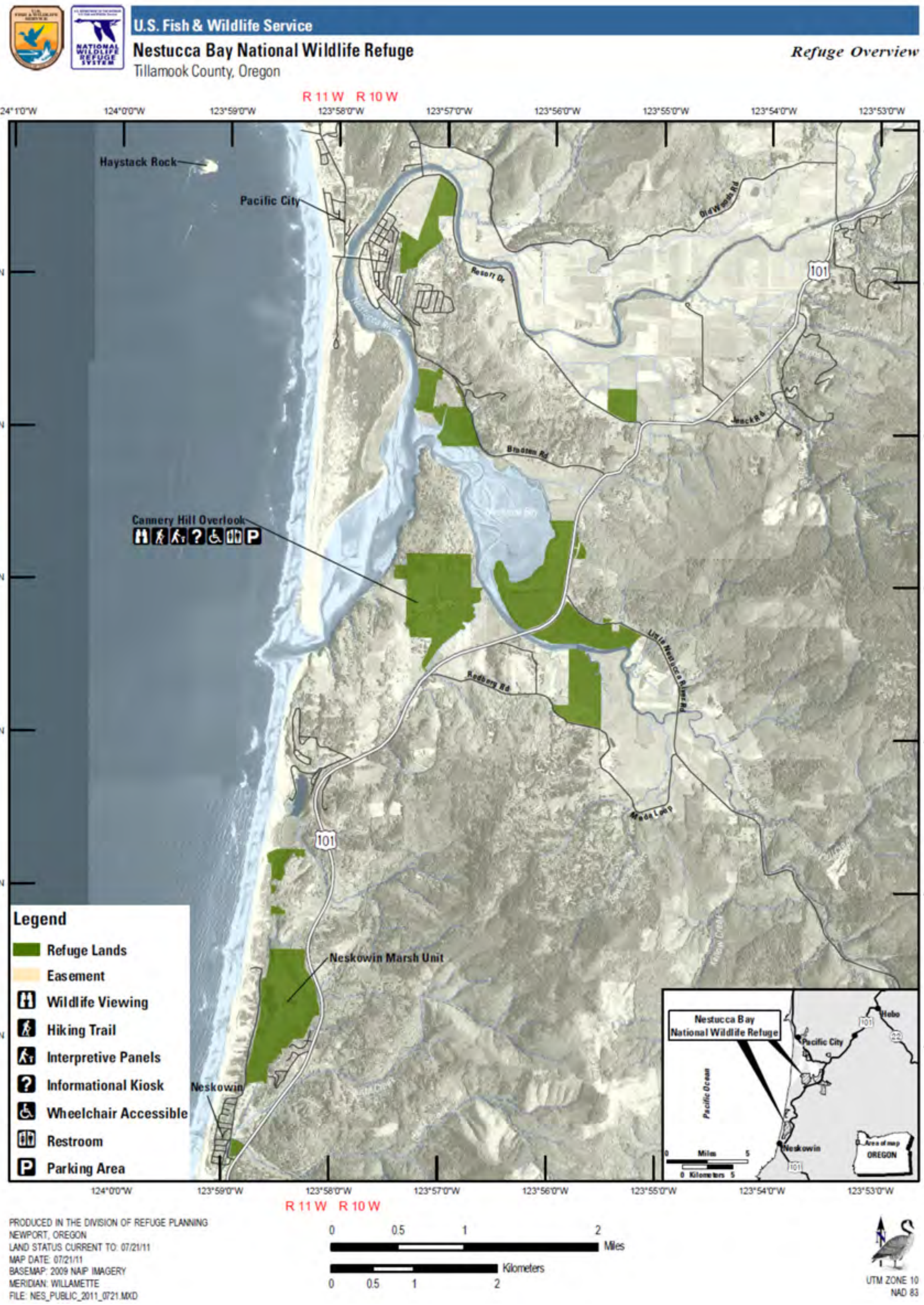
Attachment 5: National Wetlands Inventory, Four USFWS Maps of Significant Wetlands in Neskowin (South, Mid, North and Upper Neskowin)




U.S. Fish and Wildlife Service
National Wetlands Inventory
North Neskowin
Jan 26, 2011
Wetlands
Freshwater Emergent
Freshwater Forested/Shrub
Estuarine and Marine Deepwater
Estuarine and Marine
Freshwater Pond
Lake
Riverine
Other
Riparian
Herbaceous
Forested/Shrub
PEMF
PSSC
Neskowin
500 m
2000 ft


U.S. Fish and Wildlife Service
National Wetlands Inventory
Upper Neskowin
Jan 26, 2011
Wetlands
Freshwater Emergent
Freshwater Forested/Shrub
Estuarine and Marine Deepwater
Estuarine and Marine
Freshwater Pond
Lake
Riverine
Other
Riparian
Herbaceous
Forested/Shrub
PEMC
PEMF
500 m
2000 ft

Attachment 6: Map of USFWS's Nestucca Bay National Wildlife Refuge, including Neskowin Units



Attachment 7: Minutes of Community Update: NCHC Community Meeting, May 29, 2011

The mission of the Neskowin Coastal Hazards Committee (NCHC) is to—in priority order--plan ways to maintain the beach and protect the community through short term and long term strategies; recommend to state and county agencies and officials ways to maintain the beach and protect the community; and explore ways to plan for and adapt to the potential future changes in the Neskowin coastal area.

The Neskowin Coastal Hazards Committee (NCHC) completed their second public meeting on May 29th with about 90 members of the community present. The purpose of this meeting was to ask the community for their sense of priority on the following four issues the Committee is talking about.

1. Short Term Options for Active Protection
2. Long Term Options for Active Protection
3. Land use Options
4. Preserve the Beach or Protect the Property

The 90 people present weighed in through a voting process after a briefing on the items. On behalf to the NCHC, we thank you for your attendance and consideration. As a group, we are encouraged by your participation. These votes were advisory to the NCHC for consideration as they continue their work on a wide range of issues. Here is what we learned:

Short and Long-Term Options for Active Protection These include engineering and structural approaches to protect the beach and community from the impact of ocean waves, surges, and flooding.

The community members present felt very strongly that the **highest short-term option should be the protecting the Hawk Creek Bridge** as it is a key ingress/egress out of the community and contains sewer and water lines.

After that clear priority, votes tended to cluster in equal priority around three options: **continuing maintenance of the current riprap, increasing riprap height and uniformity,** and continuing to **investigate options to protect the beach and community.** The last item includes but not limited to innovative structures and near-shore devices that might reduce wave intensity.

Land Use Options These are legal incentives and regulations to protect property from the impact of ocean waves, surges, and flooding. Seventeen different options were presented to the community for consideration.

The community zeroed in on **identifying coastal hazard areas** and; **exploring possible restrictions in these high hazard areas** as the top two land use options. The Land Use

Committee will continue its work in July and August and ask for more community input at our next public meeting in September.

Preserve the Beach-Protect Property

The Committee wanted to know what those present felt should be the higher priority as they consider the range of options presented: preserve the beach or protect property? The citizens present were asked to vote on a scale of one to six with one being preserve the beach and six being protect property. The votes were nearly evenly split, indicating they **want to protect both the beach and property**.

What next?

1. The committee wanted to first get the word out to the community about what we heard from those present at the May 29th meeting. This update serves that purpose. Please share it with your friends and neighbors.

2. Our agenda for the September meeting will be refined over the summer, and sent out well in advance of the Labor Day weekend meeting. It will include sharing the latest information and recent developments, as well as soliciting input from you.

3. There are meetings in late June with the Corps of Engineers, US Fish & wildlife, the County, and the Fire District, on possible bridge options.

4. We are contacting marine engineers about options for continued maintenance, height and uniformity of the riprap revetments, and near shore options to reduce force of waves on the beach.

The Neskowin Coastal Hazards Committee is made up of local community members, county and state agencies. If you have any input or comments, please contact our Committee Chair, Commissioner Mark Labhart. He can be reached at 503-842-3403 or email him at mlabhart@co.tillamook.or.us

Attachment 8: Neskowin Coastal Hazards Active Protection Subcommittee Report From the Meeting on January 14, 2011 with the Corps of Engineers

On January 14, the subcommittee (Bill Busch, Dave Kraybill, Pete Owston, Guy Sievert, Charlie Walker, Mark Labhart, Kristen Maze) met with the U.S. Army Corps of Engineers (USACE) at their office in Portland. Six representatives from the Corps met with us, and they provided a great deal of useful information. The key discussion points are mentioned below.

USACE Regulatory Jurisdiction

Two representatives from the Corps Regulatory group attended the meeting; and gave us a chart that illustrates their regulatory jurisdiction (see attached). In short, there are three relevant sections: 1) Section 103 (Rivers and Harbors Act), governing ocean discharge of dredged material; 2) Section 404 (Clean Water Act, see attached), disposal of dredged or fill material; and 3) Section 10 (Rivers and Harbors Act), all structures and work in navigable waters. In tidal or fresh waters, Section 10 would govern any structures or work placed on the beach or out in the water; such as onshore and offshore breakwaters, etc. In tidal waters, Section 404 would apply to jetties, beach nourishment projects, and perhaps riprap, depending on the elevation of the riprap. In fresh water, Section 404 would cover fill, utility lines, outfall structures, road crossings, etc. The USACE jurisdiction also extends out 3 miles from the coastline.

Structures would require permits from the USACE. Permits in Oregon are reviewed, approved, and issued out of the Portland office. The structural design is to be prepared by the proponent (applicant). “Nationwide” permits, governing up to a half an acre of work, are required to be issued within 60 days. However, they typically also have to be reviewed by the US Fish and Wildlife Service (USFWS), which has up to 135 days. The USFWS is not meeting this timeline regularly, resulting in a delay in approval. In addition, public hearings and lawsuits are often a part of the process, further extending the timeline. Individual permits, for projects larger in scope, are usually more complex, requiring a public review, and take at least 120 days.

USACE responsibility in protecting communities from shoreline retreat and other coastal hazards

USACE has no responsibility in protecting private property. Thus it would not provide any technical or funding assistance with the existing riprap structures (or proposed new structures) that protect private property all along the Neskowin oceanfront. However, USACE has responsibility in protecting county and state infrastructure (like roads and bridges), sewer treatment plants, etc.

A discussion then ensued about the Hawk Creek Bridge. The bridge is the only means of access to the village area of Neskowin, as well as carrying water and sewer lines into the village. The Corps suggested that they could assist with remedying the community’s exposure to the potential loss of this bridge from tidal action and/or storm surge events (see below).

USACE engineering design and/or construction assistance

For those infrastructure elements that USACE identified as falling under their responsibility, the Corps has two programs: 1) Support for others (IIS); and 2) Planning assistance for states. The first program provides help for other government agencies, like Tillamook County. In planning assistance for states, the Corps would match local funding sources 50-50% for engineering studies. Once USACE decides that a project meets their requirements, the project is placed in the queue. The typical duration before funding can be obtained is 2 years.

USACE experience with beach nourishment projects

One of the participants from the Corps attending the meeting (Lynda Charles) had recently transferred from Florida. Florida has extensive experience with beach nourishment projects, which are funded by the state itself. In Florida, the design of beach nourishment projects places sand on the beach to a height higher than the height of the waves.

On the West Coast, USACE, in maintaining navigable waters, as is their responsibility, looks to use dredged materials for beach nourishment efforts. However, they suggest that the cost of transporting the dredged materials any significant distance is "prohibitive." On the Columbia River, they have experience in dredging materials onto a ship and then pumping the material onto the local shore.

USACE experience with offshore or near shore breakwater structures

On the West Coast, the Corps has extensive experience with jetties. Their experience has been that structures in the water are costly to construct, and require continuing maintenance. They cited the Tillamook jetty, where 100 feet of jetty cost $31 million. Offshore reefs, created by placing objects in the ocean below the mean water level, were also discussed. Their experience has been that the impact of the reefs are hard to predict; in one case cited, the reef blocked onshore transport of sand to the beach and actually made beach erosion even worse.

USACE experience with flood control projects

The representatives of the Corps at the meeting said they have 16 years of experience in flood control projects that involve ocean waves surging up coastal streams. The process of approving a project starts with a letter from the proponent to the USACE. The Corps then reviews the request, and, if approved, it is placed into the queue. They can provide modeling and design assistance (although the design is the responsibility of the proponent). They recommended that the request be a definable problem, like the Hawk Creek Bridge.

USACE experience with stat-of-the art shoreline, near-shore, or offshore protection solutions

The Corps representatives reported that there is a research group within the Corps, the USACE Waterways Experiment Station in Vicksburg, MS. Thus, proposed design solutions can be modeled in detail at sites like the facility in Vicksburg or the wave tank at Oregon State University in Corvallis.

USACE opinion on the adequacy of the existing and continuous riprap revetment

In the meeting we were told, from the experience of one of the Corps staff members who visited the Neskowin site, that the riprap at Neskowin is one of the best constructed riprap structures. In addition, it is their opinion that the best active protection scheme is to keep structures as far away from the ocean as possible, like our riprap revetment. Offshore or near shore structures do not perform as well under the wave conditions of our coast. In addition, they recommend that the first line of defense not be a vertical seawall (because the waves hit such a structure with their full energy and result in scour at the base of such walls). In meeting future shoreline protection requirements, they recommended that the riprap revetment be reinforced at the top and back with a seawall, taking into consideration a means of channeling the water that overtops the structure away from the wall and riprap. They also recommend that, for future maintenance and replacement of the riprap, to place layers of geotech fabric under the riprap and at the toe of the riprap.

Beverly Beach Project

Lynda Charles of the Corps provided to us a conceptual alternatives report for the Beverly Beach project. This project, in which the Corps was involved, was to rebuild a bridge on Highway 101 six miles north of Newport and to provide protection for the bridge and the highway from erosion caused by ocean waves. The report considered many of the same options that we have been considering: riprap revetment, seawall, beach nourishment, cobble revetment, sub aerial rock reef, and submerged rock reef. For this project the relative construction costs were as follows:

1) Riprap revetment at bluff toe	$4.8 million
2) Seawall at bluff toe	$3.9 million
3) Seawall at mid-beach	$15.5 million
4) Beach nourishment (4 mm)	$15.6 million
5) Cobble revetment	$3.7 million
6) Sub aerial rock reef	$34.7 million
7) Submerged rock reef	$16.8 million

With respect to beach nourishment, the relative cost depends on the use of dredge material from nearby Yaquina Bay. If materials from a different source not as close to the project were to be used, the project cost would more than double. To be effective, the berm for the beach nourishment project was designed to be 16.4 feet high and 82 feet wide. The design lengths for the sub aerial and submerged rock reefs were 500 feet and 750 feet, respectively.

In the report, no option was chosen for among the alternatives.

Attachment 9: Summary of Active Protection Subcommittee Findings[1]

Soft Protection Options

- Dynamic Revetments
- Dune Management
- Beach Nourishment

Hard Protection Options

- Jetties
- Groins
- Continuous Shore Parallel Breakwaters
- Intermittent Shore Parallel Breakwaters
- Seawalls and Bulkheads
- Riprap Revetments

Off-the-Beach Options

- Hawk Creek Bridge Protection Options
- Dune Management in the back dune area (covered in the soft protection options)

Dynamic Revetments

- Revetment made from cobbles and less steep than riprap (example: Cape Lookout)
- **PRO**: May be useful as an allowed exception in areas not eligible for riprap (between Corvallis Avenue and Neskowin North); relatively lower construction cost
- **CON**: Severe storms can mobilize the cobbles leaving the community vulnerable; More regular maintenance required; cobbles will eventually scatter all over the beach; expensive to purchase and transport material
- **CURRENT COMMITTEE ASSESSMENT**: A less adequate solution than riprap except for those areas where riprap is not permitted

Dune Management

- Use of beach grass, sand fences, and (perhaps) dune grading to encourage dune growth
- **PRO**: Useful in areas where the dunes are directly subject to wave action (between Corvallis Avenue and Neskowin North); inexpensive
- **CON**: Not suitable in areas like Neskowin where there is inadequate sand to rebuild the dunes
- **CURRENT COMMITTEE ASSESSMENT**: Insufficient sand available on the beach to be an adequate solution for Neskowin

[1] This summary was completed prior to receiving the ESA PWA Report.

Beach Nourishment

- Addition of sand to the beach to dissipate wave energy and to add to the dune to increase its volume
- **PRO**: Beach becomes higher and wider; easily constructed and maintained
- **CON**: To be effective, a great deal of sand would have to be added, and regularly replenished – thus expensive; no local source of sand; could require the addition of groins or breakwaters to keep the sand in Neskowin
- **CURRENT COMMITTEE ASSESSMENT**: May not be suitable without the addition of other structures; an expensive solution for Neskowin

Jetties

- Shore-perpendicular structures designed for harbor or inlet protection (examples: Newport and Tillamook)
- **PRO**: Effective in maintaining a navigable channel
- **CON**: Very expensive; downdrift erosion
- **CURRENT COMMITTEE ASSESSMENT**: Not relevant at Neskowin

Groins

- Shore-perpendicular structures designed to trap sand and stabilize the beach
- **PRO**: Traps sand moved along the beach by longshore current and wind
- **CON**: Expensive; normally used on sand-rich beaches; not effective on beaches with rip currents, steep beach slopes, and cross-shore transport; downdrift erosion
- **CURRENT COMMITTEE ASSESSMENT**: Likely not effective at Neskowin

Continuous Shore-Parallel Breakwaters

- Shore-parallel structures, either above or below the mean water line, designed to reduce wave energy
- PRO: Beach width might be increased; wave energy is reduced in areas behind the structure
- CON: Expensive to build and maintain; likely to require additional beach nourishment; difficult to predict impact on beach erosion
- CURRENT COMMITTEE ASSESSMENT: Expensive for the situation at Neskowin (as much as $370 million per mile to construct)

Intermittent Shore-Parallel Breakwaters

- Intermittent shore-parallel structures above the mean water line, designed to reduce wave energy
- **PRO**: Beach width might be increased; wave energy is reduced in areas behind the structure
- **CON**: Expensive to build and maintain; may increase erosion on either side of the structure; would require a feasibility study, including a quantitative analysis
- **CURRENT COMMITTEE ASSESSMENT**: Expensive for the situation at Neskowin

Seawalls and Bulkheads

- Vertical, self-supporting structures made of concrete or steel sheet piling
- **PRO**: Useful for protecting the community behind it
- **CON**: Expensive to build and maintain; likely to increase erosion on the beach due to the reflection of waves back onto the beach; scour at the toe
- **CURRENT COMMITTEE ASSESSMENT**: Not considered suitable for the Neskowin oceanfront due to likely increased beach erosion

Riprap Revetments

- Steeply sloping structure made from large rocks placed behind the beach; currently in place for most of the beachfront at Neskowin
- **PRO**: Useful in protecting the community behind it
- **CON**: Expensive to build and maintain; not high enough currently in all locations to prevent wave overtopping; potential for scour at the toe; subject to isolated failures
- **CURRENT COMMITTEE ASSESSMENT**: If properly constructed and adequately maintained, suitable for protecting the community under most circumstances in the medium term (10-20 years)

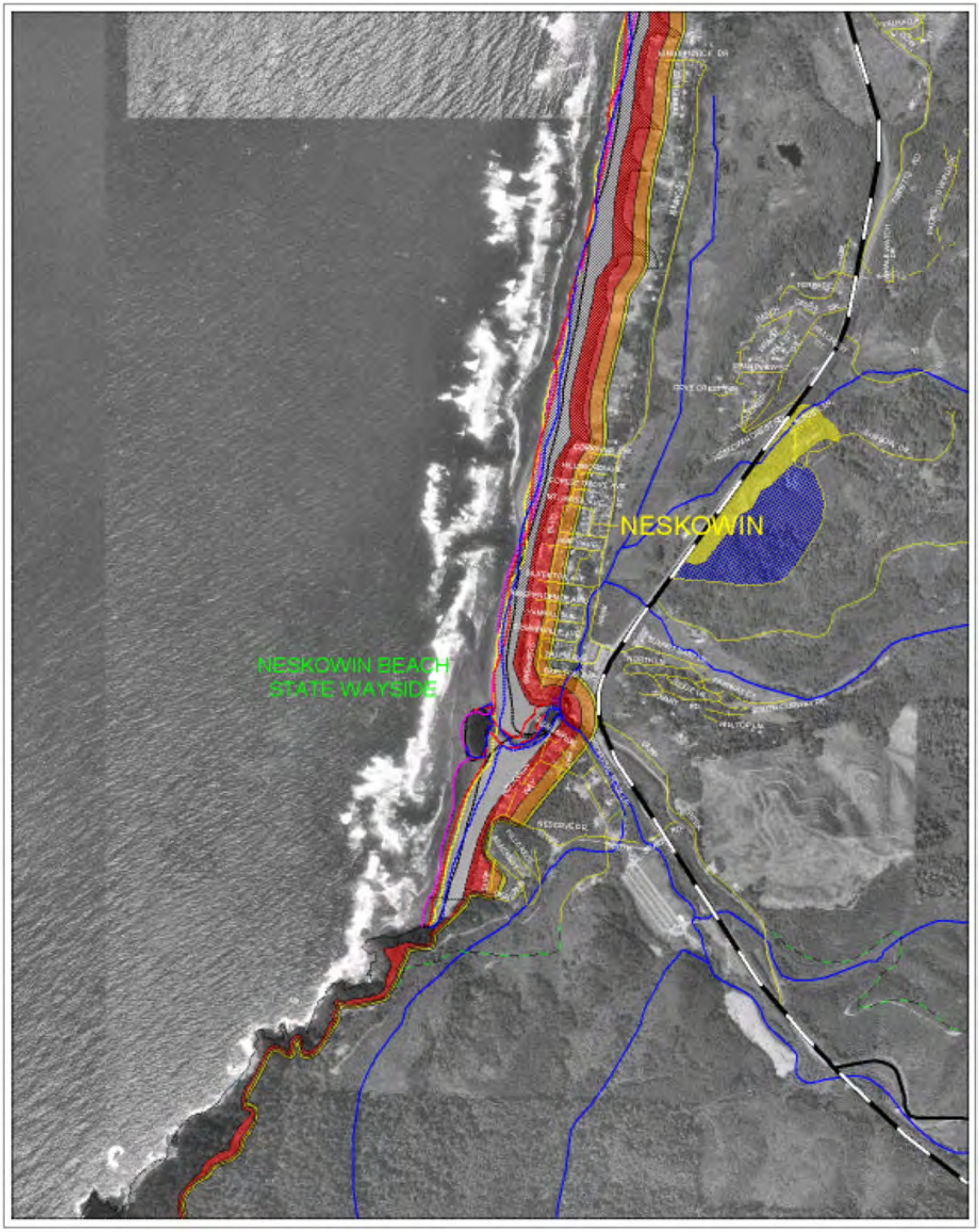
Hawk Creek Bridge Protection Options

- The Hawk Creek Bridge and the attached water and sewer lines are vulnerable to wave and tide action up the creek
- **PRO**: Protection necessary to better protect the bridge and prevent isolation of the village; funding for design and construction potentially available from USACE.
- **CON**: Cost might be high; at this time, no proposed solution
- **CURRENT COMMITTEE ASSESSMENT**: Recommend the county and USACE immediately begin a feasibility study and planning process

Options Requiring Further Study or Action

- Continued maintenance of the Riprap Revetment
- Investigate raising the height of the Riprap Revetment and making it more uniform
- Hawk Creek Bridge Protection
- Investigate new innovative options that reduce wave energy

Attachment 10: DOGAMI Map of Coastal Erosion Hazard Zones in the Neskowin Area[2]



[2] from "Neskowin," Appendix E, p. 91, of DOGAMI Open File Report (OFR) 0-01-03, *Evaluation of Coastal Erosion Hazard Zones Along Dune and Bluff Backed Shorelines in Tillamook, Oregon: Cascade Head to Cape Falcon*, by J.C. Allan and G.R. Priest, 2001.

Attachment 11: OSU Maps: Estimating Probabilities in a Changing Environment

The information and maps from DOGAMI identify zones that would be subject to erosion if certain design events occur. But what is the probability that such events will occur? Estimating such probabilities is made especially difficult by the dynamism of the coastal environment. As noted in Chapter 8 of the *Framework Plan* (Appendix D), several key factors such as global sea level and peak deep-water wave height off the Oregon coast have been changing and continue to change.

Researchers at Oregon State University's Department of Geosciences therefore began working on a method that considers such changes when estimating the probability of various design events. In a special project that focused on conditions at Neskowin, the OSU researchers developed a new probabilistic methodology to predict coastal erosion hazards. Student Heather Baron describes the results of that methodology in an unpublished master's thesis: "Incorporating Climate Change Uncertainty into a Probabilistic Methodology for Evaluating Future Coastal Change[3] Hazards and Community Exposure" (May 2011).[4]

The OSU methodology uses computer modeling to analyze an array of 1,800 scenarios. Each scenario expresses the total water level (TWL) that could be expected if a certain combination of conditions occurs. Such a combination constitutes a "design event." OSU's methodology thus expands on DOGAMI's data by introducing a large range of variables and estimating the probability of erosion potential from multiple design events over several different time periods.

OSU's computer modeling enables different combinations of assumptions about future conditions to be analyzed. The model can assess an array of values for key variables such as sea level rise, deep-water ocean wave heights, and beach characteristics such as slope. The results help researchers to estimate the probability that a given area of the shore will experience erosion under a defined combination of circumstances during a specified period.[5] Such probability is expressed in statistical terms as a "confidence level." A confidence level of 98 percent, for example, implies very high probability that, under the specified conditions, the area in question would experience hazardous erosion. In contrast, a confidence level of 50 percent is essentially a statement that the probability of erosion occurring is 50-50: it might happen, it might not.

OSU's work produced some four dozen maps of coastal erosion hazards along Neskowin's shoreline, showing at-risk areas for various time periods and based on different assumptions about variables such as sea level rise. This sub-plan focuses on four of those maps to help determine those areas of the community most likely to experience significant erosion hazards

[3] Because this is a plan for adapting to hazards associated with coastal erosion and flooding, the Neskowin Adaptation Plan typically speaks of "coastal *erosion* hazards." But design events such as a large winter storm may cause severe erosion to a beach in one place while widening it another. The scientific literature therefore sometimes speaks of "coastal *change* hazards," a term broad enough to include both erosion and accretion.
[4] Ms. Baron's faculty advisor, Peter Ruggiero, worked closely with the Neskowin Coastal Hazards Committee during the writing of the *Framework Plan*.
[5] The target years used in OSU's model were 2009, 2030, 2050, and 2100.

during the period from 2011 to 2050.OSU's pilot project analysis thus has been a great help in further locating and understanding erosion risks initially described in DOGAMI OFR 0-01-03.

Together, the four OSU maps and their legends tell us the following:

- The "design event" is a total water level with a one-percent probability. This is a severe event that, like the so-called "hundred-year flood," has a one-in-a-hundred chance of occurring in a specified time period (the present to 2050 for purposes of this sub-plan).
- If such an event occurs in the next few decades (i.e., by 2050), areas shown in the golden-brown[6] band running along the village's shoreline have the "highest risk for erosion." There is a 98 percent confidence level (near certainty) that hazardous erosion would occur here.
- An area immediately east (landward) of that high-risk area also might experience hazardous erosion. The probability of that depends on how far seaward a given property lies. If the property adjoins the area marked "Highest Risk for Erosion," there is a significant chance – approaching the 98 percent confidence level – that the property would erode. For a different property, at the landward edge of the area designated "Other Significant Risk," there is a much smaller chance of erosion. Properties in between the seaward and landward edges of the "Other Significant Risk Area "thus all face some risk, ranging from just under 98 percent odds of erosion to as little as 2 percent. The farther seaward its location, the closer the odds of a property's erosion come to the 98 percent confidence level.
- The line marked "Mean of Erosion Predictions" indicates the statistical center of the "Other Significant Risk Area." A place on this line is somewhat likely to experience erosion. The confidence level of such erosion occurring here is midway between the 98 and the 2 percent levels.

The four OSU erosion-hazard maps are shown on the following pages. Each shows a portion of Neskowin. The first map is the southernmost, with each subsequent map showing the next area to the north. The maps overlap slightly.

[6] If printed on a monochrome printer, the area appears as a medium gray.

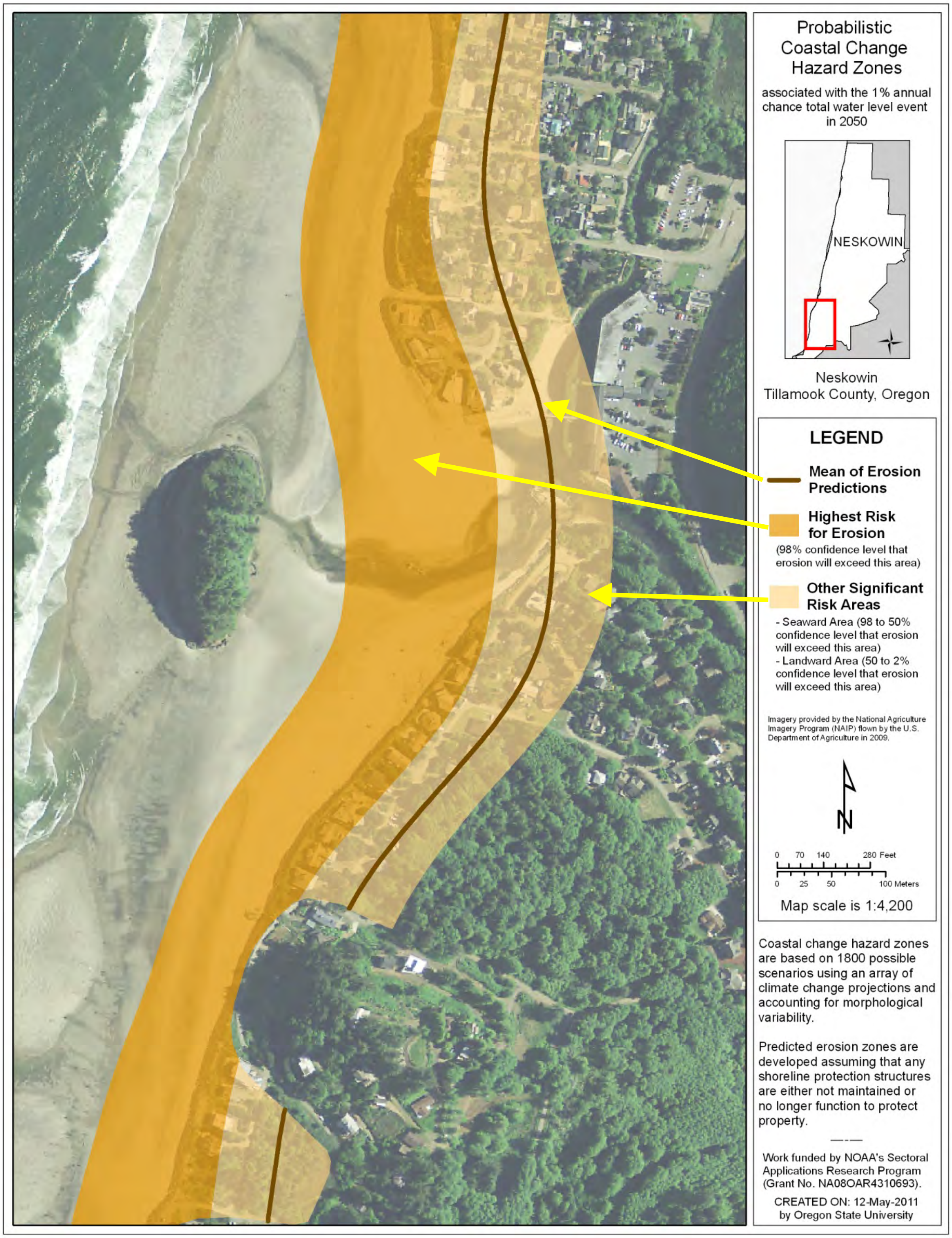


Figure 11a, Areas at Risk of Significant Erosion by 2050, Southern Neskowin

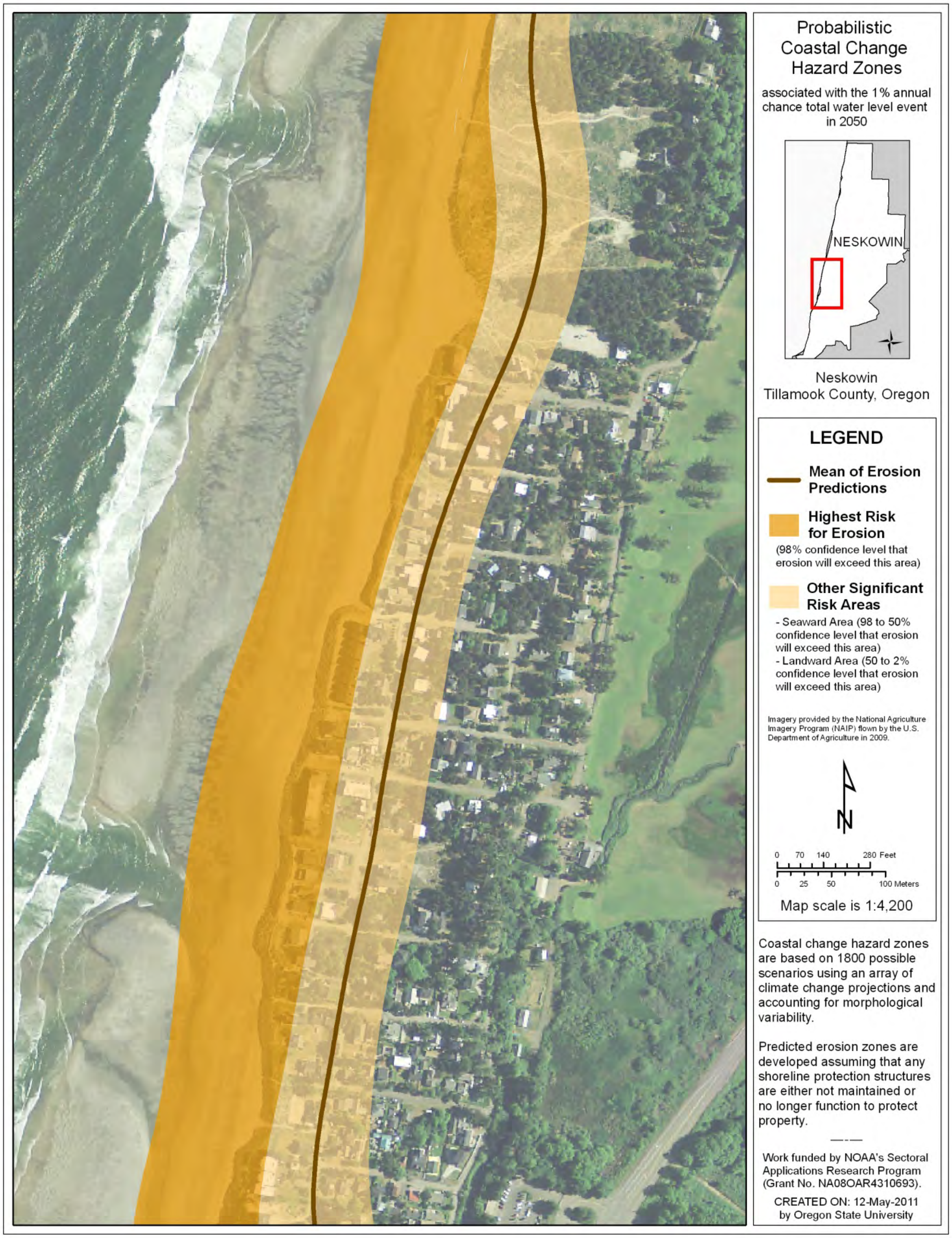


Figure 11b, Areas at Risk of Significant Erosion by 2050, Central Neskowin

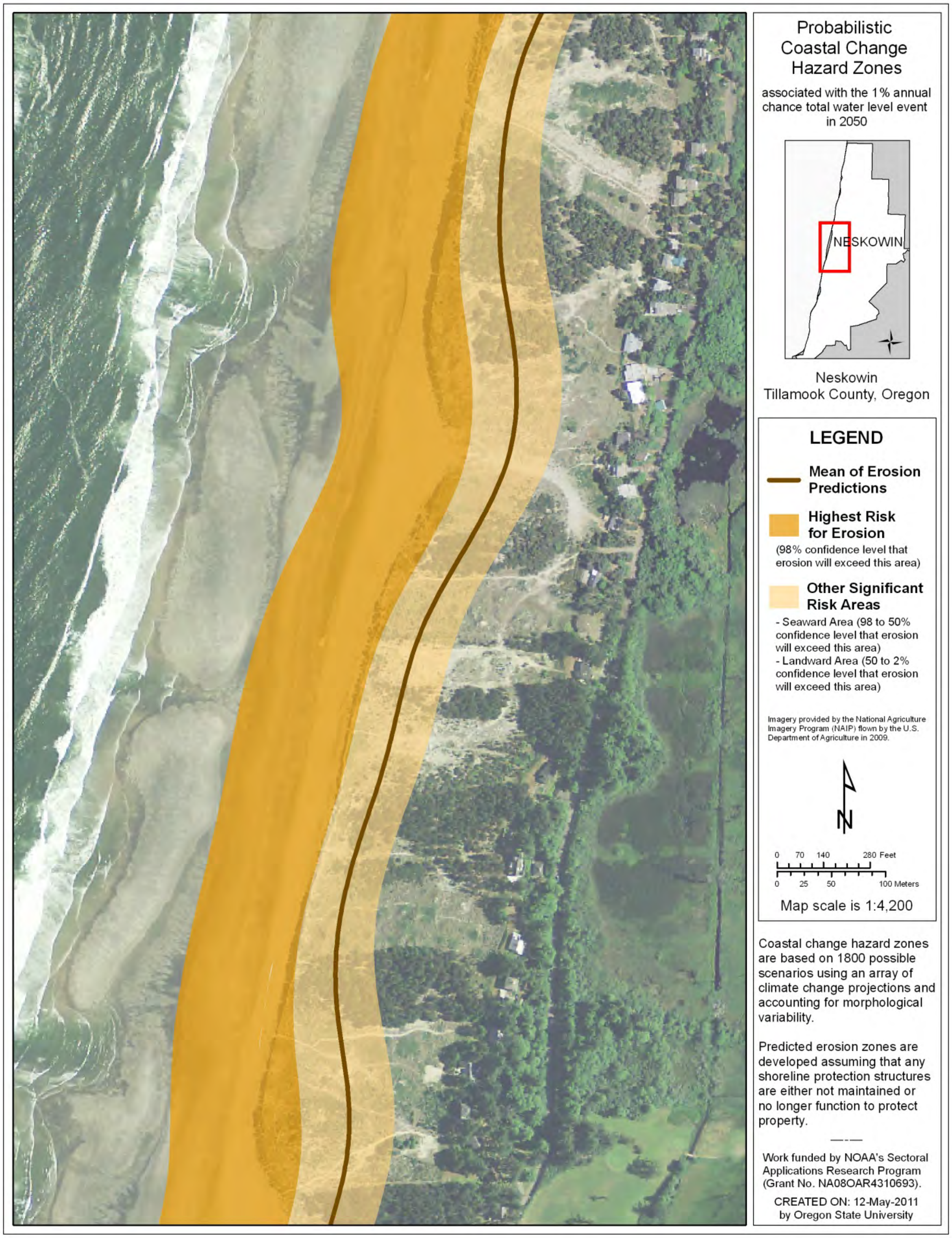


Figure 11c, Areas at Risk of Significant Erosion by 2050, North-Central Neskowin

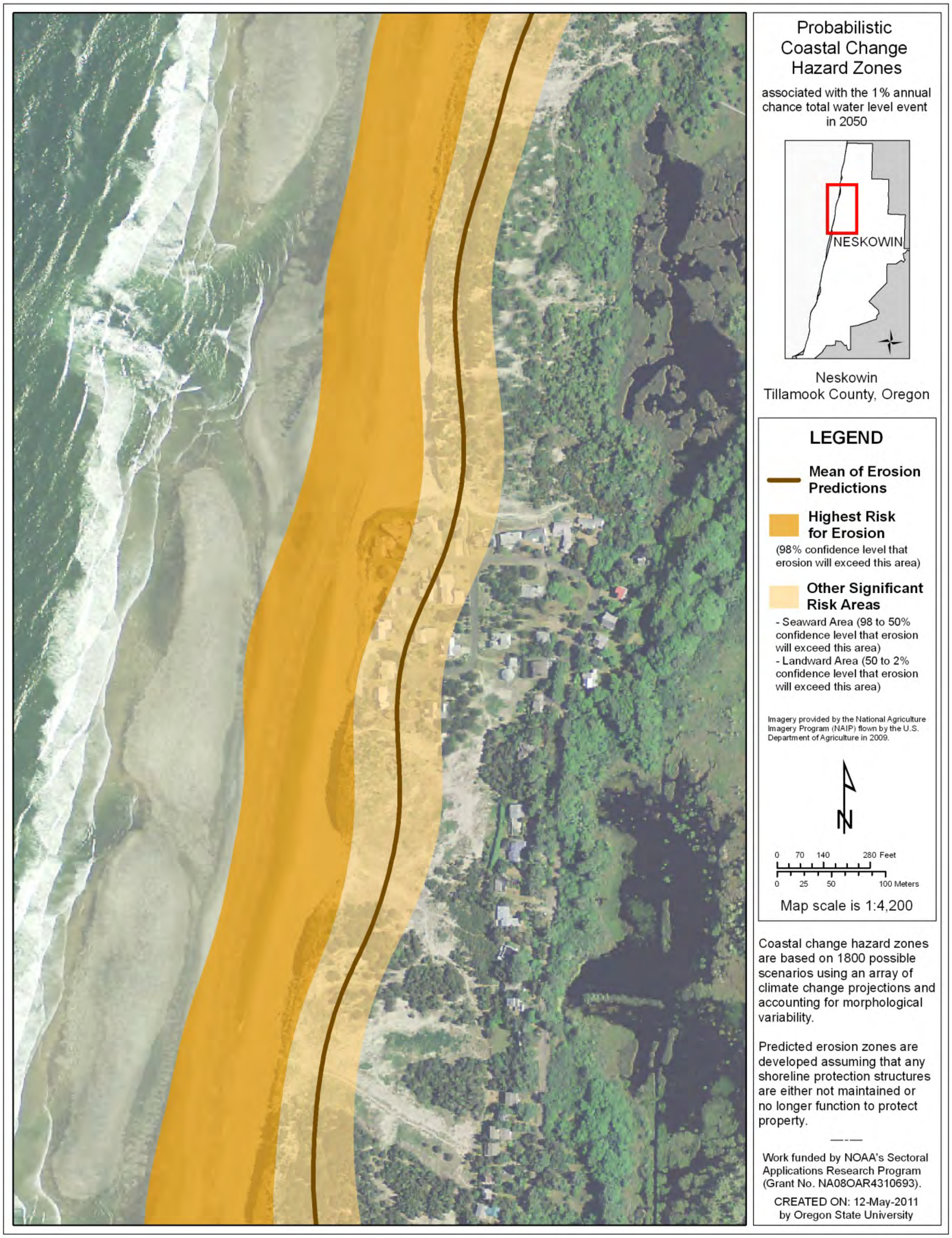


Figure 11d, Areas at Risk of Significant Erosion by 2050, Northern Neskowin

Estimating Structures at Risk

Using the erosion-risk data and maps for Neskowin, OSU researcher Heather Baron prepared the following charts to show the extent of risk to the community's homes, businesses and roads. Note that the two charts on the left indicate risk based on a **100-percent event — lesser erosion and flooding** from a total water level that could be expected to occur almost yearly. The charts on the right indicate risk associated with the much **more severe 1-percent event** – erosion and flooding from a total water level with a one-percent probability of occurrence.

Because the planning period for Neskowin's plan is from the present to 2050 and because its focus is on erosion risks from a one-percent event, the data of most interest to us in these charts are those shown beneath the two yellow arrows on the charts to the right below.

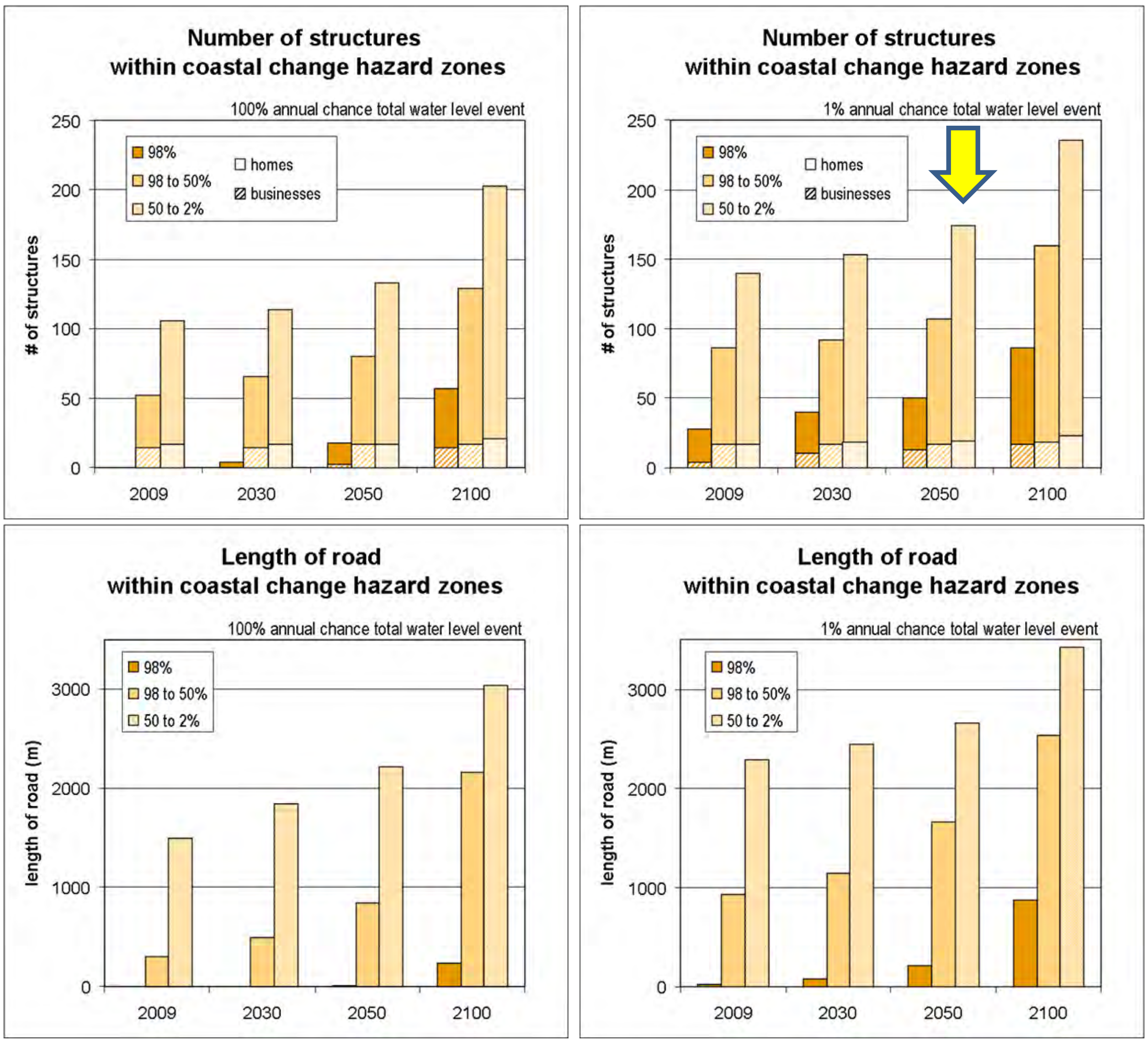


Figure 11e, Neskowin Risk Estimates

The highlighted data in the charts reveal that approximately 50 structures (mainly dwellings) are at very high risk (98 percent probability) from erosion hazards associated with a one-percent event occurring by 2050. More than 100 structures are at significant risk (probability in the range of 98 to 50 percent), and about 170 are at some risk.[7]

The charts indicate that only a few hundred meters of streets can be considered at very high risk. The length of streets facing significant or at least some risk is much greater, rising to approximately 2,700 meters (8,856 feet).

[7] Neskowin has about 400 dwellings in all. Approximately three-quarters of them are second homes, while roughly a quarter of them are occupied year-round.

Attachment 12: Geological Report Guidelines for New Development on Oceanfront Properties

Produced by the Coastal Processes and Hazards Working Group and Oregon Coastal Management Program staff (including DLCD, DOGAMI, and OPRD), this is a list of geologic factors, analyses and recommendations which should be included in geologic reports for new development on oceanfront property, as well as property close enough to the ocean to be influenced by coastal geomorphology and ocean-caused erosion.

These guidelines can be used as a supplement to the Guidelines for Preparing Engineering Geologic Reports in Oregon. They are meant to be a resource for local government review and ordinance updates, geologic and engineering consultants, and those interested in coastal property.

A. Site Description

1. The history of the site and surrounding areas, such as previous riprap or dune grading permits, erosion events, exposed trees on the beach, or other relevant local knowledge of the site.
2. Topography, including elevations and slopes on the property itself.
3. Vegetation cover.
4. Subsurface materials – the nature of the rocks and soils.
5. Conditions of the seaward front of the property, particularly for sites having a sea cliff.
6. Presence of drift logs or other flotsam on or within the property.
7. Description of streams or other drainage that might influence erosion or locally reduce the level of the beach.
8. Proximity of nearby headlands that might block the longshore movement of beach sediments, thereby affecting the level of the beach in front of the property.
9. Description of any shore protection structures that may exist on the property or on nearby properties.
10. Presence of pathways or stairs from the property to the beach.
11. Existing human impacts on the site, particularly that might alter the resistance to wave attack.

B. Description of the Fronting Beach

1. Average widths of the beach during the summer and winter.

2. Median grain size of beach sediment.

3. Average beach slopes during the summer and winter.

4. Elevations above mean sea level of the beach at the seaward edge of the property during summer and winter.

5. Presence of rip currents and rip embayments that can locally reduce the elevation of the fronting beach.

6. Presence of rock outcrops and sea stacks, both offshore or within the beach zone.

7. Information regarding the depth of beach sand down to bedrock at the seaward edge of the property.

C. Analyses of Erosion and Flooding Potential

1. Analysis of DOGAMI beach monitoring data available for the site.

2. Analysis of human activities affecting shoreline erosion.

3. Analysis of possible mass wasting, including weathering processes, landsliding or slumping.

4. Calculation of wave run-up beyond mean water elevation that might result in erosion of the sea cliff or foredune (see Stockdon, 1996).

5. Evaluation of frequency that erosion-inducing processes could occur, considering the most extreme potential conditions of unusually high water levels together with severe storm wave energy.

6. For dune-backed shoreline, use established geometric model to assess the potential distance of property erosion, and compare the results with direct evidence obtained during site visit, aerial photo analysis, *or analysis of DOGAMI beach monitoring data*.

7. For bluff backed shorelines, use a combination of published reports, *such as DOGAMI bluff and dune hazard risk zone studies*, aerial photo analysis, and field work, to assess the potential distance of property erosion.

8. Description of potential for sea level rise, estimated for local area by combining local tectonic subsidence or uplift with global rates of predicted sea level rise.

D. Assessment of Potential Reactions to Erosion Episodes

1. Determination of legal restrictions of shoreline protective structures (Goal 18 prohibition, local conditional use requirements, priority for non-structural erosion control methods).

2. Assessment of potential reactions to erosion events, addressing the need for future erosion control measures, building relocation, or building foundation and utility repairs.

E. Recommendations

1. Use results from the above analyses to establish setbacks, building techniques, or other mitigation to ensure an acceptable level of safety and compliance with all local requirements.

2. Recommend a plan for preservation of vegetation and existing grade within the setback area, if appropriate.

3. Include a consideration of a local variance process to reduce the building setback on the side of the property opposite the ocean, if this reduction helps to lessen the risk of erosion, bluff failure or other hazard.

4. Recommend methods to control and direct water drainage away from the ocean (e.g. to an approved storm water system), or if not possible, to direct water in such a way so as to not cause erosion or visual impacts.

References: Allan, J.C. and Hart, R., 2007, Assessing the Temporal and Spatial Variability of Coastal Change in the Neskowin Littoral Cell: Developing a Comprehensive Monitoring Program for Oregon Beaches, Open file report O-07-01, Oregon Department of Geology and Mineral Industries, Portland, Oregon.

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Allan, J. C., Komar, P. D. and Priest, G. R., 2003, Shoreline variability on the high-energy Oregon coast and its usefulness in erosion-hazard assessments. In: Byrnes, M. R., Crowell, M. and Fowler, C. (Editors), Shoreline mapping and change analysis: Technical considerations and management implications. Journal of Coastal Research, pp. 83-105.

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APPENDIX B: THE ENGINEERING STUDY

Page

Executive Summary of
"Neskowin Shoreline Assessment, Coastal Engineering Analysis of Existing and Proposed Shoreline Protective Structures"[1]

Preface[2]

The Neskowin Coastal Hazards Committee determined that a coastal engineering perspective was needed to evaluate thoroughly the erosion problem that Neskowin faces. In the summer of 2011, the Committee asked six coastal engineering firms to submit proposals for the evaluation. The proposed work included: (1) a science/literature review; (2) an analysis of existing and potential shoreline protective structures and other options for Neskowin; and (3) a Final Report containing key concepts, recommendations, and preliminary costs. The engineering firm ESA PWA, San Francisco, CA received the contract to carry out the study. The work was funded by generous contributions from the Neskowin Community Association, Proposal Rock Homeowners Association, South Beach Road Association, individuals from the Neskowin community, and the Oregon Department of Land Conservation and Development.

Background

The erosion problem at Neskowin has a variety causes: (1) high total water level (TWL), (2) reorientation of sediment movement between Neskowin and Pacific City (the Neskowin Littoral Cell), (3) rip currents, and (4) structural effects.

(1) Total water level is a composite measure of the tides, storm surge, seasonal variation, dynamic wave setup, wave run-up, and sea level rise. Future total water levels may be higher as a result of increased storm wave heights and El Niño activity, potentially leading to more frequent overtopping of the riprap revetment and flooding of the community (upland).
(2) The Neskowin beach currently is sediment starved because of the net northward transport of sand in the Neskowin Littoral Cell, a likely El Niño-induced pattern. Typically, this pattern would be expected to reverse (counter rotate) and bring sediment back to Neskowin. Although it is uncertain whether the counter rotation will occur, proposed erosion mitigation strategies should not block the potential future southward migration of sand.
(3) Rip current embayments are a common feature of the Neskowin shoreline. The complex interaction between incoming waves, Proposal Rock, Neskowin Creek, and the riprap produce a persistent, erosive rip current north of Proposal Rock.
(4) The influence of structural effects on beach erosion refers to the consequence of constructing the riprap revetment on a sand base. In the Neskowin area, bedrock is buried too deeply to base

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[1] This is a summary of a report prepared by ESA PWA, David Revell, Ph.D., Project Manager, dated March 12, 2013, under contract to Tillamook County at the request of the Neskowin Coastal Hazards Committee (NCHC). The aforementioned committee prepared this summary, but it does not necessarily represent the views of the NCHC.
[2] Comments by the NCHC itself are in italics.

the riprap on solid rock and, as a result, settlement, erosive undercutting, and structural damage of the revetment are common.

The effects of all of these causative factors are amplified by increased wave exposure resulting from the narrowing of the beach and the decreased ability of the beach to dissipate incoming waves.

Methods

Multiple approaches were used in the Neskowin shoreline assessment.

(1) The total water level was calculated using a composite slope run-up method that factors in the slope of the beach and the slope of the revetment. Two cross-shore profiles were used for these calculations; one profile was south of Proposal Rock, the second was north of the Rock.
(2) Future changes in the widths of the beach and the upland were estimated using a proprietary computer model for predicting changes in beach profiles (BEACH10). Beach width and erosion rate were varied in the computer simulations: beach widths were either wide (250 ft) or narrow (100 ft) and erosion rates, based on historical changes, were either low (1.99 ft/yr) or high (6.43 ft/yr).
(3) Cost estimates for existing structures and alternative erosion mitigation strategies were determined based on the experience of ESA PWA with similar projects. Life cycle costs for the existing riprap revetment were estimated from the maintenance history of the structure.
(4) Innovative options for shoreline protection were reviewed.

Results

Composite slope analysis

The composite slope run-up calculations were verified by TWL observations provided by the Oregon Department of Geology and Mineral Industries and by anecdotal observations of wave overtopping from several events. The 100-year TWL computed with the composite slope method is higher than that previously calculated by other analytical methods, and, as a result, ESA PWA recommends that the top of the riprap revetment should be raised by 8 ft (*on average*).

BEACH10 modeling

Five erosion mitigation strategies were tested with the BEACH10 model: (1) managed retreat (*no riprap present*); (2) riprap revetment; (3) seawall; (4) nourishment (the addition of sand to the beach); and (5) a segmented, shore-parallel breakwater plus nourishment. The program determined the resulting width of the beach and upland when using each of these mitigation strategies projected from the present to 2050. *The starting condition for all model runs is that the current riprap is not present.*

The managed retreat model run starts with an initial 40-foot increase in beach width (*to take the width of the current riprap into account*). After this increase, the beach width remains unchanged in the model runs, and the width of the upland decreases steadily. This decrease in upland width is equivalent to landward migration of the shoreline. In the low erosion model, the shoreline moves 80 ft landward by 2050. In the high erosion models, the shoreline moves 250 ft landward.

The upland width does not change for the other four mitigation strategies. By 2050, changes in beach width for the revetment and seawall options are: (1) a loss of 90 ft of beach for the low erosion, wide beach model; (2) a loss of the entire beach for the high erosion, wide beach model; and (3) a loss of the entire beach by 2025 for the high erosion, narrow beach model. It is important to note that because the models assume the current riprap is not present, construction of a revetment immediately subtracts 40 ft from the beach width and construction of a seawall subtracts 10 ft.

The beach nourishment and breakwater options start with an initial 100-foot increase in beach width because of the added sand. The nourishment model runs predict that the width of the beach in year 2050 will be reduced to 242 ft for the low erosion, wide beach; 94 ft for the high erosion, wide beach; and 0 for the high erosion, narrow beach. Construction of a breakwater plus nourishment is projected to lead to year 2050 beach widths of 262 ft for the low erosion and high erosion, wide beaches and 112 ft for the high erosion, narrow beach.

Cost estimates

Construction costs for five shoreline protection alternatives for Neskowin were estimated assuming a total shore length of 7,000 linear feet (1.3 miles). The proposed alternatives and their roughly-estimated, initial costs are: (1) altered riprap revetment, height increased with a rock cap, $7 million; (2) altered riprap revetment, height increased with a concrete wall, $14 million; (3) structural modifications to buildings, $14 to $27 million; (4) beach nourishment, $18 million; and (5) nearshore breakwater, $38 to $58 million. The estimates do not include costs for permitting, design, monitoring, and maintenance of these alternatives.

Life cycle costs for the current riprap revetment were estimated from the cost of repairs to the riprap between 1999 and 2008. Over this period, repair costs were approximately $73,000/yr, yielding an estimated expense of $3 million (present day dollars) for repairs to the riprap revetment between now and 2050.

Innovative options

The advantages and disadvantages of six innovative erosion mitigation options were reviewed. The options include: breakwaters, wave tripping structures, pile baffle walls, T-head groins, pile groins, and dynamic revetments. From this list, only breakwaters are viewed as being a viable alternative for Neskowin. Rejection of the other options is based on their being: (1) unable to withstand the waves in Neskowin (wave tripping structures); (2) traps for debris that could lead the structures failing under the force of the waves, in addition to being unsightly (pile baffle walls and pile groins); (3) potential barriers to the return of sand if counter rotation occurs in the littoral cell (T-head and pile groins); (4) structures that might cause rip currents (T-head groins); and (5) sources of cobble projectiles and barriers to beach access (dynamic revetments).

Findings and Recommendations

4. The ESA PWA report ends with a list of 14 findings and recommendations. These items include: (1) recommendations based on the results of their analyses (beach nourishment and breakwaters offer protection for the beach and community, managed retreat will maintain the beach); (2) suggestions for protecting structures (elevating houses, dynamic revetment and gabion matting to protect the Hawk Creek bridge; (3) descriptions of alterations that might improve the performance of the existing riprap revetment (increasing the surface roughness, overlaying additional rocks, deepening the foundation, creating a sacrificial toe by adding additional rocks on the beach in front of the riprap, limiting the ponding of water behind the revetment); (4) speculative proposals for reducing erosion (stabilizing the location of rip embayments, transferring sand from the dunes to the beach); (5) a review of life cycle costs for the present riprap revetment; and (6) a suggested mechanism to fund erosion mitigation options (formation of a geological hazard abatement district).

NESKOWIN SHORELINE ASSESSMENT

Coastal Engineering Analysis of Existing and Proposed Shoreline Protective Structures

Prepared for The Neskowin Hazards Committee

March 12th, 2013

High surf during high tide at Neskowin on Jan 9th, 2008.
Source: Armand Thibault (Published in NRC, 2012).

ESA PWA

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Introduction

The purpose of this project is to provide technical and engineering analysis to the Neskowin Coastal Hazard Committee (NCHC) to evaluate various structural alternatives that reduce threats to upland development while maintaining a beach. The project goal is to provide an objective engineering analysis that will provide the community with additional information that they can use to make decisions about how to contend with the current erosion. For purposes of this study, the NCHC requested cost estimates and results to examine potential changes over the next 15 years. ESA PWA has recommended looking out to at least 2050 when various sea level rise (SLR) estimates begin to diverge dramatically.

The specific objectives of this study are to examine a range of alternatives to mitigate erosion in a variety of ways. The first objective is to evaluate the effectiveness of each method at protecting upland properties and maintaining a beach. The second objective is to provide conceptual level cost estimates for various erosion mitigation strategies and lifecycle maintenance costs. The third and final objective is to consider innovative options to mitigate the erosion at Neskowin.

Authors

This technical report was completed by ESA PWA. Contributing individuals include: David Revell, PhD (Project Manager), Louis White, P.E., To Dang, PhD, Elena Vandebroek, M.Eng., Curtis Loeb, P.E. and Bob Battalio, P.E. (Project Director- Chief Engineer).

Background

There has been a lot of work done by various scientific experts examining the erosion at Neskowin (Figure 1), most notably led by Jonathan Allan of Oregon Department of Geology and Mineral Industries (DOGAMI) and Peter Ruggiero at Oregon State University (OSU). Both researchers have provided a tremendous amount of data and insight from their research efforts, graduate students and expertise.

The intent of this report is not to synthesis this information, but to incorporate those research findings and data sets into the engineering analyses. However, ESA PWA does feel that it is important to document some of the key events and processes that have occurred since they provide a context that should be considered in addition to the engineering analyses when making community management decisions.

Causes of Erosion and Damages

From review of the literature, there appear to be several causes for the erosion at Neskowin: total water levels, littoral cell wide reorientations related to El Niño, rip embayments, and structural effects. The actual cause of the damages is the wave exposure which has increased as the dissipative effects of the beach have diminished with decreasing beach width. Total water level is one measure of wave damage and flood potential which has been reported in the recent literature. Total water level (TWL) is a combination of tides, surge (e.g. El Niño related), dynamic wave setup, wave run-up, and sea level rise (Figure 2a). The high energy Oregon coast typically experiences high TWL on an annual event (>5.5 meters NAVD), however upland development at Neskowin was not subject to significant damage until the 1997-98 El Niño occurred. During the 1997-98 El Niño the south end of the Neskowin littoral cell was starved of sediment as part of the El Niño pattern of littoral cell wide reorientations (Komar, 1997) (which also occurred in the Netarts and Beverly littoral cells). Typically, the littoral cell would rotate back to the south and the beach would subsequently recover. However, this expected recovery has not happened in Neskowin.

Two theories exist as to why this counter rotation has not occurred:

1. The lack of recovery to the south end is possibly related to changes in wave direction influenced by the Pacific Decadal Oscillation (PDO). The PDO is a 20-30 year climate cycle which affects the north - south location of the jet stream and thus the wave-generating storm tracks. A more southerly shift in the wave direction is consistent with the current phase of the PDO (NOAA 2011). This is consistent with the short term shoreline change rates shown in Figure 3 (Ruggiero et al in press). If this theory is correct, then the implication is that the sand north in the system would eventually return to the south end of the littoral cell reducing the levels of erosion and the extent of damages to structures.

Implication if correct: Any strategies implemented to mitigate erosion must not curtail beach recovery by reducing the ability of sand to migrate to the south.

2. The second theory for the continuing erosion at Neskowin is that the impact of several large storm seasons in the past decade (1997, 1998, 1999, 2004, 2006, 2010), have moved substantial amounts of sediment offshore beyond the depth that it is actively moved by wave energy except during the largest storm events. Significant accretion shown in the Neskowin profiles near the mouth of the Nestucca River may provide some evidence that this has occurred (Figure 3).

   Implication if correct: This ebb shoal or offshore location of this sediment may be a suitable source for acquiring beach sand for nourishment in the south end.

Rip embayments, localized areas of erosion (200+ yards wide) that migrate along the beach, are another cause for the erosion and damages in Neskowin. These embayments scour sand (up to 9' from certain sections of beach) and reduce wave breaking, enabling larger wave impacts at the shoreline. Rip embayments typically develop near the north side of Proposal Rock, perhaps either due to creek discharge, lowered beach conditions, or reflected wave energy from the island (Jonathan Allan, personal communication). This rip embayment typically migrates northward with the southwesterly direction of the winter waves and focuses the erosion on or around Pacific Sands (Figure 1).

Implication: The engineering implication of this rip embayment generation zone is that altering this generation zone or stabilizing this rip embayment may reduce the armoring required to protect the upland properties north of Proposal Rock.

The final cause of damages tends to be associated with failures of the shoreline armoring structures. There are several aspects of the existing armoring which may be contributing to the erosion damages. First, the revetment structures have a tendency to settle due to several factors including sand fluidization, scour at the toe from active reflection off of the structure, and the depth to bedrock in the north of the Proposal Rock portion of the study area. An examination of the nearest groundwater wells from the Oregon Water Resources Department in the vicinity of Neskowin (Table 1) show that the depth to bedrock is well below the elevation that any of these structures are likely to be built. Another exacerbating factor to structural damages is the volume of water that overtops the revetments. This volume can saturate soils and the revetment, weakening the structural integrity and fluidizing the sand behind the structure. Such an example occurred on January 5, 2008, overtopping wave water volumes saturated dune sands and contributed to a mass failure of the structure similar to a landslide (Figure 2b, NCHC, personal communication).

Table 1: Groundwater Well Logs Nearest to Neskowin with Depth to Bedrock

Well Log	Address	Depth to Rock	Rock type
Till 1111	47405 Highway101	60'	Basalt
Till 52053	43505 Aeolian Way Loop Rd	31'	Sandstone
Till 51161	NE of Fire Hall	53'	Basalt

The revetments also have a much steeper slope than a natural beach, which contributes to elevating the wave run up elevations. The TWL calculations completed by Baron and Ruggiero for this region have utilized the empirical parameterization of wave run-up of Stockdon (2006). This Stockdon run-up equation, which integrates dynamic wave set up (an integral part to TWL on these high energy beaches), is based on wave run-up on a natural foreshore slope. This application of the Stockdon wave run-up equation to steep slopes is inappropriate and contributes to an underestimate of potential wave run up elevations and storm wave damages. (See methods and results section for composite slope method)

Implication: TWL and damage assessments need to utilize a more appropriate run-up equation.

While it is clear that sea level rise is occurring and will continue to occur for centuries with an increase in damaging coastal events, the positive indication identified by the National Research Council in a recently released report is that the tectonic uplift found along the Oregon coast will not significantly exacerbate current coastal processes. Projections of sea level rise by 2030 are 6.8cm (2.6 inches) and by 2050 17.2cm (6.7 inches) (NRC 2012). Note that the analysis conducted in this report did not factor in sea level rise or other climate change impacts.

Methods

Methods and Approach

- TWL calculation on a composite slope using traditional wave run-up equations. Calculation of run-up on a composite slope will involve estimating the dynamic wave setup and using a depth limited wave height at the toe of the structure.
- Calculate current overtopping potential based on negative freeboard (TWL elevation – structural crest elevation)
- Considerations of additional engineering of toe of structure to minimize settling
- Physical BEACH 10 modeling plotting Beach Width vs. Upland Erosion
- Calculate historic damages to structures based on storm wave events and permit database
- Cost estimates for lifecycle maintenance cost of current structures to 2025 and 2050
- Cost estimates for bolstering of existing structure with additional revetment volume
- Cost estimates for other alternatives and structures

Data Sets Used

Several data sets were acquired from various researchers and project partners. The key data sets used are discussed briefly below.

Waves – A composite time series of waves recorded at northwest buoys was acquired from Dr. Peter Ruggiero (Figure 4, Harris, 2011). This recorded time series was used to generate a future synthetic time series used in the engineering analysis. Additional information on this data set can be found in Harris 2011.

Coastal Geomorphology – Beach topographic and nearshore profile data was collected by Jonathan Allan at DOGAMI and Dr. Peter Ruggiero at Oregon State. Beach profiles were collected using survey grade GPS equipment. For more details see Allan and Hart, in review. Additional elevation data was extracted from topographic LIDAR collected by the Oregon Department of Geology and Mineral Industries in 2009 (available on the NOAA Digital Coast website).

Future TWL – Projections of existing and future water levels using the wave time series discussed above was completed by Heather Baron (2011) and provided to ESA PWA for use in this project.

Shoreline Change – Short and long term shoreline change rates were provided by Dr. Peter Ruggiero under contract with the United States Geological Survey as part of the National Assessment of Shoreline Change in the Pacific Northwest. For more details see Ruggiero et al in review (Figure 3).

Coastal Structure Physical Conditions Inventory and Permit Database – Structural conditions along the Neskowin Shoreline were surveyed in the field by Tony Stein at Oregon Parks and Recreation Department. Summary tables were examined in the Neskowin Coastal Erosion Adaptation Plan (Tillamook County, 2012). Additionally, OPRD provided a subset of the coastal armoring tracking database which contained specific dates, volumes and lengths of revetment alterations associated with permits in the Neskowin region.

Coastal Structure Elevation information – Structural characteristics were collected from available LIDAR surveys and ground-truthed with DOGAMI survey data to provide a quantitative understanding of the exposure faced by the community to existing and future hazards (Figure 5).

Engineering unit costs and designs – For more details on the unit cost, volumes and assumptions made in the cost estimating, please see Appendix 1.

Erosion Mitigation Strategies for Analyses

The following mitigation strategies were considered for analysis after consultation with the community and previous experience. Upon further review of the site and literature, several of these were selected for more detailed analysis including beach width and upland property effectiveness (BEACH10) and cost estimating.

Those measures selected for detail assessment included:

- Managed retreat – assumes natural erosion
- Altered revetment –concrete cap wall
- Altered revetment –with additional rock revetment cap (Figure 12)
- Structural adaptation – elevate structures on piles to existing floor elevation +10'
- Seawall with return - (e.g., O'Shannessy Seawall, Figure 6)
- Beach nourishment
- Nearshore breakwater (Figure 7)
- Low crested structure or groin to stabilize migrating embayments (only cost estimating)

Analysis rejected for detailed analysis (see discussion in Innovative options):

- Wave tripping structure on the beach (e.g., Taraval wall, Figure 8)

Coastal Structure Elevation Information

To assess the volumes of material needed to elevate the crest of existing structures to deal with existing hazards and rising sea levels, and to understand the existing site characteristics needed to drive the TWL wave run-up analysis, a detailed inventory of existing elevation information on the structures was conducted (Figure 5). This analysis involved extracting the crest elevation from the 2009 LIDAR and then fact checking the crest elevations using the DOGAMI profiles provided by Dr. Jonathan Allan. Results from this analysis are shown in Figure 5.

Composite Slope Wave Run-up Analysis

To assess the required changes to the existing structures and understand the volumes and materials necessary to provide conceptual cost estimates it was important to develop a TWL calculation that was consistent with observations. To do this, wave run-up on a composite slope was modeled using a computer program developed by ESA PWA. The program uses several published methods to assess the extent of wave run-up on beaches and shores with irregular topography and surface conditions. Wave run-up is computed using the method of Hunt (1959) which is based on the Irribarren number (also called the Surf Similarity Parameter), a non-dimensional ratio of shore steepness relative to wave steepness. The program also uses the Direct Integration Method (DIM) to estimate the static and dynamic wave setup and resulting water surface profile (FEMA 2005; Dean and Bender 2006; Stockdon 2006). The methodology is consistent with the FEMA Guidelines for Pacific Coastal Flood Studies for barrier shores, where wave setup from larger waves breaking farther offshore, and wave run-up directly on barriers combine to form the highest total water level and define the flood risk (FEMA 2005). This program also incorporates surface roughness of the structure which acts as friction on the uprush of the waves and uses a composite slope technique as outlined in the Shore Protection Manual (SPM; USACE 1984) and Coastal Engineering Manual (CEM; USACE 2002).

Two cross-shore profiles (called “North” and “South”) were used to estimate the wave run-up at Neskowin, as shown on Figure 9 (Location shown in Figure 1). These profiles were based on nearshore bathymetry and beach surveys collected by the State of Oregon in February 2012 (topography), September 2011 (bathymetry), and LIDAR flown in 2009.

Water levels for the analysis were taken from the nearby Yaquina Bay tide gauge operated by NOAA (ID #9435380). Wave data were taken primarily from the nearby Stonewall Banks, Tillamook, and Washington wave buoys operated by the NOAA (ID # 46050, #46089, and #46005, respectively). The resulting time series of tides, wave periods, and wave heights are shown in Figure 4 (Harris 2011, courtesy of Ruggiero).

Verification of Wave Run-up Model

The run-up calculations were compared to observations of wave run-up provided by the Neskowin community. During a high run-up event in January 9, 2008, wave run-up in excess of 34 feet was observed in the vicinity of Profile “North” at the Pacific Sands Condominiums (Figure 2; personal communication NCHC, Jonathan Allan). The revetment crest in the vicinity is approximately 28 feet in elevation, indicating that the wave run-up overtopped the revetment crest. The wave run-up calculations for this date and location yielded a run-up elevation of 36 feet, as shown in Table 2, with the note “Max R elev.”. The “Max inland limit” indicates the elevation of the landward limit of wave run-up, after overtopping. This calculation indicates that the run-up would extend approximately 200 feet farther inland if not obstructed, which corresponds to a lower elevation on the land side of the development.

Table 2 shows selected wave run-up calculations for January 9, 2009. Visual observations indicate run-up extended to about elevation 33’ at Neskowin, based on our interpretation of the information provided to us by members of the community. These calculations utilize the North Profile.

Table 2: Wave Run-up Calculations for January 9, 2009

Inputs		
SWL(ft)	Hs(ft)	T(s)
9.2	21.8	13.8

Outputs								
DWL (ft)	Hb (ft)	T (sec)	Zb (ft NAVD)	x@Zb (ft)	slope	x-run (ft)	R (ft NAVD)	Notes
14.08	4.26	12.9	8.62	365	0.205	476	32.3	Test run with second highest total water level, one hour earlier than maximum.
14.85	4.86	13.8	8.62	365	0.218	488	36.3	Test run with maximum total water level elevation.

The values in the table are:

DWL = Dynamic Water Level: This is the dynamic wave setup, estimated to be exceeded about 2% of the time.
Hb = Height of the breaking wave that drove the highest total water level
T = Wave period
Zb = the elevation of the bed at the location of Hb. Note that the depth is the DWL minus this bed elevation.
x@Zb = the horizontal coordinate of the breaking location
slope = the composite (average) slope
x-run = the horizontal coordinate of the limit of wave runup
R = the calculated wave runup in terms of the total water level elevation.

The difference (3 feet) indicates the calculation exceeds the observation. However, we believe that this difference is acceptable and verifies that the methodology is sound. It is important to consider that the run-up calculations provide the potential elevation that the run-up would extend if the revetment slope extended high enough. In reality, the wave run-up exceeds the crest of the revetment and the run-up extends inland instead of upward. It is unusual for overtopping to extend contiguously (vs. splash and spray) to an elevation more than about 5' above the crest of a revetment, because the wave momentum rushes inland as a bore. Splash and spray overtopping can take a projectile –like trajectory. These concepts are shown schematically in the Figure 10 (FEMA, 2005). This is consistent with anecdotal observations from Pete Owston as he and his wife were swept off their feet during this calibration event. Therefore we expect the potential run-up elevation to exceed the observed elevation for these overtopping conditions. Also, the calculated wave run-up parameter is called the "2% exceedance" which means that it is the value that is exceeded by only 2% of the individual run-up pulses in an event (1 out of 50 waves) and potentially comparable or greater than that associated with an observed maximum. In summary, we believe that the run-up calculation method is verified to provide reasonable results which may be a bit conservative (calculated higher than actual). Also, wave run-up calculations are not considered to have high accuracy owing to the complex hydrodynamics and empirical basis for these run-up equations.

Application of Composite Slope Wave Run-up Model

There were three primary purposes for the use of the composite slope wave run-up model. The first reason was to calculate the elevations that structural alterations needed to reach to reduce the risk of upland property damages. Secondly, this method was used to calibrate the historic damages to structures based on recorded TWL and project those future conditions to assess future damages using standard CEM practices. Once the wave run-up methodology is verified, run-up time series can be developed using existing wave and water level data. Once these time series are completed, the extreme total water level values can be identified along with their recurrence frequency (e.g. exceed once in 100 years or other time frame).

Table 3 below shows the comparison of the Baron 2011 TWL calculations using the Stockdon formulation with the composite slope method. The January 9, 2008 run-up observations and our composite slope calculations indicate that total water levels in excess of 10 meters are likely to occur more frequently than once every 100 years. Therefore, the total water level values based on Stockdon (Table 3) are too low by a significant amount (at least 3 meters (10 feet) and would not be causing impacts to the homes. However, these lower run-up elevations are also indicative of what may occur if a natural profile forms, which would require either the erosion of the dunes or the widening of the beach by several hundred feet.

Table 3: Future 100-year Total Water Levels using Stockdon Formula (Baron, 2011)

	100 yr TWL (Baron, 2011) *feet NAVD88*	100 yr TWL (current study) *feet NAVD88*
Method	Stockdon, 2006	Composite Slope Method
Present (2009 to 2010)	22.3 +/- 1.1	57.7
2025	22.3 +/- 1.1	N/A
2050	23.0 +/- 1.2	N/A

Note: The 100-year total water level was only estimated for the present. The future 100-year total water level is expected to increase with sea level rise.

BEACH10 Modeling

One of the key project objectives was to evaluate effectiveness of the erosion mitigation strategies at protecting upland and maintaining a beach. To do this, ESA PWA utilized BEACH10, a simple shore profile evolution model that tracks changes to beach dry sand widths (assumed to be between Mean High Water (MHW) and the toe of the revetments) and then compares beach width with changes to upland over time (Figure 11).

To run the BEACH10 model, two input parameters are required – initial beach width and upland width conditions and the historic erosion rates. To identify the beach widths necessary to initialize the model, ESA PWA used the profile #262 located just south of Proposal Rock (Figure 1). This led to an initial beach width and upland distance of 250 feet. To drive the erosion, ESA PWA utilized erosion rates identified in Ruggiero et al unpublished (Table 4). However, due to the uncertainties in littoral cell rotation and the alongshore variability in beach width conditions, 3 separate BEACH10 model runs were conducted.

- Model Run 1 – 250' beach width, short term erosion rate (to account for changes since 1997)
- Model Run 2 – 250' beach width, long term erosion rate (to account for a counter rotation in littoral cell)
- Model Run 3 – 100' beach width, short term erosion rate (existing condition at portions of north end)

Table 4: Historic Erosion Rates (Ruggiero et al, unpublished)

	Short Term Erosion Rates *(feet/year)*	Long term Erosion Rates *(feet/year)*
South End Armored	6.0	1.13
North End Armored*	**6.43**	**1.99**
North End Unarmored	6.99	1.7

** Value used in Beach 10 analyses*

The following assumptions were made for each erosion mitigation strategy in applying the BEACH10 model:

- Managed retreat – rip rap structure is removed and beach width remains constant and upland distance is impacted at erosion rate.
- Altered revetments – assumes placement loss due to footprint of structure is 40'.
- Structural adaptation – same as managed retreat.
- Seawall with return – assumes placement loss due to footprint of structure is 10'.
- Beach nourishment – assumes widens beach by 100' initially then background erosion rate (ignores diffusion) but that the existing structures remain so upland erosion doesn't occur.
- Nearshore breakwater - assumes widens beach by 100' initially then reduces erosion rate to 1/3.
- Low crested structure or groin to stabilize migrating embayments - not completed – needs more sophisticated modeling approach if deemed appropriate by the community.

Cost Estimates

For planning purposes, ESA PWA has provided order of magnitude cost estimates to allow cost comparison of alternatives (Table 10). These cost estimates are intended to provide an approximation of total project costs appropriate for the conceptual level of design. These cost estimates are considered to be approximately -30% to +50% accurate, and include a 35% contingency to account for project uncertainties (such as final design, permitting restrictions and bidding climate). These estimates are subject to refinement and revisions as the design is developed in future stages of the project.

This results table does not include estimated project costs for permitting, design, monitoring and maintenance. Estimated costs are presented in 2012 dollars, and would need to be adjusted to account for price escalation for implementation in future years. This opinion of probable construction cost is based on: ESA PWA's previous experience, bid prices from similar projects, and consultation with contractors and suppliers.

Lifecycle Cost Estimates

Prior damages to the rock revetment were used to estimate the cost of maintaining the shore protection function. Prior damages were estimated based on information in repair permits. The historic repair costs were then estimated using the permit data, presuming that the repair quantities were representative of prior damages. These estimates of historic repairs provide a baseline life cycle cost under existing conditions.

Future damages were estimated based on historic damages increased to account for future sea level rise and potential shore recession. The result is conceptually an increase in water depth at the toe of the structure, and the related increase in depth-limited wave height breaking on the structure. The increase in wave height breaking on the structure was used to prorate existing damages to future conditions.

Historic Events

Historic damage events were evaluated using eleven (11) permits between 1999 and 2008, with permit issue dates in 1999, 2003, 2007 and 2008 (Table 5). The repair volume was compared to the total revetment volume to develop the estimated "percent damage" as defined in the Shore Protection Manuel (USACE, 1984).

Table 5: Selected OPRD Permit Records for Benchmarks of Percent Damages in Neskowin

FID	OPRD	Permit Quantities and Structure Parameters							DATES	
		HEIGHT (feet)	WIDTH (feet)	ROCK DIAMETER (feet)	SLOPE	LENGTH (feet)	REPAIR LENGTH (feet)	REPAIR VOLUME (cubic yards)	ISSUED	APPLICATION
9	BA-443-99	14	6	3	1.5	358	85	240	19990225	2/24/1999
15	BA-466-99	14	20	2	1.5	358	75	729	19990806	4/15/1999
3	BA-464-99	14	14	2.5	2	2804	80	800	19991018	3/22/1999
5	BA-464-99	16	27	2.5	2	2804	60	324	19991018	
19	BA-549-02	9	40	3.5	2	2612	99	300	20030115	2002-11-20
55	BA-548-02	9	40	4	2	2612	88	800	20030115	2002-11-20
56	BA-549-02	8	40	3.5	2	2612	120	200	20030115	2002-11-20
57	BA-549-02	8	40	3.5	2	2612	148	240	20030115	2002-11-20
58	BA-549-02	7	40	3.5	2	2612	92	300	20030115	2002-11-20
79	BA 625-07	7-18'	25-35	3-6'	2H:1V	0	*100**	1000	20071025	2007-07-09
75	BA 631-07	8-10'	43-45'	5'	2H:1V	0	*100**	800	20080128	2007-11-28

Note: Italic numbers with (*) are assumed values of REPAIR VOLUME derived from other information in the permit.

A review of the permit dates along with the emergency status of some of the permits resulted in selection of five (5) damage events that were likely responsible for triggering the repair activity. The contribution of other events and long-term degradation may be important but could not be determined based on the limited data. These damage events are characterized in Table 6.

Table 6: Summary of Wave Conditions and Documented Failures for Select Storm Events

Date	Still Water Level (feet)	Wave Height, H_o (feet)	Period, T (sec)	Damage Volumes (cubic yards)	Length repair (feet)
02/16/1999	1.08	36	20	970	160
03/03/1999	4.24	46	17	1120	140
11/08/2002	8.00	26	20	1840	550
02/04/2006	4.22	44	17	1800	200
12/03/2007	4.45	45	16	650	100

Note: The above wave characteristics are the average of the largest TWL events of that winter season (after Sept 15)

The capacity of the revetment was quantified by calculating the wave height that the revetment could withstand using the Hudson Equation (USACE, 1984). Revetment characteristics were estimated based on information provided to us. The estimated "design wave height" is approximately 2.5 to 3 meters (up to 10 feet). Data on revetment performance indicates that impingement of design waves may result up to 5% of the revetment rocks being moved and slightly displaced. For larger wave heights, the percentage of potential damage increases in proportion to the ratio of actual wave height to design wave height (USACE, 1984). We therefore estimated the wave heights that occurred during damage events, calculated the ratio of actual height to design height, and compared the predicted percent damage to the permit-based damage. As shown in Table 7, the predicted (calculated) damages are higher than the actual (permit-based) estimates of damage by up to about 30%. Given the approximate nature of this calculation, it seems that the "calibration" is reasonable and the methodology for historic damages can be used to estimate future damages.

Table 7: Selected Damage Events and Parameters

Permit Data			Damage Event[1]									Accuracy
FID	*Damage Volume (average cy/ft)*	*Percentage Damage*	*Event*	*DATE*	*T (s)*	*H (m)*	*TIDE (m)*	*Hb_toe (m)*	*Hb_toe /HD*	*Percentage Damage*	*Damage Volume (average cy/ft)*	*Percent difference between calculated and actual*
9	6.06	0.54	1	1999-02-16	20	10.90	0.33	4.49	1.83	0.75	8.46	28%
15	6.06	0.54	1	1999-02-16	20	10.90	0.33	4.49	1.83	0.75	8.46	28%
3	8.03	0.71	2	1999-03-03	16.67	14.15	1.291	4.25	1.74	0.71	8.01	0.3%
5	8.03	0.71	2	1999-03-03	16.67	14.15	1.291	4.25	1.74	0.71	8.01	0.3%
19	8.03	0.71	3	2002-11-08 to 09	20	7.99	2.437	3.21	1.31	0.24	2.71	24%
55	8.03	0.71	3	2002-11-08 to 09	16.67	9.04	1.686	3.21	1.31	0.24	2.71	24%
56	8.03	0.71	3	2002-11-08 to 09	20	6.29	3.064	3.21	1.31	0.24	2.71	24%
57	8.03	0.71	3	2002-11-08 to 09	16.67	5.80	2.657	3.21	1.31	0.24	2.71	24%
58	8.03	0.71	3	2002-11-08 to 09	16.67	5.90	2.876	3.21	1.31	0.24	2.71	24%
79	9.00	0.80	4	2006-02-04	17.39	13.32	1.287	4.30	1.76	0.76	8.57	5%
75	9.00	0.80	4	2006-02-04	17.39	13.32	1.287	4.30	1.76	0.76	8.57	5%
72	6.50	0.58	5	2007-12-05	16	13.83	1.355	3.67	1.50	0.45	5.08	28%

[1] The wave and tide conditions for event 3 were peak values selected from the event period. The H_b and percent damage for event 3 are averages from the five peak values.

The calibration was accomplished by considering the mode of failure. It is our understanding that failure has occurred primarily when a rip current has formed and enlarged to the point of scouring deeply at a particular location, causing the rock to settle. We therefore assumed that the beach elevation at the toe of the structure was lowered during the damage event. We used scour equal to the calculated breaking wave height, measured vertically, and assumed a relatively flat slope of 0.002 (1:50). These parameters were selected to bring the calculated damage closer to the permitted repair volumes. Selecting this damage mechanism and multiple parameters required professional engineering judgment limiting the certainty of the analysis.

Future damages were estimated based on assuming a baseline condition and increased damages due to sea level rise and continued shore recession. For the baseline condition, we assumed that areas not yet repaired could be subject to damage, and the damages would occur roughly at the rate that occurred historically between 1999 and 2008. We then looked at the increase in coastal flood hazard associated with an increase in shore recession, and used this increased exposure to prorate the historic baseline damages to an estimated future damage.

Results

Composite Slope Analysis

The model was successfully verified with observations provided by DOGAMI and NCHC based on anecdotal wave overtopping observations from several events. While additional observations would be helpful, we believe that the methodology is adequate to estimate future damages. The analysis was largely dependent on NCHC and OPRD input for dates of historic events that caused observed failures. From this composite slope analysis it was determined that bolstering of the existing revetments to account for historic events under future rates of sea level rise identified by the National Research Council (2012), that the crest of the revetment should be raised by 8' to about 36' NAVD (Figure 12)

BEACH10 Modeling

The three model runs of BEACH 10 show similar patterns for each alternative (Table 8,Figure 13,Figure 14,Figure 15). In general, the options that maintain a beach width under all of the modeling scenarios for the long term planning horizon (2050) are the managed retreat, structural adaptation, and breakwater plus nourishment strategies. Conversely, upland properties are protected by the altered revetments, seawalls, and breakwaters.

For the wide beach width and high erosion rate, the results of BEACH10 are show in Figure 13. For this scenario the alternatives which retain a beach width out to 2050 are the managed retreat, structural adaptation, and breakwaters with nourishment. The repaired revetments would result in a loss of the beach first, followed by the seawall about 5 years later. The beach nourishment option maintains a beach width greater than or equal to initial conditions until about 2025 at which point it narrows to less than 100' by 2050. Under this modeling scenario upland property is protected by all of the alternatives except for the managed retreat. The structural adaptation options would protect the property, but likely lose the land around the ocean front parcels.

Table 8: Summary of Beach10 Results

		Managed Retreat		Revetment		Seawall		Nourishment		Breakwaters + Sand	
	Year	*Beach*	*Upland*	*Beach*	*Upland*	*Beach*	*Upland*	*Beach*	*Upland*	*Beach*	*Upland*
Present Conditions		250	250	250	250	250	250	250	250	250	250
Low Erosion	Post Action	290	250	250	250	280	250	350	250	350	250
	2025	290	220	218	250	248	250	292	250	317	250
	2050	290	170	160	250	190	250	242	250	262	246
High Erosion	Post Action	290	250	250	250	280	250	350	250	350	250
	2025	290	154	148	250	178	250	254	250	317	250
	2050	290	0	0	250	0	250	94	250	262	237
High Erosion Narrow Beach	Post Action	140	250	100	250	130	250	200	250	200	250
	2025	140	154	0	250	28	250	86	250	167	250
	2050	140	0	0	250	0	250	0	250	112	237

For the wide beach width and low erosion rate, the results of best case BEACH10 are show in Figure 14. In this modeling scenario, all of the options retain some beach width by 2050 providing some evidence that, if the PDO related littoral cell rotation reverses before 2050, there will be both a beach and protected upland until the next large oscillation. It should be noted that the breakwater option is intended to reduce wave energy at the shoreline, and may diminish the ability of the sand associated with the rotation to return to the south end of the littoral cell. This modeling nuance of the breakwater is beyond the resolution of the simple BEACH10 profile model and would require more sophisticated modeling.

For the narrow beach width and high erosion rate, the results of the worst case BEACH10 model run is show in Figure 15. In this modeling scenario, the options that maintain a beach are the managed retreat, structural adaptation, and breakwaters with nourishment. Under this scenario, beaches in Neskowin are gone by 2020 under the existing or altered revetments and by 2025 under the seawall strategy. Nourishment maintains a beach at mean high water until 2040. Upland property remains protected by most of the options except for the managed retreat and the structural adaptation, although the houses would likely survive if appropriately engineered.

Cost Estimates

Please note that in providing opinions of probable construction costs, ESA PWA has no control over the actual costs at the time of construction. The actual cost of construction may be impacted by the availability of construction equipment and crews and fluctuation of supply prices at the time the work is bid. ESA PWA makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to bids or actual costs. For details on the assumptions, please see Appendix 1.

Table 9: Summary of Engineers' Estimates of Construction Costs for Comparison of Alternatives

Alternative	Total Cost[1] (millions of dollars)	Unit Cost (dollars per foot)
Altered Revetment: Rock Cap	$7	$1,000
Altered Revetment: Concrete Wall	$14	$2,000
Structural Modifications to Buildings	$14 - $27	$2,000 - $3,900
Beach Nourishment	$18	$2,600
Nearshore Breakwaters	$38 - $58	$5,500 - $8,300

[1]Assumes a total length of shore of 7,000 linear feet

Life cycle cost estimate results

The rate of damages between 1999 and 2008 were calculated to be about 120 feet of damaged revetment per year, and a repair cost of ~$73,000/year. We do not have actual costs from the community, and therefore cannot verify the accuracy of this estimate. Based on this rate of damage of 120 ft/yr, the remainder of the revetment (the length not repaired) would require repair within about 40 years, for a total life-cycle period of about 50 years. The total additional repair cost anticipated is therefore is about 4 times the 1999-2008 values, which is about $3 Million between now and 2050, in present dollars. This analysis indicates a life cycle cost of about $3.7M over a life of 50 years in addition to the initial construction cost. These are baseline estimates that presume the previously repaired sections will not require repair within the next 40 years. Of interest, the potential total water levels calculated for the five damage events ranged from 44 to 51 feet NAVD88.

Future conditions were estimated by considering the increase in percent exceedence of the total water level due to sea level rise. The direct effect of relative sea level rise on depth limited wave heights at the structure is estimated to be less than a 1%. This is because the relative sea level rise is expected to be only 17 cm by 2050. However, the continued shore erosion will induce deeper depths and larger waves at the revetment. As waves increase in height, the revetment will experience more damage during storms, leading to greater maintenance costs. The damage function developed using historic data indicates that damages increase by about 10% for every 10% increase in actual wave height relative to the design wave height. The resulting increased damages are provided in Table 10.

Table 10: Life Cycle Cost Estimates

Condition	Depth Increase (feet)	Relative Wave Height Increase (feet)	Life Cycle Cost ($/yr)	Life Cycle Cost ($/decade)
Baseline (1999-2008)	-	-	$73,000	$730,000
2030	0.5	0.06	$77,000	$770,000
2050	1.0	0.12	$82,000	$820,000

Additional design considerations for the revetment

We understand that the primary failure mechanism for the revetment is undermining and sloughing of armor when a rip current establishes and intensifies at a particular reach. This implies that the revetment toe is not embedded deep enough and does not include sufficient rock armor (large rocks) volume to accommodate the scour. Typically, this situation is addressed by constructing the revetment to a lower elevation. However, such construction can be very difficult and perhaps not possible without construction of shoring to maintain a deep excavation below tide levels. Of course, shoring in the surf zone is very difficult. The challenge of founding a revetment deeply without shoring can be approached in several ways. One way is to place additional rock as needed, and anticipate that the displaced rock will settle and establish an adequate foundation over time. Another method is to construct a horizontal toe with sufficient volume to accommodate scour by settlement of the “extra” rock placed seaward of the revetment face. Alternatively, a “toe-wall” can be constructed and left in place with rock placed behind it. Such a wall may be constructed of interlocking sheet piles or adjacent pile walls driven into the beach from above.

Discussion of Innovative Options

Breakwaters. Breakwater spacing should be optimized to reduce wave energy and overall alongshore erosion rate. It is anticipated that there may be some mild accretion in direct lee of the structures, but the design objective would be to reduce net transport and reduce background erosion rates to zero. It is important however, given the uncertainty (or likelihood) that a future littoral cell counter rotation to the south would occur, that there are large enough gaps to enable some transport to both 1. Avoid upcoast effects 2. Enable sand to return if the PDO pattern shifts. More sophisticated modeling would be needed to support increasing levels of design to fine tune the specifics of shape, size, length, and offshore distance. If a lower erosion rate is achieved then the volumes of sand needed in the nourishment may be reduced with a subsequent lowering of the nourishment cost.

Wave tripping structure. A wave tripping structure located on the beach such as the Taraval Seawall (Figure 8) was considered but there are many challenges associated with such a design. First, anything temporary such as K rails or concrete blocks would likely fail in one of two ways. First, given the large wave energy, the size of such blocks would likely result in them strewn across the beach with little to no effect on wave energy dissipation. Another likely method of failure should they be anchored together would be for the scour on either side caused by alongshore flow and wave overtopping so that the structures would likely sink into the beach and become useless as an erosion control device. Should a sheet pile structure be constructed with appropriate bracings to withstand the wave loading, the acceleration of trapped longshore currents would both scour the structure and create a safety hazard for beach recreational users with high velocity currents occurring in gaps or at the end of such structures. In general, beach perching/ wave tripping structures raise many safety concerns and are likely to be relatively ineffective during high storm events.

Pile baffle wall. This type of structure could be envisioned as an offshore pier parallel to shore with dense spacing of piles. While this would serve to dissipate wave energy, the potential for debris such as large woody debris to get trapped between piles is high and would increase wave loading that could cause the structure to fail. There is also a consideration of the aesthetics.

T-head groins. This type of structure was considered as a way of limiting creek channel migration and rip channel formation. The "T" refers to a shore parallel oriented structure on the seaward end of the groin, intended to inhibit rip channel formation. However, given the large dynamic setup on Oregon coasts, we are concerned that such a structure may still induce rip channel formation and hence may not perform as intended. This option would preclude any counter rotation of sediment returning to the south end of the littoral cell. For this reason and the likely high cost this is not considered preferred or feasible.

Pile groin. This is a type of groin that allows for sediment and wave to pass through. The use of such a structure would be to partially retain sand and there may be ways to make it more aesthetically pleasing by mimicking the petrified forest. However the real benefit may be the ability to stabilize the rip embayment at the north side of Proposal Rock. However, problems associated with trapped debris causing exceedance of wave load capabilities and the uncertainty at actually stabilizing the rip embayment make this a highly uncertain alternative without more sophisticated fine scale modeling.

Dynamic revetments. Also known as cobble berms, these mimic naturally occurring cobble deposits found along much of the Oregon coast. Although these have been used in nearby locations (Cape Lookout), they are not likely to be effective in Neskowin given the deteriorated beach widths. Inside of Proposal Rock they may have some merit, but concerns about the cobbles becoming projectiles would likely require them to be constrained in some sort of gabion wave tripping device farther on the beach. The placement of such a device would be complicated by the transitory location of Hawk Creek.

Findings and Recommendations

- Beach nourishment provides additional beach width and upland property protection at least through 2030. This nourishment may provide the interim protection for several years until it can be determine whether the littoral cell may counter rotate. Assuming each property lot along the beach is 100 feet, the cost of beach nourishment per lot is about $260,000 per lot.

- Sources for beach nourishment, should this option be pursued, should include detailed investigation of the ebb shoal at the mouth of the Nestucca River.
- Elevating houses balances beach width with private residence protection (but not ground and lawn) but there are additional considerations to providing a refined cost estimate that will require additional engineering information including an inventory of the types of foundations in hazardous areas.
- Potentially reduce hazards at the Hawk Creek Bridge by using a dynamic cobble revetment to knock down wave energy propagating upstream, although it is possible that a gabion matting would be required to reduce likelihood of projectiles affecting the hotels.
- Nearshore breakwaters offer a good balance of upland property protection and maintenance of beach width but are extremely expensive to construct and maintain (assuming they are even permittable).
- The community may wish to form a Geological Hazard Abatement District (GHAD) formation to fund alternatives.
- Interim or seasonal storm response – engineered Krails installation instead of construction of additional wall at the top of the structures could reduce costs, but also may provide a false sense of security.
- Managed retreat is the only option which maintains a beach throughout all of the planning horizons and beyond. It is likely though to lead to extensive damages to the community. However, it should be noted that following an extreme event (100+ year storm or Cascadia subduction zone), it is likely the only solution over the long term. The community should consider developing a post disaster visioning strategy on how and where to rebuild following such an event.
- Anecdotally, large volumes of overtopping water have contributed to structural failures. Developing a storm water management plan that addresses managing both precipitation and wave overtopping volumes may reduce the level of dune sand saturation and reduce the level of structural damages which occur during a large storm event.
- A regional littoral cell approach to dune management planning to the north that reduces dune storage volumes in high dunes dominated by invasive European beach grasses may enable more sediment to be eroded and released during storm events and reduce post storm recovery time periods.
- Stabilization of the rip embayment that forms off of Proposal Rock may enable bolstering of structures in some areas and not entire community as a cost savings, however such stabilizing structures may also limit the return of sediment if the littoral cell counter rotates.

- One way to increase the effectiveness of the existing structure is to increase the surface roughness of the revetment. Such roughness slopes may reduce TWLs and wave run-up elevations. This can be tested with the run-up analysis but reductions of up to 3 feet in total water elevation are expected to be practical. It would be expected to have an increase in associated costs, beach loss, and greater difficulty with vertical beach access.

- The community can anticipate significant future costs to maintain the existing revetment. We estimate average costs of about $700,000 to $1,000,000 per decade, with approximately 1,000 linear feet of damage per decade.

- The revetment could be improved in several ways:

  1. Construction of a deeper foundation by way of:
     a. Extending the revetment toe by excavation and rock placement to lower elevations, and
     b. Construction of a toe-wall to inhibit undermining;

  2. Construction of a “sacrificial toe” consisting of rock placed horizontally with the objective of settlement into scour depressions with less chance of sloughing of the upper, sloped part of the revetment; and,

  3. Placement of an additional layer of armor as an “overlay” to the existing armor to provide additional volume in case of sloughing, and to reduce scour by reducing wave reflection and increasing wave dissipation in the expanded armor voids. This would require alterations to the surface of the existing structure to enable some additional rock to be placed and interlocked into the existing structure.

It should be noted that the above recommendations need to be evaluated against the substantial costs of implementation and the substantial adverse effects to beach width and associated degradation of recreation, ecology, and aesthetics. Moreover the extent to which such actions will be required or permittable is difficult to ascertain and so revetment expansion may be “open ended” if wave energy and structural exposure continue to increase.

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SOURCE: ESA PWA 2012

Neskowin Shoreline Assessment. D211715.00

Figure 1
Study Area

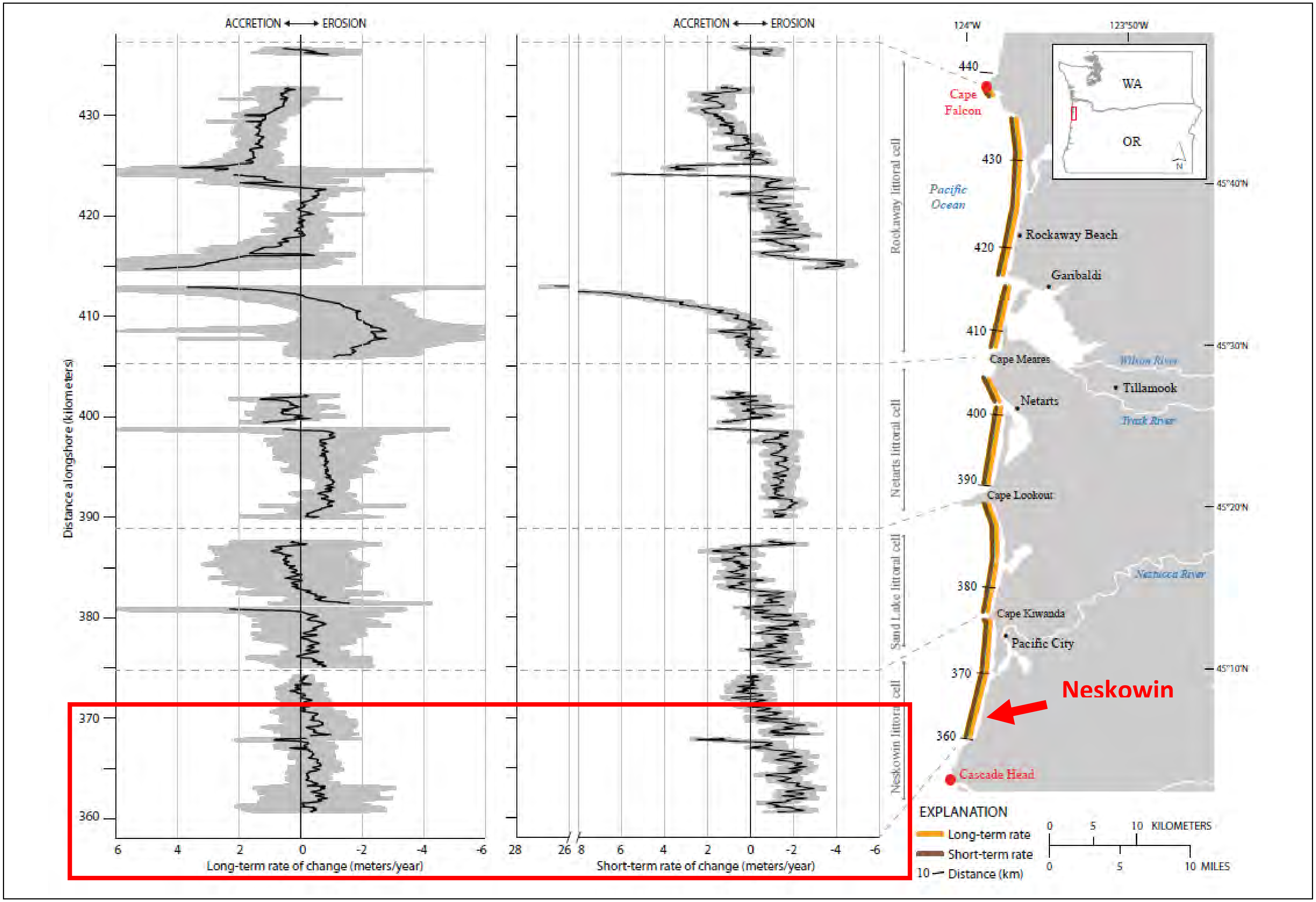
SOURCES:
A - Photo by Armand Thibault, Jan 9, 2008 (Published in the National Research Council's "Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future." Prepublication. National Academies Press: Washington D.C. 2012),

B - Photo by Pete Owston Neskowin resident January 5, 2008 courtesy of Tony Stein, OPRD

Neskowin Shoreline Assessment. D211715.00

Figure 2

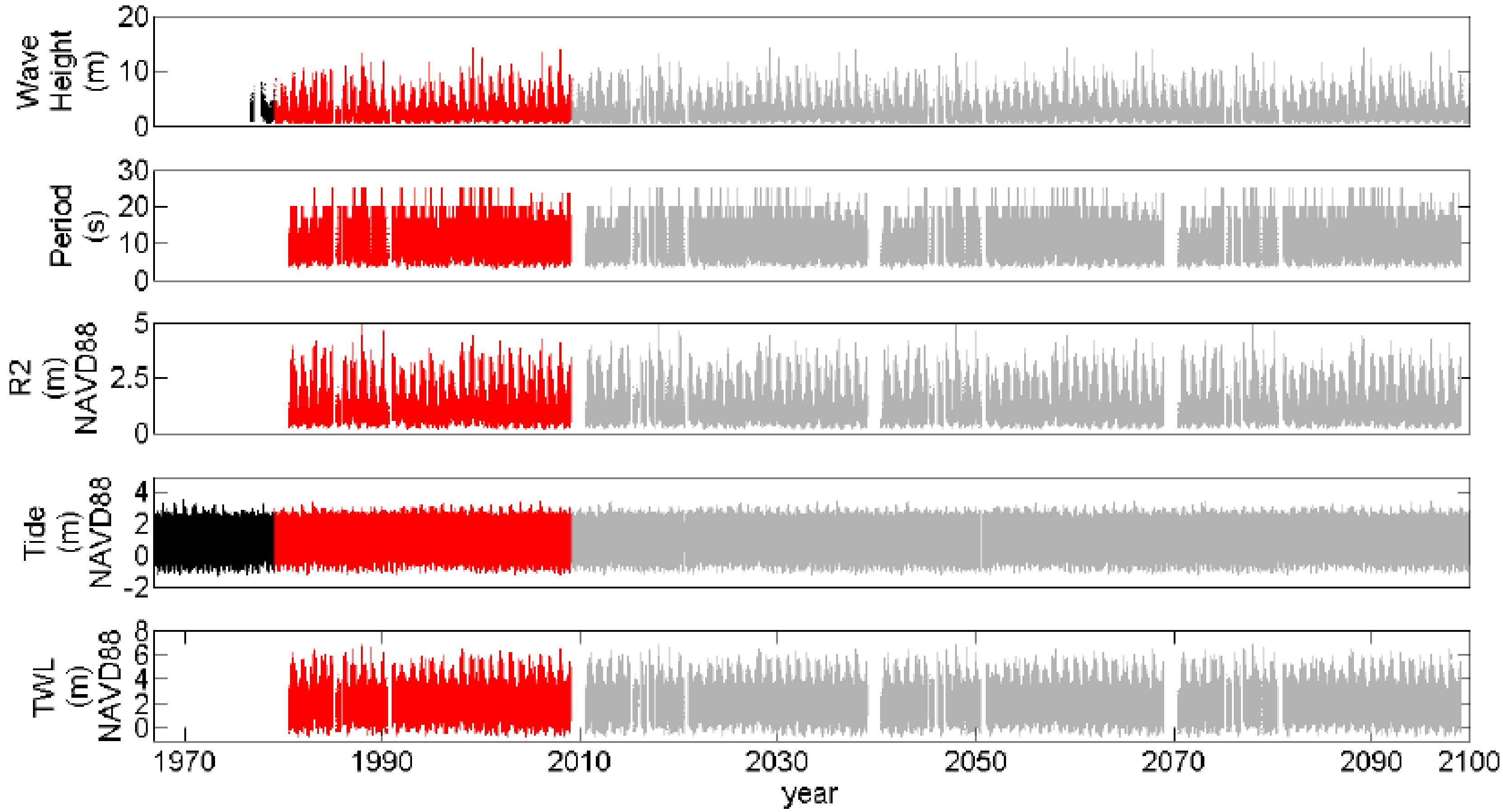
High Surf and Revetment Failure in Neskowin



SOURCE: Ruggiero et al, in press.

Neskowin Shoreline Assessment. D211715.00

Figure 3
Shoreline Erosion Rates



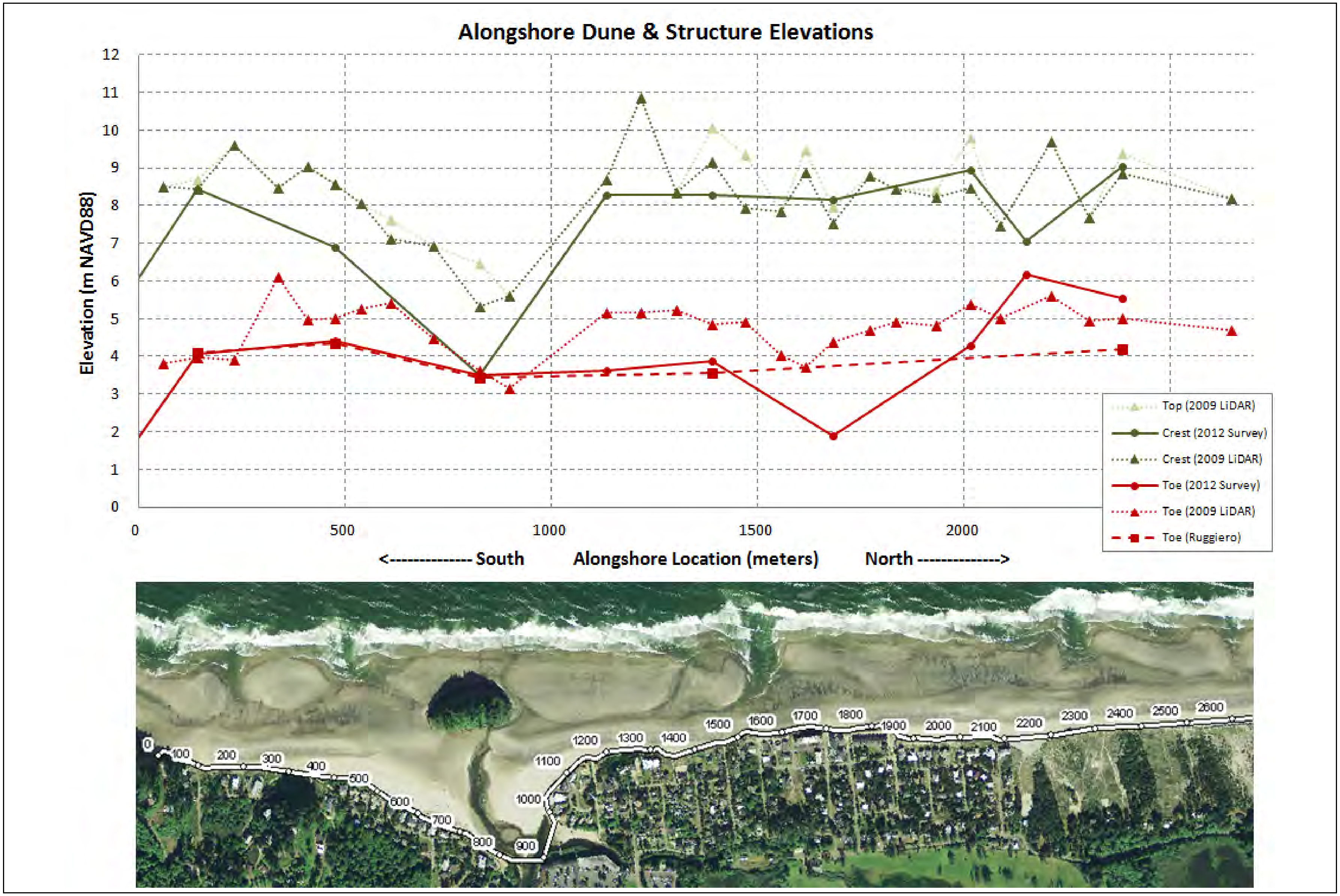
SOURCE: Figure from Harris, 2011.

Note: Red lines represent observed data, gray represent the synthetic dataset extended to 2100 using red data. Data represented by a black line was not used in the synthetic time series.

Neskowin Shoreline Assessment. D211715.00

Figure 4

Time Series of Waves and Tides



SOURCE: ESA PWA (Figure, profile interpretations), Topo data from the following sources: P. Ruggiero of Oregon State University (Beach profiles), 2009 Oregon Department of Geology and Mineral Industries (DOGAMI) LiDAR, J. Allan of DOGAMI (2012 Survey).

Neskowin Shoreline Assessment. D211715.00

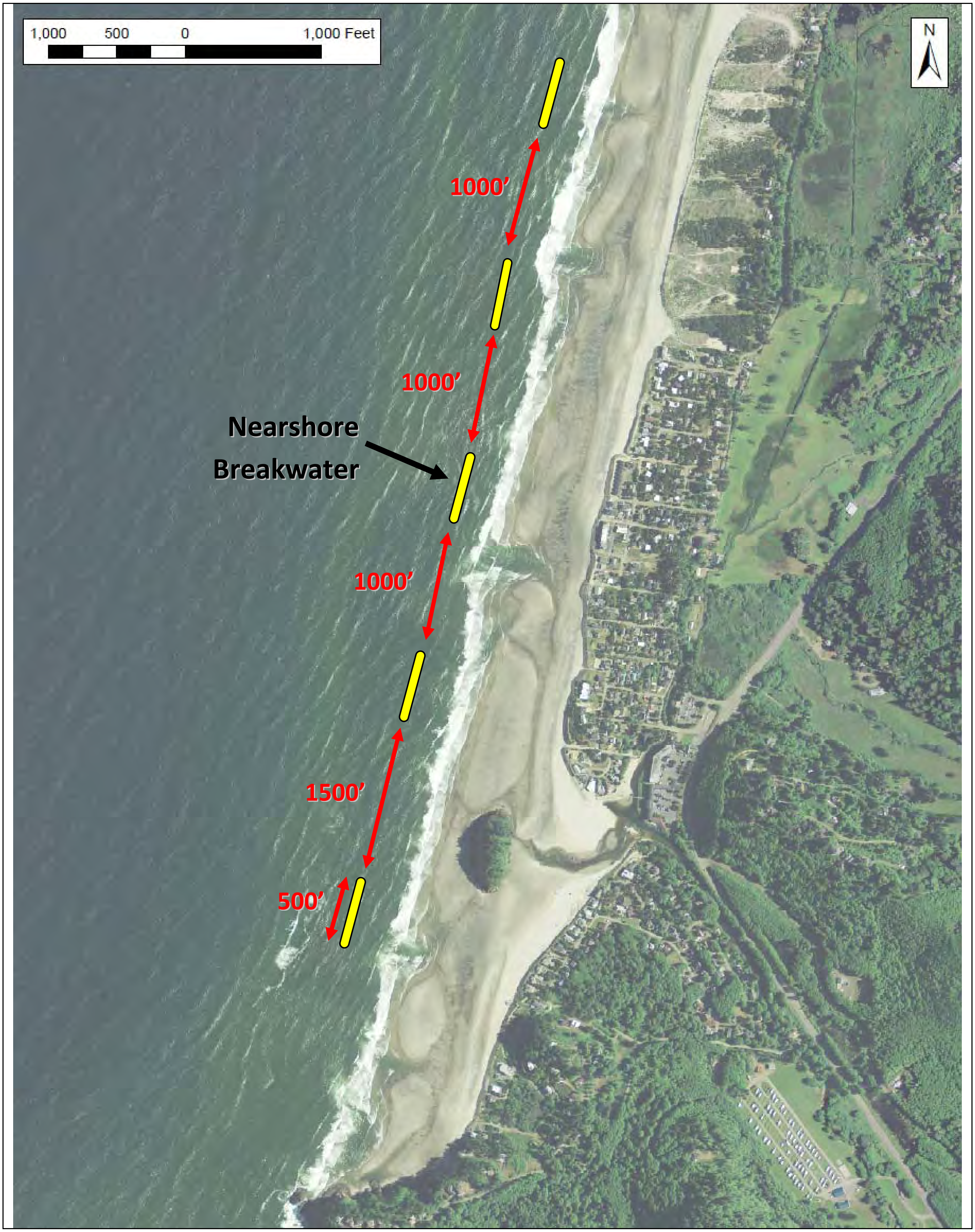
Figure 5

Alongshore Dune and Structure Elevations

SOURCE: Bob Battalio

Neskowin Shoreline Assessment. D211715.00

Figure 6
O'Shannessy Seawall



SOURCE: ESA PWA 2012

Note: Breakwater locations approximate and dimensions not to scale.

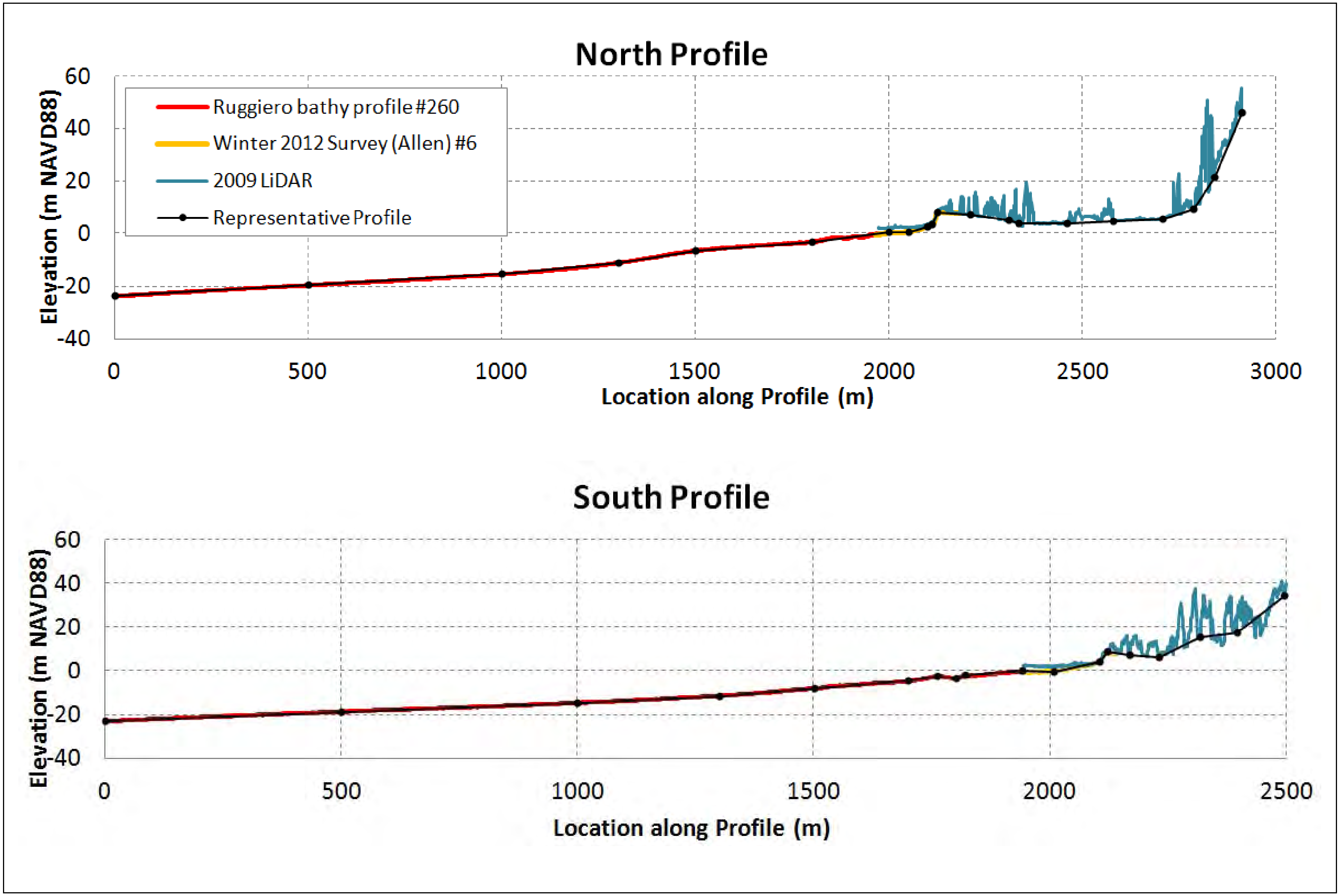
Neskowin Shoreline Assessment. D211715.00

Figure 7

Nearshore Breakwater Schematic

SOURCE: ESA PWA: Photo Left, Elena Vandebroek, 2011; Right: Bob Battalio, 1998.

Figure 8
Taraval Seawall

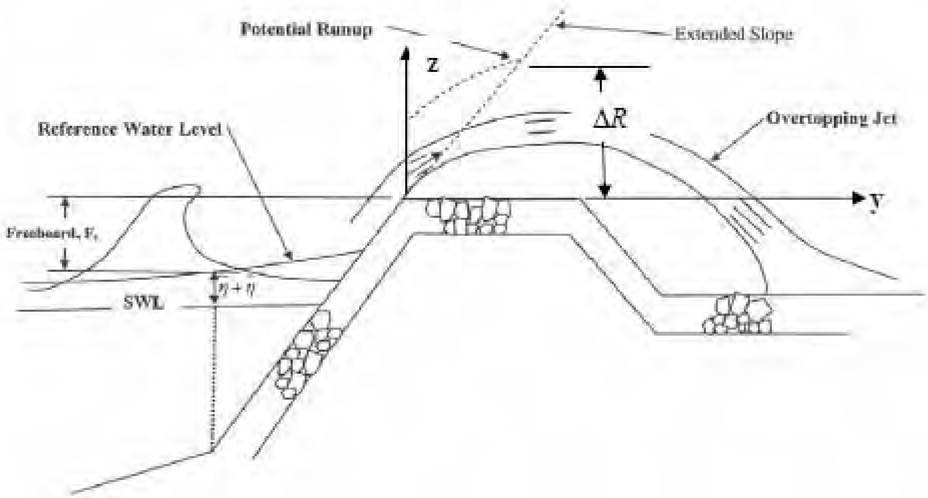


SOURCE: ESA PWA 2012 (Figure, Representative Profiles), Ruggiero et al (Bathymetry), Allan 2012 (Survey), CA Coastal Conservancy LiDAR Project (2009 LiDAR).

Neskowin Shoreline Assessment. D211715.00

Figure 9

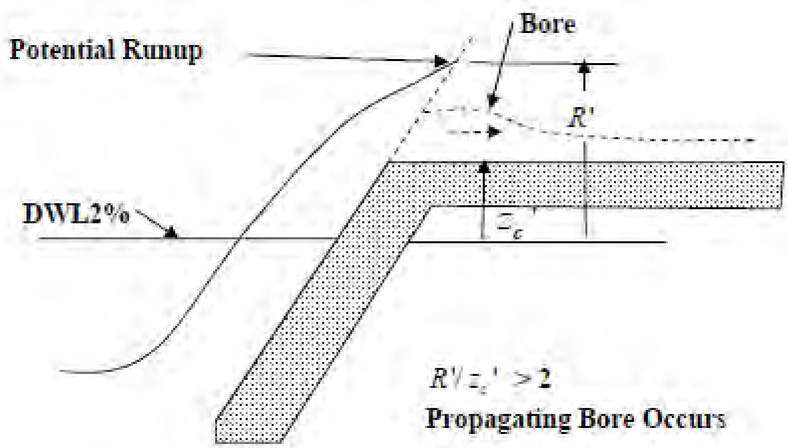
Representative Profiles for Composite Slope Analysis



Parameters Available for Mapping BFEs and Flood Hazard Zones

Overtopping Parameters Used in Hazard Zone Mapping

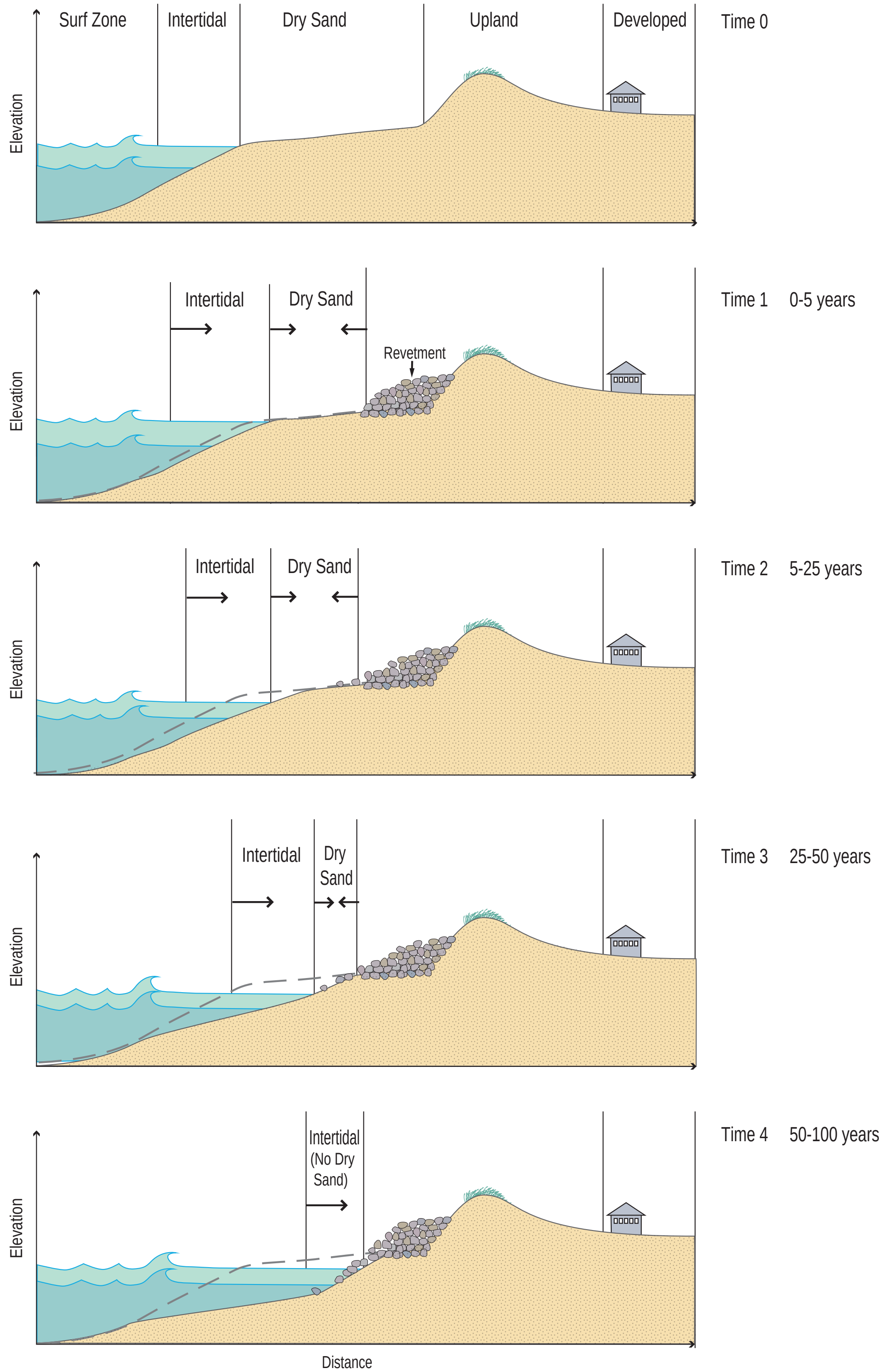
Parameter	Variable	Units
Total potential runup elevation	R	ft
Mean overtopping rate	q	cfs/ft
Landward extent of green water and splash overtopping	$y_{G,Outer}$	ft
Depth of overtopping water at a distance y landward of crest	$h(y)$	ft



Conditions for Bore Propagation Overtopping

SOURCE: FEMA Guidelines for Pacific Coast Flood Studies, 2005.

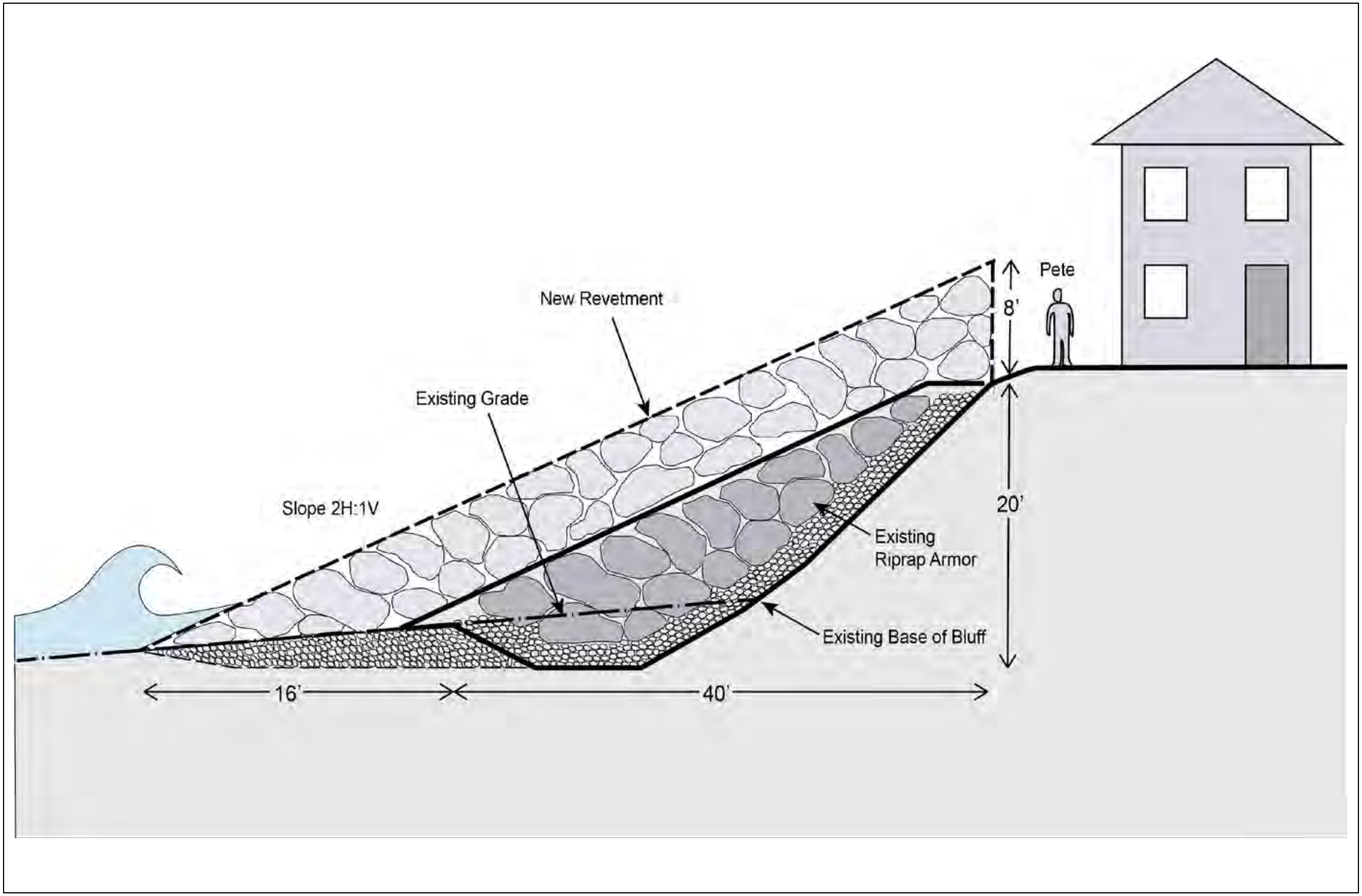
Figure 10
Schematics Defining Wave Run-up and Overtopping Parameters



SOURCE: PWA

Neskowin Shoreline Assessment. D211715.00

Figure 11
Beach 10 Definitions

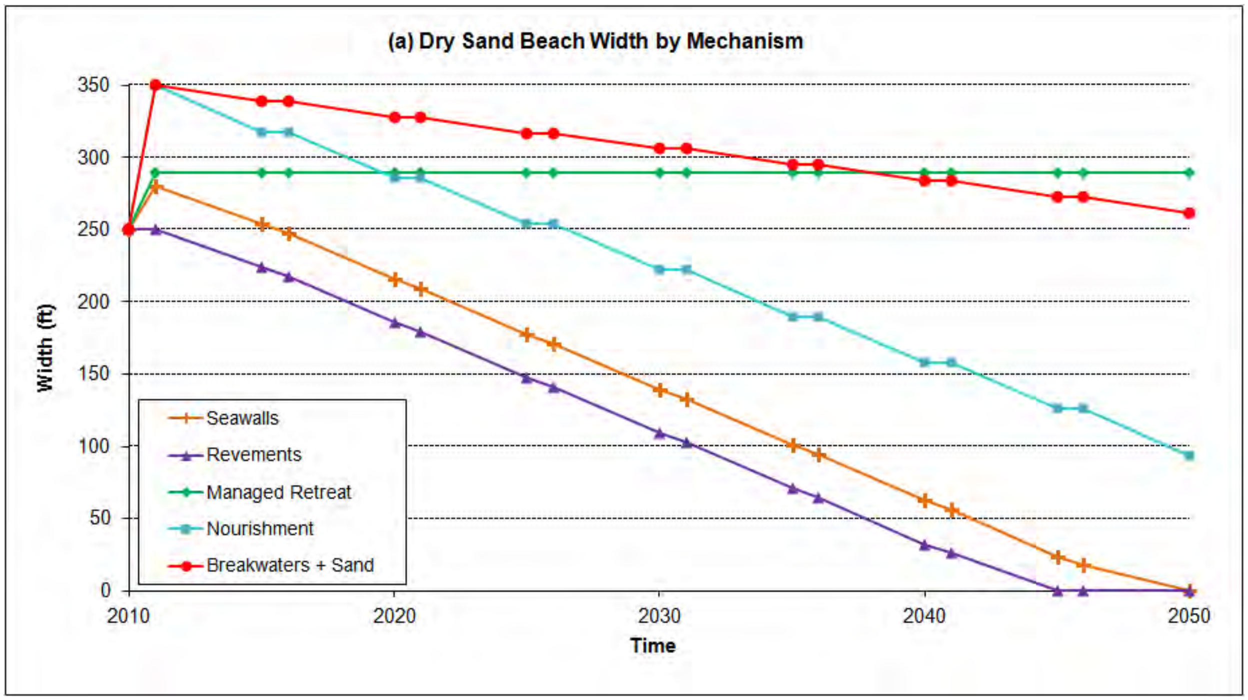


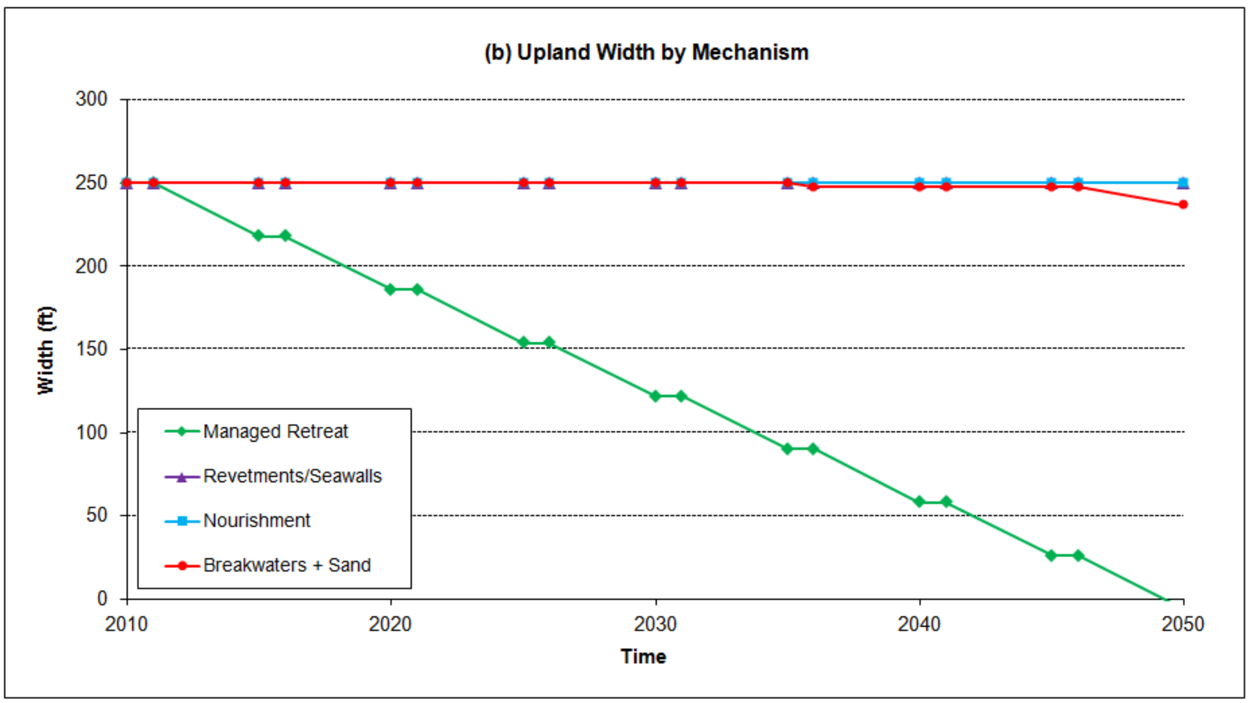
NOTE: Conceptual design not to be used for construction

Neskowin Shoreline Assessment. D211715.00

Figure 12

Conceptual Design for Expanded Revetment



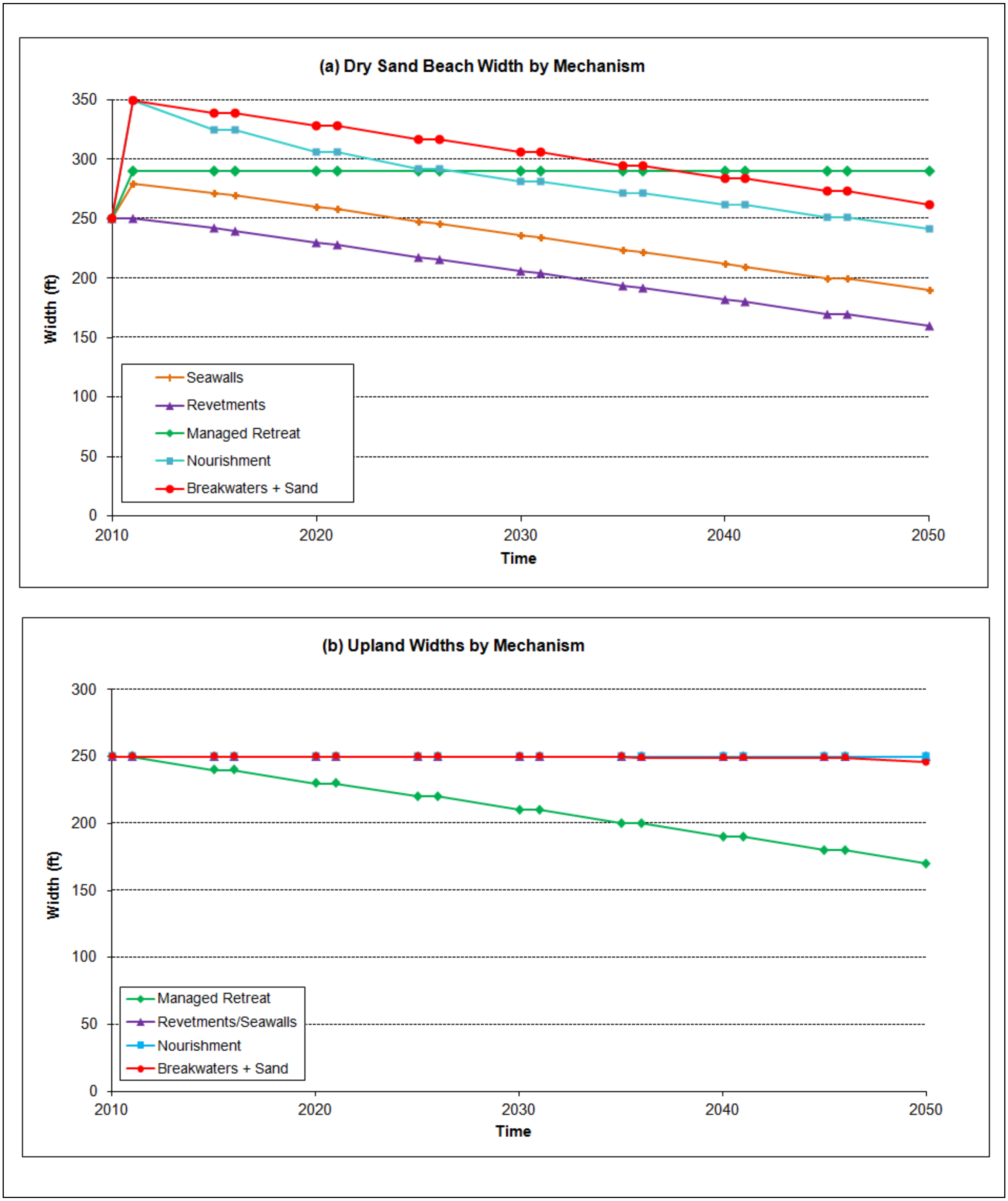


SOURCE: ESA PWA 2012

Neskowin Shoreline Assessment. D211715.00

Figure 13

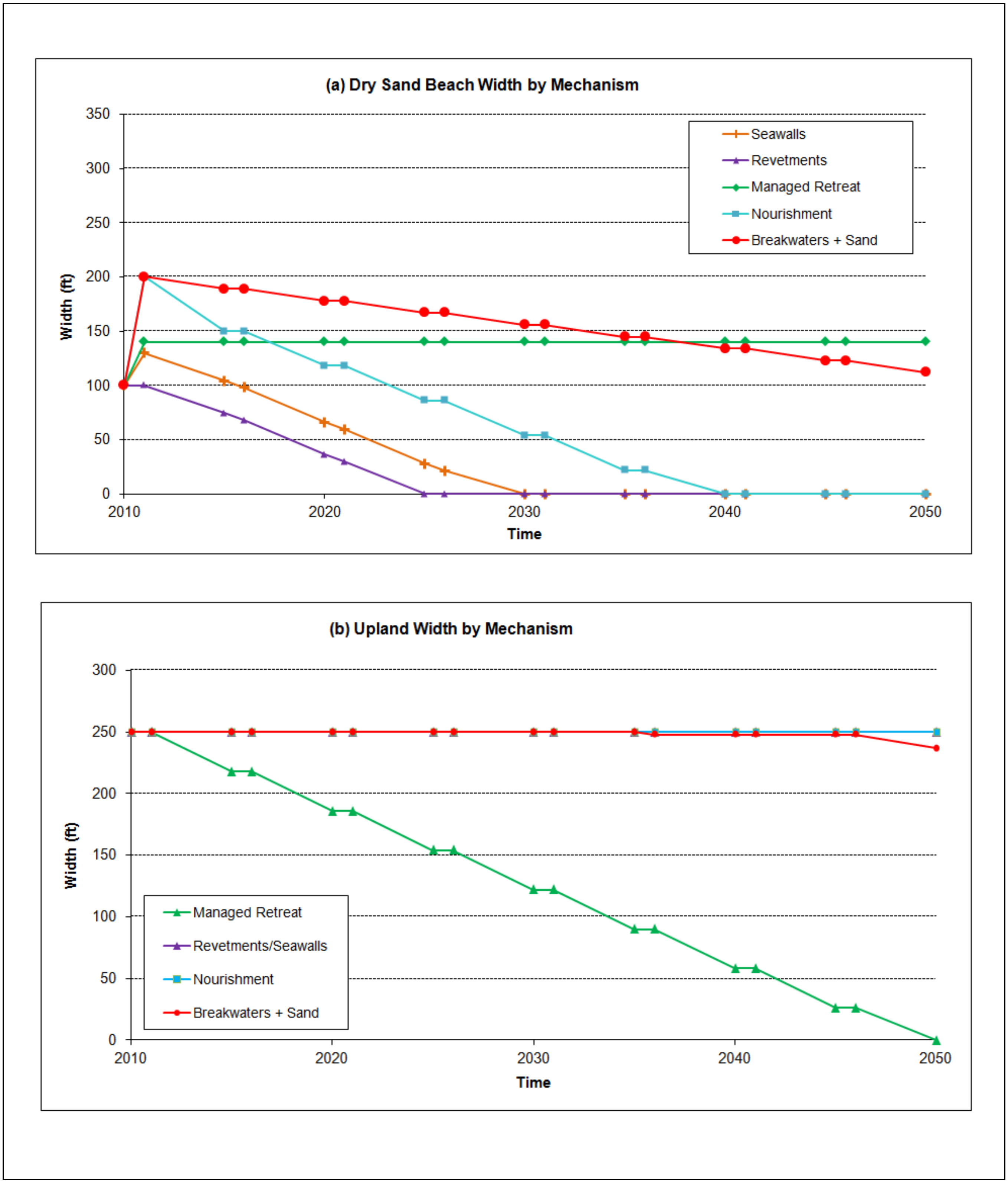
Beach10 Results: Wide Beach, High Erosion



SOURCE: ESA PWA 2012

Neskowin Shoreline Assessment. D211715.00

Figure 14
Beach10 Results: Wide Beach, Low Erosion



SOURCE: ESA PWA 2012

Neskowin Shoreline Assessment. D211715.00

Figure 15

Beach10 Results: Narrow Beach, High Erosion

ESA PWA

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memorandum

date August 10, 2012

to David Revell (ESA PWA)

from Louis White, PE (CA)

subject Appendix 1: Construction Costs of Alternatives for Neskowin Shoreline Assessment

Introduction

This memorandum provides a summary of construction costs of different alternatives identified as part of the Neskowin Shoreline Assessment project. The purpose of presenting the following costs is for comparison of different alternatives to mitigate coastal erosion problems that the local community is presently facing. The work described in this memorandum was accomplished by Louis White, P.E. and Curtis Loeb,P.E., with oversight by Bob Battalio, P.E. (OR).

Level of Cost Estimating

For planning purposes we have provided order of magnitude estimates to allow cost comparison of alternatives. These cost estimates are intended to provide an approximation of total project costs appropriate for the conceptual level of design. These cost estimates are considered to be approximately -30% to +50% accurate, and include a 35% contingency to account for project uncertainties (such as final design, permitting restrictions and bidding climate).

These estimates are subject to refinement and revisions as the design is developed in future stages of the project. This table does not include estimated project costs for permitting, design, monitoring and/or ongoing maintenance. Estimated costs are presented in 2012 dollars, and will need to be adjusted to account for price escalation for implementation in future years. This opinion of probable construction cost is based on: ESA PWA's previous experience, bid prices from similar projects, and consultation with Oregon contractors and suppliers.

Please note that in providing opinions of probable construction costs, ESA PWA has no control over the actual costs at the time of construction. The actual cost of construction may be impacted by the availability of construction equipment and crews and fluctuation of supply prices at the time the work is bid. ESA PWA makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to bids or actual costs.

Alternatives and Assumptions

Construction costs for six alternatives were estimated to a conceptual level for cost comparison purposes. These alternatives include:

- Altered Revetment: Rock Cap
- Altered Revetment: Concrete Wall
- Structural Modifications to Buildings
- Beach Nourishment
- Offshore Breakwaters

Comparative costs per linear foot of beach are presented in addition to the total cost of the alternative. For comparison purposes, a shoreline length of 7,000 feet was assumed. The cost of each alternative, or the elements of each alternative, was estimated on a construction quantity basis. Unit costs of purchasing, transporting, and placing rock and sand were estimated from previous ESA PWA experience, bid sheets, and discussions with local contractors that specialize in seawall construction in coastal Oregon. These costs reflect construction during non-emergency periods. Construction of emergency seawall repair is typically more expensive due to the emergency nature of the work, difficult working conditions, and material and labor constraints.

A summary of each alternative and the assumptions made to estimate the costs follows.

Altered Revetment: Rock Cap

- Increase elevation of existing rock revetment by 8 feet, from elevation +28 ft NAVD to +36 ft NAVD
- Assume rock size is 1-5 ton, approximately 4-7 feet in diameter, with median rock diameter of 5 feet
- Assume crest width is two rocks, or about 10 feet
- Assume sideslope of 2:1 (H:V) on both front and back sides of rock cap
- Calculated unit volume is 7.7 cy/lf; assuming an average revetment density of 1.6 tons/cy (this includes armor stone and bedding), the unit weight is approximately 12.3 tons/lf
- Assume a unit cost of $80 per ton, which includes rock purchase, transport, placing using land-based equipment, and contractor overhead and profit (Morris 2012). This yields a unit cost of $1,000/lf to increase protection with a rock cap, or a total cost of $7M for the whole shore length

Altered Revetment: Concrete Wall

- Increase elevation of protection by 8 feet, from elevation +28 ft NAVD to +36 ft NAVD
- Allow $2,000/lf to construct re-curved reinforced concrete wall, or a total of $14M for the entire shore length

Structural Modifications to Buildings

- Structural modifications to buildings involves raising the buildings vertically up to 10 feet and placed on driven pre-cast concrete piles or cast-in-drilled-hole piles (CIDH piles) to an elevation above the 100-year total water level, per FEMA guidelines.

- A unit cost of $130/sf to raise building up to 10 feet was estimated for structural modification in California (ESA PWA 2012). Due to location difference (Bay Area, CA versus coastal Oregon), we think a unit cost of $65/sf is appropriate. Further investigation into structural modifications methods for the area and building types might warrant an additional decrease in the unit cost for raising a building on piles. However we think a unit cost of $65/sf is appropriate for conceptual cost comparisons.

- Assume total structure length is 60% of total shoreline length: 60% of 7,000 lf = 4,200 lf

- Assume a range in the nominal width (landward) of structures from 50-100 ft

- Range in area is calculated to be 210,000 sf to 420,000 sf

- Total range in cost estimated at $14M to $27M; unit cost range of $2,000 to $3,900/lf for 7,000 lf of shore

Beach Nourishment

- Beach nourishment involves placing sand directly on the shore to widen the beach. This is likely to be accomplished by dredging suitable sand from offshore location, and pumping onshore

- Assume existing top of beach is at elevation +16 feet NAVD (NANOOS 2012)

- Assume depth of closure at elevation -50 feet (-15m) NAVD, estimated visually from measured bathymetry profiles, and personal communication with Peter Ruggiero (OSU 2012)

- Assume unit volume of beach nourishment at 2.5 cy/sf of beach; for widening the beach crest by 100 feet, the unit volume becomes 250 cy/lf of beach, yielding a total volume of 1.8 MCY for 7,000 lf of beach

- Assume a unit cost of $10/cy to pump sand onto the beach from offshore; total cost of project is approximately $18M, or about $2,600/lf of beach

- Assuming each property lot along the beach is 100 feet, the cost of beach nourishment per lot is about $260,000 per lot

Offshore Breakwaters

- Construction of offshore breakwaters is intended to reduce wave energy at the beach. The structures described here are low-crested, and intended to be overtopped by tides and waves, and to allow counter littoral cell-wide rotation which would naturally bring sand back to the south end of the Neskowin beach. Construction of offshore breakwaters should include beach nourishment (see above). Beach nourishment alone will likely need to be repeated periodically, and including offshore breakwaters can reduce the frequency of re-nourishing the beach over time.

- Assume nominal crest length of 500 feet

- Assume spacing of individual offshore breakwater structures to be 1,000-1,500 feet, for a total of 5 structures
- Assume rock size of 10-20 tons, or about 6-8 ft in diameter
- Assume a crest width that is 4-5 rocks wide, or about 30 feet, and sideslopes of 2:1 (H:V)
- Assume the breakwater is constructed on the nearshore bar, from elevation -5 ft NAVD at the bottom to elevation 3.3 ft NAVD at the top
- Assume approximately 2.5 feet of over-excavation to found the structure – this yields a structure that is about 11 feet tall
- Calculated unit volume is 22.4 cy/lf; at 1.6 tons/cy, this yields a unit weight of 36 tons/lf
- Use a unit cost of $200/ton for rock delivery and placement (Moffat & Nichol 2011); use a unit cost of $20/cy for excavation; combining these unit costs yields a construction cost of $8,000/lf per each offshore breakwater
- Due to uncertainties in height and spacing of structures, assume a range in unit cost of $8,000-$16,000/lf
- For 5 breakwaters, the total cost range is $20M-$40M, yielding an approximate unit shoreline cost range of $2,900/lf to $5,700/lf
- Combining the offshore breakwater costs with a one-time beach nourishment (see above) yields a cost range of $38M-$58M, or approximately $5,500/lf to $8,300/lf

Summary Table of Costs

Alternative	Total Cost[1] (millions of dollars)	Unit Cost (dollars per foot)
Altered Revetment: Rock Cap	$7	$1,000
Altered Revetment: Concrete Wall	$14	$2,000
Structural Modifications to Buildings	$14 - $27	$2,000 - $3,900
Beach Nourishment	$18	$2,600
Offshore Breakwaters	$38 - $58	$5,500 - $8,300

[1]Assumes a total length of shore of 7,000 linear feet

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OSU, 2012, Bathymetric profiles offshore of Neskowin Beach.

Neskowin Coastal Hazards Committee Recommendations Concerning the "Neskowin Shoreline Assessment, Coastal Engineering Analysis of Existing and Proposed Shoreline Protective Structures"[3]

The final section of the ESA PWA report is a summary of "Findings and Recommendations". The Neskowin Coastal Hazards Committee (NCHC) reviewed these items and offers the following recommendations and comments.

Recommendations approved by the NCHC

- **Reduce hazards at the Hawk Creek (Salem Avenue) Bridge.** The Committee feels that protection of the Salem Avenue Bridge is important and that possible solutions need further study. The ESA PWA report suggests that the height of a wave-induced bore traveling up the creek to the bridge and beyond might be reduced by construction of a dynamic revetment and possible gabion matting to prevent the cobbles from becoming projectiles. The Committee is skeptical that this would be effective and feels that such a structure would limit beach access.
- **Managed retreat.** The ESA PWA report states that managed retreat is the only option that maintains the beach in the long run but that it would lead to the seaward boundary of the community moving eastward. The Committee does not support pro-active measures to retreat landward but recognizes that reactive measures need to be developed to respond to major erosional events. The NCHC supports further study of the complex issue of managed retreat.
- **Elevating houses and structural adaptations.** The Committee feels that elevating houses is the best way to avoid damages associated with water overtopping of riprap. The Neskowin Citizens Planning Advisory Committee (CPAC) is considering guidelines for structural adaptations and home elevation.
- **Large volumes of overtopping water contributing to structural failures.** The Committee supports the ESA PWA recommendation that measures be taken to prevent water ponding behind the riprap as a result of wave overtopping or rainfall. Drainage of this water should avoid or reduce sand saturation and may well reduce damage to the riprap during a large storm event. The Neskowin CPAC is considering guidelines for this potential problem.
- **Dune management planning.** The engineering report suggests that dune management in the area that is not riprapped between the Village and Neskowin North might be used to release more sand to the beach during erosional events and reduce post storm recovery times. The NCHC feels that this approach is too speculative and might well result in unintended consequences. As a result, the Committee **does not recommend** this action. The discussion did, however, lead to the idea of considering the

[3] This is a summary of the response of the Neskowin Coastal Hazards Committee (NCHC) to the report prepared by ESA PWA, David Revell, Ph.D., Project Manager, dated March 12, 2013, under contract to Tillamook County at the request of the NCHC.

establishment of some sort of administrative natural beach and dune area in this non-riprapped portion of the community. The Committee supports the idea of studying this strategy.

- **Geologic hazard abatement district.** The engineering report suggests establishment of a geologic-hazard abatement district with taxing potential to provide financial resources for addressing the community's erosion hazards. The NCHC recognizes that this would be a complicated and controversial strategy. The Committee was unanimous in suggesting that conversation of this topic should be brought to the NCA for much broader discussion.

Recommendations for which the NCHC does not take a position

- **Modifying Neskowin's riprap revetments.** The ESA PWA report contains several possible approaches for modifying Neskowin's riprap revetments. These include: (1) increasing the height; (2) increasing the surface roughness; (3) construction of a deeper foundation; (4) construction of a sacrificial toe; and (5) placement of an additional layer of armor as an "overlay". The NCHC did not take a position on these ideas because it feels that undertaking any of them is up to individual property owners and subject to approval of the Oregon Parks and Recreation Department. It should also be noted, however, that some of the changes would probably have to cover a significant continuous length of the revetment to have a chance of being effective.
- **Interim or seasonal storm response.** Related to the above, the idea of using engineered K-rails (the concrete barriers used to separate lanes of traffic) during the winter storm season to temporarily provide additional height to the revetment might have some limited applicability in particular areas of Neskowin. But, as above, the Committee did not take a position on this strategy.

Recommendations that the NCHC rejected

- **Beach nourishment.** Beach nourishment (i.e., adding sand to the beach by dredging from the offshore ocean bottom or trucking sand in from elsewhere) was rejected because (1) there is too much chance that the additional sand would quickly disappear into the ocean and (2) it would too expensive to establish and maintain for the Neskowin community (in the millions of dollars).
- **Nearshore breakwaters.** Construction of a segmented, shore-parallel nearshore breakwater (perhaps combined with beach nourishment) was rejected by the NCHC because of very high expense to establish and maintain, presumed permitting difficulties, and a significant chance that it would not work as intended and potentially further damage the beach.
- **Stabilization of rip embayments.** Attempting to stabilize the rip embayment north of Proposal Rock was rejected by the NCHC because of uncertain effectiveness and likely occurrence of unintended consequences.

APPENDIX C: LAND USE ORDINANCES

Preface

This document is the result of over three years of study and examination by the Neskowin Coastal Hazards Committee (NCHC), the Neskowin Citizens Planning Advisory Committee (CPAC), Tillamook County staff, and staff from the Department of Land Conservation and Development (DLCD). The NCHC is a Tillamook County *ad hoc* committee formed to respond to the present erosion threat from the ocean in the County and to the beach and community of Neskowin. Since its inception in the Fall of 2009, the NCHC has met monthly, with sub-committees meeting more frequently. There have been public meetings to garner feedback and many sessions with experts to gain input, all of which have contributed to this document. The Neskowin CPAC took up the land use recommendations of NCHC in August 2012 and has proceeded to turn those recommendations that were especially relevant to the community of Neskowin into proposed plan and ordinance revisions. After considerable discussion, staff work, and five public meetings, the final approval by the CPAC members was in June 2013.

Special thanks to Mark Labhart, Tillamook County Commissioner, who has been chairman of the NCHC and liaison to numerous federal and state agencies, and without whose leadership this document would never have been developed. Credit for the development of this plan also goes to the CPAC members; Laren Woolley and Matt Spangler of the State of Oregon Department of Land Conservation & Development (DLCD); Pat Corcoran, Oregon State University Sea Grant Extension Coastal Hazards Outreach Specialist; Kristin Maze, Butch Parker, and Valerie Sutton (Soilihi), past Tillamook County staff members; and Dr. Jonathan Allan, Coastal Geomorphologist, Coastal Section Leader, State of Oregon Department of Geology and Mineral Industries, Coastal Field Office, who has shared his resources and maps with the Committee.

1. Introduction

This document, Appendix C, is an appendix to the document, *The Neskowin Coastal Erosion Adaptation Plan*, called the *Adaptation Plan* for short. The *Adaptation Plan* was developed over a three-year period. It represents a great deal of effort and research on the part of the Neskowin Coastal Hazards Committee (NCHC), in consultation with many experts on coastal processes.

One of the more important findings of the effort that resulted in the *Adaptation Plan* is that scientific evidence indicates an increasing probability of more severe coastal erosion hazards in the future. In Neskowin, scientific evidence includes a measured increase in the severity of storms in recent decades and the measured loss of an enormous quantity of sand from the beach, which may not return any time in the foreseeable future. In light of these findings, the NCHC recommended that planning now to adapt to these hazards and the changing beach environment is prudent and will, hopefully, provide an increased level of confidence for property owners and recreational beach users currently facing an uncertain future.

The NCHC considered a comprehensive list of forty different techniques for mitigating the risks of coastal forces (see Table 5 in the *Adaptation Plan*). These techniques, called Hazard Alleviation Techniques (HATs) were further broken down into two groups: active protection, or engineering, techniques, totaling 15 HATs, and land use techniques, totaling 25 HATs. The active protection HATs have been evaluated by the NCHC. The land use HATs were further consolidated into 17 summary HATs, of which 6 were then broken off as contingency HATs (see Section 5.3 of the *Adaptation Plan*), leaving 11 land use HATs. These 11 land use HATs were then passed to the Neskowin Citizens Planning Advisory Committee (CPAC) in August 2012 for further development, as detailed in Section 2 of this document.

<u>LAND USE RECOMMENDATIONS OF THE NESKOWIN CPAC</u>

The work of the Neskowin Citizens Planning Advisory Committee (CPAC) has been guided by a number of principles. First of all, land use policy and ordinance changes should work to safeguard people and property and protect the natural resources of the state, as defined by Statewide Planning Goals 7 and 18. Statewide Planning Goal 7 is also especially important in Neskowin, since data indicate that Neskowin has the one of the highest percentage of residents living in areas subject to coastal hazards along the central and northern Oregon coast. Second, land use ordinances should focus on helping the community become more resilient to coastal hazards by limiting the density of new development and improving land use requirements in the areas subject to coastal hazards. In other words, in hazard areas, we can minimize the overall risk of damage by minimizing the extent of development. Third, engineering solutions (such as riprap) should be capable of extending the viability of the community in the hazard areas. Most of the Neskowin oceanfront is already protected by riprap structures. We now know, however, that engineering solutions are not likely to be a permanent solution (see Appendix B of the *Adaptation Plan*).

The 11 land use HATs passed on to the CPAC by NCHC can be divided into three categories: 1) seven HATs that have specific application to Neskowin; 2) three that have countywide application; and 3) one that is effectively determined by a federal government agency. With respect to this last HAT (Number 11 in Section 2 of this appendix), the CPAC has made the assessment that, since the CPAC's ability, or even the County's ability, to influence or change federal policy was limited, this HAT would not be pursued. The CPAC also decided to defer consideration of the three Countywide HATs until a later date. The County has been provided a draft of a Countywide *Framework Plan* (Appendix D of the *Adaptation Plan*), of which the Neskowin *Adaptation Plan* was originally intended to be a part. Because consideration of this *Framework Plan* has been deferred, the CPAC decided to withhold consideration of these countywide HAT recommendations until the County takes up the *Framework Plan*.

Meanwhile, the CPAC assessed and determined the need to develop a strategy for implementing the seven HATs specifically applicable to Neskowin. First of all, a structure needed to be developed whereby the *Adaptation Plan* and the CPAC recommendations could be incorporated into the County's comprehensive plan and ordinances without reference to the *Framework Plan*. This structure is discussed in some depth below. Second of all, because the recommendations developed by NCHC and CPAC pertained primarily to the areas at greatest risk to coastal hazards, a mechanism needed to be developed to define this area and define how the County could ensure that compliance to the requirements in this area could be reasonably accomplished.

The State's Department of Geology and Mineral Industries (DOGAMI) has developed maps for the coast of Oregon that show the areas of coastal-hazard risks. These areas are delineated as active, high, medium, and low risk. The areas of active risk are essentially those areas already immediately subject to ocean processes; in Neskowin, these are the areas west of the top of the riprap. The areas of *high risk* are those that are subject to coastal hazards in the event of a fifty-year storm event; an event that Neskowin has experienced as recently as the late 1990s. The *medium risk* area is defined as that area subject to coastal hazards in the event of a hundred-year storm. Finally, the areas of *low risk* are those subject to coastal hazards in the event of hundred- year storm occurring after a subduction zone earthquake has lowered the shoreline. These areas can be seen in the Appendix A, Attachment 10. After due consideration of these hazard areas, the Neskowin CPAC concluded that combining the active, high, and medium risk areas into one single "regulatory trigger" coastal erosion hazard zone was appropriate. This decision serves three purposes: 1) properly delineating the area most at risk to coastal hazards over the long run; 2) simplifying administration of the zone by the County, with a simple "in or out" distinction; and 3) decoupling the hazard zone from the DOGAMI maps. This decoupling is necessary as the DOGAMI maps are potentially subject to revision, which would necessitate the redrawing of the hazard zone and applicable ordinances.

The second issue raised above is how the County could ensure compliance to the requirements in this hazard area. As discussed below, the decision by the CPAC was to create a "Coastal Hazard Zone Permit" for administering the relevant ordinances in the coastal erosion hazard zone.

SUMMARY OF DRAFT PLAN AND ZONING AMENDMENTS

The proposed plan and ordinance revisions found in Section 4 of this document are comprehensive and include everything necessary to adopt all the land use recommendations for Neskowin's coastal hazard area within Tillamook County ordinances. This information may appear at first to be quite daunting, because it is comprehensive and includes many existing elements consolidated from other parts of the County code. Once reviewed, however, it should become clear how these things are linked together and necessary.

[IMPORTANT NOTE: THESE PROVISIONS ARE ADOPTED BY TILLAMOOK COUNTY IN THE APPROPRIATE LOCATIONS WITHIN THE TILLAMOOK COUNTY COMPREHENSIVE PLAN AND IMPLEMENTING ORDINANCES. THEIR REFERENCE IN THIS APPENDIX C PROVIDES DOCUMENTATION AND HISTORICAL PERSPECTIVE ONLY AND THEY ARE NOT NECESSARILY THE PROVISIONS IN EFFECT.]

Tillamook County Comprehensive Plan and Neskowin Community Plan Amendments

Plan amendments are proposed for the Beaches and Dunes element of the Comprehensive Plan and for the Neskowin Community Plan (new section on coastal hazards). These amendments primarily provide background and establish a policy basis for the proposed zoning code amendments. These amendments also serve to adopt (by reference) the Neskowin *Adaptation Plan*, including the hazard zone maps, into the Comprehensive Plan.

First, in Section 4.1 and 4.2 of this document, there are proposed Tillamook County Comprehensive Plan revisions that affect both the Beach and Dune Element of the Comprehensive Plan and the Neskowin Community Plan. These revisions are necessary to "enable" all of the recommendations. Section 4.1 includes the revisions to the Beach and Dune Element of the Comprehensive Plan. In Section 7.2 of the Comprehensive Plan, the Neskowin *Adaptation Plan* would be adopted and included by reference into the Comprehensive Plan. In this manner, the *Adaptation Plan* would be incorporated into the County's Comprehensive Plan.

Section 4.2 includes the revisions to the Neskowin Community Plan. These revisions include a discussion of the process of adoption of the Neskowin *Adaptation Plan*, policy statements regarding coastal hazards, and the Coastal Hazards Overlay Zone (NESK CH). It also includes the Coastal Erosion Hazard Zone (CEHZ) maps, which identify the extent of the Coastal Hazards Overlay Zone (NESK CH). Thus, the Coastal Hazards Overlay Zone (NSK CH) and the Coastal Erosion Hazard Zone (CEHZ) maps are included in the Neskowin Community Plan and in the County's Comprehensive Plan by reference.

Ordinance Amendments

After an audit and evaluation by the CPAC of existing provisions in the County zoning ordinance related to hazards, it was concluded that the most efficient mechanism for implementing all of the recommended HATs would be to develop a new overlay zone specifically applicable to Neskowin. This conclusion was driven by a couple of considerations: First, given that the draft of the overall County *Framework Plan* is not on any firm schedule for adoption, and in the interest of moving forward, it is necessary at this time to limit the application of these new coastal hazard area regulations to Neskowin only. The County's zoning ordinance currently includes such community-specific zoning districts, so there is a basis for this approach. Second, the only other logical location for these regulations would be within the County's current Beaches and Dune Overlay zone; this zone, however, is already quite complicated and has a number of structural problems. Attempting to imbed a new section or otherwise integrate provisions into this zone to implement the recommended HATs for Neskowin would, in CPAC's view, be overly complex, and the result would almost certainly compound the difficulty of administering the Beach and Dune overlay.

Other notes on structure:

- The boundary of the overlay zone would be the limit of the hazard zone area depicted in the adopted sub-plan maps, i.e. the "blue and purple zones", meaning that the provisions of the overlay would apply only to proposed development within these areas.
- The overlay would apply **in place** of the current Beach and Dune overlay within the defined hazard zone area. There are, however, additional beach and dune areas in Neskowin that are outside (i.e. landward) of the hazard zone; the Beach and Dune overlay would continue to apply to these areas.
- The County's current ordinance structure does not include an overall administrative section that identifies decision types or provides for uniform review, decision and notice procedures associated with various decision types. As a result, in order to provide a mechanism for the application of the substantive provisions of the overlay, it is necessary to create a new permit type, the "Coastal Hazard Zone Permit", and to include in this zone discrete review, decision, and notice procedures for this permit. Generally, this is less than ideal (i.e. creating separate, stand-alone procedural provisions within an individual zoning district) but given the lack of an overall integrated procedural section in the County's ordinances, this is deemed to be the only practical alternative.

To make it easier to navigate through the changes, a summary table (Section 3 of this appendix) has been prepared that indicates the sections of the code where each HAT recommendation is addressed. Again, there is more to the new proposed hazard zone than the HATs, but these are generally things pulled from the existing Beach and Dune Overlay that need to be in the new zone because the Beach and Dune overlay is no longer applicable in the new zone.

2. Land Use Recommendations of the Neskowin CPAC

The *Adaptation Plan* developed by the NCHC included eleven land use recommendations for consideration of the Neskowin CPAC (see Section 5.2 of the *Adaptation Plan*). Most of them involve new or amended plan and code provisions that would affect future development. For example, the County development code could be amended to increase the distance buildings must be set back from the shoreline. Code amendments would apply only to construction of new, significantly improved, or repair/replacement of significantly destroyed structures and thus would increase community resilience to coastal hazards gradually, over a period of many years. During the 2011 Memorial Day meeting of the Neskowin Community Association, the NCHC surveyed the attendees to ask their opinion of the land use options. The results are summarized in Section 6 of this appendix.

After many meetings and considerable research, the NCHC proposed the strategies and actions set forth below. They focused on which of the 11 land use HATs (named and enumerated below) should be used for Neskowin and how they should be implemented.

The Neskowin CPAC further evaluated these HATs, and its recommendations are noted as appropriate in ***bold italics*** below.

1. Hazard Area Overlay Zone

DOGAMI has developed Hazard Risk Zone maps for Tillamook County (see Appendix A, Attachment 10). The following recommendations by the CPAC are related to this hazard information:

a. The County should adopt the DOGAMI Hazard Risk Zone Maps, modified to a single "regulatory trigger" hazard zone that combines DOGAMI's active hazard, high risk, and moderate risk zones and disregards the low risk zone as an initial step in developing appropriate zoning regulations in areas of significant risk from coastal erosion hazards. These maps are designated as Coastal Erosion Hazard Zone (CEHZ) maps.
b. The Neskowin Community Plan should include the modified Neskowin area CEHZ maps shown in Section 4.2 of this appendix. The County should restructure the County hazard regulations to incorporate and reference these maps. The key sections of the County's zoning provisions, as currently constituted, are Section 3.085 and Section 4.070.
c. The County should consider specific regulations related to these hazard zones. Many of the hazard alleviation techniques discussed within this section could utilize this hazard map information.

The CPAC recommends that a hazard overlay zone, combining the DOGAMI active, high, and medium risk zones should be adopted. The CPAC recommends that specific regulations, as noted in these recommendations, apply in this hazard overlay zone (see below).

2. Public Notification, Geologic Reports, and Regulatory Review

a. To facilitate the implementation of new standards in the coastal hazard erosion zone, the CPAC recommends that a new Coastal Hazard Zone permit be implemented. The permit would require specific review, decision, and notice procedures related to the coastal-hazard threats in the hazard zone. These procedures would include consideration of the other recommended ordinance changes in the hazard zone, as well as allow an applicant to provide evidence regarding the applicability of the hazard zone and ordinances to their property.
b. The NCHC recommended that the County also incorporate the additional requirements for coastal development from the Coastal Processes and Hazards Working Group (CPHWG) for new development on oceanfront properties. These requirements can be found in Appendix A, Attachment 12. This attachment is titled "Geological Report Guidelines for New Development on Oceanfront Properties" and was produced by the interagency Coastal Processes and Hazards Working Group (CPHWG) and Oregon Coastal Management Program staff (including DLCD, DOGAMI, and OPRD). The guidelines include additional requirements for geologic reports done in oceanfront locations to insure that reports are adequate for these areas.

The CPAC recommends that the CPHWG requirements, including a geologic report be prepared by an engineering geologist, be required for new construction in the hazard zone.

The CPAC recommends that a new "Hazard Zone" permit be required for new construction in the hazard zone. The permit will require that a geologic report be prepared and that all of the other hazard zone ordinances be addressed.

3. Special Building Techniques

a. The NCHC reviewed a variety of special building techniques, most of which are already being utilized by the County. Special building techniques addressing coastal hazards currently implemented in Tillamook County include:
    - Tillamook County, through the Oregon Structural Specialty Code requires construction techniques to protect against strong winds events (or wind loading); most coastal sites require the highest code standards (110 mph, Exposure D).
    - Tillamook County through the Oregon Structural Specialty Code requires Seismic Design Category D2 standards, which are the highest design standards for seismic safety applicable in Oregon.
    - Velocity Flood Zone ("V-Zone") standards (contained in both County and State building codes) are applicable to structures in designated coastal flood hazard areas. These standards require that the elevation of the lowest floor be at least three feet above the base flood elevation, that open piling or column-type foundations be used, and that the structure be engineered to withstand predicted hydraulic loading (wave impacts) from the base flood event.

Note that the County has limited ability to modify these requirements, which are established by the State of Oregon.

The CPAC does not recommend modifications at this time.

b. There are no current standards or requirements addressing moveable building design. The County may wish to explore this concept in certain designated hazard zones; standards may address both building design (e.g. wood-frame construction only; no slab-on-grade foundations) and building site access. For example, the County could require houses in a high-risk area to be built on a stem wall foundation that would allow a house to be relocated if coastal erosion threatened to destroy it. The County might also require road access sufficient to move the structure out of harm's way.

The CPAC recommends that new "slab-on-grade" foundations be prohibited in the hazard zone.

The CPAC recommends that new structures be moveable, either vertically or horizontally on the lot (for example, either stem wall or pile foundations). The CPAC does not recommend that a structure be required to be moveable off of the lot.

4. Safe-Site Requirement/Land Division Standards (also Prohibition of Development)

These HATs all include various concepts related to directing new development away from higher-risk hazard areas. Currently, the County does not have any substantive requirements related to safest-site location or limiting land divisions within hazard areas. The CPAC recommends that the County look into these issues as indicated below.

a. **Safest Site requirement:** The County should consider adding a "safest site" standard to both Section 3.085 (Beaches and Dune Overlay Zone) and Section 4.070 (Development Requirements for Geologic Hazard Areas). This standard would specify that proposed development on parcels within hazard areas must be located within an area most suitable for development as determined by a qualified professional as part of a geologic report. It would also be subject to standards within Section 4.070 of the County zoning ordinance.

The CPAC recommends that a "safest site" standard be administered by the County in the hazard overlay zone and that the safest site(s) be identified in the geologic report.

b. **Land Division Standards**: The County should consider adding standards within its land division ordinance that:
   - Limit creation of parcels to those which include a building site located outside the hazard risk zone; and
   - Prohibit adding to the number of existing housing units, including accessory dwelling units (ADUs), on a developed parcel that is within the hazard zone, and

- Prohibit the creation of additional multifamily dwelling units, including ADUs, within the hazard zone, and
- Require location of all new infrastructure (e.g. roads, water and sewer lines) to be landward the hazard zone whenever possible.

The CPAC recommends the limitations and prohibitions identified in the first three bullet items above.

The CPAC does not recommend the requirements for new infrastructure (fourth bullet item) at this time.

5. Setback Requirements

Currently, the County administers an oceanfront setback line (OSL) as directed by Section 3.085 (4)(A)(1)c of the County zoning ordinance. A significant reason for the OSL is to protect views by establishing a fairly uniform line that development would need to stay behind. The County could more fully consider other things besides view protection within the OSL regulations in order to establish a safer setback from hazards. The NCHC recommended that the County could consider the following:

a. The County could integrate FEMA velocity flooding information into development of a revised oceanfront setback area. One example might be that the County could direct that no development be authorized in a velocity flooding area; or, if the entire property is located in a velocity flooding area, the house must be located as far inland as possible;
b. The County should clarify within existing zoning code provisions the existing restrictions to additional seaward development on developed parcels within foredune/deflation plain areas. Statewide Planning Goal 18 and related County policy prohibit development on beaches, active foredunes, other foredunes subject to ocean undercutting and wave overtopping, and deflation plain areas subject to ocean flooding. Additional development seaward of existing development is not authorized in these areas.
c. The County could review other options related to amending the OSL, including potentially utilizing the new FEMA V-Zone analysis in some way.

In evaluating the applicability of these other setback provisions, the CPAC determined that these other provisions do not materially impact setbacks within Neskowin and that the existing Goal 18 beach and dune requirements, the existing OSL line, and the restrictions for safe site construction will be sufficient for setbacks on dune-backed property.

The CPAC does not recommend any of these setback modifications at this time.

d. The NCHC also recommended that the County could consider, for bluff-backed shorelines, a standard setback from bluff edges for new construction. One approach could be based on a 50+ annual erosion rate plus a buffer distance (see explanation below). This option would require a geologist to identify an annual erosion rate and the relevant bluff edge. The annual erosion rate would then be multiplied by the number of years (e.g. 50) to get a minimum setback. The County could also include a buffer distance beyond this potential minimum erosion distance to be used in the setback calculation. This approach could include a minimum setback, and a larger setback could be applied if recommended by the associated geologic hazard report.

The CPAC recommends that a 50-year annual erosion rate, plus a 20-foot buffer distance, be utilized for construction on sites with bluff-backed shorelines.

6. Runoff and Drainage Controls

It is clear that improper drainage and runoff from development can contribute significantly to coastal erosion. The County's current zoning code addresses runoff and drainage but only in a cursory way. Substantive requirements, if any, could come via a required geologic report in a case-by-case manner. The NCHC recommended that the County:

a. Develop a comprehensive set of standards designed to reduce runoff and drainage that contribute to coastal erosion.
b. Include within these standards a requirement that conformance with those standards be considered by the qualified professional who prepares the site-specific geologic report.
c. In developing these standards, the County should consider recently developed standards in other coastal communities.

The CPAC recommends: 1) a set of standards should be applied to the Neskowin area, as defined by the Neskowin Community boundary, and 2) include specific requirements for oceanfront property. See the proposed ordinances in Section 4.3 of this appendix.

7. Relocation of Structures from within Existing Lots or Parcels, and Substantial Improvements and Substantial Damage

a. The NCHC recommended that the County could consider implementing zoning code standards to provide incentives for the relocation of structures from higher to lower risk areas. Such incentives would include relaxation of normal setbacks, lot coverage or similar dimensional standards.

The CPAC does not recommend incentives for the relocation of structures at this time.

b. The NCHC recommended that the County should also explore the use of a threshold for "substantial improvements" and/or "substantial damage" to existing structures in high-hazard areas. Such a threshold could act as a trigger requiring the relocation of structures in high-risk hazard areas to a safer part of the parcel when such structures are substantially expanded and/or restored. County flooding provisions have similar requirements currently in place for some circumstances.

The CPAC recommends that improvement projects on a lot within the coastal hazard zone and with estimated costs greater than 50% of the real market value (RMV) on the most recent property tax statement be subject to the applicable requirements of the hazard overlay zone such as geologic reports and the hazard overlay zone permit, structural adaptations, setbacks, and runoff and drainage control.

The CPAC recommends that when reconstruction costs on a lot after damage from any cause on a lot is estimated to be greater than 80% of the RMV on the most recent property tax statement, the lot be subject to the substantive requirements of the hazard overlay zone but not to the discretionary permit process requirements.

8. Indemnification and Liability Waivers

a. Indemnification involves a requirement for permit applicants in designated hazard areas to indemnify and defend the County in any action for damages related to hazard area development brought by a third party. Indemnification has been proposed in some jurisdictions, but significant questions have been raised regarding the legal effectiveness of such a requirement. The NCHC did not recommend that the County develop indemnification requirements.
b. A liability waiver requires a permit applicant to hold the County harmless in the event permitted development is damaged by natural hazards. This requirement has been implemented in some jurisdictions, and the County may wish to explore applicable examples and research the relevant experience of jurisdictions using it. The NCHC recommended that the County explore this HAT.
c. Neither indemnification nor liability waivers actually reduce risk of damage from natural hazards, but they can serve to reduce the risk of the public incurring costs associated with this damage. They also may provide some disincentives to proposing development in higher-risk areas of a site.

The CPAC does not recommend indemnification at this time. The CPAC recommends that liability waivers be deferred for consideration at a later date and not be part of this approval process.

9. Public Education

The NCHC and CPAC believe that citizens who educate themselves regarding existing and potentially increasing coastal hazards will make better choices regarding proposed development near those hazards. Although "public education" is not generally thought of as a regulatory function of local government, the NCHC recommended that the County consider the following concepts:

a. Develop a comprehensive plan, policy, or policies indicating that increasing coastal hazards will affect citizens more and more in the future and that public education on these hazards is critical to help protect citizens of the County. Further, these policies should indicate that County officials should prepare and provide materials and develop opportunities to notify and inform key audiences.

b. Within the County's zoning code, develop a disclosure standard which would require, as part of any development permit within applicable hazard zones, a disclosure form to be filed with the County (potentially within the deed record for the parcel) to indicate such things as potential hazard risk zone(s) on the subject parcel, known geologic reports for the parcel, and other known geologic risks on the parcel.

The CPAC recommends that public education be deferred for consideration at a later date and not be part of this approval process.

10. Conservation Easements

State law (ORS 271.725) authorizes the County to acquire conservation easements by purchase or donation. Generally, such easements limit the permissible use and development of the land subject to the easement. An easement in an area subject to coastal hazards could prohibit high-risk or other inappropriate development. Conservation easements could provide an alternative, voluntary mechanism to limit or prohibit development in high-risk hazard areas. These development incentives could include things such as relaxation of normal setbacks, increased density on the remaining portion of parcels, and greater allowable building heights.

The CPAC recommends that conservation easements be deferred for consideration at a later date and not be part of this approval process.

11. Federal Emergency Management Agency (FEMA) Floodplain Provisions

a. The County currently has a significant set of requirements to address flooding. For example, the County currently regulates floor elevation, or the elevation that the first habitable floor must be above, well above the State minimum of 1 foot above the base flood elevation (BFE) and requires floor elevation to be 3 feet above BFE. The BFE is the extent or level of flooding that the FEMA analysis indicates would occur based on a 1 percent chance of occurring in any given year. It is also called a "100 year flood" and is a significant flooding event.
b. FEMA remapping of flood hazards will occur within the next two years and the County will be required by FEMA to adopt the new analysis and associated Flood Insurance Rate Maps (FIRMs).
c. Related to elevation of structures as indicated above, the NCHC indicated that, given the existing building height requirements and the potential for increasing BFEs, restrictions on building heights may seriously limit future building.

The CPAC does not recommend modifications at this time.

3. Status and Location of Land Use Recommendations in the Ordinances and Plans

NCHC/CPAC Recommendation	Status
1a Hazard Map Reference	Draft Section 3.329 (2), Page 30 and Neskowin Community Plan Section 10.2
1b Hazard Map	Neskowin Community Plan Section 10.2 and Appendix D
1c Hazard Map associated regulation	Draft Section 3.329 (1)-(12)
2a Coastal Hazard Zone permit	Draft Section 3.329 (4), Pages 31-35
2b Geologic Reports and CPHWG standards	Draft Section 3.329 (4) and (5), Pages 31-38
3a Special Building Techniques (Oregon state code)	No recommended changes
3b Construction (readily movable construction)	Draft Section 3.329 (6)(a), Page 38
4a Safest Site	Draft Section 3.329 (6)(b), Page 39
4b Land Division Standards	Draft Section 3.329(10), Page 42
4b Density restrictions	Draft Section 3.329 (6)(c&d), Page 39
4b New Infrastructure Limitations	Not recommended at this time
5 a-d Setbacks	Draft Section 3.329 (7), Pages 39-40
6 Runoff and Drainage	Draft Section 4.150, Pages 43-45
7a Incentives for moving structures within parcel	Not recommended at this time
7b Substantial Improvement	Draft Section 3.329 (4)(a), Page 31
7b Substantial Restoration and Replacement	Draft Section 3.329 (12), Pages 42-43
8a Indemnification	Not recommended
8b Liability waiver	Not recommended at this time
9a Coastal Hazard Education	Not recommended at this time
9b Hazard Disclosure	Not recommended at this time
10 Conservation Easements	Not recommended at this time
11a-c FEMA Floodplain Provisions- BFE	Not recommended at this time

4. Specific Land Use Ordinance and Plan Revisions

[IMPORTANT NOTE: THESE PROVISIONS ARE ADOPTED BY TILLAMOOK COUNTY IN THE APPROPRIATE LOCATIONS WITHIN THE TILLAMOOK COUNTY COMPREHENSIVE PLAN AND IMPLEMENTING ORDINANCES. THEIR REFERENCE IN THIS APPENDIX C PROVIDES DOCUMENTATION AND HISTORICAL PERSPECTIVE ONLY AND THEY ARE NOT NECESSARILY THE PROVISIONS IN EFFECT.]

4.1 Revisions to the Beach and Dune Element of the Comprehensive Plan

Tillamook County Comprehensive Plan
BEACHES AND DUNES ELEMENT
(Goal 18)

[Note: Add a Section 7 at the end of this plan element as indicated below]

7. Neskowin Coastal Erosion Adaptation Plan

7.1. Summary: The Neskowin area has experienced significant erosion of its beaches in recent years. As a result, the community of Neskowin faces increasing threats from coastal erosion, flooding, and inundation hazards. These forces are expected to further impact the beach, oceanfront properties, and the village behind.

Ongoing research by the Oregon Department of Geology and Mineral Industries suggests that Neskowin could experience even more negative impacts in the future. Ocean winter wave heights have increased significantly during the past decade, and are the highest they have been in the past three decades. Significantly stronger wave events are occurring earlier in the Fall/Winter and continuing until later in the Winter/Spring, effectively lengthening the period of winter erosion. The Neskowin beach/dune area continues to erode and is currently not replenishing itself. The volume of sand contained in Neskowin area beaches and dunes is much lower than in the mid-1990s (e.g., the dune face north of Proposal Rock has eroded landward ~150 ft. since 1997). The recurrence of storms with intensities comparable to those of the late 1990s, combined with high tides, would bring a strong probability of significant additional damage to the shore and further landward.

In an attempt to respond to these hazards, the Neskowin Coastal Hazards Committee (NCHC), a Tillamook County *ad hoc* committee, was formed. The NCHC worked diligently over the course of almost four years to address these hazards. *The Neskowin Coastal Erosion Adaptation Plan* is a significant result of this committee's work. The plan is a result of information, ideas, and comments provided by the NCHC. The plan has been vetted with the Neskowin community. The Neskowin Citizen Planning Advisory Committee (CPAC) has also reviewed the plan and land use implementation measures and recommended adoption of the plan and associated implementation measures. These measures were brought forward to the Tillamook County Planning Commission and Board of County Commissioners.

7.2. Plan adoption: The document "The Neskowin Coastal Erosion Adaptation Plan", dated June 2013, is hereby incorporated into the Tillamook County Comprehensive Plan by this reference.

7.3. Land use Implementation measures: *The Neskowin Coastal Erosion Adaptation Plan* includes specific, recommended land-use implementation measures aimed at increasing community resilience to these coastal erosion hazards.

7.4. Policies:

7.4a The County recognizes the significant coastal erosion hazards facing the community of Neskowin and supports efforts to increase community resiliency to these identified hazards.

7.4b The County may adopt coastal hazard maps and implementation measures based on the land use recommendations contained in the Neskowin Coastal Erosion Adaptation Plan, which is incorporated into the Tillamook County Comprehensive Plan by reference

4.2 Revisions to the Neskowin Community Plan

COMMUNITY PLAN

FOR THE

UNINCORPORATED COMMUNITY OF NESKOWIN

CONSISTING OF:

A. NESKOWIN COMMUNITY PLAN

B. TILLAMOOK COUNTY LAND USE ORDINANCE REVISIONS

C. COMPREHENSIVE PLAN AND ZONING MAP FOR NESKOWIN

D. NESKOWIN WETLANDS MAP, *Neskowin Community Plan Page i, March 31, 1999*

NESKOWIN COMMUNITY PLAN

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NOTE: OTHER DOCUMENTS REFERRED TO IN THE PLAN ARE ON FILE IN THE OFFICE OF THE TILLAMOOK COUNTY DEPARTMENT OF COMMUNITY DEVELOPMENT. *Neskowin Community Plan Page ii, March 31, 1999*

10. COASTAL HAZARDS

The Neskowin area has experienced significant erosion of its beaches in recent years; as a result, the community of Neskowin faces increasing threats from coastal erosion, flooding, and inundation hazards. These forces are expected to further impact the beach, oceanfront properties, and the village behind.

Ongoing research by the Oregon Department of Geology and Mineral Industries suggests that Neskowin could experience even more negative impacts in the future. Ocean winter wave heights have increased significantly during the past decade, and are the highest they have been in the past three decades. Significantly stronger wave events are occurring earlier in the Fall/Winter and continuing later into the Winter/Spring, effectively lengthening the period of winter erosion. The Neskowin beach/dune area continues to erode and is currently not replenishing itself. The volume of sand contained in Neskowin area beaches and dunes is much lower than in the mid-1990s (e.g. the dune face north of Proposal Rock has eroded landward ~150 ft. since 1997). The recurrence of storms with intensities comparable to those of the late 1990s, combined with high tides, would bring a strong probability of significant additional damage to the shore and further landward.

10.1 Neskowin Coastal Erosion Adaptation Plan Adoption

In an attempt to respond to coastal hazards as indicated above, the Neskowin Coastal Hazards Committee (NCHC), a Tillamook County *ad hoc* committee, was formed. The NCHC worked diligently over the course of almost four years to address these hazards. *The Neskowin Coastal Erosion Adaptation Plan* is a significant result of this committee's work. The official title of the plan is "The Neskowin Coastal Erosion Adaptation Plan" (the Neskowin Adaption Plan for short). It is incorporated into the Tillamook County Comprehensive Plan by reference. This report is the result of study and examination by the NCHC, coordination with state and federal agencies, consultants, and input and comments from the Neskowin community. The Neskowin Citizen Planning Advisory Committee (CPAC) reviewed the plan and land use implementation measures and recommended adoption of the plan and associated implementation measures that were brought forward to the Tillamook County Planning Commission and Board of County Commissioners. There have been public meetings to garner feedback and many sessions with experts to gain input, all of which have contributed to this plan. The NCHC was guided in its work by its mission statement, and the mission is evident throughout this document. The mission and objectives of the committee are as follows:
<u>Mission:</u> The mission of the Neskowin Coastal Hazards Committee is to—in priority order—plan ways to maintain the beach and protect the community through short term and long term strategies; recommend to state and county agencies and officials ways to maintain the beach and protect the community; and explore ways to plan for and adapt to the potential future changes in the Neskowin coastal area.

Objectives: 1) Become more knowledgeable about past and current dimensions of the situation and study expert projections for the future; 2) Provide information to alert Neskowin beach users to potential dangers of coastal hazards; 3) Investigate options (short and long term) for maintaining the beach and preserving the community; 4) Publish Committee findings and advocate actions likely to be most effective in fulfilling our mission; and 5) Help garner support and resources necessary to implement agreed upon actions.

10.2 Neskowin Coastal Hazards Overlay (NESK CH) Zone

General: *The Neskowin Coastal Erosion Adaptation Plan* examines land use and active protection measures. Although active protection measures are key components of the overall plan, the Neskowin Community Plan focuses on land use provisions which can be authorized and enabled by the Tillamook County Comprehensive Land Use Plan and associated policies. The Neskowin Adaptation Plan identifies key land use measures in conceptual form. The CPAC, in coordination with Tillamook County staff, developed specific land use provisions to address these concepts. As revised through the public review process, these provisions are included within the Neskowin Coastal Hazards Overlay (Nesk CH) Zone. The Nesk CH includes relevant Tillamook County Beach and Dune Overlay (BD) Zone provisions required for compliance with Statewide Planning Goal 18. In addition, it incorporates those land use implementing measures from the Neskowin Adaptation Plan determined appropriate for application to the community of Neskowin through the public review and adoption process.

Applicability: This Neskowin Coastal Hazard Overlay (Nesk CH) Zone applies within the coastal erosion hazard area as depicted by the Neskowin Coastal Erosion Hazard Zone Maps included within the Neskowin Community Plan as Appendix D. The Nesk CH Zone applies in lieu of the provisions of the Tillamook County Beach and Dune (BD) Overlay Zone within the Nesk CH Zone boundary only.

The Neskowin Coastal Erosion Hazard Zone Maps within Appendix D of the Neskowin Community are derived from DOGAMI hazard risk zone maps with modification consisting only of combining the Active, High Risk, and Moderate Risk zones identified in OFR 0-01-03 into one Hazard Zone, colored blue for dune-backed beaches and purple for bluff-backed beaches. The reference to these DOGAMI maps is DOGAMI Open File Report (OFR) 0-01-03, Evaluation of Coastal Erosion Hazard Zones Along Dune and Bluff-Backed Shorelines in Tillamook, Oregon: Cascade Head to Cape Falcon, by J.C. Allan and G.R. Priest, 2001.

10.3 Neskowin Coastal Hazard Policies

(a) Policy: The County recognizes the significant coastal erosion hazards facing the community of Neskowin and supports Neskowin community efforts to increase community resiliency to these identified hazards.

(b) Policy: The County shall adopt implementation measures based on the land use recommendations within the Neskowin Adaptation Plan, which has been included within the County comprehensive plan by reference. These provisions will be included within the Neskowin Coastal Hazards Overlay (Nesk CH) Zone.

(c) Policy: All other applicable hazard policies and implementation measures within the Tillamook County Comprehensive Plan and implementing ordinances remain applicable to the Neskowin community.

APPENDIX C:
Summary of Tillamook County Land Use Regulations Relevant to the Neskowin Community

This document summarizes various portions of the Tillamook County Land Use Ordinance and Land Division Ordinance for the purpose of education and facilitating discussion during the community planning process in Neskowin. These summarized portions are not all-inclusive, and should not be substituted for the actual ordinance in determining compliance with land use regulations. The regulations discussed below are subject to change. Zone definitions (R-1, R-2, C-1, etc.) are not summarized here; the appropriate sections of the Land Use Ordinance should be used directly for these zones.

Definitions and Abbreviations used in this summary

LUO = Tillamook County Land Use Ordinance -- deals with land use activities
LDO = Tillamook County Land Division Ordinance -- deals with subdivisions and partitions
The Department = Tillamook County Department of Community Development

Off-Street Parking Requirements (LUO Section 4.030)

Applicants are required to maintain 8-ft-by-20-ft off-street parking spaces adequate for the use of the property. For residential use, 2 spaces are required for a single-family dwelling and 1 space for each additional dwelling unit. Parking requirements for specific commercial and industrial uses are listed in the LUO.

Mobile Home and Recreation Vehicle Placement Standards (LUO Section 4.040)

Only certain zones allow Mobile Homes and RVs. Mobile Homes are allowed outright in the Rural Residential, R-3, and RMH zones, and as a Conditional Use in the R-2 zone. Recreation Vehicles are allowed outright in the Silver Valley Mobile Home Ranch (zoned RR), and as a Conditional Use in the Rural Residential and RMH zones. In the Rural Residential, R-1, R-2, and R-3 zones, temporary placement of a mobile home or recreation vehicle to be used because of a Health Hardship can be allowed as a Conditional Use.

In any residential, commercial, or industrial zone, a temporary mobile home or RV placement can be allowed for use during construction of a use for which a building permit has been issued.

Setback Requirements and Height Restrictions (LUO Sections 3.010 - 3.032)

Each zone (e.g. Rural Residential, Neighborhood Commercial) includes standards for setbacks and building height. In residential zones, the setbacks are 20 ft from the front property line, 20 ft from the rear, and 5 ft from the side property lines. On corner lots, the setbacks are 20 ft from the front, 15 ft from the street side property line, and 5 ft from the rear and non-street-side property lines. A residential use in a commercial zone has the same setbacks as in a residential zone. Other uses in a Commercial zone require 5 ft side and 10 ft front setbacks for parcels adjacent to residential zones, and no setback for parcels not abutting residential zones. In the case of a zero setback, the structure shall be placed on the property line or else set back at least 3 ft from the property line.

Building heights are limited to 24 ft for oceanfront or bayfront properties, and 35 ft elsewhere. Building height is measured as the distance between the peak of the roof and the existing (pre-development) grade, measured at the midpoint of each exterior wall and averaged.

AREAS WITHIN THE NESKOWIN COASTAL HAZARD OVERLAY ZONE (NESK CH) ARE SUBJECT TO OCEANFRONT SETBACK REQUIREMENTS OF THE TILLAMOOK COUNTY LUO SECTION 3.329 (7).

Exceptions to Dimensional Standards (LUO Sections 5.100 and 5.110)

Yard setbacks may be reduced under certain circumstances. On a lot 7500 sqft or less in size, either the front or rear yard may be reduced to 10 ft, provided certain requirements are met. On a lot less than 3000 sqft in size, front and rear setbacks combined must be at least 30 ft, but no more than 50% of the lot can be covered with any structure. On narrow lots, side setbacks may be 10% of lot width (minimum 3 ft). In certain cases, the average front setback of neighboring lots may be used as the front setback. In the Hawk Creek Hills and the First Addition to Hawk Creek Hills Subdivisions, front setbacks are 5 ft.

Structures are excluded from setbacks, with the following exceptions. Detached accessory structures may be located in the rear and side setback, but no closer than 3 ft to a property line. Projections from buildings such as eaves and chimneys can project 18 inches into setbacks. Decks, porches and steps <30 inches high may extend into setbacks provided they maintain half the front setback, 10 ft on a street side setback (corner lot), and 3 ft for other sides setbacks and the rear setback. Higher decks, etc., can project 24 inches into any setback. Decks that extend into setbacks cannot be covered or enclosed.

Geologic Hazard Areas (LUO Section 4.070)

The most common Geologic Hazard Areas include: areas mapped as active landslides; oceanfront bluffs where erosion and sliding are identified as problems in the Comprehensive Plan (e.g. the Ocean Ridge≅ area); locally known hazard areas based past occurrences; and areas of mapped landslide topography≅ where slopes exceed 19%.

In geologic hazard areas, all development must comply with standards minimizing vegetation removal, controlling runoff and erosion, and requiring prompt revegetation. Most development activity* in these areas also requires a Geologic Hazard Report completed by a geologist and an engineer and reviewed the Department. The Geologic Hazard Report is required to address the conditions of the site and surrounding area, and standards for development that will minimize the risk of geologic hazards. AREAS WITHIN THE NESKOWIN COASTAL HAZARD OVERLAY ZONE (NESK CH) ARE SUBJECT TO COASTAL HAZARD PERMIT AND MUST MEET THE REQUIREMENTS OF THE TILLAMOOK COUNTY LUO SECTION 3.329.

* (Specifically, planned developments, coast resorts, subdivisions, partitions, building permits, mobile home permits, and sand mining. On lots 20,000 sqft or larger, building and mobile home permits require Hazard Reports for areas of landslide topography only where the proposed structure is to be sited on slopes greater than 29%.)

Riparian Protection (LUO Section 4.080)

Riparian areas are defined as: 50 ft from lakes larger than 1 acre, estuaries, and the main stems of the following rivers where the river channel is >15 ft in width: Nestucca, Little Nestucca, Three Rivers, Tillamook, Trask, Wilson, Kilchis, Miami, Nehalem, and North and South Fork Nehalem River; 25 ft from other streams with channel widths of >15 ft; 15 ft from all other perennial streams. The riparian area for estuaries is measured horizontally (not as a slope distance) from the mean high-water line or the line of non-aquatic vegetation, whichever is more landward. For other water bodies the measurement is made from the ordinary high-water line.

Development is prohibited within the riparian area with the exception of: bridges; water-dependent uses; where natural features allow a smaller riparian area to protect equivalent habitat values; where an area is so degraded that additional development will have minimal negative impact. Exemptions from the riparian setback may be granted in certain areas where pre-existing lots are not large enough to provide a reasonable building envelope when the riparian setback is applied. These exemptions are required to be the minimum necessary to accommodate the use after the opposite yard setback has been reduced to half.

In addition to restricting development, the ordinance limits removal of riparian vegetation by prohibiting removal of trees or more than 50% of the understory vegetation within the riparian area (with certain exceptions).

THE NESKOWIN COASTAL HAZARD OVERLAY (NESK CH) ZONE APPLIES WITHIN THE COASTAL EROSION HAZARD AREA AS DEPICTED BY THE NESKOWIN COASTAL EROSION HAZARD ZONE MAP INCLUDED WITHIN THE NESKOWIN COMMUNITY PLAN AS APPENDIX D. IF THERE ARE ANY CONFLICTING PROVISIONS WITHIN THE NESK CH ZONE AREA, THE PROVISIONS OF THE NESK CH ZONE SHALL APPLY.

Flood Hazard (LUO Section 3.060)

This section contains standards for development activities within flood-prone areas. By enforcing this ordinance section, Tillamook County qualifies for federal flood insurance. Specific development standards depend on the flood zone, which is determined from maps provided by the Federal Emergency Management Agency (FEMA). In general, structures are required to have the first finished floor at least 1 ft (and in some areas at least 3 ft) above the 100-year flood elevation. Stricter standards are established for floodways. In Flood Hazard Areas, construction materials and utility installations are required to be resistant to flood damage. Recreation Vehicles must be highway ready or else meet the flood standards as manufactured homes. Development activities that could affect or be affected by flooding and which are not covered by a building permit or other permit are require a Development Permit under this Ordinance section (an example is the placement of fill in a floodplain).

Wetlands (LUO Section 3.092)

Wetland areas that are mapped and identified in the Tillamook County Comprehensive Plan as Significant Goal 5 (freshwater) or Goal 17 (coastal) wetlands are protected under the LUO. Development is allowed only if it will not result in major impact to significant wetlands. The relevant sections of the LUO are 3.090 Shoreland Overlay Zone (coastal wetlands) and 3.092 Freshwater Wetlands Overlay Zone.

All wetlands, whether or not they are identified as Significant in the Comprehensive Plan, are under the jurisdiction of the Oregon Division of State Lands (DSL) and the US Army Corps of Engineers and are regulated accordingly.

Neskowin Coastal Hazard Overlay (Nesk CH) Zone (LUO Section 3.329)

This Neskowin Coastal Hazard Overlay (Nesk CH) Zone applies within the coastal erosion hazard area as depicted by the Neskowin Coastal Erosion Hazard Zone Map included within the Neskowin Community Plan as Appendix D. If there are any conflicting provisions within the NESK CH zone area, the provisions of the NESK CH zone shall apply.

The purpose of the Neskowin Coastal Hazards Overlay Zone is to manage development in areas subject to chronic coastal hazards in a manner that reduces long-term risks to life, property, and the community by:

(a) Identifying areas that are subject to chronic coastal natural hazards including ocean flooding, beach and dune erosion, dune accretion, bluff recession, landslides, and inlet migration;
(b) Assessing the potential risks to life and property posed by chronic coastal natural hazards; and
(c) Applying standards to the site selection and design of new development that minimize public and private risks to life and property from these chronic hazards; such measures may include hazard avoidance and other development limitations consistent with Statewide Planning Goals 7 and 18 as well as the Hazards Element and Beaches and Dunes Element of the Tillamook County Comprehensive Plan.

The Beach and Dune Overlay Zone (LUO Section 3.085) remains applicable in beach and dune areas located landward of the Neskowin Coastal Hazard Overlay (Nesk CH) Zone.

Conditional Use (LUO Article VI)

Conditional Uses are uses that can be allowed when review shows them to be appropriate at a particular site within a zone. Notice of a pending Conditional Use decision is sent to all property owners within 250 ft of the subject property and notice is placed in the *Headlight Herald* newspaper. A 10-day public comment period is provided. At the end of this period the Department reviews the proposal relative to the Conditional Use criteria, which include such considerations as: whether the parcel is suitable for the proposed use; whether the proposed use is compatible with the surrounding area and uses on surrounding properties; and whether there are adequate public facilities for the proposed use. The proposal is also reviewed for compliance with all other applicable ordinance provisions. The Department renders a decision, completes a staff report, and sends notice of the decision to all property owners within 250 ft. There is a 10-day appeal period, during which any party to the decision may appeal the Department's decision to the Planning Commission. At the end of the appeal period, if no appeal has been filed, the decision is final.

Variance (LUO Article VIII)

A Variance is a deviation from a dimensional requirement of the ordinance, which is granted to avoid causing undue or unnecessary hardship by rendering the parcel incapable of reasonable economic use. The procedure is the same as that described above for a Conditional Use. The criteria that a Variance request must meet serve to establish whether: requiring a specific standard be met on the property would preclude the enjoyment of a substantial property right; the proposal will preserve the rights of adjoining property owners; there are no reasonable alternatives requiring lesser or no Variance.

Non-Conforming Use or Structure (LUO Article VII)

...is a use or structure that does not conform to one or more standards of the LUO, yet which existed prior to those standards going into effect. (Also known as a grandfathered use or structure) Non-conforming structures may be altered so long as there is no change in the external dimensions. If a Variance is approved, a non-conforming structure can be expanded up to 20%. Any additional expansion requires the structure be brought into compliance with all applicable standards. There are similar standards for non-conforming uses.

Minor Partition

A Minor Partition is the creation of two or three parcels from a single parcel within one calendar year, and does not involve creation of an access easement. Each parcel created must abut a public or private road for at least 25 ft. A Minor Partition is completed by a Registered Surveyor, is submitted to the Tillamook County Surveyor's office, and is reviewed by Community Development only for compliance with the lot dimension standards of the zone.

Major Partition (LDO Sections 10-16)

A Major Partition is either the creation of an access easement, or the creation of an access easement and two or three parcels from a single parcel within one calendar year. A Major Partition is required to meet the standards of the Tillamook County Land Division Ordinance (LDO), including construction of improvements (e.g. roads) to the standards of the LDO. The applicant submits a Tentative Partition Plan, which is reviewed by this department for completeness and compliance with LDO and LUO standards. Upon approval of the Tentative Plan, there is a 21-day appeal period. Following this appeal period, the applicant has 45 days to complete improvements and obtain Final Plan approval. Unlike for a Subdivision, there is no public hearing for a Major Partition.

Subdivision (LDO Sections 20-43)

A Subdivision is the creation of more than three lots from a single lot or parcel within a calendar year. The applicant submits a Tentative Plat, along with sufficient supporting documentation to show compliance with all applicable standards of the LUO and LDO. The proposal is sent to agencies having an area of responsibility affected by the subdivision (e.g. the appropriate water district, the Oregon Department of Fish and Wildlife, the appropriate fire district) for their review and input. The applicant is given an opportunity to amend the proposal based on agency input. This department prepares a staff report for the Planning Commission, including a recommendation of approval or denial. Then a public hearing is held before the Planning Commission. If the Planning Commission approves the Tentative Plat, the applicant has 12 months to complete improvements (e.g. roads and utilities) and obtain Final Plat approval. Time extensions are possible.

Planned Development (LUO Section 3.084)

A Planned Development is a specific type of Subdivision that is allowed in areas where natural features or other factors make flexibility in subdivision design essential. Subdivision layout, lot dimensions, and setback requirements are established through the Planned Development process (the requirements of the underlying zone do not apply). The applicant submits a development plan (a conceptual proposal, not a hard-and-fast plat), which is reviewed by this department and appropriate agencies. Based on staff's Planned Development Review, the applicant can amend the development plan before presenting it to the Planning Commission. The Planned Development typically is heard by the Planning Commission in conjunction with at least the first phase of the Subdivision(s) that will implement the development plan.

Appeal (LUO Article X)

Administrative land use decisions made by the department may be appealed to the Planning Commission. Decisions of the Planning Commission, whether on appeal or a decision originating with the Planning Commission (such as a Subdivision), may be appealed to the Board of County Commissioners. Board decisions may be appealed to the state Land Use Board of Appeals (LUBA). LUBA decisions are appealable to the state Court of Appeals, and from there to the Oregon Supreme Court.

APPENDIX D:

Neskowin Coastal Hazard Overlay Maps
(see next 2 pages)


Coastal Erosion Hazard Zone
Moderate-HighDune Erosion Hazard
Bluff Erosion Hazard
N
W
E
S
500 250 0 500 1,000 Feet
Coastal Erosion Hazard Zones obtained from DOGAMI Open File Report O-01-03
Evaluation of Coastal Erosion Hazard Zones Along the Dune and Bluff Backed Shorelines in Tillamook County, Oregon, Cascade Head to Cape Falcon
by Jonathan C. Allan and George R. Priest, 2001


Coastal Erosion Hazard Zone
Moderate-HighDune Erosion Hazard
Bluff Erosion Hazard
N
W
E
S
500
250
0
500
1,000 Feet
Coastal Erosion Hazard Zones obtained from DOGAMI Open File Report O-01-03
Evaluation of Coastal Erosion Hazard Zones Along the Dune and Bluff Backed
Shorelines in Tillamook County, Oregon, Cascade Head to Cape Falcon
by Jonathan C. Allan and George R. Priest, 2001

4.3 Neskowin Coastal Hazards Overlay Zone Ordinances

[IMPORTANT NOTE: THESE PROVISIONS ARE ADOPTED BY TILLAMOOK COUNTY IN THE APPROPRIATE LOCATIONS WITHIN THE TILLAMOOK COUNTY COMPREHENSIVE PLAN AND IMPLEMENTING ORDINANCES. THEIR REFERENCE IN THIS APPENDIX C PROVIDES DOCUMENTATION AND HISTORICAL PERSPECTIVE ONLY AND THEY ARE NOT NECESSARILY THE PROVISIONS IN EFFECT.]

3.329: NESKOWIN COASTAL HAZARDS OVERLAY ZONE (Nesk CH)

(1) PURPOSE: The purpose of the Neskowin Coastal Hazards Overlay Zone is to manage development in areas subject to chronic coastal hazards in a manner that reduces long term risks to life, property, and the community by:

(a) Identifying areas that are subject to chronic coastal natural hazards including ocean flooding, beach and dune erosion, dune accretion, bluff recession, landslides, and inlet migration;

(b) Assessing the potential risks to life and property posed by chronic coastal natural hazards; and

(c) Applying standards to the site selection and design of new development which minimize public and private risks to life and property from these chronic hazards; such measures may include hazard avoidance and other development limitations consistent with Statewide Planning Goals 7 and 18 as well as the Hazards Element and Beaches and Dunes Element of the Tillamook County Comprehensive Plan.

It is recognized that risk is ever present in identified hazard areas. The provisions and requirements of this section are intended to provide for full identification and assessment of risk from natural hazards, and to establish standards that limit overall risk to the community from identified hazards to a level acceptable to the community. It must be recognized, however, that all development in identified hazard areas is subject to increased levels of risk, and that these risks must be acknowledged and accepted by present and future property owners who proceed with development in these areas.

(2) AREAS INCLUDED: All lands within coastal erosion hazard zones as depicted on the Coastal Erosion Hazard Zone map adopted as Appendix D to the Neskowin Community Plan are subject to the provisions of this section.

(3) PERMITTED USES: Within the Neskowin Coastal Hazards Overlay Zone, all uses permitted pursuant to the provisions of the underlying zone may be permitted, subject to the additional requirements and limitations of this section.

(4) COASTAL HAZARD AREA PERMIT:

(a) Except for activities identified in subsection (4)(b) as exempt, any new development, new construction or substantial improvement, as defined in Article I, in an area subject to the provisions of this section shall require a Coastal Hazard Area Permit. The Coastal Hazard Area Permit may be applied for prior to or in conjunction with a building permit, grading permit, or any other permit or land use approval required by Tillamook County.

(b) Except for beach or dune areas subject to the limitations of subsection (8) of this section, the following activities are exempt from the requirement for a Coastal Hazard Area Permit:

(A) Maintenance, repair, or alterations to existing structures that do not alter the building footprint or foundation and do not constitute substantial improvement;

(B) An excavation which is less than two feet in depth or which involves less than twenty-five cubic yards of volume;

(C) Fill that is less than two feet in depth or that involves less than twenty-five cubic yards of volume;

D) Exploratory excavations under the direction of a certified engineering geologist or registered geotechnical engineer;

(E) Construction of structures for which a building permit is not required;

(F) Removal of trees smaller than 8 inches dbh (diameter breast height);

(G) Removal of trees larger than 8 inches dbh (diameter breast height) provided the canopy area of the trees that are removed in any one year period is less than twenty-five percent of the lot or parcel area;

(H) Yard area vegetation maintenance and other vegetation removal on slopes less than 25% slopes;

(I) Forest operations subject to regulation under ORS 527 (the Oregon Forest Practices Act);

(J) Maintenance and reconstruction of public and private roads, streets, parking lots, driveways, and utility lines, provided the work does not extend outside the previously disturbed area;

(K) Maintenance and repair of utility lines, and the installation of individual utility service connections;

(L) Emergency response activities intended to reduce or eliminate an immediate danger to life or property, or flood or fire hazard;

(M)Restoration, repair, or replacement of a lawfully established structure damaged or destroyed by fire or other casualty in accordance with subsection (12) of this section; and

(N) Construction/erection of beachfront protective structures subject to regulation by the Oregon Parks and Recreation Department under OAR 736, Division 20.

(c) Application, review, decisions, and appeals for Coastal Hazard Area Permits shall be in accordance with the following requirements:

(A) A property owner or authorized agent shall submit an application for a Coastal Hazard Area Permit to the department on a form prescribed by the department.

(B) Upon determination that the application is complete, the department may refer the application to affected cities, districts, and/or local, state and federal agencies for comments.

(C) Upon completion of the period for comments from affected agencies, the director shall approve or deny the application, or, at the director's discretion, refer the application to the Planning Commission for a public hearing.

(D) Notice of a decision by the director to approve or deny an application shall:

(i) Be provided to the applicant and to the owners of record of property within 250 feet of the subject property on the most recent Tillamook County property tax assessment roll;
(ii) Be provided to the Neskowin Citizen Planning Advisory Committee;
(iii) Explain the nature of the decision and the use or uses that could be authorized;
(iv) List the applicable criteria from this ordinance that apply to the subject decision;
(v) Set forth the street address or other easily understood Information identifying the location of the subject property;
(vi) State that a copy of the department's staff report and record of decision is available for inspection at no cost and can be provided at reasonable cost;

(vii) Provide the name and telephone number of the department staff person to contact for additional information; and,
(viii) Provide an explanation of the procedure and deadline for appealing the decision to the commission for a public hearing.

(E) A decision by the director to approve or deny an application for a Coastal Hazard Area Permit may be appealed in accordance with Section 10.020.

(F) An approved Coastal Hazard Area Permit shall be valid for a period of two (2) years from the effective date of the decision. If development authorized by the permit is not initiated within this two (2) year time period, the Coastal Hazard Area permit shall expire.

(d) In addition to a completed application as prescribed in subsection (c), an application for a Coastal Hazard Area Permit shall include the following:

(A) A site plan that illustrates areas of disturbance, ground topography (contours), roads and driveways, an outline of wooded or naturally vegetated areas, watercourses, erosion control measures, and trees with a diameter of at least 8 inches dbh (diameter breast height) proposed for removal;

(B) An estimate of depths and the extent of all proposed excavation and fill work;

(C) Identification of the bluff- or dune-backed hazard zone or landslide hazard zone for the parcel or lot upon which development is to occur. In cases where properties are mapped with more than one hazard zone, an engineering geologist shall identify the hazard zone(s) within which development is proposed.

(D) A geologic report prepared by an engineering geologist that meets the content requirements of subsection (5);

(E) If engineering remediation is required to make the site suitable for the proposed development, an engineering report, prepared by a registered civil engineer, geotechnical engineer, or certified engineering geologist (with experience relating to coastal processes), which provides design and construction specifications for the required remediation; and,

(F) A Hazard Disclosure Statement, executed by the property owner, which sets forth the following:

(i) A statement that the property is subject to potential chronic natural hazards and that development thereon is subject to risk of damage from such hazards;

(ii) A statement that the property owner has commissioned a geologic report for the subject property, a copy of which is on file with Tillamook County, and that the property owner has reviewed the geologic report and has thus been informed and is aware of the type and extent of hazards present and the risks associated with development on the subject property;

(iii) A statement acknowledging that the property owner accepts and assumes all risks of damage from natural hazards associated with the development of the subject property.

(e) A decision to approve a Coastal Hazard Area Permit shall be based upon findings of compliance with the following standards:

(A) The proposed development is not subject to the prohibition of development on beaches and certain dune forms as set forth in subsection (8) of this section;

(B) The proposed development complies with the applicable requirements and standards of subsections (6), (7), (8), and (10) of this section;

(C) The geologic report conforms to the standards for such reports set forth in subsection (5) of this section;

(D) The development plans for the application conform, or can be made to conform, with all recommendations and specifications contained in the geologic report; and

(E) The geologic report provides a statement that, in the professional opinion of the engineering geologist, the proposed development will be within the acceptable level of risk established by the community, as defined in subsection (5)(c) of this section, considering site conditions and the recommended mitigation.

(f) In the event the director determines that additional review of a Coastal Hazard Area Permit application by an appropriately licensed and/or certified professional is necessary to determine compliance with the provisions of this section, the County may retain the services of such a professional for this purpose. All costs incurred by the County for this additional review shall be paid by the applicant as a part of the application fee for a Coastal Hazard Area Permit established pursuant to Section 10.050.

(g) In approving a Coastal Hazard Area Permit, the director or commission may impose any conditions that are necessary to ensure compliance with the provisions of this section or with any other applicable provisions of the Tillamook County Land Use Ordinance.

(5) GEOLOGIC REPORT STANDARDS

(a) Geologic reports required by this section shall be prepared consistent with standard geologic practices employing generally accepted scientific and engineering principles, and shall, at a minimum, contain the items outlined in the Oregon State Board of Geologist Examiners "Guidelines for Preparing Engineering Geologic Reports in Oregon", or other published best practice guidelines for engineering geologic reports, consistent with current scientific and engineering principles. Reports shall reference the published guidelines upon which they are based. All engineering geologic reports are valid for purposes of meeting the requirements of this section for a period of five (5) years from the date of preparation. Such reports are valid only for the development plan addressed in the report. Tillamook County assumes no responsibility for the quality or accuracy of such reports.

(b) For the purposes of Section 3.329, geologic reports should be prepared by these guidelines for engineering geologic reports. All references in Section 3.329 that refer to geologist reports assume that they are prepared with these guidelines.

(c) In addition to the requirements set forth in subsection (5)(a), geologic reports for lots or parcels abutting the ocean shore shall, to the extent practicable based on best available information, include the following information, analyses and recommendations:

(A) Site description:

(i) The history of the site and surrounding areas, such as previous riprap or dune grading permits, erosion events, exposed trees on the beach, or other relevant local knowledge of the site.

(ii) Topography, including elevations and slopes on the property itself.

(iii) Vegetation cover.

(iv) Subsurface materials – the nature of the rocks and soils.

(v) Conditions of the seaward front of the property, particularly for sites having a sea cliff.

(vi) Presence of drift logs or other flotsam on or within the property.

(vii) Description of streams or other drainage that might influence erosion or locally reduce the level of the beach.

(viii) Proximity of nearby headlands that might block the longshore movement of beach sediments, thereby affecting the level of the beach in front of the property.

(ix) Description of any shore protection structures that may exist on the property or on nearby properties.

(x) Presence of pathways or stairs from the property to the beach.

(xi) Existing human impacts on the site, particularly any that might alter the resistance to wave attack.

(B) Description of the fronting beach:

(i) Average widths of the beach during the summer and winter.

(ii) Median grain size of beach sediment.

(iii) Average beach slopes during the summer and winter.

(iv) Elevations above mean sea level of the beach at the seaward edge of the property during summer and winter.

(v) Presence of rip currents and rip embayments that can locally reduce the elevation of the fronting beach.

(vi) Presence of rock outcrops and sea stacks, either offshore or within the beach zone.

(vii) Information regarding the depth of beach sand down to bedrock at the seaward edge of the property.

(C) Analyses of Erosion and Flooding Potential:

(i) Analysis of DOGAMI beach monitoring data for the site (if available).

(ii) Analysis of human activities affecting shoreline erosion.

(iii) Analysis of possible mass wasting, including weathering processes, landsliding or slumping.

(iv) Calculation of wave run-up beyond mean water elevation that might result in erosion of the sea cliff or foredune. [1]

(v) Evaluation of frequency that erosion-inducing processes could occur, considering the most extreme potential conditions of unusually high water levels together with severe storm wave energy.

(vi) For dune-backed shoreline, use an established geometric model to assess the potential distance of property erosion, and compare the results with direct evidence obtained during site visit, aerial photo analysis, or analysis of DOGAMI beach monitoring data.

(vii) For bluff-backed shorelines, use a combination of published reports, such as DOGAMI bluff and dune hazard risk zone studies, aerial photo analysis, and fieldwork to assess the potential distance of property erosion.

(viii) Description of potential for sea level rise, estimated for local area by combining local tectonic subsidence or uplift with global rates of predicted sea level rise.

(D) Assessment of potential reactions to erosion episodes:

(i) Determination of legal restrictions of shoreline protective structures (Goal 18 prohibition, local conditional use requirements, priority for non-structural erosion control methods).

(ii) Assessment of potential reactions to erosion events, addressing the need for future erosion control measures, building relocation, or building foundation and utility repairs.

(E) Recommendations:

(i) Use results from the above analyses to establish setbacks (beyond any minimums set by this section), building techniques, or other mitigation measures to ensure an acceptable level of safety and compliance with all local requirements.

(ii) Recommend a foundation design, or designs, that render the proposed structures readily moveable.

[1] Stockdon, H. F., Holman, R. A., Howd, P. A. and Sallenger, A. H., 2006, Empirical parameterization of setup, swash, and runup: Coastal Engineering, 53, p 573-588.

(iii) Recommend a plan for preservation of vegetation and existing grade within the setback area, if appropriate.

(iv) Include consideration of a local variance process to reduce the building setback on the side of the property opposite the ocean, if this reduction helps to lessen the risk of erosion, bluff failure or other hazard.

(v) Recommend methods to control and direct water drainage away from the ocean (e.g. to an approved storm water system);or, if not possible, to direct water in such a way so as to not cause erosion or visual impacts. In addition, the report shall specify erosion control measures as necessary to conform to the requirements of Section 4.150.

(d) Geologic reports required by this section shall include a statement of the engineering geologist's professional opinion as to whether the proposed development will be within the acceptable level of risk established by the community, considering site conditions and the recommended mitigation.

As used in this section, "acceptable level of risk" means the maximum risk to people and property from identified natural hazards deemed acceptable to the community in fulfilling its duty to appropriately protect life and property from natural hazards. For development subject to the provisions of this section, the acceptable level of risk is:

(A) Assurance that life safety will be protected from the identified hazard(s), excluding a tsunami resulting from a Cascadia megathrust earthquake, for a period of [*50-70*] years, considering site conditions and specified mitigation; and

(B) A high likelihood that the proposed structures will be protected from substantial damage from the identified hazard(s), excluding a Cascadia megathrust earthquake and resultant tsunami, for a period of [*50-70*] years, considering site conditions and specified mitigation.

(e) Geologic reports required by this section shall include a statement certifying that all of the applicable content requirements of this subsection have been addressed.

(6) ADDITIONAL DEVELOPMENT LIMITATIONS IN COASTAL HAZARD AREAS: In addition to the conditions, requirements, and limitations imposed by any required geologic report, all development subject to a Coastal Hazard Area Permit shall conform to the following requirements:

(a) Moveable structure design: Except for non-habitable accessory structures (e.g. garages, storage buildings), to facilitate the relocation of structures that become threatened by coastal hazards, slab-on-grade construction is prohibited.

(b) Safest site requirement: All new construction or substantial improvement shall be located within the area most suitable for development based on the least exposure to risk from coastal hazards as determined by an engineering geologist as part of a geologic report prepared in accordance with subsection (5). Notwithstanding the provisions of the underlying zone, as necessary to comply with this requirement:

(A) Any required yard or setback may be reduced by up to 50%; and,

(B) The maximum building width may be increased to up to 90% of the distance between opposite side lot lines.

(c) New lot or parcel development prohibition: On lots and parcels created after *[insert effective date of this section],* new construction or substantial improvement in the area subject to the provisions of this section is prohibited.

(d) Residential density limitation: Notwithstanding the residential density allowances of the underlying zone, on lots or parcels which are developed with an existing dwelling or dwellings, the construction of additional dwelling units, including accessory dwelling units, is prohibited.

(7) MINIMUM OCEANFRONT SETBACKS: In areas subject to the provisions of this section, the building footprint of all new construction or substantial improvement subject to a Coastal Hazard Area Permit shall be set back from the ocean shore in accordance with the following requirements:

(a) Of the following, the requirement that imposes the greatest setback shall determine the minimum oceanfront setback:

(A) A setback specified in a required geologic report;

(B) A setback that coincides with the Oceanfront Setback Line (OSL) determined pursuant to Section 3.085 (4)(A)(1)c.; or

(C) On bluff-backed shorelines, a setback from the bluff edge a distance of 50 times the annual erosion rate (as determined by an engineering geologist) plus 20 feet (or other distance determined to be an adequate buffer). The bluff edge shall be as defined in the required geologic report.

(b) On lots or parcels subject to the minimum oceanfront setback, the required yard setback opposite the oceanfront may be reduced by one foot for each one foot of oceanfront setback provided beyond the required minimum, down to a minimum of 10 feet.

(c) On lots or parcels created prior to the effective date of this section, where the application of the minimum oceanfront setback, together with any other required yards and/or setbacks, results in a building footprint area of less than 1,500 square feet, the minimum oceanfront setback may be reduced by an amount necessary to provide a building footprint of not more than 1,500 square feet.

(8) ADDITIONAL LIMITATIONS ON DEVELOPMENT ON BEACHES AND DUNES: In addition to the conditions, requirements, and limitations imposed by any required engineering geologic report, all development subject to a Coastal Hazard Area Permit in identified beach and dune areas shall be subject to the following requirements:

(a) Foredune breaching and restoration shall be conducted in a manner consistent with sound principles of conservation. Such breaching maybe permitted only:

(A) To replenish sand supply in interdune areas;

(B) On a temporary basis in an emergency, such as for fire control, hazard removal or clean up, draining farm lands, or alleviating flood hazards; or

(C) For other purposes only upon adoption of an exception to Statewide Planning Goal 18.

(b) Applications for development that will utilize groundwater resources shall provide a hydrologic analysis that demonstrates that groundwater withdrawal will not:

(A) Lead to the loss of stabilizing vegetation;

(B) Lead to a deterioration of water quality; or

(C) Result in the intrusion on salt water into water supplies.

(c) Foredune grading may be performed only as authorized by and in accordance with a foredune management plan adopted and acknowledged in conformance with Statewide Planning Goal 18.

(d) Identified beach and dune areas that are not subject to an exception to Goal 18, Implementation Requirement 2, as set forth in Section 6.1d of the Beaches and Dunes Element of the Tillamook County Comprehensive Plan, shall be subject to the following requirements:

(A) Required geologic reports shall address, in addition to the requirements of subsection (5), the following:

(i) The type of use proposed and the adverse effects it might have on the site and adjacent areas;

(ii) Temporary and permanent stabilization programs and the planned maintenance of new and existing vegetation;

(iii) Methods for protecting the surrounding area from any adverse effects of the development; and

(iv) Hazards to life, public and private property, and the natural environment that may be caused by the proposed use.

(B) On beaches, active foredunes, other foredunes that are only conditionally stable and subject to ocean undercutting or wave overtopping, and interdune areas (deflation plains) that are subject to ocean flooding:

(i) Residential developments and commercial and industrial buildings are prohibited.

(ii) Other development in these areas shall be permitted only if findings are provided which demonstrate that the proposed development is adequately protected from any geologic hazards, wind erosion, undercutting, ocean flooding and storm waves, and is designed to minimize adverse environmental effects.

(9) REQUIREMENTS FOR BEACHFRONT PROTECTIVE STRUCTURES:

(a) In reviewing a Land Use Compatibility Statement (LUCS) for an Oregon Parks and Recreation Department Ocean Shore Permit authorized by ORS 390.640, the director may determine that an application to construct a beachfront protective structure is in compliance with the local comprehensive plan and implementing regulations only if the beachfront protective structure will be placed where development existed on January 1, 1977, or where an exception to Goal 18, Implementation Requirement 2 has been adopted as set forth in Section 6.1d of the Beaches and Dunes Element of the Tillamook County Comprehensive Plan.

(b) For the purposes of this subsection, "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.

(c) Review and decisions on Land Use Compatibility Statements for Ocean Shore Permits shall be conducted in accordance with the requirements for an administrative action in accordance with Section 10.020.

(10) LAND DIVISION REQUIREMENTS: All land divisions in areas subject to the provisions of this section shall:

(a) All new lots must have a building site located outside the Nesk-CH Overlay Zone. In accomplishing this, each lot or parcel must have a minimum 1,500 contiguous square feet of building footprint which complies with all required lot setbacks and is located landward of the area subject to the provisions of this section.

(11) CERTIFICATION OF COMPLIANCE: Permitted development shall comply with the recommendations in any required geologic or engineering report. Certification of compliance shall be provided as follows:

(a) Plan Review Compliance: Building, construction or other development plans shall be accompanied by a written statement from an engineering geologist stating that the plans comply with the recommendations contained in the geologic report for the approved Coastal Hazard Area Permit.

(b) Inspection Compliance: Upon the completion of any development activity for which the geologic report recommends an inspection or observation by an engineering geologist, the engineering geologist shall provide a written statement indicating that the development activity has been completed in accordance with the applicable geologic report recommendations.

(c) Final Compliance: No development requiring a geologic report shall receive final approval (e.g. certificate of occupancy, final inspection, etc.) until the department receives:

(A) A written statement by an engineering geologist indicating that all performance, mitigation, and monitoring measures specified in the report have been satisfied;

(B) If mitigation measures incorporate engineering solutions designed by a licensed professional engineer, a written statement of compliance by the design engineer.

(12) RESTORATION AND REPLACEMENT OF EXISTING STRUCTURES:

(a) Notwithstanding any other provisions of this ordinance, application of the provisions of this section to an existing use or structure shall not have the effect of rendering such use or structure nonconforming as defined in Article VII.

(b) Replacement, repair, or restoration of a lawfully established building or structure subject to this section that is damaged or destroyed by fire, other casualty or natural disaster shall be permitted, subject to all other applicable provisions of this ordinance, and subject to the following limitations:

(A) Replacement authorized by this subsection is limited to a building or structure not larger than the damaged/destroyed building.

(B) Structures replaced pursuant to this subsection shall be located no further seaward than the damaged structure being replaced.

(C) Replacement or restoration authorized by this subsection shall commence within one year of the occurrence of the fire or other casualty that necessitates such replacement or restoration.

(D) Where the cost of restoration or replacement authorized by this subsection equals or exceeds 80 percent of the RMV of the structure before the damage occurred, such restoration or replacement shall also comply with subsections (6) and (7) of this section.

(c) A building permit application for replacement, repair or restoration of a structure under the provisions of this subsection shall be accompanied by a geologic report prepared by an engineering geologist that conforms to the standards set forth in subsection (5). All recommendations contained in the report shall be complied with in accordance with subsection (11).

(d) A building permit application for replacement, repair, or restoration authorized by this subsection shall be processed and authorized as an administrative action pursuant to Section 10.020.

4.150 NESKOWIN EROSION CONTROL AND STORMWATER MANAGEMENT

(1) PURPOSE: *The Neskowin Coastal Erosion Adaptation Plan* directs that erosion control and stormwater management be addressed within the Neskowin community boundary. Fluctuations in water levels and discharge of sediments within community streams and creeks ultimately impact coastal erosion. The purpose of this section is to ensure that new land divisions and other substantial developments within the Neskowin Community Growth Boundary provide for adequate control of erosion and sedimentation during construction and other ground disturbing activities. Furthermore, measures should be incorporated for long-term management of stormwater in a manner that minimizes impacts on coastal erosion and other related adverse impacts to the community.

(2) APPLICABILITY: The provisions of this section shall apply to:

(a) All lands within the Neskowin Community Growth Boundary as set forth on the Tillamook County Comprehensive Plan map;

(b) All development subject to approval by Tillamook County pursuant to Section 3.080, Section 3.082, Section 3.084, Section 4.130, or the provisions of the Tillamook County Land Division Ordinance; and,

(c) All development within the Neskowin Coastal hazard Overlay Zone (NESK CH) area that requires a coastal hazard area permit.

(3) EROSION CONTROL: All applications for development subject to the provisions of this section shall include detailed plans for the control of erosion and sedimentation during the course of construction and/or other ground disturbing activities. Such plans shall, at a minimum, incorporate the following measures:

(a) Stripping of vegetation, grading, or other soil disturbance shall be done in a manner which will minimizes soil erosion, allow the soil to be stabilized as quickly as practicable, and disturb the smallest practical area at any one time during construction;

(b) Development plans shall minimize cut or fill operations so as to prevent off-site impacts;

(c) Sedimentation barriers, as described in the Oregon Department of Environmental Quality publication "Best Management Practices for Stormwater Discharges Associated with Construction Activities" shall be placed to control sedimentation and minimize any sediment discharge from the site. Such barriers shall be installed prior to site clearing or grading activities;

(d) Temporary vegetation and/or mulching shall be used to protect exposed critical areas during development; and,

(e) Permanent plantings and any required structural erosion control and drainage measures shall be installed as soon as practical.

(4) STORMWATER MANAGEMENT: Applications for development subject to the provisions of this section shall include plans for the long-term management of stormwater that, at a minimum, conform to the following requirements:

(a) Provisions shall be made to effectively accommodate increased runoff caused by altered soil and surface conditions during and after development. The rate of surface water runoff shall be structurally controlled where necessary to prevent increased erosion; and

(b) Permanent drainage provisions adequate to convey surface runoff from the twenty-year frequency storm to suitable drainageways such as storm drains, natural watercourses, or drainage swales shall be provided. In no case shall runoff be directed in such a way as to significantly decrease the stability of bluff faces, foredune areas, known landslides, or other areas identified as unstable slopes prone to earth movement, either by erosion or increase of groundwater pressure.

(c) A geologic report, required within the NESK CH Overlay Zone, shall address management of surface water runoff at or behind active foredunes and riprap structures in order to reduce erosion and structure failure potential.

(5) MAINTENANCE: All erosion control and stormwater management measures shall be maintained in a manner that ensures that they function in accordance with their approved design. Failure to maintain erosion control or stormwater management measures in accordance with approved plans shall constitute a violation of this ordinance subject to enforcement pursuant to Article XI.

5. Next Steps

The recommendations proposed in this Appendix are preliminary. Amendments to this Adaptation Plan could be implemented by the County, with the support and encouragement from the Neskowin CPAC, and could provide the detail needed to clarify and codify the implementation of this Adaptation Plan. It is anticipated that County staff will take the lead in presenting such proposed amendments for review by citizens and hearing bodies, ultimately bringing about adoption by the Tillamook County Board of Commissioners.

6. Results of Public Survey of May 29, 2011: Preferences Regarding Land Use Options

Table 1. Results of Public Survey of May 29, 2011: Preferences Regarding Land Use Options				
	(1) First Choice	(2) Medium priority	(3) Lower Priority	(4) Total (unweighted)
Strengthen floor elevations/floodplain rules	4	3	2	**9**
Strengthen Geotechnical Report Standards	3	5	0	**8**
Special Building Techniques	5	6	1	**12**
Indemnification/Liability Waiver	0	3	1	**4**
Setback from High Hazard	4	4	8	**16**
Safest Site Requirements	3	1	2	**6**
Land Division Standards	3	8	12	**23**
Hazard Area Overlay Zone	2	1	6	**9**
Prohibition of Development	29	9	3	**41**
Strengthen Public Notice/Review	0	7	6	**13**
Strengthen Public Education	2	3	3	**8**
Conservation Easements	1	3	2	**6**
Control Runoff and Drainage	8	10	7	**25**
Elevate Existing Structures	0	1	3	**4**
Make Structures Movable	1	2	1	**4**
Relocate Structure	3	3	1	**7**
"None of the above"	6	5	7	**18**
TOTALS	**74**	**74**	**65**	**213**

APPENDIX D: THE FRAMEWORK PLAN

Page

This draft framework plan, as included in Appendix D, is only for the purpose of providing needed background scientific information and context for the Neskowin Adaptation Plan. The draft framework plan is currently not in force or effect in the County and will not be unless the County amends its comprehensive plan to specifically include and implement it. As such, no policies or provisions herein are operative as a result of its inclusion within this appendix.

Adapting to Coastal Erosion Hazards in Tillamook County:

FRAMEWORK PLAN

Final Draft, June 10, 2011

Development of this plan was supported through financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, through a grant to the Oregon Department of Land Conservation and Development.

Acknowledgments

This plan was prepared for Tillamook County with funding from the Oregon Coastal Management Program (OCMP) of the Department of Land Conservation and Development (DLCD). The following persons participated in the project and contributed greatly to the development of this plan:

Jonathan Allan, Oregon Department of Geology and Mineral Industries

Heather Baron, Oregon State University (Graduate Student Researcher)

Patrick Corcoran, Oregon State University Extension

Kristin Maze, Tillamook County Department of Community Development

Gerald Parker, Tillamook County Department of Community Development

Mitch Rohse, Planning Consultant (Lead Author)

Peter Ruggiero, Oregon State University

Tony Stein, Oregon Parks and Recreation Department

Nathan Wood, US Geological Survey

Laren Woolley, Oregon Department of Land Conservation and Development (Project Manager)

Also, this plan benefitted greatly from comments, ideas and information submitted by the Neskowin Coastal Hazards Committee (NCHC), chaired by **Mark Labhart**, Chair of the Tillamook County Board of Commissioners. From its inception in 2009, this committee of volunteers has spent countless hours helping the community of Neskowin and Tillamook County to develop effective methods for dealing with the significant local hazards from coastal erosion.

Contents

1. Our Dramatic, Dynamic Coast

With its rugged headlands, long sandy beaches, and rich estuaries, Tillamook County's coast surely is one of the most scenic places we can imagine. It also is one of the most dynamic.

Along the county's sixty-one miles of shoreline, all is in motion. Wind builds and sculpts great dunes. Waves and tides conspire to create, remove, and then create again broad expanses of sandy beach. Ocean currents and winter storms batter the shore. Even the land itself is moving, as great tectonic plates beneath the sea meet the continent and slide beneath its western edge.

Such dynamism challenges those who would live, work and visit here. Our efforts to settle on these coastal lands, build homes and businesses, and then serve them with roads, water and power are attempts to impose stability on a not-so-stable environment. The challenges of doing so are most apparent along the dune-backed and bluff-backed beaches that make up 90 percent of the county's coastline.

Most of these dunes and bluffs are receding – moving landward as the ocean attacks their base. Such coastal erosion brings landslides, ocean flooding and other events that damage property, injure people, and destroy resources. We describe these events as coastal hazards. We cannot stop them or control the natural forces that cause them. We can, however, plan for and adapt to coastal hazards and thereby reduce their impacts and costs. That's what this document is all about.

> *"All of the measurements on the Oregon coast confirm that it has one of the highest wave-energy climates in the world."*
>
> *"[T]he coastal zone is fundamentally different from inland areas because of its instability."*
>
> OSU Professor Paul D. Komar, in "Ocean Processes and Hazards along the Oregon Coast," *Oregon Geology*, Volume 54, Number 1, January 1992. pp. 4,7. On-line in PDF at http://www.oregongeology.org/pubs/OG/OGv54n01.pdf

This is Tillamook County's policy framework for adapting to the hazards of coastal erosion and ocean flooding – the framework plan, for short. You might also call it a risk-management, readiness, or preparedness plan. It is a document with three broad aims:

- To identify the extent of and risk from erosion and related geologic hazards in coastal areas of Tillamook County; and
- To develop policies, actions and programs that will lessen impacts and costs of coastal erosion hazards to the people, places and resources of this county;
- To develop suitable measures for reducing our vulnerability to variable and uncertain climatic and geologic forces.

2. The Erosion Hazard Adaptation Plan

2.1 The growing need for an adaptation plan

Tillamook County already has a comprehensive plan and related land use ordinances as well as a County Hazard Mitigation Plan. Why, then, is it necessary now to develop an adaptation plan for dealing with coastal erosion hazards? There are several answers to that question. First, this plan is intended to implement policies related to natural hazards within the county's comprehensive plan and hazard mitigation plan. It will provide better links between these documents to establish a sound local policy framework for addressing hazards related to a changing climate. It also is intended to open a dialogue about the threat from both short- and long-term coastal erosion.

Second, the extent and rate of coastal erosion in many areas are increasing. Several key factors that contribute to erosion have been changing, and they are changing in a ways that increase the likelihood of coastal erosion, landslides and ocean flooding. For example, sea level has been rising steadily for several decades. Scientists expect that rise to continue and, most likely, accelerate. Winter storm wave heights in the region have increased dramatically over the past three decades. And the intensity, and perhaps frequency, of winter storms also is growing. Such changes require us to reconsider which lands may be vulnerable to coastal erosion hazards and to reevaluate risks from those hazards.

> "**Adaptation:** Actions by individuals or systems to avoid, withstand, or take advantage of current and projected climate changes and impacts. Adaptation decreases a system's vulnerability, or increases its resilience to impacts."
>
> *Climate Change 101: Understanding and Responding to Global Climate Change*, published by the Pew Center on Global Climate Change and the Pew Center on the States, January 2009, at http://www.pewclimate.org/docUploads/Climate101-Adaptation-Jan09.pdf

The recent changes to our coastal environment are neither trivial, detectable only by sensitive laboratory instruments, nor so small that their effects will not be felt for decades. Quite the contrary: these changes already are having a significant impact on some communities.

Residents of Neskowin, for example, observed in the late 1990s that their beach was eroding, making beachfront homes more vulnerable to ocean flooding. In some places, the beach had receded more than 150 feet in just a few years. Property owners responded by installing riprap (stone revetments) on the face of the foredune. Now, however, winter storm waves periodically wash over the top of the revetment in some places, damaging both the riprap and the property it is intended to protect. Neskowin responded in 2009 by forming the Neskowin Coastal Hazards Committee to investigate ways to protect their beach and the adjoining properties. They continue to work with county officials to find solutions to the growing risk from coastal erosion. Many of the committee's ideas and suggestions are reflected in this plan.

A third reason for developing this adaptation plan is that the very lands most vulnerable to coastal hazards often are the most sought-after sites for development. New homes and businesses continue to be built along the coast. That not only increases the number of people and properties at risk from erosion hazards, but it also reduces natural protection in some cases. For example, "armoring the shore" with shoreline protective structures sometimes causes major erosion of a sandy beach. That diminishes the beach's effectiveness as a natural buffer against winter waves.

Finally, key state and federal agencies such as Oregon's Departments of Land Conservation and Development (DLCD) and Geology and Mineral Industries (DOGAMI) have recognized the growing threat from coastal hazards. They have increased their efforts to identify the location and extent of coastal erosion and flood hazards and have expanded programs to deal with them. Their work, however, depends on cooperation by affected local governments. Coastal cities and counties need to integrate state and federal programs for hazard planning into their local comprehensive plans.

The main objective of this erosion hazards adaptation plan is a more resilient community – a community made less vulnerable to coastal erosion hazards by being better prepared for them.

Adapting to a changing environment

"In addition to the effects of normal variability in Oregon's climate, significant changes in temperature, precipitation patterns, and other climate factors like ocean conditions are expected to increasingly affect Oregon's communities, natural resources, and economy. As with the effects of climate variability, long-term changes in climate conditions have the potential to result in very costly conditions and outcomes. Natural hazards, water supply problems, drought, habitat changes and loss of ecosystem services will all affect Oregon's citizens, communities, and economy. But fortunately, many of the potential costs and consequences of climate change may be anticipated and planned for. As such, it is both prudent and important to develop measures, programs and approaches to reduce the costs of climate variability and change on Oregon."

The Oregon Climate Change Adaptation Framework: Summary of Key Findings and Recommendations,

2.2 Origins of the adaptation plan

At the request of the Neskowin Coastal Hazards Committee in 2009, Tillamook County officials began working with the committee and with several state agencies to find ways for dealing with the increasing risk from coastal hazards. To provide technical data and conduct risk assessments for the county, the Oregon Department of Land Conservation and Development's Ocean and Coastal Management Program (OCMP) partnered with four other agencies:

- Oregon Department of Geology and Mineral Industries (DOGAMI)
- Oregon Parks and Recreation Department (OPRD)
- Oregon State University
- US Geological Services (USGS)

In 2010 the Department of Land Conservation and Development awarded a grant to Tillamook County to develop this adaptation plan, using the information from the agencies listed above. The county hired planning consultant Mitch Rohse to write the plan. Throughout the project, the county's Department of Community Development worked closely with the agencies and consultant and managed the project.
A first draft of the plan was completed and submitted to county officials in February 2011. It was reviewed and extensively revised in response to comments and new technical information and maps, to produce a revised draft of June 10, 2011.

2.3 Structure of the plan

This plan has two parts: a framework plan, which you are reading now, and a tier (eventually) of community sub-plans for the different communities and areas along Tillamook County's coast. The framework plan is a general document applicable to the county's entire coast. It describes key issues, defines the area subject to the adaptation plan, summarizes coastal erosion hazards, explains how they affect the county, and presents various methods for dealing with them. It is the information and policy foundation on which the community sub-plans will be built.

The community sub-plans focus on the specifics of each place. They explain which hazards affect which places, assess risks, and present specific actions, measures, and programs for dealing with those risks. One sub-plan, for Neskowin, is being developed right now. Others will follow, as resources and technical data become available. The final number of sub-plans isn't known yet.

Tillamook County's coastal erosion hazards adaptation plan thus will take form as shown in the diagram below. The diagram shows seven sub-plans, but the actual total could come to be more than a dozen.

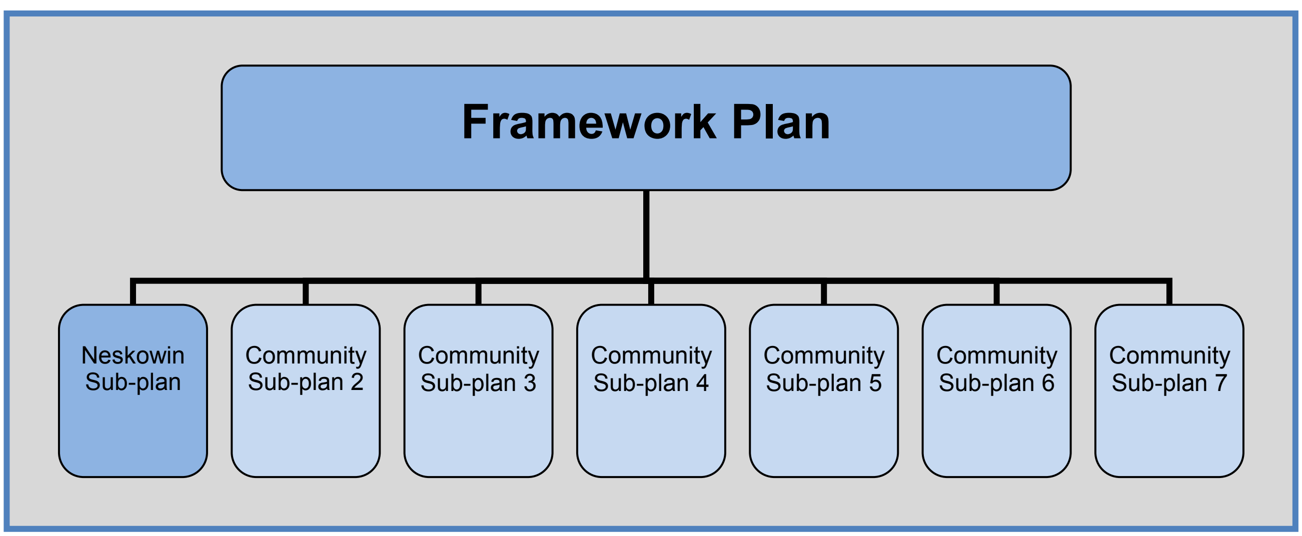


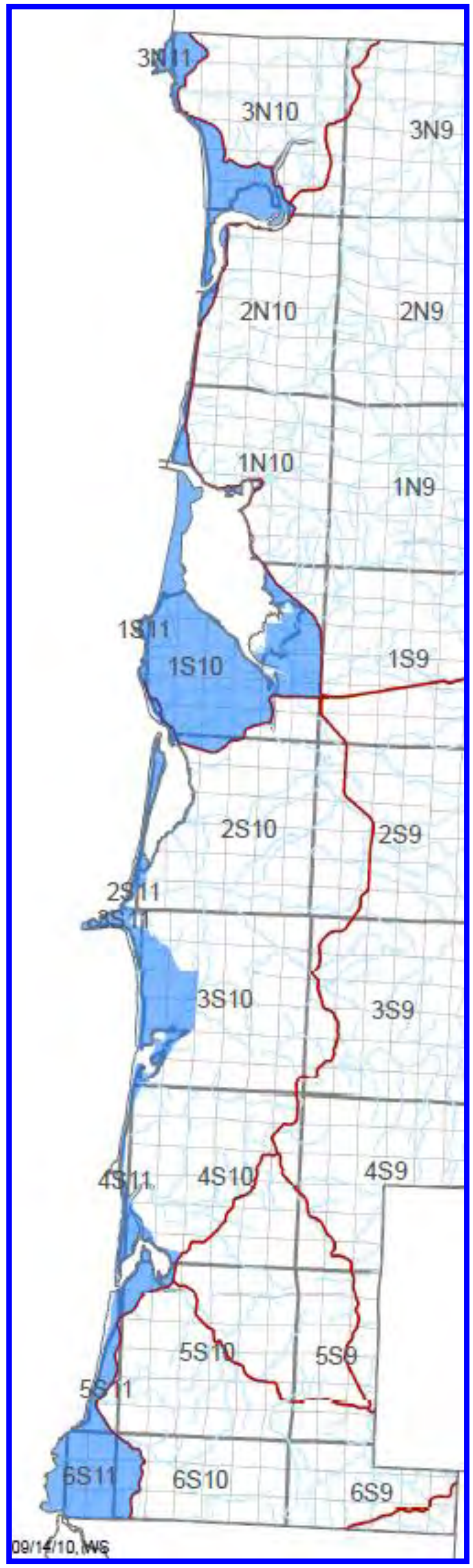
Figure 1: Tillamook County's erosion hazards adaptation plan has two "tiers": a broad framework plan, and a set of detailed sub-plans for the various coastal communities.

2.4 The planning area

One of the most basic questions in developing a plan like this has to do with geography: What lands should be addressed by and subject to the plan? Obviously, a plan for adapting to coastal hazards must include coastal areas that might be affected by such hazards. It's less obvious, however, where the upland boundary of such a planning area should be set.

For this plan, the county relies on a well-known and long-established boundary set forth in Statewide Planning Goal 17, *Coastal Shorelands*. For Tillamook County, Goal 17 describes the planning area thus:

> Inventories shall be conducted to provide information necessary for identifying coastal shorelands and designating uses and policies. These inventories shall provide information on the nature, location, and extent of geologic and hydrologic hazards and shoreland values, including fish and wildlife habitat, water-dependent uses, economic resources, recreational uses, and aesthetics in sufficient detail to establish a sound basis for land and water use management.
>
> The inventory requirements shall be applied within an area known as a coastal shorelands planning area. This planning area is not an area within which development or use is prohibited. It is an area for inventory, study, and initial planning for development and use to meet the Coastal Shorelands Goal.
>
> The planning area shall be defined by the following:
>
> 1. All lands west of the Oregon Coast Highway as described in ORS
>
> 366.235, except that:
>
> (a) In Tillamook County, only the lands west of a line formed by connecting the western boundaries of the following described roadways:
>
> Brooten Road (County Road 887) northerly from its junction with the
>
> Oregon Coast Highway to Pacific City,
>
> McPhillips Drive (County Road 915) northerly from Pacific City to its junction
>
> with Sandlake Road (County Road 871),
>
> Sandlake-Cape Lookout Road, (County Road 871) northerly to its junction with Cape Lookout Park,
>
> Netarts Bay Drive (County Road 665) northerly from its junction with the Sandlake-Cape Lookout Road (County Road 871) to its junction at Netarts with State Highway 131, and
>
> northerly along State Highway 131 to its junction with the Oregon Coast Highway near Tillamook.



Lands subject to this plan are shown in the shaded area along the coast. On-screen, the area is blue.

D - 8

To visualize this planning area, imagine that you want to take a scenic drive along Tillamook County's coast line. Your journey starts on the north side of the county, near Cape Falcon, on Highway 101 (the Oregon Coast Highway). You drive south on 101, past Manzanita, around Nehalem Bay, and through Rockaway Beach and Garibaldi. Near Tillamook, Highway 101 turns inland, away from the coast. You therefore leave the state highway and follow a series of county roads that hug the coast. Along the way, you pass through or near Cape Meares, Oceanside, and Netarts, arriving at Pacific City. From there, you come back onto to Highway 101 and follow it past Neskowin to Tillamook County's southern border (with Lincoln County). All of the lands, beaches, and headlands west of that route are "the planning area" covered by this plan.

Using Goal 17's definition of the planning area has three main benefits:

- It encompasses lands most likely to be affected by coastal hazards.
- It uses an established boundary, one already recognized in county and state planning documents.
- Because it is defined in terms of prominent physical features (roads and the Pacific Ocean), the area is readily seen, convenient to map, and congruent with property lines.

Here's an important point to remember about the planning area: inclusion in it does not necessarily mean that a property is at risk from coastal erosion hazards. In fact, many properties in this area will face little or no risk. Some may be at moderate risk from one hazard or another. Other properties may be facing high risk from erosion and related hazards. The "planning area" is simply the initial region where we start to make more detailed assessments of risk and then adopt suitable adaptation measures.

Conversely, being located outside the planning area does not mean a property can be assumed to be hazard-free. All parts of Tillamook County face some risk from natural hazards such as earthquakes. The erosion hazard planning area just marks the portion of the county where hazardous coastal erosion is most likely to occur.

2.5 The planning period

Most comprehensive plans in Oregon have a "planning period" of 20 years. That is, they project population, zone land for development, and estimate need public services and facilities from the time the plan is adopted to a point 20 years in the future.

In planning how to deal with geologic hazards, however, we need to look further into the future. While we certainly need to be mindful of short-term erosion that can be caused a single severe storm, a twenty-year window doesn't give us a broad enough view to estimate the probability and effects of long-term coastal erosion. This adaptation plan, therefore, uses a planning period of 40 years, from its inception in 2010 to the year 2050. One can readily make a case for some different period, but 2050 is a convenient target because several state and federal agencies with programs concerning hazards and climate change use the same year. For example, 2050 is the "time horizon" suggested in 2007's House Bill 3543 and used by the Oregon Global Warming Commission and the Intergovernmental Panel on Climate Change (IPCC).

2.6 The probabilistic plan

Traditional land use plans are "deterministic." That is, they are based on simple cause-and-effect relationships, where actions determine outcomes. With deterministic plans, specific outcomes are assumed to be predictable. We can say with assurance, even certainty, that if we take action "X," then we can expect outcome "Y."

For example, type and density of development determine demand for public services such as streets. Single-family dwellings in low-density subdivisions, for instance, can be expected to generate about 10 vehicle trips per dwelling each day. A subdivision with 100 such dwellings thus will create a demand for additional capacity of about 1,000 vehicle trips per day in the streets that serve it. Using such calculations, planners can accurately predict the impact that new development will have on a community and the systems and facilities that serve it.

When the cause-and-effect relationship is straightforward and we have reliable data or evidence of that relationship, the deterministic approach may be quite effective. But when we must deal with complex relationships that are neither fully understood nor adequately documented, the deterministic approach is likely to mislead. We thus need a better way to foresee our future and plan for it.

Such is the case with natural hazards: the cause-and-effect relationships are quite complex and outcomes therefore are far less predictable. We can be sure that certain geologic events such as a large earthquake will happen *sometime* in our future. They have happened in the past, and all the variables necessary for them to happen again still exist. On the other hand, we lack the information needed to accurately predict the precise time, location or magnitude of such events. The key geologic and climatic forces affecting our coast are highly variable, and our planning methods need to reflect that.

> "Extraordinary events can happen without extraordinary causes."
>
> *The Drunkard's Walk: How Randomness Rules Our Lives*, by Leonard Mlodinow (New York: Vintage Books, 2008), p. 20

Scientists deal with this problem of uncertainty by estimating the probability – the likelihood – that various hazard events will occur. By analyzing factors and forces that cause the events, they can give planners and policy makers estimates of risk on which to base plans and policies regarding development. The result is a plan that identifies areas of higher or lower risk, depending on the probability that a given hazard would cause significant damage there. The strongest protection is given to higher-risk areas. Lesser forms of protection are specified for areas facing less risk.

That is how this plan works. It is based on statistical estimates of erosion rates and the likelihood that related hazard events that will occur in a given place within a specified period. The statistical analysis and data come from scientists at the US Geological Service, the Oregon Department of Geology and Mineral Industries, and Oregon State University.

Probability does have a problem: it involves statistical analysis that is (a) complex and (b) sometimes counterintuitive. For example, the common "gambler's fallacy" causes many people to assume that if a coin is tossed ten times and comes up heads every time, the odds that it will be tails on the eleventh toss are much greater than fifty-fifty. Not so: assuming the coin is evenly balanced, the odds on the eleventh throw are the same as those on the first. The preceding ten throws have no influence on the eleventh.

The same is true of the so-called "hundred-year flood." If such a flood occurred in 2011, another could occur again the very next year. Yet many people assume that the one-in a-hundred probability means that the second such flood cannot occur for many decades to come. Over many thousands of years, the hundred-year interval is indeed likely to be the general pattern. But in any one century, the interval may depart dramatically from that pattern.

Also, the apparent simplicity of a statistic such as the "one-percent" or "hundred-year" flood often misleads. The Federal Emergency Management Agency (FEMA) describes that counterintuitive aspect of probability this way:

> The 1-percent AEP [*annual exceedance probability*] flood has a 1-percent chance of occurring in any given year; however, during the span of a 30-year mortgage, a home in the 1-percent AEP (100-year) floodplain has a 26-percent chance of being flooded at least once during those 30 years! The value of 26 percent is based on probability theory that accounts for each of the 30 years having a 1-percent chance of flooding.
> http://pubs.usgs.gov/gip/106/pdf/100-year-flood_041210web.pdf

2.7 How This Plan Fits with Climate Adaptation and Hazard Mitigation Planning

This coastal erosion hazard adaptation framework plan is one of several plans that address natural hazard risks to people, communities, and infrastructure in Tillamook County. As noted in Section 2.1, the fact that there are several plans can be confusing, but each one has a different emphasis or scope, and they all relate to each other. This section explains where this plan, which focuses on the coastal (ocean shore) portion of Tillamook County, and the county's overall hazard mitigation planning effort fit into the broader context of planning to reduce vulnerability to the effects of climate variability.

The Federal Emergency Management Agency (FEMA) requires all states and communities to develop natural hazard mitigation plans in order to be eligible for certain hazard mitigation grant programs, and in the case of the states, to be eligible for certain categories of disaster assistance. Tillamook County adopted its Hazard Mitigation Plan in 2005, and is now in the process of revising and updating it to reflect the state's recently adopted hazard mitigation plan framework. See http://opdr.uoregon.edu/stateplan.

Tillamook County's coastal erosion hazard adaptation plan—this framework together with the community sub-plans—is well suited to be one element of the county Hazard Mitigation Plan. As part of the County's process to update the hazard mitigation plan, this framework plan, and future community sub-plans, address increasing coastal erosion hazard risks. Other elements of the hazard mitigation plan will address other hazards, like flooding and wildfire. Finally, the hazard mitigation plan will be implemented in part through the county comprehensive land use plan.

Some natural hazards—floods, wildfires, drought, and erosion, to name a few—are driven by climate factors. Variability in climate conditions—more or less rain, cooler or warmer temperatures—is partly responsible for these natural hazards. Planning to address the effects of variable climate conditions has led some communities to develop comprehensive climate adaptation plans. Although this coastal erosion hazard adaptation framework plan addresses some components of climate variability (e.g., increased storminess and wave heights, sea level rise), it was not intended to address the full array of potential climate change factors and is not a comprehensive climate adaptation plan. Generally, climate adaptation plans are broader in scope than a hazard mitigation plan, since some adaptation measures—developing a new source of drinking water, or restoring riparian vegetation—fall outside the scope of natural hazard planning.

A full-scale planning approach to adapt to future climate conditions is much broader than this coastal erosion adaptation plan or the county hazard mitigation plan. However, hazard mitigation plans can be used to implement elements in a local climate adaptation plan. Planning for climate variability and future climate conditions is becoming one of the most important areas of land use planning. Tillamook County has not developed a comprehensive climate adaptation plan, but may consider doing so in the future. In the meantime, this plan contains measures that could be implemented to reduce vulnerability to some aspects of variable climate conditions, with its primary focus to reduce the county's exposure to the effects of coastal erosion.

The 2005 Tillamook County Hazard Mitigation Plan's focus is to "coordinate the participation of all public agencies and local government participants within Tillamook County" so as "to reduce or avoid long-term vulnerabilities to identified hazards." It currently deals mainly with a broad range of catastrophic or episodic events such as earthquakes, fires, and floods, and is countywide in its scope. The revised plan intends to also focus on the chronic and increasing hazard of coastal erosion along dune-backed and bluff-backed beaches, and with related hazards such as landslides.

The county's broader task is to revise the hazard mitigation plan and to look for opportunities to implement hazard mitigation polices, strategies and measures through the Tillamook County Comprehensive Plan. The county believes that this coastal hazard adaptation framework plan (and community sub plans), the hazard mitigation planning effort, and the county comprehensive plan should be well coordinated to more effectively address coastal hazards within Tillamook County.

Readers can view the 2005 Tillamook County Hazard Mitigation Plan on-line at http://www.co.tillamook.or.us/gov/ComDev/documents/planning/Hazard%20Mitigation%20Plan.pdf

For more information on adaptation planning . . .

The National Oceanic and Atmospheric Administration (NOAA) maintains a website on coastal adaptation planning at http://collaborate.csc.noaa.gov/climateadaptation/default.aspx The site includes a state-by-state listing of adaptation plans and projects and links to them. Click on "Resources."

For a report on the need for and progress of adaptation planning in the US, see Susanne C. Moser's *Good Morning, America! The Explosive U.S. Awakening to the Need for Adaptation.* 2009. 42 pp. On-line in PDF at http://www.csc.noaa.gov/publications/need-for-adaptation.pdf

Coastal erosion a significant hazard in Tillamook County . . .

"The hot-spot zones of erosion during the major El Niños of 1982-83 and 1997-98 represent some of the most significant impacts to coastal properties in recent decades. That erosion was the combination of the exceptionally high water levels experienced during the winter months, and the northward movement of the beach sand by the waves that reach the coast from the southwest, so that the property losses were greatest in the hot-spot areas. Examples of significant hot-spot erosion problems along the Oregon coast include the following.

•Neskowin, with the hot-spot area of maximum beach and foredune erosion having occurred immediately north of Cascade Head. *[In Tillamook County]*

•The erosion and flooding impacts to Cape Lookout State Park at the south end of Netarts Spit, to the north of the Cape, during both the 1982-83 and 1997-98 El Niños. *[In Tillamook County]*

• Impacts to The Capes development of condominiums that were constructed on a high sand bluff that was eroded by the northward migration of the inlet to Netarts Bay. *[In Tillamook County]*

•Extensive erosion of the Bayshore development on Alsea Spit during both major El Niños, caused by the northward migration of the Bay's inlet.

•The erosion of the beach and foredunes in Port Orford north of The Heads, resulting in the loss of the community's sewage disposal facility, and leading subsequently to a breach through the dunes that carried water into Garrison Lake that was its source of fresh water."

Peter Ruggiero, Paul D. Komar, Cheryl A. Brown, Jonathan C. Allan, Deborah A. Reusser and Henry Lee II, "Impacts of Climate Change on Oregon's Coasts and Estuaries," Chapter 6 in *Oregon Climate Assessment Report* (2010), K.D. Dello and P.W. Mote (eds). Oregon Climate Change Research Institute, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR.

3. Principles and Priorities for the Plan

When this framework plan was proposed, Tillamook County specified certain principles and priorities to be followed during its preparation. These have guided the plan's writers and contributors throughout its design and development:

a. To accurately assess the likelihood of future coastal erosion and related hazards and to identify areas in Tillamook County most vulnerable to them
b. To assess risk from coastal erosion hazards
c. To describe appropriate implementing measures, programs, and actions based on risk assessment
d. To protect county residents and visitors from injury and harm caused by coastal erosion and related hazards
e. To reduce costs and damage to private property
f. To reduce costs and damage to public property and infrastructure
g. To protect coastal resources and natural systems
h. To facilitate and coordinate efforts of public agencies to respond to and manage coastal erosion hazards
i. To inform county residents and visitors about coastal erosion hazards
j. To consider costs of and funding sources for adaptation measures
k. To establish a strategy for monitoring and measuring the performance of the adaptation measures, programs and actions used to implement the plan
l. To establish and maintain a process for adaptation planning that encourages and ensures extensive community involvement
m. To use science-based information and data from objective, authoritative sources such as public agencies or academic institutions in all risk assessment and adaptation planning (that is, the principle of "best available science")
n. To ensure that the adaptation plan complements and is consistent with Tillamook County's comprehensive plan, implementing measures, and functional plans
o. To ensure that the adaptation plan complements and is consistent with state and federal programs relating to coastal erosion hazards.

4. The Policy Setting

The State of Oregon has strong policies regarding land use, development, and protection of natural resources. These policies are set forth in 19 statewide planning goals and in related administrative rules and statutes. Cities and counties throughout Oregon have adopted local comprehensive plans that comply with those state policies, and Tillamook County is no exception. The county's plan was approved – the technical phrase is "acknowledged to comply with Oregon's statewide planning goals" – by the state's Land Conservation and Development Commission (LCDC) in 1983.

The adaptation plan therefore is not introduced into a policy vacuum. It must complement and reinforce existing state and local policies related to natural hazards, coastal communities, and natural resources. The key elements of this existing policy set are summarized in Tables 1 and 2:

TABLE 1: Key Local Policies and Programs Related to Coastal Hazards

Policy or Program	Responsible Agency
Tillamook County Comprehensive Plan	County Dept of Community Development http://www.co.tillamook.or.us/gov/ComDev/
Tillamook County Transportation System Plan	County Dept of Community Development http://www.co.tillamook.or.us/gov/ComDev/
Tillamook County Hazard Mitigation Plan	County Dept of Emergency Management http://www.co.tillamook.or.us/gov/EMGMGNT/default.htm
Unincorporated community plans for Barview-Watseco-Twin Rocks; Neahkahnie; Neskowin; Netarts; Oceanside; Pacific City-Woods	County Dept of Community Development http://www.co.tillamook.or.us/gov/ComDev/
City of Bay City Comprehensive Plan	City Hall http://www.ci.bay-city.or.us/Development.htm
City of Garibaldi Comprehensive Plan	Development & Building Dept http://www.ci.garibaldi.or.us/db.html
City of Manzanita Comprehensive Plan	City Manager's Office http://www.ci.manzanita.or.us/3Services/building.html
City of Nehalem Comprehensive Plan	Not available
City of Rockaway Beach Comprehensive Plan	Dept of Community Development http://www.rockawaybeachor.us/
City of Tillamook Comprehensive Plan	Planning Dept http://www.tillamookor.gov/departments/planning.html
City of Wheeler Comprehensive Plan	Not available

TABLE 2: Key State Policies and Programs Related to Coastal Hazards	
Policy or Program	**Responsible Agency**
Goal 5, *Natural Resources, Scenic and Historic Areas, and Open Spaces*	Dept of Land Conservation and Development (DLCD) http://www.oregon.gov/LCD/index.shtml
Goal 7, *Areas Subject to Natural Hazards*	Dept of Land Conservation and Development (DLCD) http://www.oregon.gov/LCD/index.shtml
Goal 16, *Estuarine Resources*	Dept of Land Conservation and Development (DLCD) http://www.oregon.gov/LCD/index.shtml
Goal 17, *Coastal Shorelands*	Dept of Land Conservation and Development (DLCD) http://www.oregon.gov/LCD/index.shtml
Goal 18, *Beaches and Dunes*	Dept of Land Conservation and Development (DLCD) http://www.oregon.gov/LCD/index.shtml
National Flood Insurance Program for Oregon	DLCD is the state's NFIP coordinator for FEMA http://www.oregon.gov/LCD/HAZ/floods.shtml
Oregon Coastal Management Program	Oregon Coastal Management Program (OCMP) http://www.oregon.gov/LCD/OCMP/index.shtml
Oregon Shore Law ("Beach Bill")	Oregon Parks and Recreation Dept (OPRD) http://www.oregon.gov/OPRD/RULES/index.shtml
Removal-Fill Permits	Division of State Lands (DSL) http://oregonstatelands.us/DSL/PERMITS/index.shtml
Natural Hazards (Coastal Erosion, Tsunamis, Earthquakes, etc.)	Dept of Geology and Mineral Industries (DOGAMI) http://www.oregon.gov/DOGAMI/earthquakes/earthquakehome.shtml
Oregon Global Warming Commission's *Roadmap to 2020* (on greenhouse gas reduction)	Oregon Global Warming Commission http://www.keeporegoncool.org/content/roadmap-2020
Oregon Climate Change Adaptation Framework, December 2010	State of Oregon (Multi-Agency Team) http://www.lcd.state.or.us/LCD/docs/ClimateChange/Framework_Final.pdf
Oregon Climate Assessment Report, December 2010	Oregon Climate Change Research Institute (OCCRI) http://www.keeporegoncool.org/content/oregon-climate-assessment-report-released

5. Coastal Erosion in Tillamook County

Coastal erosion is the general term used to describe a variety of natural processes and events that occur daily along the beaches, dunes, bluffs and headlands of Tillamook County. The Pacific Ocean here is engaged in a relentless quest to move east. It does this with varying degrees of success, scouring sand from beaches, eroding dunes, and undercutting bluffs. The great waves of the Pacific are abetted by strong winds and heavy winter rains that work together to constantly reshape the shoreline. The resulting erosion is hazardous to coastal life and property in several ways, described in this chapter.

Just as pain can be classified as acute or chronic, geologic hazards can be thought of in two broad categories: *episodic* and *chronic*. The former are sporadic, mostly unpredictable, events such as earthquakes. These types of hazards are sudden, short-lived events. In their most extreme form, they can inflict major damage to an entire region in a matter of minutes. In contrast, chronic hazards such as coastal erosion usually occur slowly, steadily and often imperceptibly. [1] They are more process than event. But one should not conclude that chronic hazards are less important or less damaging than catastrophic hazards. Indeed, because chronic hazards – especially coastal erosion – occur so steadily and persistently over long periods of time, their impacts on and damage to the community may be much greater.

The effects of coastal erosion sometimes are compounded by other geologic hazards. [2] For example, a massive subduction zone earthquake would cause some beaches and dunes to drop (subside) several feet, thereby causing sudden and widespread erosion, landslides and ocean flooding. For that reason, earthquakes and tsunamis are described at some length in the following chapter, on forces and factors that affect coastal erosion. The main focus of this plan, however, is on erosion of dune-backed and bluff-backed coastal beaches, and on costs and consequences of such erosion.

That coastal erosion should be considered a hazard may not be obvious. After all, the sand we observe washing into the sea during a walk on the beach seems to pose little danger to the walker or to cottages that line the shore. It is, however, the cumulative effects of such erosion that pose the danger. Those cumulative effects may be summarized as *narrowing beaches*, *shifting sand spits*, *crumbling bluffs and dunes*, *landslides*, and *ocean flooding*, as described in the following sections.

[1] Coastal erosion, however, is not always a slow or chronic hazard: one extreme winter storm can bring sudden and massive erosion.
[2] ORS 516.010(6) defines "geologic hazard" as "a geologic condition that is a potential danger to life and property which includes but is not limited to earthquake, landslide, flooding, erosion, expansive soil, fault displacement, volcanic eruption and subsidence."

5.1 Narrowing Beaches

A broad expanse of sand serves as a natural buffer, cushioning the ocean's impact on dunes, bluffs – or development – along the shore. For that reason, wide beaches of fine sand are often described as "dissipative": that is, they dissipate wave energy. In contrast, narrower, steeper and coarser beaches are described as "reflective." During high water and storms, waves on reflective beaches break closer to shore, having lost little of their energy before impact. The potential for erosion of the shore and damage to structures thus is greater along reflective beaches.

Many beaches in Oregon undergo an annual cycle in which they lose sand in winter but regain it in summer. Winter storms wash sand out to sea, sometimes taking a beach down to bedrock, revealing what is called the *shore platform* or (formerly) *wave-cut platform*. The sand lost in winter then is restored in summer, when the longshore current reverses and offshore waves grow smaller. Over the course of a year, a beach exposed to this cycle thus experiences no significant net loss or gain of sand. Such a beach is said to be in dynamic equilibrium. Here, the width of the beach will wax and wane with the seasons, but over the long term, will remain fairly constant.

Some beaches, however, do not remain in equilibrium. Rather, they experience long-term net losses (erosion) or gains (accretion) of sand. A beach that is losing sand may decrease in height and width, as well as recede (move landward). In contrast, a beach that is accreting may increase in height and width and also *prograde* – that is, grow toward the sea.

Littoral Cells

A littoral cell is a section of shoreline bounded on either end by a headland and backed by dunes or bluffs, with a sandy beach at water's edge. The cells typically are, in a geologic sense, self-contained: the sand of the beaches, dunes and nearshore waters in the cell is contained by the headlands and circulates within the cell. Tillamook County has four of these cells.

The largest and northernmost is the *Rockaway Littoral Cell*. It extends from Cape Falcon on the north to Cape Meares on the south.

The *Netarts Littoral Cell* extends from Cape Meares south to Cape Lookout.

The *Sand Lake Littoral Cell* extends from Cape Lookout south to Cape Kiwanda.

The *Nestucca* (or *Neskowin) Littoral Cell* extends from Cape Kiwanda at Pacific City south to Neskowin and Cascade Head.

The Nestucca littoral cell, which extends from Cape Kiwanda and Pacific City on the north to Neskowin and Cascade Head on the south, is one example of a beach out of balance. Since the late 1990s, the cell has experienced a net loss of sand (through June 2006) estimated to be between 1.3 million and 2.0 million cubic yards.[3] To picture just how much sand that is, think of houses full of sand. A 2,000 square-foot dwelling with nine-foot ceilings has a volume of 667 cubic yards. One million cubic yards of sand is

[3] Jonathan C. Allan and Roger Hart. *Assessing the temporal and spatial variability of coastal change in the Neskowin littoral cell: Developing a comprehensive monitoring program for Oregon beaches*. Portland, Oregon Department of Geology and Mineral Industries, 2007, p. 1.

1,500 housefuls. By any measure, then, a net loss of as much as 2.0 million cubic yards is a dramatic change.

The greatest sand loss in the Nestucca littoral cell has occurred in the southern part of the cell. The northern part has experienced some accretion, increasing the height of the dune along the Nestucca River spit. This relatively small build-up, however, is far exceeded by the net loss of sand over the entire littoral cell.

Long-term accretion may cause sand inundation, where a growing dune moves into a developed area, damaging beachfront property and structures. This has occurred at Pacific City, for example. The more hazardous result from a beach out of balance, however, is long-term erosion. The continuing loss of sand causes the beach to narrow and recede, reducing its effectiveness as a buffer. Waves run up farther onto shore, and more wave energy is released there, often causing damage to property, infrastructure and resources. The photo here shows such damage at Neskowin, where the beach has narrowed markedly during the past decade.

"High surf and the impact on the riprapped Neskowin shoreline on January 9, 2008." This photo by Armand Thibault appeared in the *Oregonian* article "State monitoring shifting sands on coast," March 1, 2009.

The average size of a beach's individual particles of sand ("median grain size") plays a significant role in the beach erosion rate. The correlation may seem counter-intuitive: beaches with fine-grained sands erode *less* rapidly than beaches with coarse sands. All other things being equal, beaches with small sand particles thus are generally more effective buffers from ocean waves.[4]

[4] Paul D. Komar, in "Ocean Processes and Hazards along the Oregon Coast," *Oregon Geology*, Volume 54, Number 1, January 1992. p. 7. On-line at http://www.oregongeology.org/pubs/OG/OGv54n01.pdf

5.2 Shifting Sand Spits

Sand spits are perhaps the most dynamic of all coastal landforms. Wind and waves are constantly re-shaping them, thereby creating a highly unstable environment. That is the harsh lesson of Bayocean, an entire community lost to the forces of coastal erosion. See text box and photo below.

Bayocean: A Town Taken by the Sea

"June 22, 1912 was opening day for the community of Bayocean on the prominent spit at the mouth of Tillamook Bay. Buildings included a post office, a large enclosed swimming pool, a three-story hotel, a bowling alley, and 59 homes and summer cottages. Investments totaled well over a million dollars (1912). Erosion was first noticed in the 1920's, and in 1939 the first breach of the spit occurred. With final breaching in 1952, the community was totally destroyed. Today at low tide many of the original lots are as much as a quarter of a mile out to sea"

DOGAMI's *The ORE BIN*, Vol. 38, No.5, May 1976, p. 74 http://www.oregongeology.com/pubs/og/OBv38n05.pdf

Typically, the most dynamic, unstable part of a spit is its tip, where the width or location of a beach may vary by hundreds of feet per year.

For precisely the reasons described above, little new development occurs on sand spits today. It is largely prohibited by state planning laws and coastal management program requirements. Some development already exists on the spits, however, as does key public infrastructure such as roads and parks.

5.3 Crumbling Bluffs and Dunes

Ocean waves often attack the toe of dunes, bluffs and cliffs, thereby undercutting them and making them more prone to landslides and sloughing. Meanwhile, wind and rain attack the face of these landforms. The combined attack often causes the upper edge of the landform to move landward in a process called "bluff recession."

A rapid retreat of the land may cause severe damage to structures along high-bank shores. Oceanfront yards may suddenly shrink or disappear, as shown in the photo below (taken by Tony Stein, of the Oregon Parks and Recreation Department, at Lincoln Beach).

"Cliff" or "Bluff"?

In everyday usage, the words *cliff* and *bluff* are pretty much interchangeable. Some geologists, however, view them as two distinct landforms. For example, Hapke, Reid and Richmond say, "Throughout the literature, *cliff* frequently refers to a slope formed in stronger, more-resistant rock units, whereas *bluffs* are slopes eroded in softer, unlithified material, such as glacial till or ancient dunes."* We maintain that same distinction in this plan.

*Cheryl Hapke, Dave Reid, and Bruce Richmond, *Rates and Trends of Coastal Change in California and Regional Behavior of the Beach and Cliff System, Journal of Coastal Research,* May 2009, p. 604
http://allenpress.com/pdf/COAS_25.3_603_615.pdf

Structures may tumble onto the beach below. And in extreme cases, an entire complex of buildings may be damaged, as was the case at The Capes, in Netarts.

Dunes and bluffs of soft sedimentary material are the landforms most vulnerable to coastal erosion, but even headlands and sea cliffs of the hardest rock are not immune. They too erode, albeit more slowly. For example, geologists estimate that in Tillamook County, a hard basalt bluff exposed to wave action can be expected to erode at an average rate of one to two inches per year. In contrast, a bluff composed of softer alluvial deposits – loosely consolidated sand, mud, silt and gravel – typically erodes 3 to 6 inches per year.[5]

[5] Allan, Jonathan C., and George R. Priest. *Evaluation of coastal erosion hazard zones along dune and bluff backed shorelines in Tillamook County, Oregon: Technical report to Tillamook County*, Portland, Oregon Department of Geology and Mineral Industries, 2001.

5.4 Landslides

Erosion often occurs as a gradual wearing down of coastal landforms, a process so slow that we cannot see its effects from one day to the next. But erosion also occurs in dramatic fits and starts, as large quantities of material lose their fight with gravity. These episodic forms of erosion are *landslide*s, which are defined simply as the perceptible downslope movement of soil, rock or debris. There are three main forms of this event: *falls*, *slides* and *flows*.

As the name suggests, a *fall* is the sudden dropping of soil or rock from a steep slope onto land at the base of the slope. The falling material flies through the air or bounces or rolls down the slope until coming to rest. Along Tillamook County's coast, the two most common types of fall are rockfalls from sea cliffs and sloughing from sandstone bluffs. A *slide* is a similar type of event in which soil or rock moves not by falling freely through the air but by sliding downward along a less-than-vertical slope.

Falls and slides are quite common on coastal headlands, cliffs and bluffs. The continual landslides often create large piles of broken rock and debris where the steep face of the slope meets the beach. The deposits of small fragments of loose material that build up at the base of these landslides are referred to as *talus* or *scree*.

Key Factors Affecting Coastal Landslides

- Type of material of which the bluff is made
- Height of bluff
- Slope of bluff face
- Surface water and runoff
- Groundwater and pore pressure
- Drainage from development at top of bluff
- Vegetation
- Wave action at toe of bluff
- Extent of debris at toe of bluff
- Type of beach at base of bluff
- Shorefront protective structures at toe of bluff
- Human activity accelerates erosion of bluff – digging caves in it, for example

Flows, the third form of landslide, occur when masses of shale, loose rock or water-soaked soil take on the characteristics of a fluid and move downslope as an earthflow, mudflow or debris flow. Debris flows, also called "rapidly moving landslides," are common in Tillamook County, not only on the coast but also in the interior, on the steep wet slopes of the Coast Range.

When a large block of material suddenly gives way and slides downslope as a single mass – a process called *block failure* – the resulting landslide is referred to as a *slump*.

The state Department of Geology and Mineral Industries (DOGAMI) recently undertook a statewide analysis of areas that have experienced landslides or are prone to them. The result of that analysis is "SLIDO," the "Statewide Landslide Information Database for Oregon." It is available on-line as an interactive map showing landslide areas in red, at http://www.oregongeology.org/sub/slido/index.htm

Even a cursory look at the state map reveals a lot of red in Tillamook County, much of it concentrated along the county's coast: landslides are a significant hazard here. Numerous variables affect the frequency and extent of landslides at a given location. The most important usually is the type of material of which the bluff is made.

In addition, the *height* and *slope* of a bluff play a significant part in landslides. Likewise, water is a key factor. *Runoff* at the crest and over the face of the bluff as well as *groundwater* may saturate loose soils, making them much more prone to landslides. *Vegetation* at the crest and on the face of a bluff serves to hold loose unconsolidated soils together, thus increasing resistance to water and wind erosion. *Wave action* at the base of a bluff is significant, especially if it leads to undercutting. The extent of *debris* at the base of a bluff is important: slide debris, sand and driftwood all may serve to buffer the impact of the waves, thus protecting the bluff from undercutting.

Also, the *type of beach* below the bluff makes a difference. A broad expanse of fine sand in a *dissipative beach* will absorb a large part of the wave energy that might otherwise erode the bluff or dune behind the beach.

In addition to the natural factors described above, the actions of man play a significant part in reducing – or increasing – the probability of landslides at some locations. Plantings, proper drainage and structures protecting the toe of a bluff all can slow coastal erosion and thereby lessen the frequency and extent of landslides. But other actions may increase the threat. Irrigation and improper drainage of developed properties near the crest of the bluff increase the likelihood of landslides. Likewise, climbing on or defacing fragile slopes accelerates the erosion caused by natural forces.

The state's Department of Geology and Mineral Industries (DOGAMI) has examined the history of landslides in Tillamook County, mapped the location of major slides, and estimated the risk of landslides at bluff-backed beaches. The results of DOGAMI's study are presented in a report by Jonathan C. Allan and George R. Priest, *Evaluation of Coastal Erosion Hazard Zones along Dune and Bluff Backed Shorelines in Tillamook County, Oregon: Cascade Head to Cape Falcon*, 2001.

For more information on landslides . . .

See Oregon Department of Geology and Mineral Industries (DOGAMI) website on "Coastal Hazards" at
http://www.oregongeology.org/sub/earthquakes/Coastal/CoastalLandslides.htm

Visit the Oregon Department of Land Conservation and Development's Natural Hazard program website on "Landslides" at
http://www.oregon.gov/LCD/HAZ/landslides.shtml

5.5 Flooding

Floods are defined in terms of the floodwater's elevation with regard to some standard reference point. In Tillamook County, that reference typically is a fixed elevation called the National Geodetic Vertical Datum of 1929 (NVGD 29).[6] It corresponds roughly to what in everyday language is called "mean sea level." When one speaks of a flood's "elevation," it thus means the height of the floodwater's surface above NGVD 29. The higher a flood's elevation in comparison to the elevation of the flooded land, the greater the depth of the floodwater. For example, if floodwaters at a certain place reach an elevation of 100 feet above NGVD 29 and the elevation of the land there is 90 feet above NGVD 29, the depth of the floodwaters is ten feet.

The word *flood* covers a wide range of conditions, from routine annual inundation of lowlands near a river to catastrophic inundation of urban areas. To develop programs for dealing with flood hazards, a more precise definition is needed to answer the question of just which floods are considered hazardous. When the federal government initiated the National Flood Insurance Protection Program in 1968, it adopted just such a definition for what has come to be called the "base flood" (or less commonly, the "design flood"). The USGS explains the term this way:

> In the 1960's, the United States government decided to use the 1-percent annual exceedance probability (AEP) flood as the basis for the National Flood Insurance Program. The 1-percent AEP flood was thought to be a fair balance between protecting the public and overly stringent regulation. Because the 1-percent AEP flood has a 1 in 100 chance of being equaled or exceeded in any 1 year, and it has an average recurrence interval of 100 years, it often is referred to as the "100-year flood"."
>
> The 1-percent AEP flood has a 1-percent chance of occurring in any given year; however, during the span of a 30-year mortgage, a home in the 1-percent AEP (100-year) floodplain has a 26-percent chance of being flooded at least once during those 30 years! The value of 26 percent is based on probability theory that accounts for each of the 30 years having a 1-percent chance of flooding.
> http://pubs.usgs.gov/gip/106/pdf/100-year-flood_041210web.pdf

Under the National Flood Insurance Program, the Federal Emergency Management Agency (FEMA) works with state agencies and local governments to determine local flood elevations. The elevations are carefully mapped, and lands with elevations lower than those of the base flood are subject to flood hazard regulations. Such areas then qualify for federally supported flood insurance. Lending institutions require landowners to purchase such insurance before they will lend money for development of flood-prone land.[7]

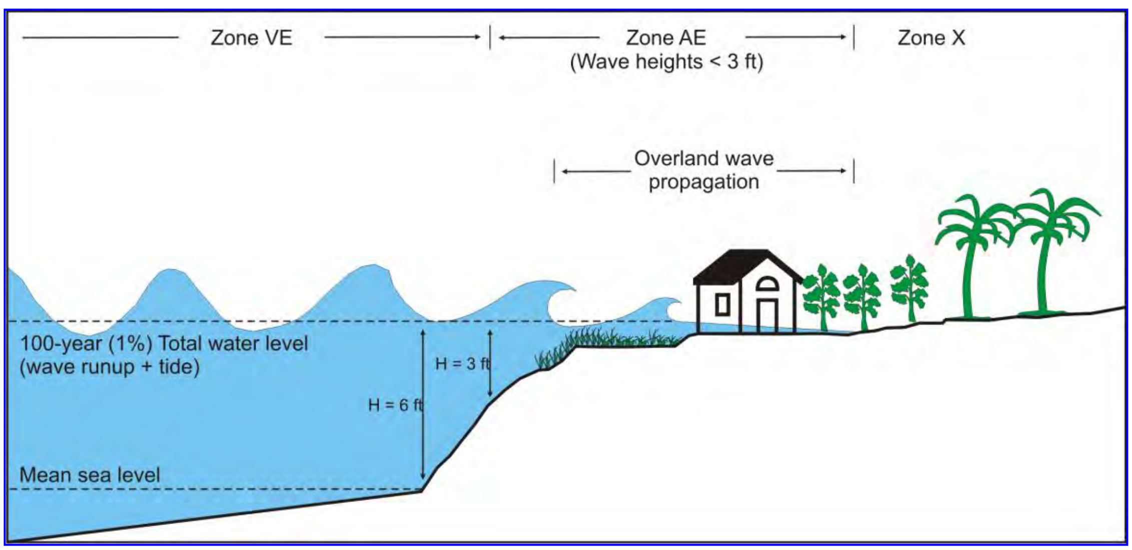
[6] The more recent and increasingly common standard datum is NAVD 88: "North American Vertical Datum of 1988."

[7] The National Flood Insurance Program is voluntary: communities may opt out, but most choose to participate. In Tillamook County, all local governments participate in the program.

Riverine Flooding
For many people, the word "flood" conjures up an image of an inland waterway overflowing its bank. Lands subject to such inundation from standing or slowly moving water are said to be in the *floodplain*. In low-lying areas next to rivers, the extent of the floodplain may be very broad, taking in thousands of acres. On flood insurance rate maps, most floodplains are designated with a code beginning with the letter "A" and are said to be in an "A Zone."

Flood hazard regulations permit development in such an "A Zone" but specify standards for such development so as to protect people and property. Typically, new residential development must be designed and built so that the floor of the lowest habitable room is at least one foot above the base flood elevation. The regulations require tie-downs and anchors for structures that might otherwise be carried away by floodwaters. They also prohibit designs or forms of development that would displace or alter the flow of floodwaters in such a way as to damage other properties.

Ocean Flooding
In coastal areas, flooding often contrasts with riverine flooding in two ways: floodwaters come from the sea and they are pushed by powerful winds and ocean waves. The strong winds often generate floodwater waves that can increase the flood damage. If coastal floodplains are likely to experience waves higher than three feet, they are designated "V" (for "velocity") and are said to be in a "V Zone," as shown in the diagram below, from DOGAMI's Jonathan Allan (May 2011):



Tillamook County experiences strong winds. It is one of just six counties in Oregon where new construction must be built and designed to withstand winds of 105 mph.[8] (Other counties in Oregon are subject to less stringent design standards with respect to

[8] *2010 Oregon Structural Specialty Code*, p. 384, at http://ecodes.biz/ecodes_support/free_resources/Oregon/10_Structural/10_PDFs/Chapter%2016_Structural%20Design.pdf

wind.) Given the existence of such strong winds, it is not surprising that many flood-prone areas here are classified in a V Zone rather than an A Zone.

As one would expect, development standards that apply to areas in a V Zone are more rigorous than those that apply in an A Zone. Buildings not only must be elevated but their foundations must be made of pilings or columns that allow passage of water and waves. Foundations must be strong enough to withstand battering from waterborne logs and debris. Walls enclosing such foundations must be designed to break away in the event of a flood.[9]

An especially hazardous form of ocean flooding is *wave overtopping*, in which a large wave spills over the crest of a dune, bank or shoreline protective structure. The milder form of this event, splash overtopping, may cast relatively small amounts of saltwater and spray on structures and areas at the crest of the bank. A much more hazardous event, greenwater overtopping, may bring large volumes of seawater over the crest, damaging structures and flooding areas behind the crest.

Large winter storm waves generally break initially at some distance offshore. But after such a wave first breaks, it re-forms, breaks again, and so on, moving through the surf zone and eventually coming onto shore as "swash" or "wave runup." It is this re-formed wave that washes onto – and sometimes over – shorefront structures.

The likelihood that a wave will overtop a shorefront protective structure depends on several variables. The most important are the height of the structure and a combination of variables that we'll call the *wave height factors*: the main factors are height of the runup, height of tide, and storm surge (all measured against a standard reference elevation). The diagram on the next page shows how total water level is calculated.[10] Note that "R," wave runup, is calculated using a number of variables, such as deepwater wave height, that are not shown in the diagram. The reference elevation in this case is the North American Vertical Datum of 1988.

[9] *2010 Oregon Structural Specialty Code*, Section 1612.5.2, at p. 389

[10] From Ruggiero, P.; Komar, P.D.; McDougal, W.G.; Marra, J.J.; and Beach, R.A., 2001. Wave runup, extreme water levels and the erosion of properties backing beaches. ***Journal of Coastal Research***, 17(2), 407-419, in PDF at http://www.csc.noaa.gov/cspPNW/waveRunup.pdf

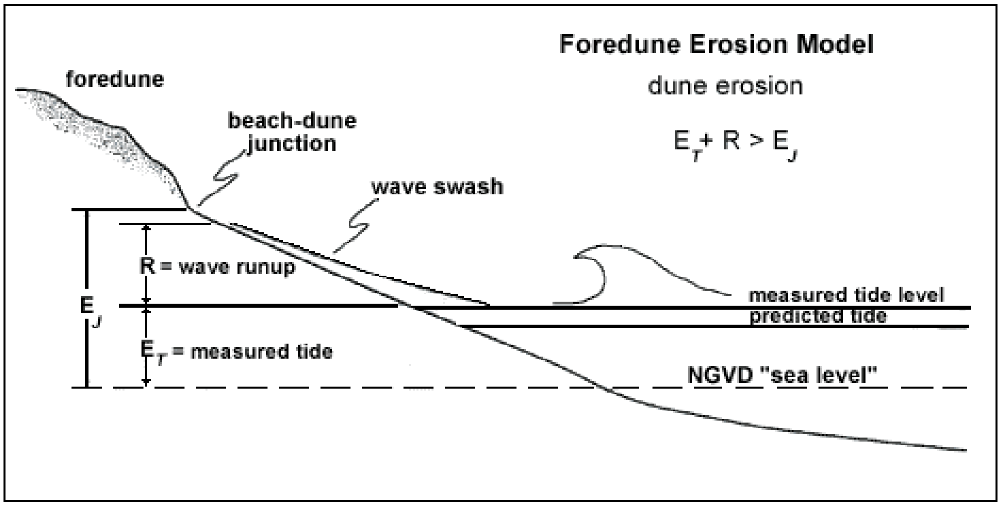


Figure 1. The total water level, the sum of the measured tide (E_T) and the runup of waves (R) on the beach, compared with the elevation (E_J) of the toe of the foredunes.

If these factors combine to produce a wave higher than a shoreline protective structure or natural bank behind a beach, then wave overtopping occurs. If the wave reaches heights more than twice as high as the structure or bank, greenwater overtopping occurs.

For example, suppose that a certain riprap revetment is 15 feet high, and runup, tide and storm surge together total 14 feet. In this case, waves will not overtop the riprap. But if we change the example so that height of the wave factors totals 16 feet, some splash overtopping will occur. And if the wave has a height more than twice that of the riprap, we can expect greenwater overtopping. The rule of thumb, then, is this:

- If the ratio of wave height to structure height is less than 1.0, wave overtopping will not occur.
- If the ratio of wave height to structure height is greater than 1.0 but less than 2.0, splash overtopping will occur.
- If the ratio of wave height to structure height is 2.0 or more, greenwater overtopping will occur.

Ocean flooding is a hazard not only to buildings and infrastructure but also to natural resources. It may contaminate freshwater wetlands and water bodies, resulting in damage to wildlife habitat and to sources of drinking water.

Coastal erosion and ocean flooding are inextricably linked. Erosion of beaches, dunes and spits at key locations can greatly increase the extent and severity of flooding. Because such erosion has been increasing along Tillamook County's coast, it is likely that a growing number of structures and property along the coast will experience such flooding. Peter Ruggiero, an assistant professor in the OSU Department of Geosciences who has conducted extensive research on this topic, summarizes the problem thus:

> The rates of erosion and frequency of coastal flooding have increased over the last couple of decades and will almost certainly increase in the future. The

Pacific Northwest has one of the strongest wave climates in the world, and the data clearly show that it's getting even bigger.[11]

For more information on ocean flooding . . .

Visit the Oregon Department of Land Conservation and Development's Natural Hazard program website on "Floods" at http://www.oregon.gov/LCD/HAZ/floods.shtml

See the website for "The National Flood Insurance Program," Federal Emergency Management Agency at http://www.fema.gov/plan/prevent/floodplain/index.shtm

A wave overtops the revetment in front of a Neskowin motel during a storm on January 5, 2008. Photo by Armand Thibault

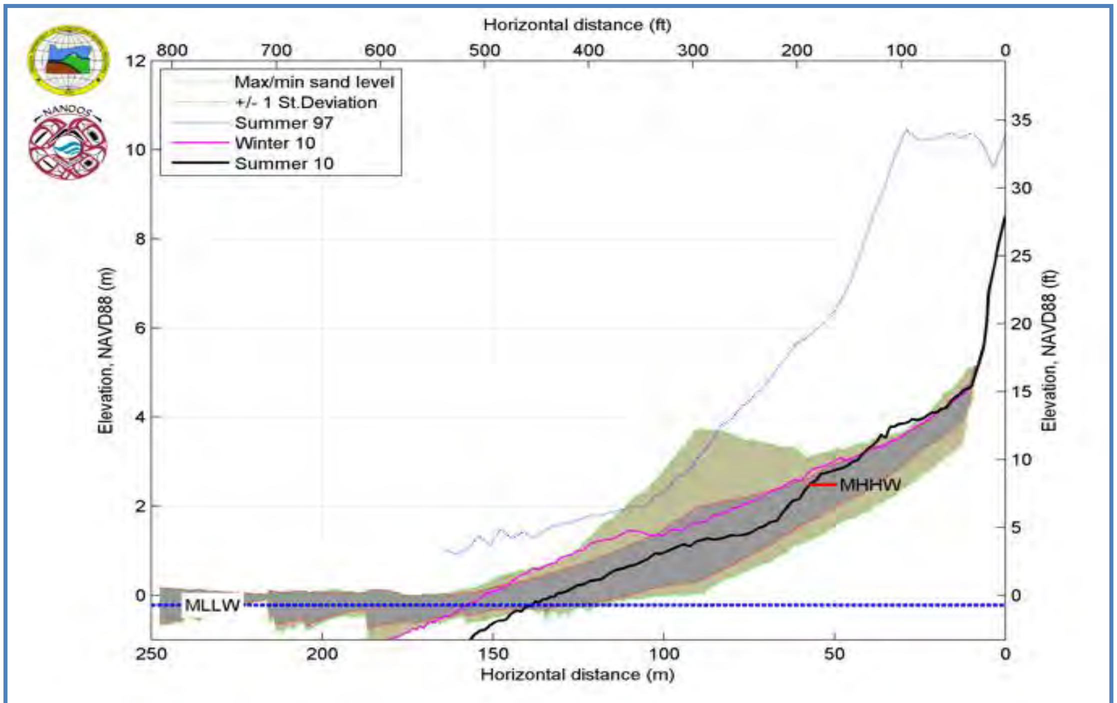
[11] Dennis Newman. "Waves on the Oregon Coast Keep Getting Bigger" in *NaturalOregon.Org,* January 25, 2010. http://www.naturaloregon.org/2010/01/25/waves-on-the-oregon-coast-keep-getting-bigger/

6. Monitoring and Measuring Erosion

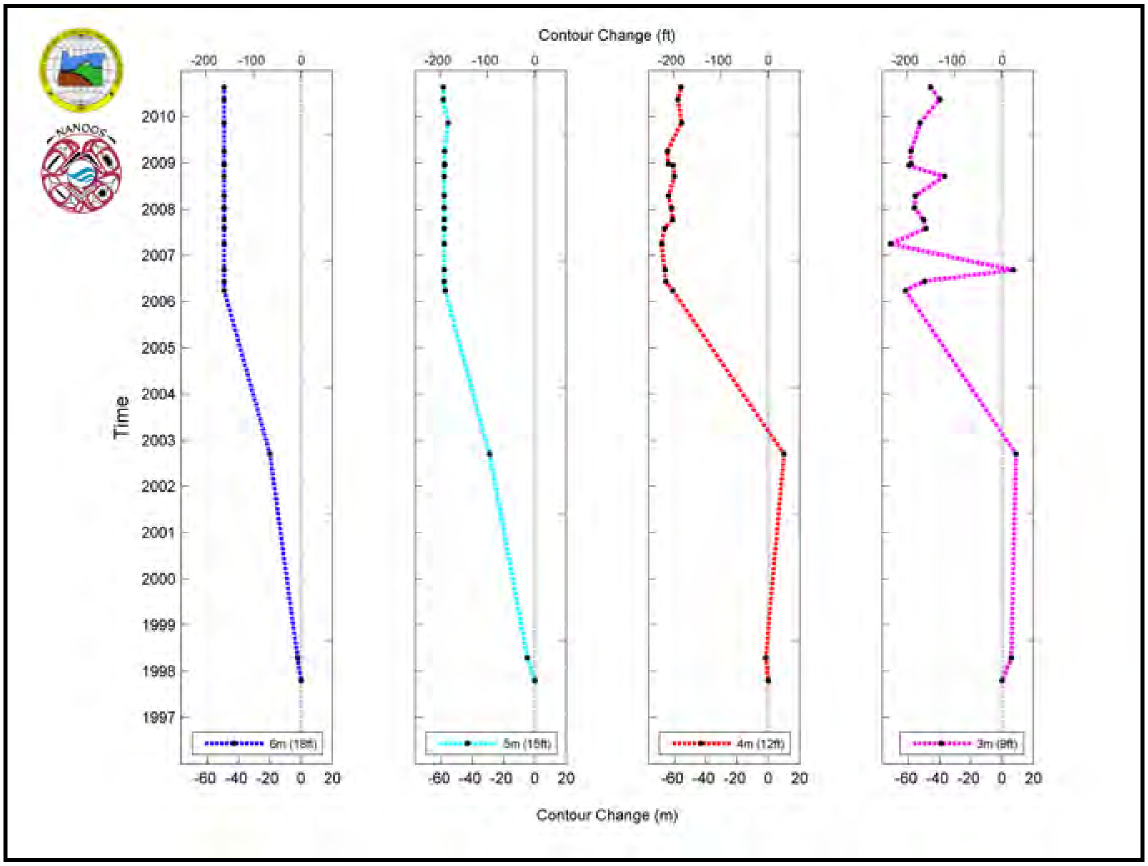
Erosion of dune-backed and bluff-backed beaches has been systematically measured and recorded in Oregon for several decades. For example, researchers at the state Department of Geology and Mineral Industries (DOGAMI) have collected data and created maps of shifting shorelines in Tillamook County for many years. By periodically surveying beach elevations and distances in the same locations since the late 1990s, the researchers produced a series of “beach profiles” and “contour change plots” for four large sections of the county’s coastline.

The selected profile locations are spaced evenly along the beach at intervals of about half a mile. Each shows a cross section of the beach extending from the low water line (“mean lower low water”) to the toe of the foredune. The profiles are measured every few months, and the resulting data are graphed to show a beach’s erosion or accretion over time – or both. This monitoring measures changes at various elevations – near the water’s edge, mid-way up the beach, along the toe of the dune, and so on. The cross-sectional “profile” of those elevations at one point along a beach may show accretion of sand at lower elevations and erosion farther up on the beach. It therefore cannot be said that “the beach” is growing or eroding at this point.

Here, for example, is “Nesk01,” a cross-sectional profile of the beach at the west end of McMinnville Street in Neskowin. Comparing the Summer 1997 and the Summer 2010 data, one can see significant erosion at all contours (levels) of the beach.



As with all the monitoring locations, DOGAMI also provides a second diagram showing "contour change" at Nesk01. The first two charts show steady erosion at the higher elevations (five and six meters, near the toe of the dune), from 1998 to 2006. After 2006, however, there's no erosion at that elevation: the face of the dune was riprapped in 2006, preventing further erosion. The two lower contours (on the right side of the diagram) show a pattern of significant erosion from 1998 to 2006, with reduced erosion and more year-to-year variation after 2006.



This monitoring of Tillamook County's coast was started in the late 1990s, so the profiles typically reveal a 12- or 13-year record of movement. See the results at http://www.nanoos.org/nvs/nvs.php?section=NVS-Products-Beaches-Mapping
Be sure to read the "Overview" tab at this website before proceeding to the charts for individual beaches. The explanation provided in "Overview" will make it easier to understand the complex charts.

It is difficult to reach general conclusions about such a detailed set of data and charts. Even on the same beach, one profile may show considerable variation over time, growing seaward one year and receding landward the next. Likewise, two profiles at the same beach may be quite different, as one level of the beach remains stable while another erodes rapidly. Such variation may be indicative of "hot spots" where rip-current embayments cause rapid erosion. In spite of such variation, a few general observations may be made:

Nehalem Spit: The study area labeled “Nehalem Spit” has eight profiles along a five-mile stretch of beach extending from Neahkanie Beach (just north of Manzanita) to the southern tip of Nehalem Bay State Park. In its southern half, along Nehalem Spit, the beach has mostly receded since observations began there in 1998. In its northern half, near Manzanita, the beach has accreted up to 200 feet at some elevations.

Rockaway Beach: This study area extends about six miles, from Nedonna Beach south to Barview. Its ten profiles show significant erosion in most areas during the 12 years of observation. Recession in excess of 200 feet is common, and it exceeds 400 feet in some places.

Bayocean Spit: This study area has seven profiles over the four-mile length of the Bayocean Peninsula, from its northern tip to the southern base near Cape Meares. The northern part has experienced significant accretion in the past 12 years, with some profiles showing 200 feet of seaward growth. The southern part reveals a mixed history, with erosion up to 100 feet in some areas, and moderate accretion in a few others.

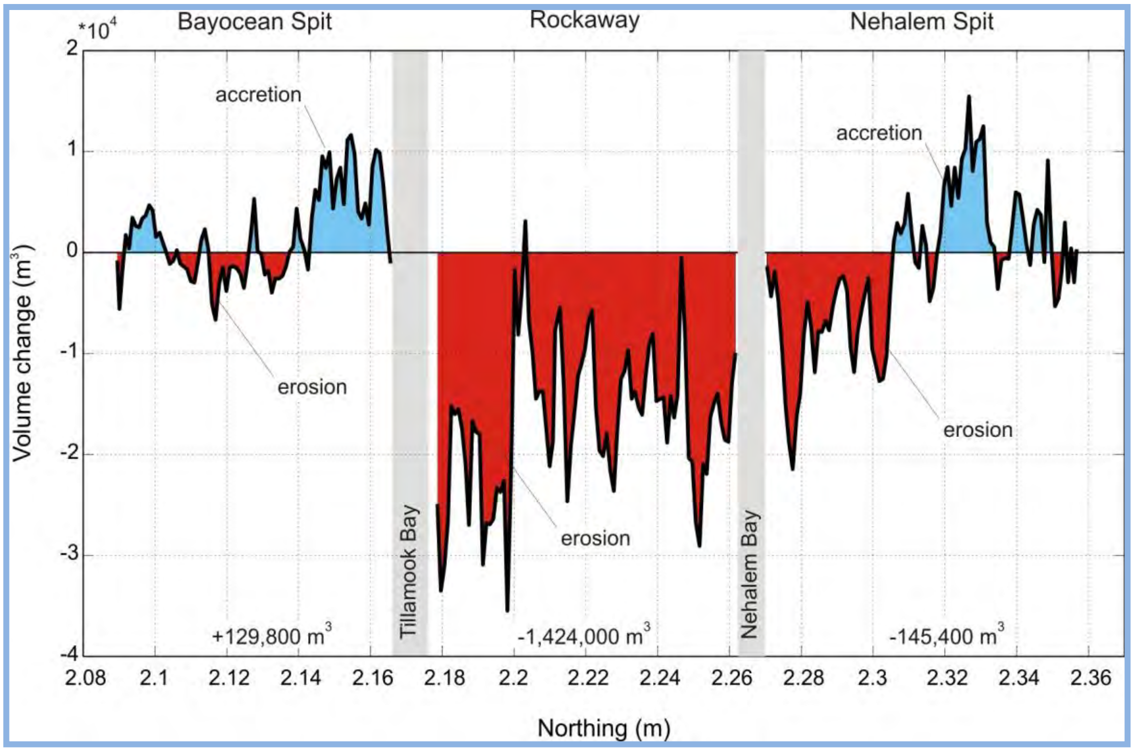
Neskowin: This study area reaches about seven miles from Cape Kiwanda on the north to Proposal Rock at Neskowin on the south. It corresponds roughly with the Nestucca littoral cell. The 15 profiles along this beach indicate a wide variety of conditions. Several profiles in the northern part of the cell, along the beach at Pacific City and Bob Straub State Park, show significant accretion. In the southern part of the cell, the profiles tell a much different story – one of significant and increasing erosion over the 12 years of observation. Several of the Neskowin profiles show landward recession in excess of 200 feet.

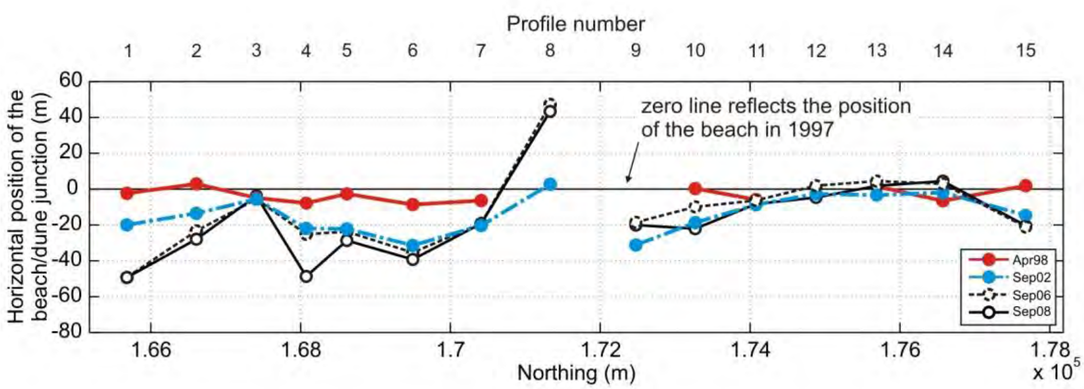
The pattern of erosion and accretion along the main beaches of Tillamook County are shown graphically in the following two summary charts of DOGAMI’s observations in recent years.

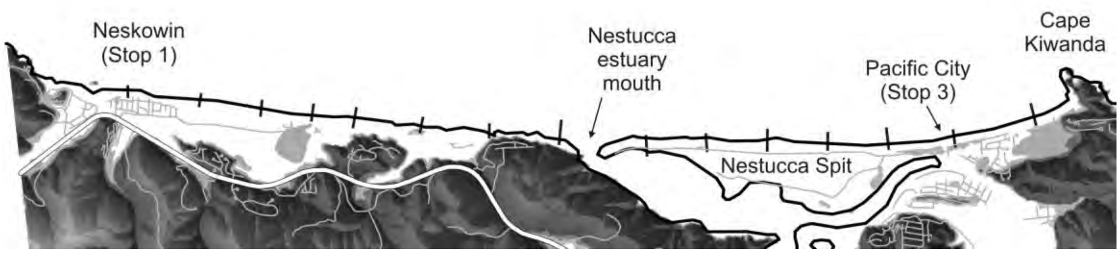
This first diagram summarizes change in volumes of sand (in cubic meters) for the northern half of the county. Areas above the zero line (which appear on-screen in blue) indicate beaches where sand volume has been increasing – that is, accretion. Areas below the zero line (which appear on-screen in red) indicate beaches where the volume of sand has been diminishing: i.e., erosion. Note the significant erosion that has occurred along Rockaway Beach.

The second diagram (below) focuses on the Neskowin (a.k.a. Nestucca) littoral cell, from Cape Kiwanda to Cascade Head. The diagram indicates the horizontal distance in meters that the beach has moved either landward or seaward from the beach’s baseline position in 1997. For each profile, there is a dot showing the position of the beach as observed in the years 1998, 2002, 2006 and 2008. Where a dot appears above the zero line, the beach has moved seaward: the beach is growing. Only profile number 8, just south of the Nestucca Bay mouth, shows such growth. Where a dot appears below the zero line, the beach is eroding and retreating landward. Note that in profiles 1 and 4, at

Neskowin, the beaches retreated approximately 50 meters (164 feet) during the decade of observations.







In 2007 DOGAMI published a detailed analysis of the first ten years of data from their observations at Neskowin.[12] It reported this:

> The beaches remain in a state of net deficit compared to their condition in 1997, with the estimated loss of sand as of June 2006 being on the order of 1 to 1.5 million m^3 (1.3 to 2.0 million yd^3) of sand. Whether the beach recovers fully and how long it takes remain important scientific and management questions, which will be answered as the beaches are monitored. (p. 1)
>
> [M]uch of the shore between Neskowin and the Nestucca estuary mouth will probably continue to be highly susceptible to major storm erosion events and will likely remain so until sand from the north end of the [littoral] cell has returned to the south. (p. 16)

For more information on coastal erosion and related hazards . . .

Visit the website of the Oregon Department of Land Conservation and Development's Ocean and Coastal Management Program (OCMP), "Shoreland Processes and Hazards," at http://www.oregon.gov/LCD/OCMP/ShorHaz_Intro.shtml

See Oregon Department of Geology and Mineral Industries (DOGAMI) website on "Geologic Hazards on the Oregon Coast" at http://www.oregon.gov/DOGAMI/earthquakes/Coastal/CoastalHazardsMain.shtml

See the Environmental Protection Agency (EPA) website on *Coastal Zones and Sea Level Rise*: http://www.epa.gov/climatechange/effects/coastal/ This site presents readable explanations of various coastal processes as well as useful links to other websites. See references cited near the end of the webpage.

Check the Surfrider Foundation's *State of the Beach Report for Oregon*, "Oregon Erosion Response," at http://www.surfrider.org/stateofthebeach/05-sr/state.asp?zone=wc&state=or&cat=er

See the West Carolina University Coastal Hazards Information Clearing House, *Learn About Coastal Hazards*, 2005: http://www.wcu.edu/coastalhazards/libros/index.html
Of the 10 chapters presented, Chapter 5 is probably the most useful, but all are informative.

[12] **Allan, Jonathan C., and Roger Hart.** *Assessing the temporal and spatial variability of coastal change in the Neskowin littoral cell: Developing a comprehensive monitoring program for Oregon beaches*. Portland, Oregon Department of Geology and Mineral Industries, 2007. 31 pp.

7. Development in Erosion-Prone Areas

The type, location and extent of development along the coast in Tillamook County affects risk from coastal erosion and related hazards in three major ways.

First, development in areas subject to coastal erosion increases a community's exposure and sensitivity to coastal hazards. Adaptation, through measures such as stronger building code requirements in hazard-prone areas, can help somewhat, but the development in harm's way increases a community's vulnerability to coastal hazards in any case.

Second, development of beach houses, hotels, restaurants and other tourist attractions along eroding beaches areas draws with it the support services and infrastructure needed to service the coastal community. Sewers, water systems, police, fire protection and other critical facilities become more vulnerable by being extended into hazard-prone areas. This matter is address in detail later in this plan, in Chapter 10 titled "Systems Most Vulnerable to Coastal Hazards."

Finally, greater development in coastal areas also is followed by more extensive construction of shoreline protective structures such as jetties and revetments. Some of these structures, while serving their primary purpose of protecting various forms of shoreline development, also may bring harmful, albeit unintended, consequences. They may redirect erosion to unprotected areas, increase the extent of erosion, or reduce the effectiveness of natural erosion protection that is provided by broad sandy beaches.

With regard to jetties, their sometimes dramatic effect on coastal erosion has been long observed and well documented. Oregon's Department of Geology and Mineral Industries describes the situation thus:

> The most significant historical shoreline changes identified in Tillamook County has (*sic*) occurred in response to humans, 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. For example, erosion in the vicinity of the Cape Meares community has resulted in the coastline retreating by some 850 ft since 1927. However, erosion at Cape Meares appears to have stabilized since the construction of the south jetty. In contrast, erosion from jetty construction has been much less along the Rockaway-Manzanita beaches.[13]

It is, however, unlikely that major new jetties will be constructed in Tillamook County. The county's largest rivers now have jetties at the north and south sides of their mouths. Although those jetties continue to exert some effect on coastal erosion, construction of new jetties need not be considered a significant factor in this plan.

[13] Jonathan C. Allan and George R. Priest. *Evaluation of coastal erosion hazard zones along dune and bluff backed shorelines in Tillamook County, Oregon: Technical report to Tillamook County*, Portland, Oregon Department of Geology and Mineral Industries, 2001, p. iv.

The situation is different, however, with regard to another type of shoreline protective structure: the revetment. Construction of revetments in Tillamook County jumped after the major erosion from the 1997-1998 winter storms. Today, the county has about 21,500 feet (4 miles) of armored shoreline,[14] with the longest stretches along beaches in Rockaway Beach and Neskowin.

Current state law limits construction of shoreline protective structures. Generally, they are permitted only where necessary to protect property "where development existed on January 1, 1977," and in areas exempted from Goal 18, *Beaches and Dunes*, by an exception to that statewide planning goal.[15] In Tillamook County, several large expanses of sandy coast remain that are unarmored now but probably would be eligible for such armoring in the future.

These statistics raise several questions:

- Is the sudden increase in revetment construction in Tillamook County after 1998 a one-time "spike" or does it indicate the beginning of a trend?
- How much additional revetment construction might the county expect if increases in ocean wave heights and sea level threaten a larger number of shoreline properties?
- Would construction of additional revetments cause significant narrowing and erosion of beaches in Tillamook County?
- Is revetment construction in response to naturally occurring beach erosion a significant public policy concern?

These questions are not easily answered. To find at some partial answers, we address the topic of revetments and related shoreline protective structures in the next part of this chapter.

Recently armored shoreline at Neskowin, April 2010.

[14] Data from Jonathan Allan, DOGAMI, in an email message from Jonathan Allan to Mitch Rohse, February 4, 2011.
[15] The quoted passage is from Statewide Planning Goal 18, *Beaches and Dunes*.

7.1 Shoreline Protective Structures

Beaches are dynamic systems in constant motion. The direction or extent of a beach's motion varies with local conditions, of course. Some beaches *prograde*, or advance seaward, because sand is accreting (accumulating) there. More often, however, beaches recede, migrating landward as if to escape the relentless pounding of the waves. Such a retreat erodes property and may damage or destroy houses and other structures built along the shore. A common response to that problem is to "armor the beach" – that is, to build a structure to block the beach's landward migration.

Such "shoreline protective structures" are of three main types: seawalls, bulkheads, and revetments. *Seawalls* typically are made of concrete, with the wall presenting a flat vertical face toward the sea. A few are built with a concave face, which is intended to direct some of the waves' impact upward and thus reduce scouring of sand at the toe of the structure. At left is a photo of a seawall at Nelscott, in Lincoln City.

Bulkheads are vertical retaining walls often made of concrete blocks, wood or steel. The simplest ones consist of posts driven into the sand and then backed with horizontal planks. Some bulkheads are "gravity structures," walls that derive their strength largely from the mass of their components – concrete blocks, for example. Large bulkheads may be built with steel plates driven into the sand by heavy equipment. Generally, seawalls keep water and waves out, while bulkheads hold sand or soil in – keeping the front yard of a beach house from sloughing onto the beach, for example. Both types of structures may serve a dual purpose, blocking waves *and* impounding sand, but most bulkheads cannot withstand frequent buffeting from large waves.

Revetments are stone facings or barriers placed along the front of a dune or a beach's upper slope. Along the Oregon coast, the most common type of shoreline protective structure is a type of revetment called *riprap*. This type of coastal armor consists of large rocks, often weighing several tons, placed along the face of a dune or bluff. Unlike seawalls and bulkheads, which are vertical, riprap revetments slant away from the ocean at a fairly shallow angle (less than 35 degrees from horizontal). This slanting and the coarse texture of the rocky face cause riprap to absorb some wave energy rather than reflect it, as seawalls and bulkheads do.

The effectiveness of riprap depends on its design, the size and quality of its rock, and the manner in which the rock is placed. Although riprap sometimes has been "installed" simply by backing a truck up to the beach and dumping rock there, most riprap today is "engineered." That is, the riprap is carefully set in place one rock at a time by an excavator to form an interlocking surface, as shown in the photo above. In addition, the toe of the structure is extended deep into the sand, often down to bedrock. Drainage cloth and one or more gravel base layers are then topped with the largest, individually placed rocks. Riprap usually is designed to have a slope of 1 ½: 1 or 2:1. The number before the colon refers to horizontal distance; the number after refers to height. Riprap with 2:1 slope thus, in cross section, is twice as thick at its base as it is high.

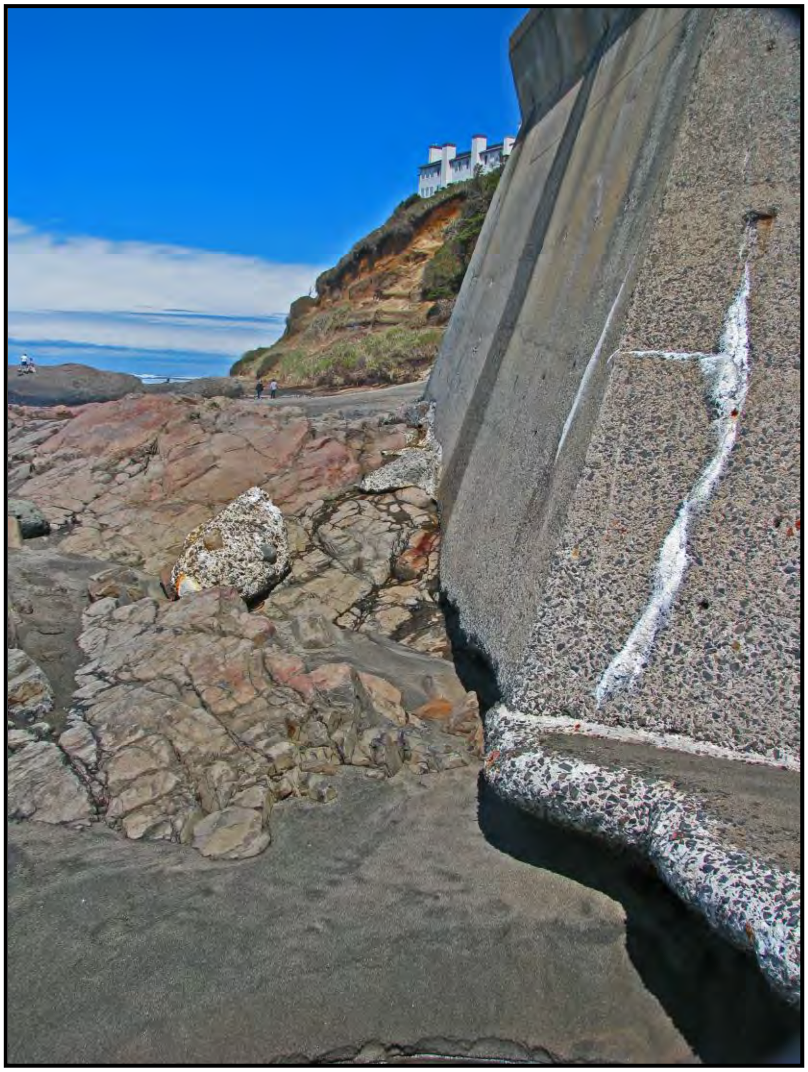
Although riprap may appear to be indestructible – a permanent solution to the sea's attack on beachfront properties – it is not. The same storm waves that throw massive logs about like matchsticks are also quite capable of dislodging multi-ton boulders from riprap. This coastal “armor” therefore needs continual maintenance and repair. The life of a riprap revetment depends on many variables, such as design of the structure and the intensity of storms that attack it. The “design life” of such a structure typically is 20-25 years,[16] but it is not uncommon for riprap revetments to fail long before that.

Shown on the next page are “before” and “after” photos of riprap at South Beach in Neskowin. The upper photo, taken on April 12, 2010, shows old riprap in poor condition. The uneven, jumbled appearance of the old riprap is the result of many years of wear and perhaps of poor installation methods. The lower and larger photo, taken on September 29, 2010, shows new riprap installed in 2010.

[16] Gary B. Griggs, “Responding to Oregon’s Shoreline Erosion Hazards: Some Lessons from California,” in *Coastal Natural Hazards*, edited by James W. Good and Sandra S. Ridlington, Oregon Sea Grant, Oregon State University, Corvallis, OR, 1992

7.2 Scour

A common problem with shoreline protective structures is *scour*, a washing away of sand and rock at the base of the structure. Scour is caused by the action of waves rebounding from the structure. To keep waves from undermining the structure, the toe of the revetment or seawall typically extends well below the surface of the beach, often down to bedrock. This photo of the seawall for the Inn at Spanish Head in Lincoln City shows how sand has been scoured away from the toe of the structure by winter storms. The photo was taken in April 2010. By autumn of 2010, sand covered the base of the seawall, as the beach demonstrated its usual cycle of losing sand in the winter and having it restored in the summer.



Riprap resting on sand rather than bedrock eventually settles. In doing so, the toe of the structure is likely to move seaward, increasing the odds that it will be undermined by scour.

7.3 The Price of Protection

Each proposal to build a new shoreline protective structure brings with it an old question: Will the new structure – usually riprap – cause significant erosion of the beach? Does this *con*struction to protect coastal property mean *de*struction of the beach? The question is asked because many miles of beach in the US have narrowed or disappeared after their shorelines were armored with seawalls and revetments.

There is considerable anecdotal and historical evidence to support the general proposition that shoreline protective structures often contribute to beach erosion. But the general proposition offers no precise answer to the question of how much a specific structure in a specific place might erode the beach there.

Coastal armoring can cause beach erosion in three main ways: *passive erosion* (or *outflanking*); *active erosion*; and *sand impoundment*.

Passive Erosion: Coastal armoring blocks the usual landward recession of sandy beaches. If some parts of a receding beach are armored while others are not, the armored properties remain fixed in one place, while the beach continues to migrate landward in the places where it encounters no structures. Eventually, the beach in front of the shoreline protective structures disappears beneath the waves in the process called *passive erosion* or *outflanking*. The latter term is less common but perhaps more accurate, since the structure itself does not cause erosion of the beach. In this photo, for example, the unarmored land on either side of the riprapped property continues to recede, while the armored home site becomes a small headland, outflanked by the landward-moving sand and sea. This "passive erosion" leaves the armored property with no beach in front of it.[17]

Active Erosion: Depending on their position in the surf zone, hard shorefront structures may reflect some wave energy back onto the beach. That in turn may increase the erosive force of the waves, causing them to scour sand away from the base of the structure and wash it out to sea, thus causing *active erosion*. The extent of such erosion varies from one beach to another. In the words of one researcher, "the debate about the effect of seawalls on beaches has not been fully resolved," so further study of active erosion remains to be done.[18]

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[17] Photo from page 10 of *Climate Ready Communities: A Strategy for Adapting to Impacts of Climate Change on the Oregon Coast*, Department of Land Conservation and Development's Ocean and Coastal Management Program, August 2009, at
http://www.oregon.gov/LCD/docs/publications/climate_ready_communities.pdf

[18] Peter Ruggiero, "Impacts of Shoreline Armoring on Sediment Dynamics," in Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, *Puget Sound Shorelines and the Impacts of*

Sand Impoundment: Shoreline protective structures enclose sand or sand-producing materials on their landward side, a process called *sand impoundment*. On some beaches, such impoundment eliminates an essential source of sand needed to replace that eroded by the sea. With its sand supply thus reduced, the beach diminishes.

“End erosion” or “end effect” is a special case. It is beach erosion observed at either end of a shoreline protective structure. If a shoreline has been receding rapidly, the disjunction between the protected and unprotected area may be quite prominent. Some people see this as “active erosion” caused by the shoreline protective structure. Others consider it “passive erosion,” natural erosion that would have occurred on the unprotected properties in any case, even if no protective structure had been built.

Of the processes described above, the greatest controversy centers on the assertion that armoring causes significant *active* erosion in front of the structures. A recent NOAA report, for example, says, “Many people feel that seawalls initiate active erosion and are therefore detrimental to coastal environments, yet recent investigations may suggest otherwise.” [19] Two extensive examinations of beaches in California found little difference in the extent of active erosion at armored and unarmored beaches.

Proponents of shoreline protective structures also argue that any beach erosion resulting from coastal armoring can be corrected by measures such as beach nourishment, and they assert that benefits from the structures often outweigh costs from beach erosion.

The US Army Corps of Engineers takes the middle ground in the discussion, saying this about revetments:

> Most revetments do not significantly interfere with transport of littoral drift. They do not redirect wave energy to vulnerable unprotected areas, although beaches in front of steep revetments are prone to erosion. Materials eroded from the slope before construction of a revetment may have nourished a neighboring area, however. Accelerated erosion there after the revetment is built can be controlled with a beach-building or beach-protecting structure such as a groin or a breakwater.[20]

Opponents of shorefront protective structures are adamant that such structures inevitably harm beaches wherever the structures are built. Perhaps the best known and most outspoken of those opponents is Orrin Pilkey, James B. Duke Professor Emeritus of Earth Sciences at Duke University. He says:

Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 179-186.

[19] The studies (one by Kraus and McDougal in 1996, the other by Griggs *et al* in 1994 and 1997) are described on page 10 in *The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary,* NOAA, February 2005, at http://sanctuaries.noaa.gov/special/con_coast/stamski.pdf

[20] From the Corps' *Coastal Engineering Manual* (available only on-line), “Revetments,” at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;141&g=41

> On an eroding shoreline, hard structures such as riprap seawalls cause beaches to disappear. It doesn't matter whether the structure is wood, steel or rock, any beach retreating against any fixed object will eventually disappear.[21]

We thus encounter considerable difference of opinion and conflicting evidence about the impact of armoring on beaches. Clearly, extensive armoring has indeed eroded *some* beaches, eventually causing them to disappear. The millions of dollars spent on beach replenishment in Florida and Hawaii attest to that. Whether coastal armoring destroys beaches in *every* case seems far less certain.

We conclude here that shoreline protective structures simply are one among several factors that contribute to beach erosion. Geologist Jonathan Allan, PhD, Coastal Section Leader for the state's Department of Geology and Mineral Industries, puts it this way: "My overall impression on the potential effects of structures is that the changes taking place at various sites on the Oregon coast associated with the natural process of erosion and dune retreat are dwarfing any 'end effect' or erosion due to scour, simply because the forces associated with large waves, coupled with high tides and El Niños, coupled with the development of rip embayments, dominate erosion processes on the Oregon coast and hence are the primary force of change."[22]

Of course, the potential beach-eroding effects of shore protective structures are not the only issues surrounding the structures. Armoring of the coast also is likely to reduce public access to the beach. It endangers people and pets walking on the beach who find themselves trapped between incoming waves and a wall they cannot ascend. Armoring alters and may adversely affect coastal resources such as wildlife habitat and wetlands. It may be unsightly. Finally, the structures themselves often displace large areas, thus narrowing the sandy beach. For example, a revetment 100 feet long and 20 feet high, with the common slope of 1.5: 1, may extend up to 30 feet seaward from the toe of a dune or bluff, thereby displacing 3,000 square feet of sandy beach. This is referred to as *placement loss*.[23]

For all these reasons, most coastal states (including Oregon) regulate development of new shoreline protective structures. A typical regulation allows new armoring to be built only where it is needed to protect existing development. Approval usually is conditional: that is, the armoring structures must satisfy various conditions regarding size, slope, height, type of materials, etc. Maine and North Carolina are reported to "prohibit"

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[21] Orrin H. Pilkey and Andrew S. Coburn, "Beaches or Buildings: It's Your Choice ," Duke University Program for the Study of Developed Shorelines, in an undated letter written in 2010 in response to an inquiry from a resident of Neskowin

[22] Jonathan Allan, in an email message of August 2, 2010, to the Neskowin Coastal Hazards Committee

[23] Such issues were addressed in the recent USGS publication *Puget Sound Shorelines and the Impacts of Armoring Proceedings of a State of the Science Workshop, May 2009*, edited by Hugh Shipman, Washington State Department of Ecology; Megan N. Dethier, University of Washington; Guy Gelfenbaum, U.S. Geological Survey; Kurt L. Fresh, National Oceanic and Atmospheric Administration; and Richard S. Dinicola, U.S. Geological Survey, at http://pubs.usgs.gov/sir/2010/5254/

construction of new shoreline protective structures.[24] It seems likely, however, that the prohibitions contain at least some exceptions.

Oregon's Statewide Planning Goal 18, *Beaches and Dunes*, declares, "Permits for beachfront protective structures shall be issued only where development existed on January 1, 1977." "Development," however, is defined broadly, and the goal also allows for certain exceptions. The net result is that permits continue to be granted for new shoreline protective structures.

Goal 18 goes on to set four criteria for the review of permit applications for new "shore and beachfront protective structures":

"(a) visual impacts are minimized;
(b) necessary access to the beach is maintained;
(c) negative impacts on adjacent property are minimized; and
(d) long-term or recurring costs to the public are avoided."

Permits for new shorefront protective structures are administered by the Oregon Parks and Recreation Department (OPRD), under the Ocean Shores Program, at http://www.oregon.gov/OPRD/RULES/oceanshores.shtml

[24] Gary B. Griggs, "California's Coastal Hazards Policies: A Critique," in *Coastal Natural Hazards*, edited by James W. Good and Sandra S. Ridlington, Oregon Sea Grant, Oregon State University, Corvallis, OR, 1992, p. 134

7.4 Other Activity in Erosion-Prone Areas

Other than the development and construction activities described above, there are several other human activities that can increase coastal erosion and hazards. They include defacing of sandstone bluffs, faulty drainage and runoff control methods, extensive removal of driftwood, and sand mining. Such activities can accelerate erosion at any given site. Their effects, however, are highly localized and thus are probably not as significant as the other forces and factors discussed above. This is not to say that the county condones activities such as that pictured below.

Jimmy may ♡ Jessica, but the owner of the property above this bluff in Lincoln City will not ♡ Jimmy's handiwork, which hastens erosion and undercutting of the bluff. Photo by Louann Rohse

8. Climatic and Geologic Forces Affecting Erosion

The frequency, extent and impact of coastal erosion hazards at any given place depend on an array of climatic and geologic variables such as storm-wave height, tide, and landform. For example, a winter storm with significant deep-water wave heights of 20 feet during a low tide may have little effect on a beach backed by dunes. In contrast, a storm with the same wave heights during a high tide might cause harmful erosion to the same beach and damage structures on the dune. To develop an effective plan for dealing with coastal hazards, then, we need to understand the main variables – the forces and factors affecting coastal erosion.

The large number of these variables complicates our task. The work is made even more difficult by the fact that some of them change from hour to hour (tides, for example) and some of them are undergoing long-term changes that are difficult to predict. For example, sea level is rising, so the same type and size of storm that causes little erosion or damage in 2012 could cause significant erosion and damage in 2032, simply because sea level then will be higher.

A further complication is that the long-term changes in some variables are not occurring in an orderly, straight-line trend. Some appear to be accelerating, others are cyclical, and still others exhibit no identifiable pattern.

This lack of predictability means that for some variables we cannot rely on straight-line projections from past events and conditions to predict our future. Rather, we can only make informed estimates, often expressed in terms of probabilities.

The most significant forces and factors for Tillamook County are described in this section, roughly in order of their significance with regard to coastal erosion and hazards in our county.

Our changing coast

"The changing climate will likely have significant impacts along the coast and estuarine shorelines of Oregon. Changes associated with global climate change include rising sea levels, storminess, rising water temperatures and ocean acidification. The impacts of these changes include increased erosion, inundation of low lying areas and wetland loss and decreased estuarine water quality. Impacts from coastal erosion and flooding are already affecting the Oregon Coast . . . , and are an analogue for future climate change impacts. Beach elevations have been lowered as a result of extreme waves, and many beaches have seen little post-storm recovery in the intervening years. *Coastal infrastructure will be under increased risk of inundation and damage under a changing climate with impacted sectors including transportation and navigation, shore protection and coastal flood structures, water supply and waste and stormwater systems, and recreation, travel and hospitality.*" [*Emphasis added*]

K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Executive Summary, Oregon Climate Change Research Institute, Dec. 2010, p. 18

This categorizing and ranking of forces and factors is both general and subjective. One could readily argue, for example, that the first three items below are all too inter-related to be considered separate variables. Our selection of these particular variables is based mainly on distinctions made in the scientific literature. As for our rough ranking of the variables by their countywide impact and significance, it too derives from comments and judgments in the scientific literature, such as this:

> Model results suggest that if decadal-scale increases in storm intensity (wave height) continue into the future, this process will have a greater impact on increasing the probability of coastal hazards, via the relationship between wave height and wave runup, than even relatively high estimates of relative sea level rise (RSLR) rates over the next century. RSLR appears to be more important to potential hazards than an increase in the frequency of major El Niño events (from approximately one to two events per decade). The combined effect of each of these climate controls operating simultaneously is predicted to increase erosion/flood frequency by as much as an order of magnitude for some beach slopes and dune crest elevations.[25]

Climatic and Geologic Forces Affecting Coastal Erosion

Major Forces of Increasing Importance	**Deepwater Wave Height** **Relative Sea Level (RSL) Rise** **El Niño/La Niña Southern Oscillation (ENSO)**
Significant Forces of Ongoing Importance	**Rip Current Embayments** **Astronomical Tides** **Storm Surge** **Winter Storm Frequency**
Lesser Forces of Varying Importance	**Vertical Land Movement** **Sediment Supply**
Wild Cards: Unpredictable Forces	**Subduction Zone Earthquakes** **Tsunamis**

[25] Peter Ruggiero. "Impacts of Climate Change on Coastal Erosion and Flood Probability in the US Pacific Northwest." Proceedings of *Solutions to Coastal Disasters 2008,* Oahu, HI

8.1 Deepwater Wave Height

This is one of the most important factors affecting coastal erosion. It also is one of the most rapidly changing factors: winter wave heights in the Pacific Northwest have been increasing dramatically for the past several decades, and that trend is expected to continue.

The basic relationship between deepwater wave heights and coastal erosion is straightforward: the larger the waves, the greater the erosion and the greater the potential for damage to coastal structures, resources and infrastructure. Researchers generally focus on two aspects of wave height: *significant wave height* or SWH (an average of heights of the largest one-third of waves occurring at a given deepwater location), and largest wave heights. The largest waves typically are about 1.8 times the significant wave height.[26]

Wave height is a function of three main variables: wind speed, wind duration, and *fetch* (the extent of ocean across which the winds blow). Winter winds blowing toward our coast from the north Pacific and Gulf of Alaska typically have high speed, long duration, and thousands of miles of fetch, a combination that produces very large waves.

Projections of future wave heights are expressed in terms of probability of occurrence. For example, a "25-year SWH" means a significant wave height that could be expected to occur once in 25 years. A "100-year SWH" means a significant wave height likely to occur only once in a 100 years. A 100-year wave would be both larger and less likely to occur than a 25-year wave.

A US Coast Guard vessel approaches a 20-foot high wave near the Columbia River bar. Photo from NOAA, at http://www.noaa.gov/features/03_protecting/oregonwaves.html

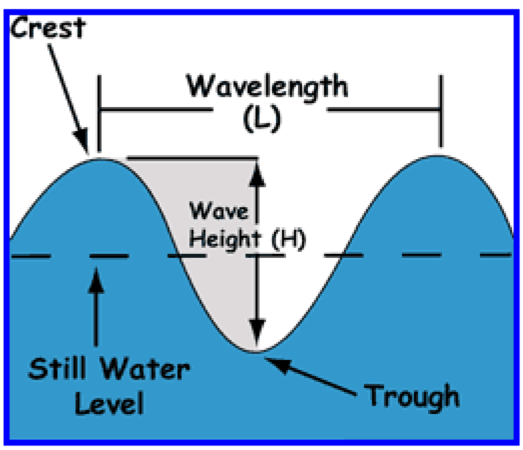
[26] Komar, Paul D. "Ocean Processes and Hazards along the Oregon Coast," *Oregon Geology*, Volume 54, Number 1, January 1992, p. 6. (PDF on-line at http://www.oregongeology.org/pubs/OG/OGv54n01.pdf)

Recent study by scientists at the Oregon Department of Geology and Mineral Industries and at Oregon State University indicates that annual significant wave height averages and maxima have been increasing for several decades and continue to increase. The researchers conclude that "the annual averages of deep-water significant wave heights (SWHs) have increased at a rate of approximately 0.015 m/yr [*0.05 ft/yr*] since the mid-1970s, while averages of the five highest SWHs per year have increased at the appreciably greater rate of 0.071 m/yr [*0.23 ft/yr.*]."[27]

In other words, heights of the largest waves have been growing at an average rate of almost 3 inches per year. OSU researchers observed what they describe as "a remarkably continuous increase in the rate of SWH increase."[28]

Prior to the 1990s, winter storms typically generated maximum wave heights of about 25 feet, and it was thought that the extreme event – the 100-year wave height – would be about 10 meters (33 feet). During the winter of 1997-1998, however, multiple waves of 10 meters and higher were observed at offshore buoys. This prompted further study, which resulted in a better understanding of winter storm wave heights and new projections. The OSU researchers now estimate that "the 25-year SWH . . . can be extrapolated to increase by approximately 2.4 m [7.9 ft] over the next 25 years, reaching a SWH of 15.6 m [51.2 ft]."[29]

In addition to height, *length, speed* and *period* are also important characteristics of winter storm waves.



The above diagram is from the Office of Naval Research's website on wave characteristics, at http://www.onr.navy.mil/focus/ocean/motion/waves1.htm

Wave length is the horizontal distance between the highest parts of two successive wave crests, as shown in this diagram.

The *speed* of a wave is equal to its wavelength divided by its wave period. A typical large deepwater wave off the Oregon coast would move at a rate of 12 meters per second or about 25 mph.[30]

The *period* of a wave is the time it takes for two consecutive crests to pass the same point. Wave periods along the along the Oregon typically range from six to twenty seconds. The larger the waves, the greater the distance between their crests and the longer it takes for

[27] Ruggiero, Peter, Paul Komar and Jonathan Allan, "Increasing Wave Heights and Extreme Value Projections: The Wave Climate of the U.S. Pacific Northwest" in *Coastal Engineering*, Vol. 57, 2010, p. 539.
[28] *Ibid*., p. 544.
[29] Ibid., p. 547.
[30] The rate at which the wave energy moves also is significant. In deep water, such energy moves at half the speed of the ocean waves.

each wave to pass a given point. When reports speak of long waves or long-period waves, then, they are referring to large, high-energy waves.

The power of a wave is a function of the characteristics described above: the larger, faster and longer a wave is, the more energy it can release. The relationship, however, is not linear: "[W]ave power is proportional to the wave height *squared*, proportional to the square root of wavelength and linearly proportional to the wave period."[31] The key point here is that a wave's energy (and hence its capacity to cause erosion and damage to structures) is proportional to the *square* of its height. A ten-foot wave thus is not twice as powerful as a five-foot wave. Rather, it is four times as powerful![32] The increasing height of winter storm waves off the Oregon coast thus is especially significant among the forces and factors that influence coastal hazards in Tillamook County.

See diagram on next page for a description of breaking waves.

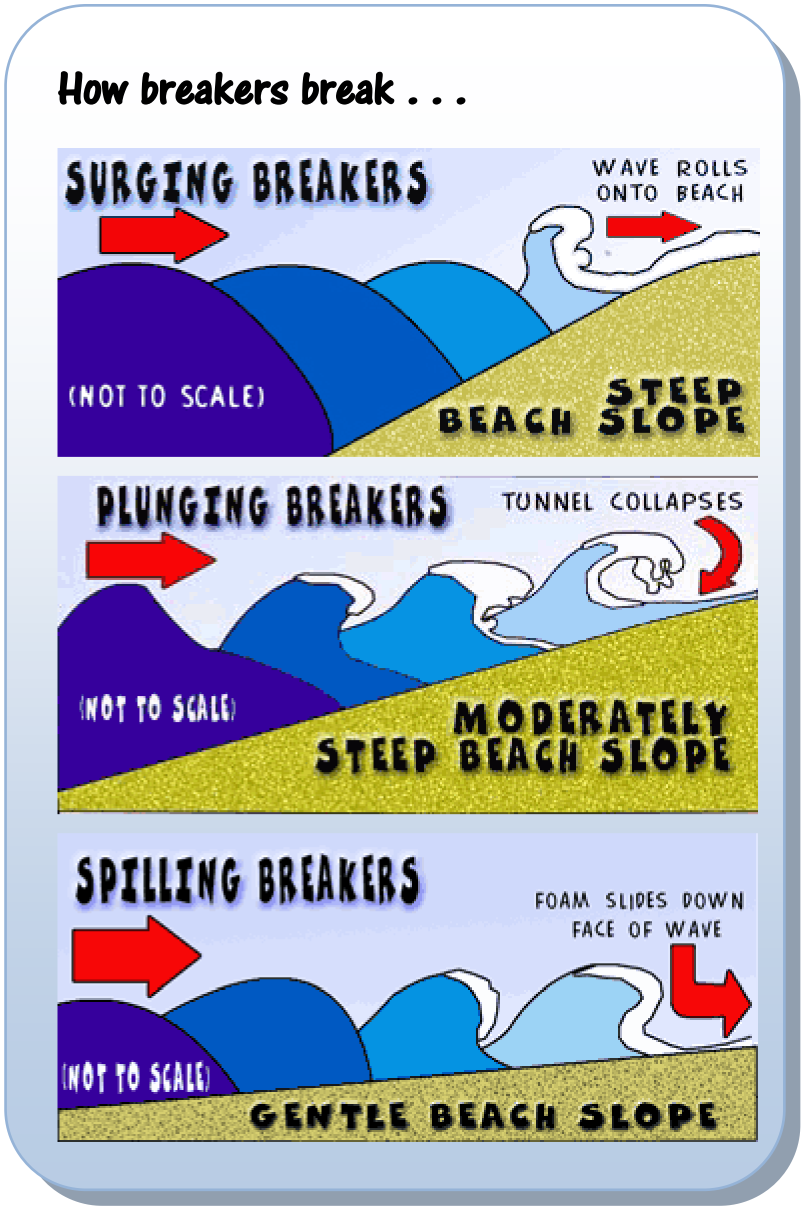
[31] Ted K.A. Brekken, Annette von Jouanne and Hai Yue Han, "Ocean Wave Energy Overview and Research at Oregon State University," School of Electrical Engineering and Computer Science, Oregon State University, Corvallis, Oregon, 2010, at http://files.asme.org/asmeorg/NewsPublicPolicy/Newsletters/METoday/Articles/20814.pdf

[32] The square of the five-foot wave's height is 25. The square of the 10-foot wave's height is 100. The ratio of 100 to 25 reduces to 4 to 1.

As waves come ashore, they typically take one of the three forms shown here: *surging*, *plunging*, or *spilling*. The slope of the shoreline is the main determinant of the breaking wave's form.

In Tillamook County, most dune-backed and bluff-backed shores are buffered by a sandy beach with a gentle slope on the order of 0.04 or 1 in 25. The waves breaking on such beaches thus tend to be "spilling breakers," the third type shown in the diagram here, from the Office of Naval Research. See http://www.onr.navy.mil/focus/ocean/motion/waves2.htm

A broad sandy beach acts a buffer, absorbing much of the breaking waves' energy. Hence, such beaches are called "dissipative." When a beach erodes and narrows, more wave energy gets transmitted to the dunes, bluffs, or structures that back the beach, increasing the risk of erosion and damage at the backshore.



8.2 Relative Sea Level (RSL) Rise

The worldwide increase in sea level over the past several decades has been widely reported and well documented. The Intergovernmental Panel on Climate Change (IPCC) describes the increase in these words:

> Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm/yr and since 1993 at 3.1 [2.4 to 3.8] mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear.[33]

The IPCC's 2007 assessment goes on to project six scenarios for sea level rise by the end of this century. The most conservative scenario projects an increase of 0.18 to 0.38 meters above levels observed during the last decade of the 20th century. The least conservative projects an increase of 0.26 to 0.59 meters.[34] The IPCC's projections therefore suggest that we can expect global sea level to rise this century by as little as 7 inches (about the same as what occurred during the 20th century) and as much as 23 inches.

Many authorities regard even the highest of the IPCC projections as too low. For example, the Oregon Climate Change Research Institute says, "It is near certain that global mean sea level will increase, possibly by 2-4 feet by 2100."[35] Other credible projections range as high as 2m (6 ½ ft). For a discussion of the varied viewpoints among experts on this topic, see page 214 of the 2010 *Oregon Climate Assessment Report* at http://occri.net/wp-content/uploads/2011/01/OCAR2010_v1.2.pdf

Increases in sea level by even a few feet over a century may sound trivial. For coastal beaches and low-lying areas, however, they are quite significant. Sandy beaches in Tillamook County typically have shallow slopes averaging 0.04 (4 units of vertical "rise" for every 100 units of horizontal "run"). All other things being equal, a one-foot rise in sea level will bring ocean waters 25 feet farther onto such a beach. The resulting increase in erosion and perhaps in flooding would by no means be trivial.

The global rise in sea level is, of course, an averaging of conditions worldwide. To fully understand the impact of sea level rise at any given place, however, we need to consider local conditions. Measurements of *relative* sea level rise incorporate those key conditions. In Tillamook County several factors combine to make relative sea level rise quite significant.

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[33] Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report* (A Summary of IPCC's Fourth Assessment Report (AR4)), p. 2. On-line at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

[34] *Ibid*., p. 8

[35] K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Legislative Summary, Oregon Climate Change Research Institute, December 2010, p. 1

First, offshore waters here are typically colder and denser during the summer, and warmer and less dense during the winter.[36] This counter-intuitive cycle results from seasonal changes in offshore currents and upwelling that bring colder waters to our coast during summer. Because winter waters off the Pacific Northwest are warmer and less dense, relative sea level rises during the winter, which unfortunately compounds the impact of winter storms. The difference between summer and winter water levels is significant: it averages 20 to 25 centimeters (8 to 10 inches).[37]

Second, major El Niño events exacerbate the situation by making winter offshore waters even warmer, increasing thermal expansion, and thereby causing a greater rise in relative sea level. Sea level during an El Niño event thus is likely to be "10s of centimeters" higher than sea level during a non-El Niño winter.[38] (Ten centimeters constitute roughly four inches.)

Third, coastal land elevations near the sea sometimes rise or fall as a result of tectonic activity. Sudden subsidence of as much as several feet already has been discussed above, in sections on earthquakes and tsunamis. But more gradual rising or falling also occurs, as tectonic plates flex and bend. When coastal lands rise faster than the level of the sea, they are said to be *emergent*. When they rise less rapidly than the sea or are falling, they are said to be *submergent*. Researchers from OSU and DOGAMI say this:

> In brief, the southern one-third of the Oregon coast is tectonically rising faster than the eustatic [global] rise in sea level so its shores are emergent, whereas along most of the northern half of the Oregon coast the land-elevation changes have been small, so the measured rates of sea-level rise are close to the eustatic value, the result being that this stretch of shore is slowly submergent, being transgressed by the ocean.[39]

Coastal areas in Tillamook County are not rising as fast as sea level and thus are submergent. Sea level rise is outpacing land level rise by about one millimeter per year:

> It is apparent from the geomorphology of the coast and locations of communities which have experienced erosion, that the stretches of shore that are tectonically rising faster than the global rise in sea level (such as Crescent City) have been relatively immune from those hazards, while the areas that are not rising rapidly (such as in Tillamook County, Oregon) are those that have experienced the greatest impacts from erosion and flooding." [40]

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[36] Paul D. Komar, Jonathan C. Allan and Peter Ruggiero. "Sea Level Variations along the U.S. Pacific Northwest Coast: Tectonic and Climate Controls." Currently accepted by and in press at the *Journal of Coastal Research*. 2010, p. 3

[37] Peter Ruggiero et al., "Impacts of Climate Change on Oregon's Coasts and Estuaries" in K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, December 2010, p. 219. See also Paul D Komar, Jonathan C. Allan and Peter Ruggiero, 2011, "Sea Level Variations along the U.S. Pacific Northwest Coast: Tectonic and Climate Controls" in *Journal of Coastal Research* (currently at publisher).

[38] *Ibid*., p. 4.

[39] Paul D. Komar, Jonathan C. Allan and Peter Ruggiero. "Sea Level Variations along the U.S. Pacific Northwest Coast: Tectonic and Climate Controls." Currently accepted by and in press at the *Journal of Coastal Research*. 2010, p. 3.

[40] Peter Ruggiero et al., "Impacts of Climate Change on Oregon's Coasts and Estuaries" in K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Legislative Summary, Oregon Climate Change Research Institute, December 2010, p. 217

8.3 El Niño/La Niña Southern Oscillation (ENSO)

El Niño and La Niña are the two main phases in a periodic shifting – an oscillation – of the usual climatic patterns and circulation of the equatorial Pacific. In terms of ENSO's effect on Tillamook County and its offshore waters, El Niño is the warmer/wetter phase, and La Niña, the cooler phase. With regard to coastal hazards affecting the county, El Niño is the more critical phase, because a strong event brings an increase in ocean water levels[41], more winter storms, and larger winter storm waves.[42] Both the frequency and the intensity of El Niño events *may* be increasing, but the science on this point is by no means settled. No one knows for sure.

ENSO events begin along the equator in the Pacific Ocean. During normal (that is, non-ENSO) times, warmer waters pool in the southwestern Pacific, pushed there by trade winds from the northeast. Meanwhile, cooler waters reside in the eastern Pacific, along the coast of South America. The warm waters in the southwestern Pacific bring higher relative sea level, lower atmospheric pressure, and heavy rains. The eastern Pacific experiences cooler water temperatures, higher atmospheric pressure, drier weather, and *upwelling*. Upwelling is the rising of cold water from the ocean's depths to the surface along the western coasts of the Americas.

For reasons not yet fully understood, this pattern periodically shifts. The trade winds diminish or reverse, the eastern part of the equatorial Pacific grows warmer, and upwelling slows, bringing hard times to coldwater fisheries such as those along the Peruvian coast. The advent of such warm waters off Peru typically has occurred around Christmas, so Peruvian fishers named the event "El Niño," after the Christ child.

El Niño events occur every two to seven years and last six to eighteen months. They often cease abruptly, with a sudden reversal of circulation that brings colder-than-normal water and air temperatures to the eastern equatorial Pacific. This is "La Niña." An El Niño warming usually, but not always, is followed by a La Niña cooling.

The strength of these oscillations varies. Effects from the lesser ENSO events are felt mainly along the equator, in southern Asia and western South America. The stronger events, however, can have significant effects on the Pacific northwest, especially in winter. Generally, El Niño brings us warmer sea temperatures, higher water levels, lower barometric pressures, and a shift in the direction of winter storm tracks. The result often is an increase in rainfall and in the size and number of winter storms. All of that in turn increases the risk of coastal erosion and flooding.[43] In contrast, the briefer La Niña phase brings colder waters, lower water levels, and colder weather.

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[41] OSU researchers report that the strongest El Niños bring an increase in water levels of up to 0.4 m (1.3 ft). See Komar, Allan and Ruggiero's "Sea Level Variations . . . ," *op. cit*., p. 12.

[42] Jonathan C. Allan and Paul D. Komar, *Morphologies of beaches and dunes on the Oregon coast, with tests of the geometric dune-erosion model*. Portland, Oregon Department of Geology and Mineral Industries, 2005, p. 6

[43] "The increase in rainfall often leads to landslides and the failure of coastal cliffs. Additionally, the increase in storms generates large waves that attack the coastline with a greater frequency than during non-El Niño years. During the severe El Niño events of 1982-83 and 1997-98, extensive coastal erosion was

The powerful 1997-1998 El Niño contributed to winter storms and deepwater wave heights off the Oregon coast that at the time were considered "100-year" events – that is, conditions expected to occur only once every hundred years.

During El Niño conditions in the Pacific northwest, winter storm tracks typically shift to the south. The usual track for storms arriving in Oregon is from the southwest and west, but the El Niño storms tend to come straight from the south. This produces a northward current that then is deflected toward shore by the Coriolis force.[44] One result is an increase in erosion at the southern end of some littoral cells: the southern "hotspot" loses sand, while the northern end of the cell gains. This El Niño effect probably explains at least some of the erosion recently observed in Neskowin, at the south end of the Nestucca littoral cell, and the accretion of sand at Pacific City, at the north end.

At the time of this writing, the most recent ENSO is in its La Niña phase, which is expected to last at least through the spring of 2011.[45] See NOAA's "El Niño Website" at http://www.elnino.noaa.gov/ for current ENSO conditions and forecasts.

Although NOAA 's capacity to predict individual El Niño events is becoming more refined (see sidebar), long-term trends remain unknown. The Oregon Climate Change Research Institute states, "At present it is not known whether or not El Niño intensity and frequency will increase under a changing climate."[46]

In addition to El Niño/La Niña southern oscillation, there also exists a Pacific Decadal Oscillation (PDO) that affects climate and surface water temperatures off

Predicting El Niño . . .

"The largest El Niño in the twentieth century, in 1997-1998, had many effects around the world, such as torrential rains in California that caused widely reported mudslides, in which homes slid into the sea. The running joke on late-night TV in 1998 was to blame everything on El Niño. Effects of this El Niño, including the heavy rains across California, were correctly predicted by NOAA's National Centers for Environmental Prediction six months in advance. As a result, overall property losses were a billion dollars less than what they had been for the previous large El Niño in 1982-1983. Today fairly accurate prediction of an El Niño six months to a year in advance has become possible using computer models that ingest millions of gigabytes of real-time data from instruments on buoys deployed across the Pacific Ocean. But even with this system we still cannot always correctly predict the specific effects of an El Niño for particular regions."

Bruce Parker, *The Power of the Sea: Tsunamis, Storm Surges, Rogue Waves, and Our Quest to Predict Disasters*. Palgrave MacMillan, New York, 2010, p. 206. (Dr. Parker is former chief scientist for the National Ocean Service.)

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recorded along the western coast of the United States." USGS, at http://coastal.er.usgs.gov/hurricanes/extreme-storms/elnino.html

44 Paul D. Komar, Jonathan C. Allan and Peter Ruggiero. "Sea Level Variations along the U.S. Pacific Northwest Coast: Tectonic and Climate Controls." Currently accepted by and in press at the *Journal of Coastal Research*. 2010, p. 5

45 "El Niño/Southern Oscillation (Enso) Diagnostic Discussion," National Weather Service's Climate Prediction Center/Ncep/Nws, 6 January 2011, at http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf

46 K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, December 2010, p. 209

the coast of the Pacific Northwest. Although it bears a different name, it is essentially a low frequency modulation of ENSO. This oscillation occurs over a much longer cycle, typically 20 to 30 years. Over the past century, there have been roughly two complete oscillations – that is, 20-30 years of relatively cooler temperatures, then 20-30 years of warming, followed by another 20-30 years of cooling, and, most recently, several decades of warming. The PDO was only recently discovered and is not fully understood. Neither its extent nor its timing can be predicted.[47]

[47] National Weather Service's Climate Prediction Center, at http://www.cpc.ncep.noaa.gov/products/outreach/glossary.shtml#CPC

8.4 Rip Current Embayments

Rip currents are “rivers” or “jets” of seawater returning to the ocean after waves break upon a beach. Rip currents are dangerous to unprepared swimmers, helpful to surfers seeking a ride out to the big waves offshore, and quite effective at carrying sediment from shore to sea. This last quality means that rip currents may cause rapid localized erosion, especially along dune-backed beaches. The indentations caused by such erosion are referred to as *rip current embayments*.

Long sandy beaches may have a series of such embayments, producing a scalloped edge (a “cuspate shoreline”) revealed in aerial photos such as this one of Lighthouse Beach, New South Wales, Australia. Six rip currents (marked by yellow arrows) are visible. Photo by AD Short from “Beach Recovery,” http://www.beachrecovery.com/wave-action

Rip currents often are volatile: their position or strength can change quickly, and they sometimes appear and then disappear within a matter of hours. [48] But even a short-lived rip current can cause significant erosion. Their lack of predictability and power to erode

[48] NOAA’s website on the science of rip currents says: “Some shorelines are characterized by permanent rip currents which may be found in a fixed location such as a break in a reef or other hard structure. Some rip currents are persistent, lasting for many days or months in one location. Rip currents may also migrate along a stretch of coastline. Rip currents may also be ephemeral, forming quickly and lingering for a few hours or days before dissipating and disappearing.” See http://www.ripcurrents.noaa.gov/science.shtml

beaches dramatically in a short time make them a challenging factor in dealing with coastal erosion and hazards.

Geologists from the state's Department of Geology and Mineral Industries (DOGAMI) report the following:

> Analyses of historical shoreline changes along the Tillamook County coastline indicate that 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 "hotspot erosion" of the coast. Previous work suggests that such processes can cause up to 125 ft of beach erosion.[49]

The photo below shows a rip current embayment in the southern part of Rockaway Beach.

"Figure 6.12 Ongoing shoreline retreat over the past decade in the Rockaway cell and localized hotspot erosion effects have resulted in substantial sections of the shore having to be rip-rapped in order to safeguard property. SLR [sea level rise] expected over the next century and enhanced storms will almost certainly increase the risk of failure of such structures and the potential loss of homes and important infrastructure backing the beach.(Photo courtesy of Mr. Don Best, 2009.)" *This photo and caption are from the Oregon Climate Change Research Institute's Oregon Climate Assessment Report, Dec. 2010, p. 230.*

For more information, see the National Weather Service's website on "Rip Current Science" at http://www.ripcurrents.noaa.gov/science.shtml See also Matthew Dalon, Merrick Haller and Jonathan Allan's "Morphological Characteristics of Rip Current Embayments on the Oregon Coast" in ASCE's *Coastal Sediments '07* (14 pp.).

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[49] Jonathan C. Allan and George R. Priest. *Evaluation of coastal erosion hazard zones along dune and bluff backed shorelines in Tillamook County, Oregon: Technical report to Tillamook County*, Portland, Oregon Department of Geology and Mineral Industries, 2001, p. iv.

8.5 Astronomical Tides

In its broadest sense, the word *tide* means any change in water level. Most often, however, the word refers to *astronomical tide*, the cyclical change in water level caused by variations in gravitational pull by the sun and moon and by Earth's rotation. Astronomical tide is a significant factor with regard to coastal hazards: events such as winter storms or tsunamis that occur during high tide are much more likely to cause major erosion and damage to beachfront structures.

This photo of a ship stranded at low tide is from NOAA's online tutorial on tides, at http://oceanservice.noaa.gov/education/tutorial_tides/lessons/tides_tutorial.pdf

Tides are at their highest when the moon is full or new. These higher-than-average water levels are referred to as *spring tides*. The phrase has nothing to do with the season of that name: the reference here is to the word meaning *to jump*, as in "spring up." Tides are lowest during the moon's first and third quarter phases. The lower waters are neap tides.[50]

Oregon has four tides each day. From highest to lowest, they are "higher high water," "lower high water," "higher low water," and "lower low water." During neap tides, the tidal range – the difference between higher high water and lower low water – is at its smallest. During spring tides, that range is at its greatest: we get the highest high tides and lowest low tides then.

Tides are essentially very long-period waves. The crest of each wave is a high tide; the trough, a low tide. The tides rise and fall with great regularity, at intervals of just over six hours. For example, if higher high water occurs at noon, lower low water will occur shortly after 6:00 p.m. Local variations in latitude, bathymetry and shoreline topography, however, greatly affect the timing of these cycles. For example, tides at

[50] Origins of the word *neap* are unclear. Various writers describe it as being of Old English, Middle English or even Greek derivation, but there seems to be general agreement that the root word means "scanty."

places in Tillamook County generally occur later than those at more southerly locations such as Newport, which is one degree of latitude farther south.[51]

Tides are monitored by a worldwide network of tidal stations. In the United States, those stations are maintained by NOAA's National Ocean Service (NOS). Oregon has 26 such stations, two of which are in Tillamook County: Garibaldi and Netarts Bay. Tidal datums for those two stations are found at

http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9437540 Garibaldi, OR&type=Datums

http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9437262 NETARTS, NETARTS BAY, OR&type=Datums

Tidal range, the difference between the highest and lowest water levels on a given day, varies from place to place around the world. It may exceed 50 feet at some locations, such as the famous Bay of Fundy. In Oregon, however, the typical tidal range is five to seven feet. For example, the mean (average) range of tide at Garibaldi is 6.26 feet. The mean range at Netarts Bay is 5.02 feet. That range may double during periods of extreme tides, which often are observed in June and December.

Modern scientific instruments and data collection systems enable us to forecast tides with great precision. In Oregon, the main data collection and forecast center is in Newport, at the Hatfield Marine Science Center (HMSC). Tide tables from the HMSC predicting the extent and time of each day's tides are available on-line at http://hmsc.oregonstate.edu/weather/tides/tides.html

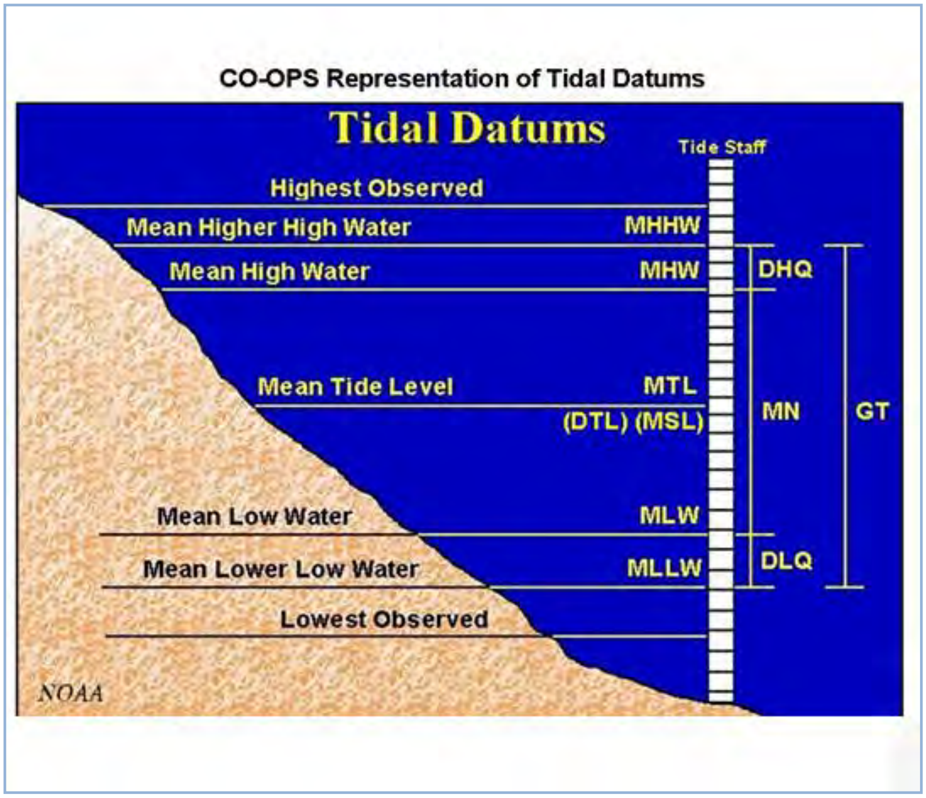
Tidal elevations are expressed in terms of distance between the water's surface and the mean lower low water (the long-term average of the lower of each day's two low tides). Local tides are measured with respect to a standard reference point known as the *tidal datum* or *station datum*. NOAA defines the term thus:

> A fixed base elevation at a tide station to which all water level measurements are referred. The datum is unique to each station and is established at a lower elevation than the water is ever expected to reach. It is referenced to the primary bench mark at the station and is held constant regardless of changes to the water level gauge or tide staff. http://tidesandcurrents.noaa.gov/datum_options.html

Thus, if we say that Garibaldi will experience a high tide of 8.0 feet today at noon, the statement means that the water level there at noon will be eight feet above mean lower low water (MLLW). That average is calculated with respect to the Garibaldi station datum, which corresponds roughly with the lowest water level likely ever to occur there. A "minus tide" is one lower than mean lower low water. A "plus tide" is one higher than mean higher high water.

[51] The Hatfield Marine Science Center at Newport maintains a tidal adjustment table showing such differences to the nearest minute for places on the Oregon coast, at http://hmsc.oregonstate.edu/weather/tides/tideadj.html

The main datums used in reference to tides and water levels are illustrated in the following diagram from NOAA's Tides and Currents website, at http://tidesandcurrents.noaa.gov/datum_options.html. ("CO-OPS" stands for "Center for Operational Oceanographic Products and Services.")



It's important to note that observed tidal elevations often differ from predicted elevations. Such differences occur because the predictions are based on mathematical models that do not take into account local or regional variations such as barometric pressure. For example, if a low-pressure system is moving onto the Pacific coast during a high tide, the observed elevation at high tide may be significantly higher than the predicted elevation.

Although tidal cycles and ranges generally are considered to be utterly predictable and unchanging, tidal ranges and maxima can indeed change over time. For example, local changes may occur because of alterations in the morphology of bays and beaches. There also is some evidence that tidal ranges may be increasing (slightly) on a global scale, for reasons not fully understood. For purposes of this plan, however, we may assume that tides will continue to occur within the ranges described above and our capacity to make accurate long-term predictions will remain undiminished.

8.6 Storm Surge

Storm surge is an increase in water level caused by the winds and lowering of atmospheric pressure associated with a storm approaching the coast. When a storm moves ashore, offshore water levels rise as the wind pushes the water against the land. And because a storm usually is associated with a low pressure system, the resultant drop in barometric pressure also contributes to the rise in water level.[52]

While *storm surge* is the preferred term for this temporary increase in water levels, a variety of other terms are sometimes used (and misused) to describe this phenomenon, including *sea surge*, *storm wave*, *storm tide* and even *tidal wave*. It is also referred to as *meteorological tide*, to distinguish it from astronomical tide, the familiar cyclical change in water level resulting from gravitational forces of the moon and sun.

The surging sea . . .

"Storm surges are most dangerous when they coincide with high tides. They are responsible for the majority of flooding and destruction associated with hurricanes. Ninety percent of people killed by hurricanes are killed by storm surge. Severe hurricanes can produce storm surge to 12 meters (40 feet) in height."

From *Water Encylcopedia*'s "Waves," at http://www.waterencyclopedia.com/Tw-Z/Waves.html#ixzz1AxDjEocI

In some parts of the world, especially low-lying coastal areas in the tropics, storm surges can be both massive and deadly, flooding vast areas, washing villages away, and creating tidal bores that rush up coastal rivers, destroying everything in their path. Bruce Parker, author of *The Power of the Sea*, refers to them as "the sea's greatest killer."

Although storm surge is an important component in the total water level off Oregon's coast, and hence a factor influencing coastal hazards, it plays a relatively small part. For example, in the unusually large storm of March 2-3, 1999, the surge measured by the Yaquina Bay tide gauge was only 0.48 meter – slightly more than 1½ feet.[53] In estimating the "design erosion event" – the extreme high-water level that would cause maximum erosion – Allan and Komar observe, "Storm surges are much less important on the Oregon coast, and as seen in the 'design' Scenario . . . , it is the combination of the tide plus wave runup that produces the erosion."[54]

As noted above, the heights of deepwater waves and the intensity of winter storms along the Oregon coast both are increasing, and they are expected to continue to do so. Storm surge elevations along the same coast therefore may do the same.

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[52] "A 1 mb change in atmospheric pressure causes approximately a 1 cm change in sea level." Department of Oceanography, Naval Post-Graduate School's "Tides: Basic Concepts and Terminology," at http://www.oc.nps.edu/nom/day1/partc.html

[53] Allan, Jonathan C., and Paul D. Komar. *Morphologies of beaches and dunes on the Oregon coast, with tests of the geometric dune-erosion model*. Portland, Oregon Department of Geology and Mineral Industries, 2005, p. 3.

[54] *Ibid*., p. 8

8.7 Winter Storm Frequency

As noted above, the offshore waters of the Pacific Northwest are experiencing a well-documented increase in winter storm wave heights. There also is some evidence of an increase in the number of winter storms. The Oregon Climate Change Research Institute (OCCRI) describes the situation this way:

> The Oregon Coast has been historically prone to severe winter storms, which are the dominant factor for flooding and erosion on the coast. Storminess has been increasing, and consequently the frequency and magnitude of these coastal flooding events will probably continue to increase.[55]

The institute goes on to say:

> [W]e have limited ability to predict future trends in wave heights or coastal storms, but if the trend continues, impacts will be substantial. Storminess and extreme storm events have already been increasing very rapidly, leaving unarmored coastal areas vulnerable to flooding and erosion. The North Pacific winter storm track is projected to shift northward, meaning slightly fewer, but more intense storms.

The OCCCRI's 2010 report also speaks of "increased occurrences of *severe* storms" along the Oregon coast [emphasis added).

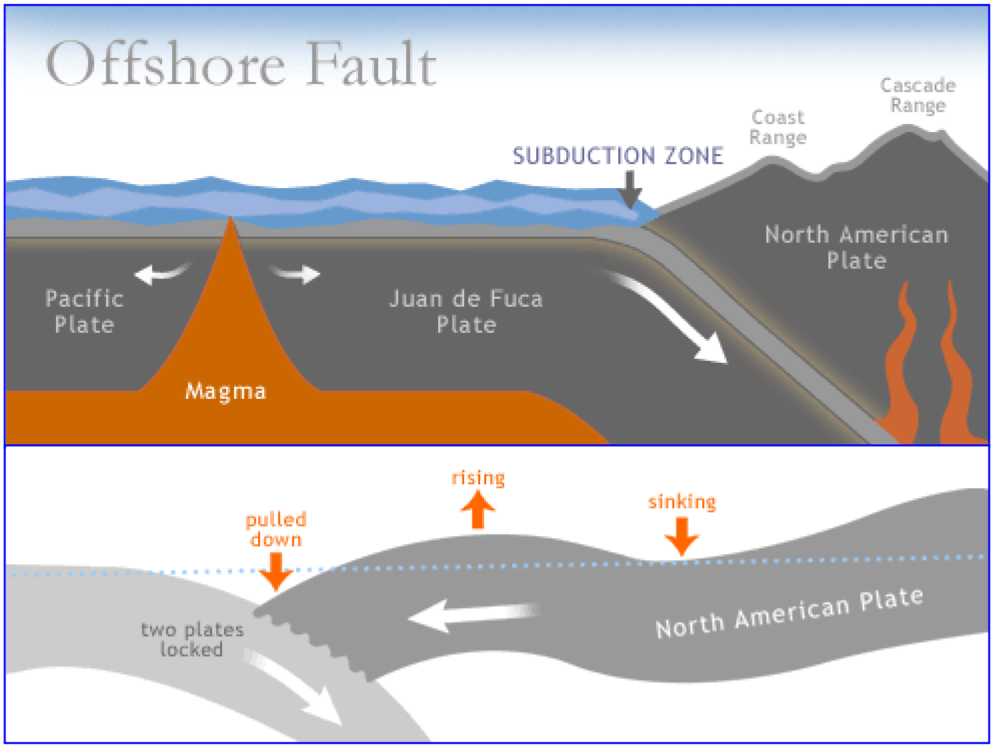
The evidence for an increasing frequency of winter storms off the Oregon coast thus seems mixed and somewhat tentative. We find no evidence that the frequency of such storms might *decrease*. As discussed in Section 6.3 above, there is some evidence that the number and strength of El Niño events will increase. If so, then the frequency of winter storms is likely to increase accordingly.

> "The details about what a warmer planet will look like are still coming into focus, but there is one thing our environmental future will surely hold: a lot of restless water." Quoting the IPCC, Casey says "the ocean has been absorbing more than 80 percent of the heat added to the climate system."
>
> Susan Casey, *The Wave: In Pursuit of the Rogues, Freaks, and Giants of the Ocean.* Doubleday, New York, 2010. P. 17

[55] K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Executive Summary, Oregon Climate Change Research Institute, December 2010, p. 19

8.8 Vertical Land Movement

We describe sudden vertical movement of land as an earthquake: a Cascadia Subduction Zone earthquake, for example, could cause land along Oregon's coast to suddenly drop as much as six feet in a matter of minutes. There is, however, another form of vertical land movement that also affects coastal erosion and flooding. This more gradual movement is caused by shifting of the great tectonic plates, as shown in the diagrams below.



"Earthquakes and Washington's Coast"

"The surface of the earth is made of plates. These plates are always on the move, shifting over or under each other. When plates move suddenly, an earthquake occurs. Part of the earth's crust, the Juan de Fuca Plate, is spreading away from the Pacific plate, several hundred miles offshore. The Juan de Fuca plate is being pushed under the North American plate – a process called subduction."

"The Juan de Fuca Plate is pushing deep under the North American Plate. The colliding edges of these plates are locked, one plate pressed into the other. As the plates press and move, stress builds up – until the lock breaks."

From "Washington's Coast," Washington State Department of Ecology, at http://www.ecy.wa.gov/programs/sea/coast/waves/fault.html

In the long intervals between subduction zone earthquakes, the offshore Juan de Fuca Plate and the North American Plate on which Tillamook County sits continue to flex and bend. If the landward North American Plate bends upward, the result may be a gradual increase of the land's elevation. If the plate bends downward, subsidence – a downward movement of the land may occur.

These changes in elevation are small, but over long periods of time they may cause a beach to become more or less vulnerable to erosion. Along the eastern seaboard and gulf coast of the United States, many areas are experiencing significant subsidence along with rising sea levels. Along the Oregon coast subsidence, where it does occur, is less rapid.

South of Newport, coastal areas are experiencing a gradual increase in elevation. This increase exceeds the current rate at which sea level is rising. Along the central Oregon coast, the land is more or less stable: it is experiencing little vertical movement. In Tillamook County, the land is rising slightly, about one millimeter per year. But sea level is rising more rapidly (about two millimeters per year), resulting in the "submergence" described in Section 8.2, on sea level rise.[56]

Vertical land movement along the coast in Tillamook County thus is a fairly significant variable among the forces and factors affecting coastal erosion and hazards. It is, however, impossible to predict whether such movement will remain constant in the decades to come.

[56] See Paul D. Komar, Jonathan C. Allan and Peter Ruggiero. "Sea Level Variations along the U.S. Pacific Northwest Coast: Tectonic and Climate Controls." Currently accepted by and in press at the *Journal of Coastal Research*. 2010.

8.9 Sediment Supply

The sand that makes up Tillamook County's beaches is sediment brought to our coast by wind and water. Some of it comes from rivers and streams, which carry sediment to the sea. Some comes from erosion of and runoff from coastal bluffs, cliffs and dunes. And some is borne by the wind.

In stable littoral cells, beach erosion and sediment replacement are roughly in balance: the width of the beaches there will fluctuate with the seasons, but over the long term, the extent of the beaches is fairly constant. But in littoral cells where the sediment supply is reduced, beaches may diminish, thereby increasing the risks of erosion and flooding.

The supply of sediment to beaches in the Pacific Northwest has been reduced by several forces. First, dams on major rivers such as the Columbia have diminished the amount of sediment transported to the sea. Second, jetties sometimes alter the natural circulation in littoral cells, increasing sediment on some beaches and decreasing it to others, most notably in the case of the Columbia River jetties. Third, the growth of broad estuaries in some coastal rivers has gradually reduced the amount of sediment reaching the sea: the estuaries trap the sediment before it gets to the beach. Finally, armoring of the coastline with shorefront protective structures such as seawalls and revetments impounds sediment that would otherwise be carried to the beach.

Unfortunately, few quantitative studies of sediment budgets have been performed in Oregon. We therefore must speak of sediment transfer largely in qualitative terms rather than specify any precise amounts.

8.10 Earthquakes

Of the hazards evaluated in this plan, earthquakes are the most difficult to predict. Scientists continue their work to develop a reliable method to forecast the time, place and magnitude of future temblors. For now, however, no such method exists. We simply cannot say with much precision when or where the next earthquake will strike or how strong it will be.

If we accept the geologists' somewhat whimsical premise that "if it happened before, it can happen again," then history does provide some basis for prediction. By examining the number and magnitude of earthquakes that have occurred at or near a given place, one may reach broad conclusions about the probability of quakes happening there again. Recent history is deceptively comforting: in the century and a half since Tillamook County was founded (in 1853), few large earthquakes have occurred here.

Consider, for example, the list of earthquakes maintained by the Pacific Northwest Seismograph Network, at the University of Washington.[57] It lists the larger earthquakes (magnitude 4.0 or larger) that have occurred in Oregon and Washington since the late 1800s. The list contains hundreds of entries, but only one indicates a location in Tillamook County: on November 17, 1957, a magnitude 5.0 earthquake struck near the City of Tillamook.[58]

Based largely on recent historical evidence, then, we might conclude (wrongly) that Tillamook County is at very low risk from earthquakes. Indeed, the county (like most of Oregon) was officially classified as a region of "low seismic hazard" until the 1990s. That changed, however, as evidence of major seismic event activity in earlier times began to emerge. In 1993, the seismic hazard rating for western Oregon was upgraded from a rating of 2B to 3. The southern Oregon coast now has the highest (most hazardous) rating, of 4, and re-classification of the northern coast, including Tillamook County, to

A Matter of Some Magnitude

Earthquakes are rated numerically by magnitude: the larger the number, the more powerful the earthquake. That is, the more energy is released. Magnitude often is abbreviated to "M," as in "an M 6.0 earthquake."

Quakes less than M 3.0 are considered small and cause little damage. Those in the range from M 4.0 to 5.9 are moderate and may cause damage to poorly constructed buildings. Earthquakes of 6.0 or more may cause considerable damage. The 2010 earthquake that devastated Haiti, for example, had a magnitude of 7.0. The largest ever recorded was in Chile in 1960 – an M 9.5.

Magnitude formerly was measured on the Richter scale. In popular usage the phrase "*an earthquake of – on the Richter scale*" still is common, but among seismologists, Richter has been replaced by the *moment magnitude scale*. It is more accurate for describing strong earthquakes of magnitudes greater than 7.0. Below that level, values on both scales are quite similar, so an earthquake of, say, 5.0 on the Richter scale is also a 5.0 on the moment magnitude scale.

Both scales are logarithmic (base 10), not linear. Each whole-number increase in magnitude thus represents a *tenfold* increase in the strength of an earthquake. For example, an M 6.0 earthquake is ten times as strong as an M 5.0.

See USGS explanation at http://earthquake.usgs.gov/aboutus/docs/020204mag_policy.php

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[57] See http://www.ess.washington.edu/SEIS/EQ_Special/pnwtectonics.html
[58] See list at http://www.pnsn.org/HIST_CAT/catalog.html

seismic zone 4 is under consideration.[59] The seismic zone rating determines what standards will apply to the construction of new buildings.

The Next Big One

The increase in Oregon's seismic risk rating came about after studies in the 1990s revealed our region to have a long history of large earthquakes. Scientists learned that coastal areas in the Pacific Northwest during the past 10,000 years have undergone a series of massive earthquakes caused by the movement of tectonic plates. Off the Oregon and Washington coast the Juan de Fuca and the North American plates are converging at a rate of one or two inches per year. In the process known as *subduction*, the Juan de Fuca plate slides under the North American plate. The intersection of the two plates is a 600-mile fault known as the Cascadia Subduction Zone.

Subduction is neither smooth nor continuous. Rather, it occurs in fits and starts. As the two plates converge, friction between them resists sheering force for long periods of time. As pressure on the two plates increases, they may bend but still not move. Eventually, however, sheering force exceeds frictional resistance, and the plates shift, with that sudden, dramatic release of energy that we describe as an earthquake.

Of the four main types of earthquakes, subduction events (also known as megathrust earthquakes) are the most powerful. For example, the largest earthquake ever measured, an M 9.5 event that struck Chile in 1960, was a subduction earthquake. Likewise, the M 9.2 temblor that struck Alaska on Good Friday in 1964 also resulted from subduction.

Recent studies find that equally powerful subduction earthquakes rocked the coast of Tillamook County in the distant past. The last one is thought to have occurred on January 26, 1700. There were of course no seismographs or seismologists in Oregon to record such events three centuries ago, so one may ask how scientists can pinpoint such a precise date. The answer lies in a compelling combination of clues:

- Layers of silt on the deep sea floor off the Oregon coast indicate underwater landslides probably caused by an earthquake.
- Marshes and forest soils along the coast were buried by sand and silt, suggesting that land there suddenly subsided and was flooded by seawater.
- Tree rings in some coastal old-growth timber reveal evidence of subsidence and subsequent drowning of the tree roots.
- Native American lore tells of huge waves during a winter storm destroying coastal villages.[60]

[59] Oregon Department of Geology and Mineral Industries (DOGAMI), *Geologic Hazards on the Oregon Coast*, at http://www.oregongeology.com/sub/earthquakes/coastal/CoastalHazardsMain.htm

[60] Ruth S Ludwin et al. *Dating the 1700 Cascadia Earthquake: Great Coastal Earthquakes in Native Stories.* Seismological Research Letters Volume 76, Number 2 March/April 2005. http://www.pnsn.org/HIST_CAT/SRL76-2Ludwin.pdf

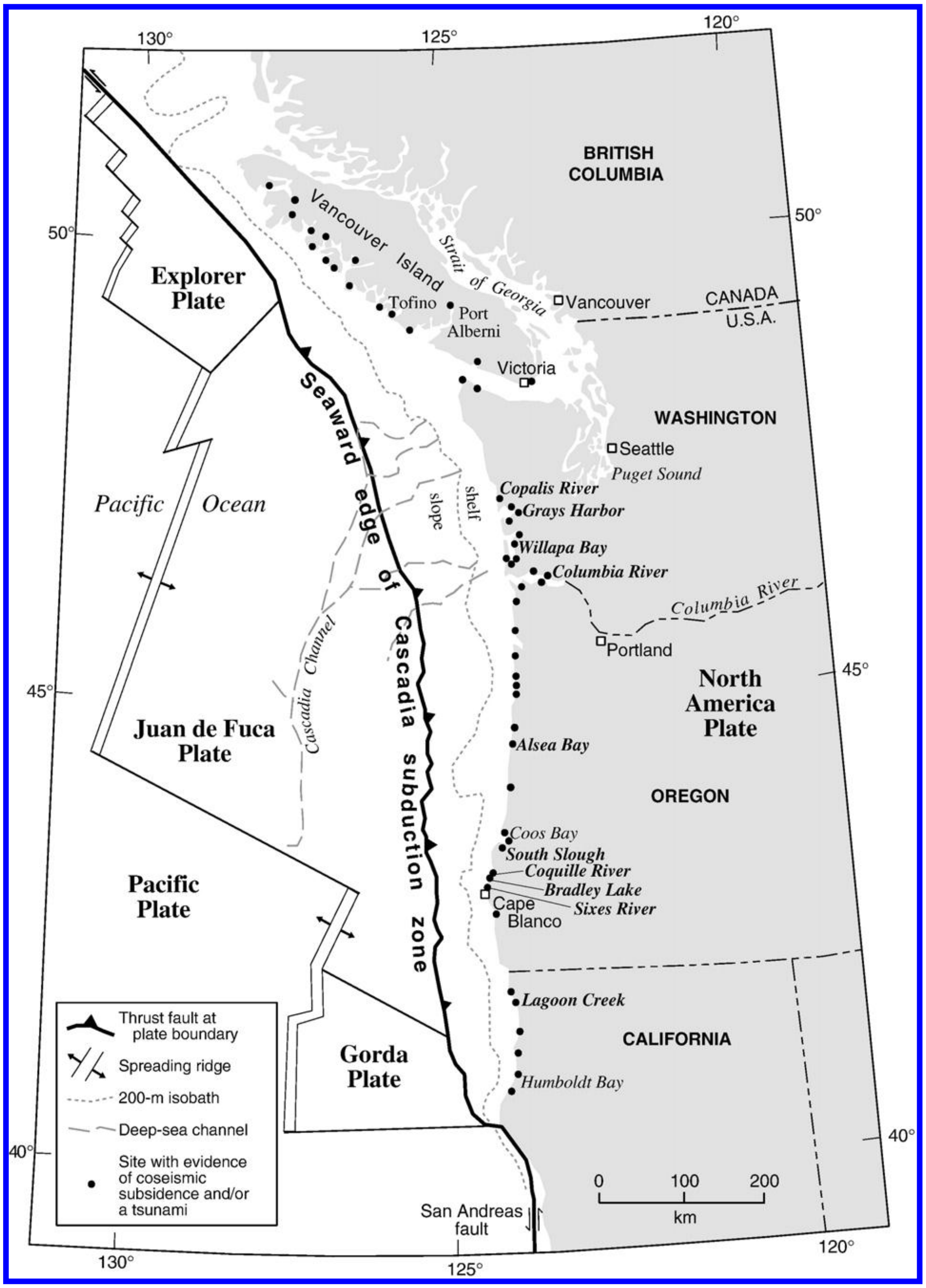
- Official records from villages on the southeast coast of Japan show that a tsunami struck there on the evening of January 26, 1700. It was not, however, accompanied by an earthquake – at least, by an earthquake felt in Japan.[61]

The big Cascadia quake of 1700 is estimated to have been an event of magnitude 8.7 to 9.2. It was certainly large, but by no means unique. Rather, it was one in a series of megathrust earthquakes that have occurred off the Pacific Northwest coast for millennia. Geological evidence suggests that major earthquakes of magnitude 8.0 or greater have occurred in the Cascadia Subduction Zone for the past 10,000 years, once every 300 to 600 years, with the last one having struck in 1700.[62]

The map on the following page shows the Cascadia Subduction Zone and the numerous sites along our coast where evidence has been found of past subduction zone earthquakes.

[61] Brian F. Atwater, Musumi-Rokkaku Satoko *et al*. *The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America*. US Geologic Survey, Reston, VA, 2005. http://pubs.usgs.gov/pp/pp1707/pp1707.pdf

[62] Oregon Department of Geology and Mineral Industries' *Cascadia* newsletter of Winter 2010, available on-line at http://www.oregongeology.org/pubs/cascadia/CascadiaWinter2010.pdf



"Location of coastal sites along the Cascadia subduction zone with evidence for great Cascadia earthquakes and accompanying tsunamis (after Atwater and Hemphill-Haley, 1997, their Fig. 1)."

Alan R. Nelson, Harvey M. Kelsey, Robert C. Witter. "Great earthquakes of variable magnitude at the Cascadia subduction zone" in *Quaternary Research* 65 (2006) 354–365, p. 355.
http://www.colby.edu/personal/w/wasulliv/GE331%20Papers/Subduction%20tectonics/Nelson%20et%20al.,%202006.pdf

When will the next "Big One" occur? DOGAMI says, "[W]e can expect another of these great earthquakes and tsunamis at any time."[63] The authors of *The Orphan Tsunami* agree:

> The next Cascadia earthquake is inevitable. . . . for now, it is prudent to assume, simplistically, that the next great Cascadia earthquake has a one-in-ten chance of occurring in the next 50 years, and that it may attain magnitude 9."[64]

The Cascadia Region Earthquake Workgroup offers a similar estimate, suggesting that a major subduction earthquake in Cascadia has a 10 to 14 percent chance of occurring in the next 50 years.[65]

Ghost forest. At first glance, this may appear to be a photo of people wading in shallow surf at Neskowin during a low tide. The "people," however, are really stumps of ancient trees. How did trees come to be in the intertidal zone, beneath sand and saltwater? The answer is *subsidence*: geological evidence strongly suggests that a huge subduction zone earthquake caused the land here to suddenly drop as much as six feet. Suddenly exposed to salt water and waves, the trees quickly died, lost their foliage, limbs and trunks, and became a ghostly forest of stumps.

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[63] *Cascadia* newsletter of Winter 2010,Oregon Department of Geology and Mineral Industries, available on-line at http://www.oregongeology.org/pubs/cascadia/CascadiaWinter2010.pdf

[64] Brian F. Atwater, Musumi-Rokkaku Satoko *et al*. *The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America*. US Geologic Survey, Reston, VA, 2005. P. 101 http://pubs.usgs.gov/pp/pp1707/pp1707.pdf

[65] Cascadia Region Earthquake Workgroup (CREW), *Cascadia Deep Earthquakes*, 2008, p. 4. On-line at http://www.crew.org/PDFs/Casc%20Deep%20EQ%20web.pdf

Magnitude versus Intensity

Although magnitude tells us the amount of energy released by an earthquake, the effects of an earthquake at any given location depend on a variety of factors such as distance from the epicenter of the quake. Seismologists measure such impacts in a variety of ways. One of the more generalized measures is "intensity," a subjective term for describing earthquakes in terms of their effects on people and structures.

Because intensity varies with one's location with respect to a given earthquake, many different intensities may be reported for one event. Several different scales have been developed to define intensity with at least some precision. The most common seems to be the "Abbreviated Modified Mercalli Intensity Scale," which rates intensity from I to XII, as shown below:

> ***"Abbreviated Modified Mercalli Intensity Scale***
>
> **I**. Not felt except by a very few under especially favorable conditions.
>
> **II**. Felt only by a few persons at rest, especially on upper floors of buildings.
>
> **III**. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
>
> **IV**. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
>
> **V**. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
>
> **VI**. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
>
> **VII**. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
>
> **VIII**. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
>
> **IX**. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
>
> **X**. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
>
> **XI**. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
>
> **XII**. Damage total. Lines of sight and level are distorted. Objects thrown into the air." [66]

[66] From the US Geological Survey's website at http://earthquake.usgs.gov/learn/topics/mag_vs_int.php

Intensity relates to magnitude as shown in the following table, also from the USGS:

Magnitude	**Typical Maximum Modified Mercalli Intensity**
1.0 - 3.0	**I**
3.0 - 3.9	**II - III**
4.0 - 4.9	**IV - V**
5.0 - 5.9	**VI - VII**
6.0 - 6.9	**VII - IX**
7.0 and higher	**VIII** or higher

Aerial photo showing damage to a freeway interchange near Los Angeles. The damage was caused by the 1994 Northridge earthquake, of magnitude 6.7. USGS Photo.

For more information on earthquakes . . .

See Oregon Department of Geology and Mineral Industries (DOGAMI) website on "Earthquake Hazards in the Pacific Northwest" at http://www.oregongeology.org/sub/earthquakes/EQs.htm

Visit the US Geological Survey's website, "Reducing Earthquake Hazards in the Pacific Northwest" at http://earthquake.usgs.gov/regional/pacnw/

See the Pacific Northwest Seismic Network's home page at http://www.pnsn.org/welcome.html

8.11 Tsunamis

Tsunami is a Japanese word meaning "harbor wave." Another term for the same phenomenon is *seismic sea wave.* Tsunamis are fast-moving long-period waves caused by earthquakes or, less often, by volcanoes or landslides. They sometimes are called "tidal waves," but that label is misleading: tsunamis are not caused by tidal action.

Tsunamis move through the open ocean at speeds of 500 to 600 miles per hour. In deep water, their height is insignificant. Sailors might not even notice one passing under their ship. But as tsunamis enter shallow waters, they can rise to great heights, sometimes in excess of 100 feet.

The paradox of the tsunami is that its arrival onshore sometimes is marked not by a fearsome wave but by a "drawback," a receding of ocean waters. This occurs when the trough of these very long-period waves is the first part to arrive on the coast. Unfortunately, this unusual drawing down of the sea may attract curious onlookers who come to view the exposed sea floor or to gather stranded fish. When the crest of the tsunami comes ashore later, such onlookers will be very much in harm's way. A sudden receding of nearshore waters thus should be treated by all as a strong warning to seek higher ground.

Tillamook County's coastline is vulnerable to tsunamis from two different types of event: strong (M8.0 or larger) distant earthquakes, and "local" great earthquakes in the Cascadia Subduction Zone, just off the Oregon coast.

The 1960 Hilo Tsunami

On May 22, 1960, the largest earthquake in modern history occurred off the coast of Chile. The M9.5 quake caused a tsunami that arrived in Hilo, Hawaii, 15 hours later.

"*The first tsunami wave to arrive at Hilo was only about three feet high . . . which led many evacuated people to return to their homes, thinking the danger was over. But it was the third wave that was deadly, thirty-five feet high and shaped like a steep tidal bore. Entire city blocks in Hilo were swept bare, and the city was devastated. The tsunami picked up twenty-two-ton boulders from the bay-front seawall and carried them inland six hundred feet. The force of the water on two-inch-thick pipes holding parking meters bent them parallel to the ground. It swept away an eleven-ton tractor.*"

Bruce Parker, *The Power of the Sea: Tsunamis, Storm Surges, Rogue Waves, and Our Quest to Predict Disasters*. Palgrave MacMillan, New York, NY, 2010, p. 152. Dr. Parker is former chief scientist of NOAA's National Ocean Service.

A recent example caused by a distant event is the tsunami on the Pacific Northwest coast caused by the massive subduction zone earthquake that occurred off the east coast of Japan on March 11, 2011. It took just over 9.5 hours for the Japan tsunami to reach our coast, where it struck Port Orford first.

Another example is the "Good Friday Earthquake," which occurred in Alaska on March 27, 1964. This M9.2 earthquake produced tsunamis along the entire coast of North America as far south as Catalina Island, California. Although tsunamis caused by distant earthquakes are quite capable of causing great damage, it takes these waves several hours to travel from the place of their origin to our shores. That provides time for local authorities to sound a warning and for coastal residents and visitors to seek high ground.

The two photos below show the power of the tsunami caused by the March 11, 2011, earthquake in Japan. The first photo shows water rushing into a residential area in Natori. The second, also from Natori, shows houses swept off their foundations by the tsunami and rafted together by the floodwaters along with other debris. Photos from Kyodo/Reuters News Service.

An example of a tsunami in the Pacific Northwest caused by a local subduction zone earthquake is the 1700 Cascadia event described in the preceding section. This "big one" generated waves that caused great damage and reached far inland. Homegrown tsunamis of this type are especially dangerous because they arrive with little warning. Tillamook County residents can expect to have only 15 to 30 minutes between the time when a large subduction zone earthquake first shakes the ground and the moment when its companion tsunami rushes ashore. The crest of a tsunami from a local subduction zone earthquake of M8.0 or more could be as high as eight meters (26 feet).[67]

The impact of a tsunami on any given stretch of coast depends in part, of course, on the magnitude and proximity of the earthquake that caused it. For Tillamook County, then, the most dangerous event would be a large and local Cascadia Subduction Zone earthquake. But size and proximity are not the only variables that determine a tsunami's extent and effect: height of the tide, topography of the shoreline, contours of the nearshore ocean floor, and direction of the wave all are significant.

For example, the tsunami waves generated by the 1964 Good Friday Earthquake in Alaska caused greater damage in Crescent City, California, than they did to any coastal community in Oregon. Why? The answer lies mainly in *bathymetry*, the shape and contours of the ocean floor, not only near Crescent City but also many miles offshore. That bathymetry and perhaps the configuration of the harbor acted as a sort of funnel, directing more of the tsunamis' energy toward shore.

Crescent City's experience was instructive in several ways. First, it demonstrated the deceptive nature of the tsunami. Although we often speak of "a tsunami" in the singular, a series of waves is the more common event. In Crescent City's case, the first wave arrived at 11:59 p.m., four hours after the earthquake that generated it. That wave was small and did little damage. A larger wave arrived at 12:40 a.m. on March 28, but it too caused little concern. In fact, local authorities still had issued no alarm. At 1:20 a.m., a 15-foot wave changed all that, breaching a jetty, smashing boats, and flooding a tavern, where patrons had to swim for their lives. But that wasn't the end of it. The largest wave of all, 15.7 feet above the expected high tide, struck at 1:45 a.m. Together, this tsunami series destroyed property over an area of 29 city blocks and killed 11 people.[68]

Second, it demonstrated the importance of having adequate warning systems and strong programs for public education about tsunamis. It seems likely that some lives were lost in Crescent City because local warnings were sounded too late, and most of them were radio messages that went unheard by residents whose radios were turned

[67] Nathan Wood, *Variations in City Exposure and Sensitivity to Tsunami Hazards in Oregon*, US Geological Survey Scientific Investigations Report 2007-5283, p. 2.
[68] Robert S.,Yeats, *Living with Earthquakes in the Pacific Northwest*. Oregon State University Press, Corvallis, Oregon, 1998. Crescent City's experience with the 1964 tsunami is described on pp. 167-176.

off. Sirens would have been more effective. Likewise, lives probably could have been saved if citizens had been better informed about multi-wave nature of tsunamis.

Such lessons prompted efforts by coastal communities and states to better prepare their citizens for tsunamis. In Oregon, an important part of that preparation was the work done by the state Department of Geology and Mineral Industries (DOGAMI) in the 1990s to map tsunami-prone areas of the Oregon coast. DOGAMI's work yielded three sets of maps, showing tsunami evacuation zones, areas subject to ORS 455.446 and 455.447, and tsunami inundation. For details about the maps and for on-line access to them, see http://www.oregongeology.org/tsuclearinghouse/faq-tsunami.htm

DOGAMI's evacuation and inundation maps show tsunami runup that is expected to result from what was once considered the "worst-case scenario": a Cascadia subduction zone earthquake of magnitude 8.8. That standard was based on studies done in the 1990s. Research done more recently, however, suggests that a larger earthquake and a higher or more damaging tsunami could occur.[69] DOGAMI's tsunami-inundation zone maps thus should be considered an estimate of the area that would be affected by a *major* tsunami, not necessarily the worst-case extreme.[70]

Key maps show that all low-lying areas in Tillamook County fronting the Pacific Ocean are at risk of tsunami inundation. In addition, low-elevation lands along coastal bays, lakes and rivers face a similar risk. The communities of Cape Meares, Oceanside, Neskowin, Netarts, Pacific City, Rockaway Beach and Tierra del Mar all would face significant risk because much of their development has occurred at low elevations, only a few feet above sea level. Even Cloverdale, which lies four miles inland, would experience some flooding along Highway 101 as a tsunami rushes up the Nestucca River valley.

USGS quadrangle maps showing the tsunami-evacuation zone also are available on-line at http://www.oregongeology.org/tsuclearinghouse/pubs-evacbro.htm These maps show details such as structures, but they are somewhat dated. For example, the Neskowin quadrangle was prepared in 1985, so structures built after that year do not appear on the map. In most cases, more up-to-date details can be found by using the "zoom" and "aerial" functions on the main tsunami inundation map at http://www.nanoos.org/data/products/oregon_tsunami_evacuation_zones/index.php

That a community has some or even a great deal of tsunami-prone land, however, tells us little about its *vulnerability*. For example, if most of the community's key resources

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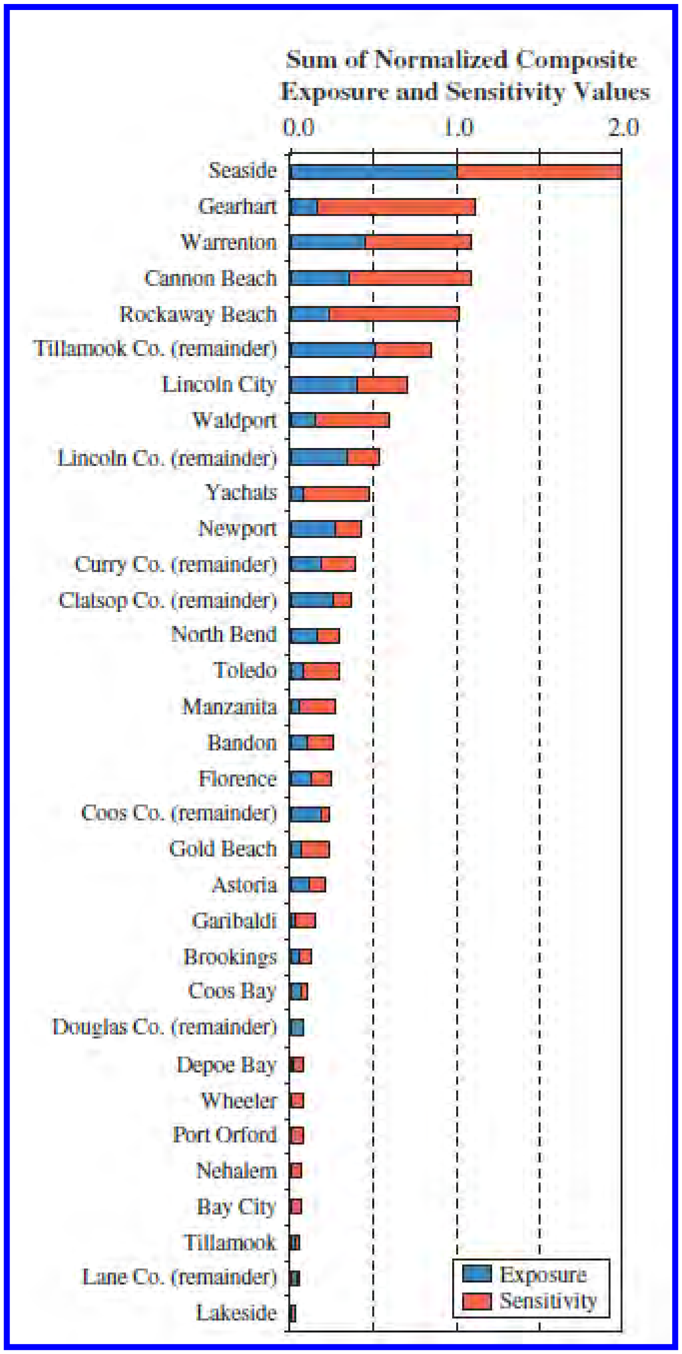
[69] Nathan Wood, *Variations in City Exposure and Sensitivity to Tsunami Hazards in Oregon*, US Geological Survey Scientific Investigations Report 2007-5283, p. 4.

[70] "In 2010, DOGAMI implemented a 4-year program (with funding from NOAA) to completely redo tsunami inundation zones for a range of potential "local" and "distant" earthquake sources, and ultimately the creation of an entirely new suite of tsunami evacuation maps for the entire Oregon coast. At the time of this writing, these new maps have been completed for the southern Oregon coast (Bandon to the Oregon/California border). New inundation modeling is presently underway for Tillamook County and the final maps should be available by December 2011." Personal communication from Jonathan Allan to Mitch Rohse, April 26, 2011

and assets are on high ground and the community is well-prepared for a tsunami, it may face little risk to life or property.

Vulnerability to tsunamis has been analyzed in recent work done by the US Geological Survey (USGS). In 2007, the USGS conducted a detailed study of community vulnerability to tsunami inundation for the entire Oregon coast.[71] The USGS study used a variety of measures such as the percentage of a community's developed land area in a tsunami-inundation zone. It then developed a composite index for summarizing the combined exposure and sensitivity of coastal communities to tsunamis. The study shows the city of Seaside to have the highest vulnerability of any community on the entire coast: it has both high exposure and high sensitivity to tsunami inundation. In Tillamook County, Rockaway Beach is rated as highly vulnerable, mainly because a large percentage of the city's businesses, homes, land values and population lie within the inundation zone. Rural Tillamook County (including the unincorporated communities of Cape Meares, Cloverdale, Oceanside, Neskowin, Netarts and Pacific City) ranks just below Rockaway Beach. It has a high vulnerability rating because of both high exposure and high sensitivity. This diagram from the USGS study shows the vulnerability rankings for the entire Oregon coast in graphic form.



From *Variations in City Exposure and Sensitivity to Tsunami Hazards in Oregon*, by Nathan Wood, US Geological Survey Scientific Investigations Report 2007-5283, 37 Figure 22, page 27.

[71] Nathan Wood, *Variations in City Exposure and Sensitivity to Tsunami Hazards in Oregon*, US Geological Survey Scientific Investigations Report 2007-5283, 37 pages.

Tillamook County's vulnerability to tsunami inundation has not gone unnoticed. The county has worked with DOGAMI and with the National Oceanic and Atmospheric Administration (NOAA) to increase public awareness and community resilience. As a result, Tillamook County is now one of three counties[72] in Oregon to be rated *TsunamiReady* by NOAA and the National Weather Service. Likewise, the cities of Manzanita, Nehalem, Rockaway Beach, and Wheeler also have achieved *TsunamiReady* status. NOAA's criteria for the tsunami readiness can be viewed on-line at http://www.tsunamiready.noaa.gov/guidelines.htm

The Oregon legislature passed laws in 1995 regulating development in tsunami-inundation zones. The main effect of those laws, now codified as Oregon Revised Statutes (ORS) 455.446 and 455.447, is to prohibit (with certain exceptions) the following types of new "essential" and "special occupancy" structures from being constructed in tsunami-prone areas:

- "Hospitals and other medical facilities having surgery and emergency treatment areas";
- "Fire and police stations";
- "Structures and equipment in government communication centers and other facilities required for emergency response";
- "Buildings with a capacity greater than 250 individuals for every public, private or parochial school through secondary level or child care centers";
- "Buildings for colleges or adult education schools with a capacity greater than 500 persons";
- "Jails and detention facilities."

For other new "essential facilities," "hazardous facilities," "major structures," and special occupancy structures" that may be permitted in a tsunami-inundation zone, developers first must consult with the state Department of Geology and Mineral Industries to consider the "impact of possible tsunamis on the proposed development" and "for assistance in preparing methods to mitigate risk at the site of a potential tsunami." See ORS Chapter 455 at http://www.leg.state.or.us/ors/455.html

For more information on tsunamis . . .

To learn more about tsunamis on the Oregon coast, visit the website maintained by Oregon's Department of Geology and Mineral Industries, at http://www.oregongeology.org/tsuclearinghouse/default.htm

See the US Geological Survey's website on tsunamis in the Pacific Northwest at http://walrus.wr.usgs.gov/tsunami/cascadia.html

Visit *Tsunami!* at http://www.ess.washington.edu/tsunami/index.html, a website hosted by the University of Washington's Department of Earth and Space Sciences. The site is "dedicated to providing general information about tsunamis, their causes and history as well as what to do in case of a tsunami."

The National Oceanic and Atmospheric Administration (NOAA) provides on-line information about tsunamis at http://www.tsunami.noaa.gov/

[72] The two other Oregon counties rated TsunamiReady are Coos and Douglas.

Climatic and Geologic Forces Affecting Coastal Erosion

	Factor	Relevance to Hazard(s)	Recent Conditions in on Northern Oregon Coast	Predicted Trend to 2050	Predicted Rate of Change	Quality of Evidence	Key Information Source
1	Deepwater wave heights	Probably the single most significant factor affecting coastal erosion and flooding. The larger the wave, the greater its impact on shore.	Max heights in range of 30 - 40 ft. Rising for at least 3 decades	Increase to max heights >50 ft	Increase 3-4 inches per yr in next 25 yrs	High	OSU, DOGAMI, NOAA
2	Sea level rise	An increase in sea level increases the extent of wave runup on shore, thus increasing erosion, flooding, and wave damage to shore properties	Rising worldwide, most recently at about 12" per century	Significant increase: 3.5 to 11.5 inches	At least 7-23 inches by 2100	High	NOAA, OSU, DOGAMI, IPCC (2007)
3	Frequency and intensity of El Niño events	El Niños increase erosion and flooding. They bring stronger winds, bigger waves, higher water levels, and more southerly storm track	Occur every 2 to 7 years. Max rise in water level, 1.3 ft	Unknown	Unknown	Medium	NOAA, DOGAMI, OSU
4	Rip current embayments	Strong rip currents cause rapid erosion at "hotspots," cutting deeply into beach and sometimes breeching spits. They often stop, start and move rapidly, hence are unpredictable	Uncertain; may be increasing, especially during El Niño events	Unknown	Unknown	Medium	OSU, NOAA, DOGAMI
5	Astronomical tide	Major factor in erosion when storms occur during high tide. Highly predictable.	4 tides per day; mean annual range 5-6 ft	No change	No change	High	OSU, NOAA, DOGAMI
6	Storm surge	Moderate factor in erosion during winter storms on Oregon coast. Has potential to be a big factor if occurring during high tide.	Max of 4.6 ft	Unknown	Unknown	High	OSU, NOAA, DOGAMI
7	Winter storm frequency	Frequency and extent of wave impact on shore is directly related to number of winter storms. More storms mean more erosion and flooding.	May be increasing	Probable increase, with El Niño	Unknown	Medium	NOAA, OSU
8	Vertical land movement	Subsidence increases extent of and damage from erosion and flooding, especially with RSL rise	Slight uplift (0.5 – 1.5 mm per year)	No change	No change	High	USGS
9	Decrease in sediment supply	Dams and shoreline structures reduce sediment that replenishes beaches, thus increasing beach erosion. Broad estuaries trap sand, keeping it from beaches.	Supply has declined. Extent and effect of decline uncertain.	Continuing decrease in supply	Unknown; probably gradual	Low	DOGAMI, OSU
10	Earthquakes	"Local" Cascadia Subduction Zone (CSZ) quake likely to cause sudden subsidence of coastal areas (~2-6 ft)	No recent major earth-quakes in NW	10-14 % chance of great quake (>M 8.0) in next 50 years		Medium	DOGAMI, USGS
11	Tsunamis	Local CSZ > M 9.0 could cause inundation and wave runup to elevations as high as 100 ft. The county is also susceptible to the effects of distant tsunamis, which can produce significant inundation and runup, though not as high as a local event.	Last known local CSZ quake, Jan 26, 1700. Most recent distant tsunami (Japan), Mar 11, 2011	At least 10-14 % chance of major tsunami in next 50 years		Medium	DOGAMI, USGS

9. Assessing Risks and Vulnerability

The definition of *risk* seems simple enough: in everyday usage, the word just means the possibility of suffering harm or loss. We often use it as a synonym for *danger*.

This seemingly simple little word, however, has great significance in fields such as finance, insurance, medicine, engineering and, most recently, climate change. It thus has been the subject of numerous writings attempting to bring greater precision to a broad term. A variety of definitions have emerged. For purposes of this plan, we use a definition from the field of engineering: *Risk is the probability that a specified event will occur times the consequences of that event, or, in mathematical form*, $\boldsymbol{R = P \times C}$.

Risk thus involves two main elements: *probability* and *consequences*. Consider, for example, the risk associated with walking across a narrow pedestrian bridge that spans a windy, rocky canyon. Now suppose that the bridge consists of a single plank six inches wide, without handrails, and the canyon is 1,000 feet deep. Clearly, the probability of falling is high, and the consequences of the resulting fall would be disastrous. Crossing the canyon, then, would obviously be a high-risk situation.

Risk decreases, however, with a change in either of the two variables. Suppose, for example, the bridge is not a six-inch wide plank but a sturdy, well-engineered structure with handrails. The *probability* of falling therefore decreases, as does risk, even though the consequences of a fall into the deep canyon remain severe. Conversely, if the “canyon” is only ten feet deep, with a soft layer of snow at the bottom, the risk of crossing is much less, even if the bridge still consists of that rail-less six-inch wide plank. That’s because the *consequences* of a fall are considerably less.

With coastal hazards, the probability of a hazardous event occurring usually is expressed as a percentage. For example, to describe an unusually powerful storm, we say “There’s a 1 in 100 (or one percent) chance of such a storm occurring.” In other words, out of every one hundred storms, we would expect just one to be so powerful.

Consequences can be expressed in variety of ways. Sometimes, they are stated in numerical units, such as dollars. In cases where such precision is not possible, consequences may be conveyed in terms of rankings along an ordinal scale, such as 1 to 5, with “1” indicating the least impact from a hazard and “5” representing extreme harm or damage. In many cases, consequences are simply expressed by descriptors such as “minor,” “moderate,” and “severe.”

In planning how to deal with coastal erosion, we cannot alter the likelihood that the climatic and geologic forces causing erosion will occur. We can’t stop sea level from rising or reduce the height of the waves that attack our coast. We can, however, estimate the probability that hazardous erosion will occur in any given place, assess that place’s *vulnerability*, and then take measures to lessen such vulnerability. Consequences thus are reduced, and risk is thereby lowered.

In assessing risk, scientists use the word *vulnerability* not only to describe the extent to which a community or place may experience a hazardous event but also that place's ability to withstand or quickly recover from the event. Vulnerability thus is defined to be a combination of three essential factors: *exposure*, *sensitivity*, and *resilience*. These three terms are explained in the diagram below.

Vulnerability **= Exposure + Sensitivity + Resilience**

Exposure **means the amount of a community's assets – population, buildings, resources, infrastructure – that lie within a hazard-prone area.** *Exposure* is an absolute term typically expressed in units such as people, dollars, or acres. For example, suppose that Community "A" has 50 homes containing 100 residents in tsunami-prone areas, while Community "B" has only 25 homes containing 50 residents in a tsunami-inundation zone. Community "A" has twice as much exposure. At least, it does if we consider only numbers of homes and people. We could change the result, however, if we measured other variables, too, such as value of real property or number of workers in the tsunami inundation zone.

Sensitivity **is a relative term to describe the degree to which a community's assets are exposed to the risk.** It is usually expressed as a percentage. Using the example above, suppose the 25 homes and 50 residents in Community "B" make up 50 percent of its population, while the 50 homes and 100 residents in "A" represent only 10 percent of the larger town's total number of homes and people. In such a case, "B" would have less exposure but greater sensitivity to tsunami inundation.

Resilience **means the capacity of a community to withstand, adapt to, and recover from a hazard event.** Again using the example of communities "A" and "B" and tsunamis, suppose that "A" has taken strong measures to inform its citizens about tsunamis, designated well-marked evacuation routes, and adopted strong code provisions regarding new development in tsunami-inundation zones. Meanwhile, "B" has done none of that. "A" would be the more resilient community, even though it has more exposure than "B."

As we saw in section 8.11 above, Tillamook County's coast is highly vulnerable to tsunamis because our coastal communities have a great deal of exposure to tsunamis and also are highly sensitive to them, because a large percentage of community assets lie with the tsunami-inundation zone. Tillamook County has, however, increased its resilience by taking measures to become "tsunami ready."

This adaptation plan is a similar type of measure. It is intended to increase the county's resilience with respect to the hazard of coastal erosion.

9.1 Estimating Exposure to Coastal Erosion

To evaluate exposure to coastal erosion in Tillamook County, the state's Department of Geology and Mineral Industries (DOGAMI) has studied and monitored erosion along the coast for the past decade. It has used new technology – Lidar ("light detection and ranging") and GPS surveys – to identify the location and extent of erosion along dune-backed and bluff-backed beaches. (The monitoring process and the results have already been described in Chapter 6.) DOGAMI and the county therefore have extensive, high-quality data to describe the coastal erosion that has been occurring over the past decade and more.

But where is hazardous erosion likely to occur in the future? To answer that question, researchers estimate the extent of erosion likely to occur under wide a range of conditions. The key variable is the total water level (TWL) at that critical point where the beach meets the adjoining dune or bluff. The higher the TWL, the greater the potential for erosion.

As explained earlier in this plan (on page 29) the total height of the ocean water level at a given beach is the sum of several "wave height factors," such as wave runup, tide and storm surge. One can create various scenarios by assuming certain combinations of these variables. For example, the "worst-case scenario" that can reasonably be expected would be a huge storm occurring at high tide after sea level has risen substantially. DOGAMI's scientists created a variety of scenarios and used them to delineate areas subject to high, moderate or low risk.

To estimate water levels, DOGAMI focused on two scenarios: the 50-year storm and the 100-year storm. The former, of course, is the storm more likely to occur. The 100-year storm, although less likely, would do greater damage and affect a larger area. The table below shows the factors used to define the two events.

Water Level Calculation: Water Height in Feet at Toe of Dune or Riprap

Wave Factor	50-Year Storm	100-Year Storm
Mean high tide	7.55	7.55
Monthly mean water level	1.31	1.31
Storm surge	3.28	5.58
Sea level rise	0	1.31
Wave runup*	14.34	17.72
Total	**26.48 feet**	**33.47 feet**

*Wave runup in turn is estimated using the assumptions shown in the table below.

Factors for Computing Wave Runup

Factor	50-Year Storm	100-Year Storm
Beach slope	4 percent	4 percent
Deep-water significant wave height	47.6 feet	52.5 feet
Wave period	17 seconds	20 seconds
Deep-water wave length	1,481 feet	2,050 feet

Data in the two tables above are from information submitted to the Neskowin Coastal Hazards Committee by DOGAMI's Jonathan Allan, for the committee's meeting of April 29, 2010.

Using scenarios for "design events" such as the storms described above, DOGAMI then was able to define and map four coastal erosion hazard zones along the two main types of beaches found in Tillamook County, dune-backed and bluff-backed. Dune-backed beaches typically erode more rapidly, in direct proportion to severity of storms and wave runup. In contrast, erosion of bluff-backed beaches is most directly related to the geological make-up of the bluff. The four types of hazard zones are summarized in the table below.

Beach Erosion Hazard Zones in Tillamook County			
Dune-Backed Beaches			
Zone	**General Location of Zone**	**Zone Width**	**Design Event**
Active Hazard	Sandy beach and foredune face	Width of beach plus dune face*	Significant erosion or accretion occurring now
High Risk	250-280 ft landward of dune-beach junction	250-280 ft	**Large storm:** Wave heights to 47.6 ft; above-avg. high tide; storm surge 3.3 ft
Moderate Risk	Next 415-460 ft landward of high-risk zone	415-460 ft	**Severe Storm:** Wave heights to 52.5 ft plus sea level rise of 1.3 ft
Low Risk	Next 460-510 ft landward of moderate-risk zone	460-510 ft	**Extreme Event**: Severe storm plus 3.3 ft subsidence from CSZ earthquake
Bluff-Backed Beaches			
Zone	**General Location of Zone**	**Zone Width**	**Design Event**
Active Hazard	Sandy beach; bluff toe; bluff face to top edge	Width of beach plus bluff face*	Significant erosion or accretion occurring now
High Risk	First 20-30 ft landward of bluff top edge	20-30 ft**	Gradual erosion at low mean rate over 60 yr period; bluff talus at ideal angle of repose
Moderate Risk	Next 40 to 250 ft land-ward of high-risk zone	40-250 ft**	Block failures, retreat to angle of repose; erosion over 60-100 yr period
Low Risk	Next 60-490 ft landward of moderate-risk zone	60-490 ft**	Erosion over 60-100 yr period; maximum slope failure; erosion to ideal angle of repose
* The active hazard zone occasionally extends landward beyond the dune face for various reasons.			
** Width of zone varies widely with composition of material in bluff			
This table summarizes information from Jonathan C. Allan and George R. Priest's *Evaluation of coastal erosion hazard zones along dune and bluff backed shorelines in Tillamook County, Oregon: Technical report to Tillamook County*, Portland, Oregon Department of Geology and Mineral Industries, 2001. 93 pp.			

9.2 Estimating Probabilities in a Changing Environment

The information and maps from DOGAMI identify zones that would be subject to erosion if certain design events occur. But what is the probability that such events will occur? Estimating such probabilities is made especially difficult by the dynamism of the coastal environment: as noted in the preceding chapter, several key factors such as global sea level and deep-water wave height off the Oregon coast have been changing and continue to change.

Researchers at Oregon State University's Department of Geosciences therefore began working on a method that considers such changes when estimating the probability of various design events. In a special project that focused on conditions at Neskowin, the OSU researchers developed a new probabilistic methodology to predict coastal erosion hazards. The results of that methodology are described in an unpublished master's thesis by student Heather Baron: "Incorporating Climate Change Uncertainty into a Probabilistic Methodology for Evaluating Future Coastal Change[73] Hazards and Community Exposure" (May 2011).[74]

The OSU methodology uses computer modeling to analyze an array of 1,800 scenarios. Each scenario expresses the total water level (TWL) that could be expected if a certain combination of conditions occurs. Such a combination is a "design event." OSU's methodology thus expands on DOGAMI's data by introducing a large range of variables and estimating the probability of erosion from multiple design events over several different time periods.

OSU's computer modeling enables different combinations of assumptions about future conditions to be analyzed. The model can assess an array of values for key variables such as sea level rise, deep-water ocean wave heights, and beach characteristics such as slope. The results help researchers to estimate the probability that a given area of the shore will experience erosion under a defined combination of circumstances during a specified period.[75] Such probability is expressed in statistical terms as a "confidence level." A confidence level of 98 percent, for example, implies very high probability that, under the specified conditions, the area in question would experience hazardous erosion. In contrast, a confidence level of 50 percent is essentially a statement that the probability of erosion occurring is 50-50: it might happen, it might not.

OSU's work has produced four dozen maps of coastal erosion hazards along Neskowin's shoreline, showing at-risk areas for various time periods and based on different assumptions about variables such as sea level rise. The map on the next page is one example: it shows probabilities of coastal erosion at Neskowin to the year 2050. These maps will enable Neskowin and Tillamook County to better assess Neskowin's exposure and to develop suitable policies and implementing measures to address the risk in that community.

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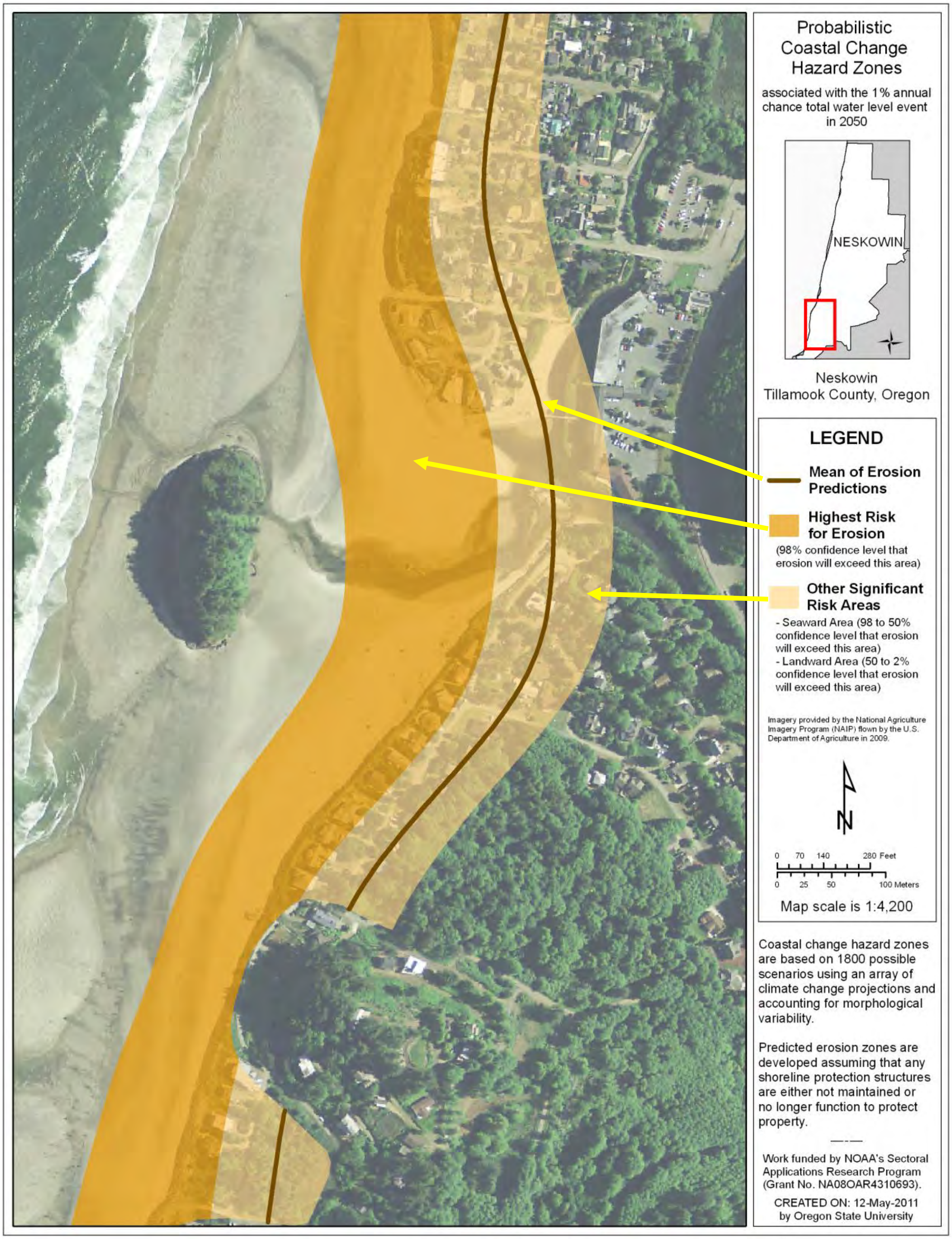
[73] Because this is a framework plan for adapting to hazards associated with coastal erosion and flooding, it typically speaks of "coastal *erosion* hazards." But design events such as a large winter storm may cause severe erosion to a beach in one place while widening it another. The scientific literature therefore sometimes speaks of "coastal *change* hazards," a term broad enough to include both erosion and accretion.

[74] Ms. Baron's faculty advisor, Peter Ruggiero, reviewed and commented on the first draft of this framework plan and worked closely with the Neskowin Coastal Hazards Committee during the writing of this plan.

[75] The target years used in OSU's model were 2009, 2030, 2050, and 2100.



This example of the maps prepared by OSU shows the familiar beach at Neskowin. Proposal Rock is the large dark oval near the breakers on the left side of the aerial photo. Together, the map and legend tell us the following:

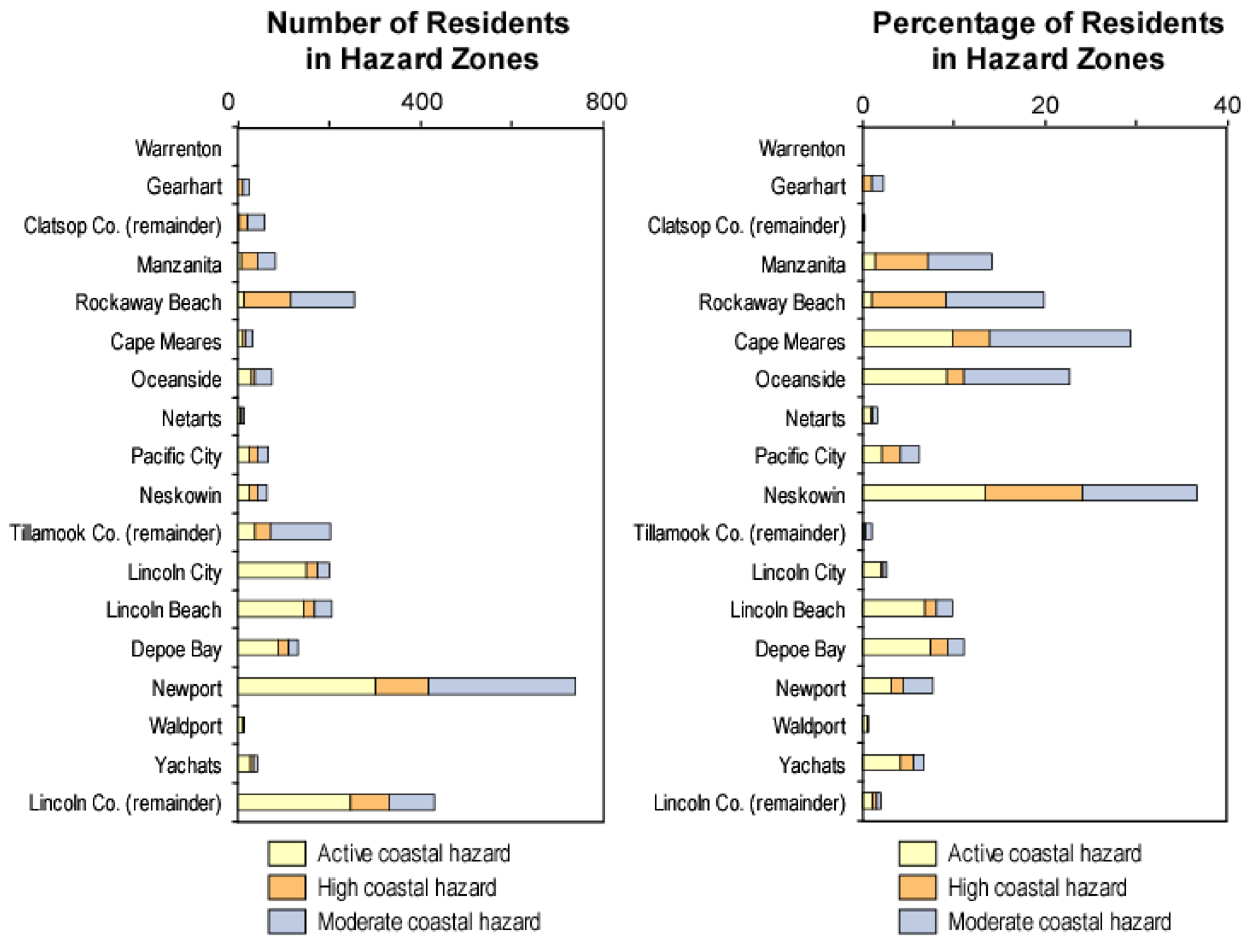
- The “design event” is a total water level with a one percent probability – a very high water level that, like the so-called “hundred-year flood,” has a one-in-a-hundred chance of occurring.
- If such an event occurs in the next few decades (by 2050), areas shown in the golden-brown[76] band running along the village’s shoreline have the “highest risk for erosion.” There is a 98 percent confidence level (near certainty) that hazardous erosion would occur here.
- An area immediately east (landward) of that also might experience hazardous erosion. The probability of that depends on how far seaward a given property lies. If the property adjoins the area marked “Highest Risk of Erosion,” there is a significant chance – approaching the 98 percent confidence level – that the property would erode. For a different property, at the landward edge of the area designated “Other Significant Risk,” there is a much smaller chance of erosion. Properties in between the seaward and landward edges of the Other Significant Risk Area thus all face some risk, ranging from just under 98 percent odds of erosion to as little as 2 percent. The farther seaward its location, the closer the odds of a property’s erosion come to the 98 percent confidence level.
- The line marked “Mean of Erosion Predictions” indicates the statistical center of the “Other Significant Risk Area.” A place on this line is somewhat likely to experience erosion. The confidence level of such erosion occurring here is midway between the 98 and the 2 percent levels.

Dune-backed beach at south end of Rockaway Beach, near Twin Rocks, looking north toward Cape Falcon. As one might guess from the presence of the drift logs behind the low foredune, this is an area subject to severe erosion.

[76] If printed on a monochrome printer, the area appears as a medium gray.

9.3 Estimating Sensitivity to Coastal Erosion Hazards

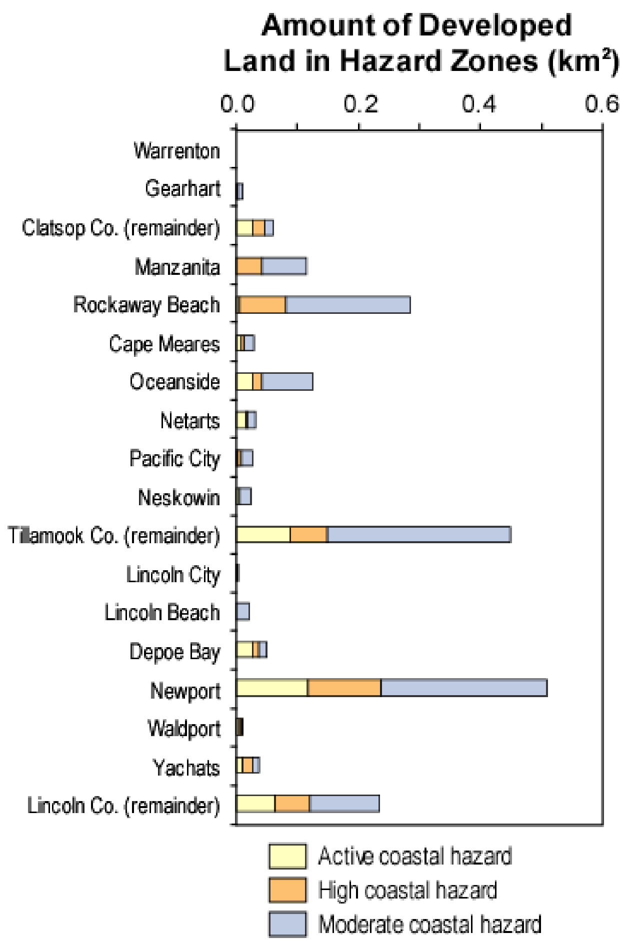
Researchers from DOGAMI and OSU have used erosion maps and data to determine the *exposure* and *sensitivity* of coastal communities in Oregon to coastal erosion.[77] The chart on the left, showing the number of residents living in the active, high, or moderate erosion zones, is one measure of a community's exposure to erosion hazards. The chart on the right, showing the percentage of a community's residents living in the active, high, or moderate erosion zones, indicates a community's sensitivity to coastal erosion.

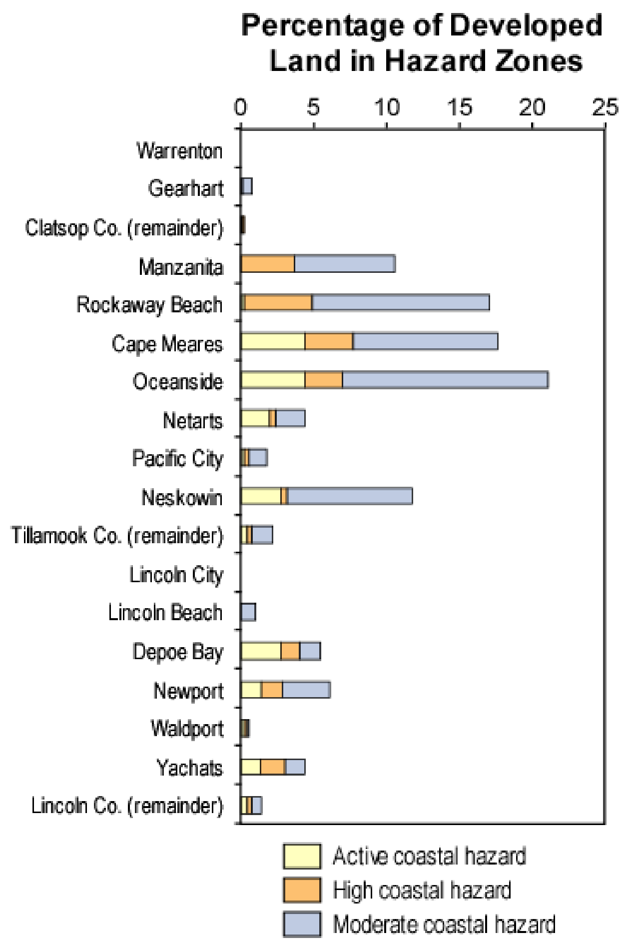


Note that the Tillamook County communities of Manzanita, Rockaway Beach, Cape Meares, Oceanside and Neskowin all share a common feature: because they are small communities, they do not have large numbers of people living in the three most hazardous erosion zones. By that measure, they may be considered to have only moderate exposure to erosion hazards. But because a large *percentage* of their residents reside in the three erosion zones, the communities do have a high sensitivity to such hazards. All five communities therefore are quite vulnerable to the hazards associated with coastal erosion, at least in terms of percentage of residents living in hazard-prone areas.

[77] These charts are based on DOGAMI's data and maps showing recent coastal erosion. They are not based on the OSU computer models and maps described in Section 9.2 on the preceding pages.

Another way to assess such vulnerability is to consider the extent of a community's developed land that lies within the erosion zones. The charts on the next page show the same five Tillamook County communities to be vulnerable to erosion hazards. They also reveal that rural areas of the county have significant amounts of developed land in erosion-prone areas.





Again, the small communities of Manzanita, Rockaway Beach, Cape Meares Oceanside, and Neskowin are revealed to have only moderate exposure to coastal erosion in terms of the absolute acreage of developed land in the active, high, or moderate erosion zones. But because they all have a high percentage of developed land in erosion-prone areas, they are sensitive to the hazard – and thus should be considered quite vulnerable.

The chart on the left also reveals that rural coastal areas of Tillamook County have a large amount of developed land in the active, high or moderate erosion zones. The amount is small when compared to the total acreage of the county, so the chart on the right indicates little sensitivity to the hazard. Coastal portions of the county that are not within municipal limits of incorporated cities and not within the boundaries of unincorporated rural communities thus have high exposure to coastal erosion and should be considered vulnerable to it, even though their sensitivity in county-wide terms is low.

10. Vulnerable Assets and Systems

As noted in the preceding chapter, risk from coastal erosion is the product of two key factors: the probability that hazardous erosion will occur and the consequences that would result from such erosion. We have little capacity to influence the probability that various geologic forces and events will occur. We can, however, control, to varying degree, the consequences: we can reduce costs and injuries from such events by taking steps to lessen our vulnerability.

Recall that vulnerability is a combination of three basic factors: *exposure*, *sensitivity*, and *resilience*. We can exert some control over exposure by ensuring that key assets and systems are not placed in hazardous areas. Likewise, we can limit a community's sensitivity by seeking to keep the majority of its assets and systems out of harm's way. Finally, we have a wide range of options with which to make any given place or community more resilient. We thus have considerable control over this aspect of vulnerability.

Consider, for example, the new city hall proposed for Cannon Beach, shown in the architectural rendering below. The new building would replace the old city hall, which is quite vulnerable to earthquakes and tsunamis. Plans call for the new structure to be elevated about 15 feet above

ground on stilts and protected by low walls. Tsunami waves would pass underneath it. Meanwhile, it would provide a vertical evacuation site for up to 1.000 people."[78] The structure thus would reduce the community's vulnerability to tsunamis in two ways: by increasing the resilience of the city government's main building, and by greatly increasing Cannon Beach's resilience.[79]

[78] Jay Raskin, Yumei Wang, Marcella M. Boyer, Tim Fiez, Javier Moncada, Kent Yu, and Harry Yeh, *Preliminary White Paper on Tsunami Evacuation Buildings (TEBs): A New Risk Management Approach to Cascadia Earth-quakes and Tsunamis,* March 20, 2009, on-line at http://www.ci.cannon-beach.or.us/docs/PS/CBTEB%203-20-09%20version.pdf

[79] For more information on vertical tsunami evacuation sites, see FEMA's See FEMA's "Guidelines for Design of Structures for Vertical Evacuation from Tsunamis" at http://www.fema.gov/library/viewRecord.do?id=3463

This example from Cannon Beach illustrates a key point in adaptation planning – that certain assets and systems are critical to a community's resilience: if they can be protected from hazards such as ocean flooding, the community will be far less vulnerable. Any discussion of these assets and systems must begin with a community's most important asset – people.

The people who live, work, visit and play along Tillamook County's coast are protected by emergency services such as police, fire protection, emergency communications such as 911 and reverse-911 calling, and medical treatment and transportation. In coastal areas, additional specialized services have been established to protect boaters, swimmers and people playing on the beach. For example, communities along our coast have personnel trained for beach and water rescues and specialized equipment, such as personal watercraft and four-by-four vehicles that can operate in sand. These programs and services for responding to hazard events are *emergency management*. That's not what this plan is about. Rather, it is about *risk management* – reducing vulnerability by reducing a community's exposure and sensitivity to coastal hazards and increasing its resilience. This type of risk management is accomplished by making good decisions about how and where we develop along the coast.[80] To do that, we need to consider the extent and type of physical assets and systems that already exist there. There are four main categories of these assets and systems.

The first category is the *built environment* – the homes, stores, motels and other structures on or near the coast that are vulnerable to shoreline erosion and hazards such as ocean flooding. The second is the service structures such as roads, water systems and sewers that together we describe as *infrastructure*. The third consists of *natural resources* such as beaches and wetlands. The fourth comprises a variety of key buildings and structures generally referred to as "*critical facilities*" They are "critical" in that they are especially vulnerable to coastal hazards *or* are essential for dealing with hazard events. A hospital is an example of a critical facility that is both vulnerable and essential. For that reason, hospitals should not be built in areas at risk from coastal hazards. The table on the next page shows the four systems and the main elements of each.

[80] "Community vulnerability . . . is primarily determined by how communities occupy and use hazard-prone land." Nathan Wood, *Variations in City Exposure and Sensitivity to Tsunami Hazards in Oregon*, US Geological Survey Scientific Investigations Report 2007-5283, p. 2.

Main Assets and Systems Vulnerable to Coastal Hazards			
Built Environment	**Infrastructure**	**Natural Resources**	**Critical Facilities**
Shorefront homes and other buildings subject to wave overtopping or beach, dune or bluff erosion	Roads, streets and bridges subject to coastal erosion or flooding	Beaches and dunes	Evacuation routes, including roadways, bridges and sidewalks,
Structures in low-lying areas subject to ocean flooding or tsunami inundation	Facilities for water treatment and distribution	Freshwater wetlands	Fire and police stations
Shorefront protective structures such as revetments and bulkheads	Facilities for sewage treatment and collection	Wildlife habitat	Hospitals
Coastal parks and recreational facilities	Law enforcement facilities	Surface water bodies (rivers, streams, lakes, estuaries, reservoirs)	Daycare centers; retirement centers; and nursing homes
Beach access facilities for the public (stairs, walkways, viewing platforms)	Fire protection facilities	Riparian areas	Places of public assembly including auditoriums, churches, theaters, gymnasiums and stadiums
Port facilities; marinas	Emergency medical services	Drainage swales	Schools
Historical, cultural or archeological resources in areas subject to erosion and flooding	Electrical distribution facilities such as transformers		Electricity generating plants and substations
	Natural gas distribution or storage facilities		Shelters, missions and residential care facilities
	Bicycle and pedestrian paths		Communications centers
	Regional pipelines or transmission systems		Dams
	Transit systems		Facilities for processing, storing or distributing hazardous materials
	Pump stations		Dikes and floodgates
			Airports

10.1 Built Environment

For assets in the "built environment" group, vulnerability is largely a result of exposure: they are, by definition, structures located in a coastal erosion hazard zone. Their vulnerability can be reduced only through the use of hazard alleviation techniques described in Chapter 11 or by relocating the structure. Relocation has, to this been point, been little used along the Oregon coast. That may change, however, as coastal erosion accelerates in some areas. In other states, most notably Alaska, entire communities have been relocated (at great cost) to safer upland sites after a combination of rising sea level and melting ice caused severe erosion.[81]

10.2 Infrastructure

Infrastructure is, to a large extent, tied to the built environment. To the extent that development occurs in the erosion hazard zone, the infrastructure that serves such development will have high exposure to hazards and thus high vulnerability. One example of such vulnerability was observed during the El Niño winter of 1997-1998, when extensive beach erosion caused severe damage to the City of Port Orford's sewage treatment system.[82]

Vulnerable infrastructure

"Coastal infrastructure will come under increased risk to damage and inundation under a changing climate with impacted sectors including transportation and navigation, coastal engineering structures (seawalls, riprap, jetties etc.) and flood control and prevention structures, water supply and waste/storm water systems, and recreation, travel and hospitality."

K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, December 2010, p. 209, at http://occri.net/wp-content/uploads/2011/01/OCAR2010_v1.2.pdf

10.3 Natural Resources

Of the natural resources affected by coastal erosion, the most vulnerable are, of course, the sandy beaches themselves and freshwater wetlands near the beaches, often located in the deflation plain behind the primary dune. One example is the extensive wetland in Neskowin between Highway 101 and the developed area on the village's foredune. Saltwater intrusion into wells and wetlands is a significant threat, not only to wetland resources in Tillamook County, but in coastal areas worldwide. The IPCC estimates that 30 percent of coastal wetlands worldwide may be lost by the end of this century, largely due to sea level rise.[83]

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[81] United States Government Accountability Office (GAO), *Alaska Native Villages: Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion,* GAO-09-551, June 2009, at http://www.gao.gov/htext/d09551.html

[82] Paul D. Komar, "El Niño and Coastal Erosion in the Pacific Northwest," *Oregon Geology*, Volume 60, Number 3, May/June 1998, p. 61

[83] Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report* (A Summary of IPCC's Fourth Assessment Report (AR4)), p. 10. On-line at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Estuaries also are vulnerable: climate change and sea level rise are likely to increase salinity of estuarine waters, altering and perhaps damaging significant fish and riparian habitat. Shallow tidal basins are especially vulnerable to such estuarine inundation. For example, in the Nestucca Bay National Wildlife Refuge, "7%-30% of the dry land is predicted to be lost" by 2100.[84]

Vulnerable wildlife

"The 2010 *State of the Birds* evaluated vulnerability to climate change for every avian species in North America (NABCI, 2010). Among all Oregon birds, nine species were given the highest rating for vulnerability and *all were coastal species*. *[Emphasis added]* Two of these species were breeding Black Oystercatchers (*Haematopus bachmani*; Fig. 7.4) and Pigeon Guillemots (*Cepphus columba*), and seven were species that migrated through or wintered on the Oregon coast: Surfbird (*Aphriza virgata*), Wandering Tattler (*Tringa incana*), Yellow-Billed Loon (*Gavia adamsii*), Black Turnstone (*Arenaria melanocephala*), Western Sandpiper (*Calidris mauri*), Rock Sandpiper (*Calidris ptilocnemis*), and Short-Billed Dowitcher (*Limnodromus griseus*; also found in the Willamette Valley and Great Basin)."

"Rising sea levels and ocean acidification threaten breeding and feeding habitats, respectively, for these Black Oystercatchers, one of nine bird species in Oregon given the highest rating for vulnerability to climate change by the North American Bird Conservation Initiative (NACBI, 2010). Photo by Brian Guzzetti." From K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, December 2010, p. 277, at http://occri.net/wp-content/uploads/2011/01/OCAR2010_v1.2.pdf

[84] K.D. Dello and P.W. Mote, editors, *Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, December 2010, p. 236

10.4 Critical Facilities

The term "critical facilities" has long been used by planners to encompass a large and varied group of land uses that are especially vulnerable to hazards such as flooding and therefore should not be constructed on hazard-prone sites. Recent studies of risk management, however, have grown more precise in identifying and classifying such facilities, and that precision is reflected in Oregon's statutes. As noted in Section 8.11, the Oregon legislature passed laws in 1995 to regulate development in tsunami-inundation zones. Now codified as Oregon Revised Statutes (ORS) 455.446 and 455.447, the laws distinguish four categories of land uses that are restricted or prohibited from being built in tsunami-prone areas:

Essential Facilities

"(A) Hospitals and other medical facilities having surgery and emergency treatment areas;
(B) Fire and police stations;
(C) Tanks or other structures containing, housing or supporting water or fire-suppression materials or equipment required for the protection of essential or hazardous facilities or special occupancy structures;
(D) Emergency vehicle shelters and garages;
(E) Structures and equipment in emergency-preparedness centers;
(F) Standby power generating equipment for essential facilities; and
(G) Structures and equipment in government communication centers and other facilities required for emergency response."

Hazardous Facilities

"Structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be of danger to the safety of the public if released."

Major structures

"Buildings over six stories in height with an aggregate floor area of 60,000 square feet or more, every building over 10 stories in height and parking structures as determined by Department of Consumer and Business Services rule."

Special occupancy structures

"(A) Covered structures whose primary occupancy is public assembly with a capacity greater than 300 persons;
(B) Buildings with a capacity greater than 250 individuals for every public, private or parochial school through secondary level or child care centers;
(C) Buildings for colleges or adult education schools with a capacity greater than 500 persons;
(D) Medical facilities with 50 or more resident, incapacitated patients not included in subparagraphs (A) to (C) of this paragraph;
(E) Jails and detention facilities; and
(F) All structures and occupancies with a capacity greater than 5,000 persons."

The above terms were developed in consideration of the catastrophic hazard of tsunamis, not the chronic hazard of coastal erosion. The four-part division is useful, however, in considering what types of land uses should be limited or prohibited in a coastal erosion zone. This plan identifies these four main categories:

Essential facilities are those buildings and structures needed to perform or support emergency services during or immediately after a hazard event such as a landslide – fire and police stations, for example.

Hazardous facilities are those that, if damaged during a hazard event, would pose a danger to the public – fuel storage tanks, for example.

Places of public assembly are facilities where large numbers of people gather – churches, theaters, and auditoriums, for example.[85]

Special occupancy structures are buildings that house populations especially vulnerable to hazard events – schools, day-care centers, retirement homes and jails, for example.

Placing these types of land uses in the coastal erosion zone increases the community's vulnerability to coastal hazards. Having essential facilities there increases vulnerability because the facilities lose their effectiveness by being themselves at risk from coastal hazards. Hazardous facilities in the erosion zone increase the vulnerability of others by putting them at risk from fires, explosions or contamination if the facility is damaged or destroyed by a coastal hazard such as a landslide. Siting places of public assembly in the erosion zone increases vulnerability by putting large numbers of people in harm's way, increasing the risk to them from hazard events and making their evacuation more difficult. Finally, placing special occupancy structures in the erosion hazard zone increases vulnerability by increasing risk of hazards for those people least able to avoid or withstand them.

Finally, a special category of land uses to be considering in risk management is the group of service systems known as *lifelines*. Lifelines are linear utility or infrastructure networks or segments thereof essential to public health and safety during and after a hazard event. The term includes critical roads, water lines, electricity distribution facilities, pipelines and communications. The distinction between, say, an evacuation route considered a lifeline and an ordinary street that's not considered a lifeline sometimes is difficult to discern. The general rule, however, is that networks or segments of networks counted as lifelines should be developed as much as possible outside of hazard-prone area or given special protection where they must extend into such areas.

For an example of how lifelines have been classified and mapped in one community, see *Lifelines and Earthquake Hazards in the Greater Seattle Area*, by Haugerud, Ballantyne, Weaver, Meagher and Barnett, at http://geomaps.wr.usgs.gov/pacnw/lifeline/index.html

For the smaller coastal communities in Tillamook County, the lifelines of greatest concern are likely to be collector streets that link developed areas west of Highway 101 to that highway or the main north-south county road. Most of these collectors share many or all the following characteristics:

- They are vital ingress routes for first responders during emergencies and hazard events.
- They are equally vital egress routes for people evacuating the community.

[85] ORS 455.640(5) presents this definition: "'Structures of public assembly'" means structures which the public may enter for such purposes as deliberation, education, worship, shopping, entertainment, amusement or awaiting transportation."

- They are east-west routes perpendicular to the coast. They therefore pass through low-lying flood-prone areas such as deflation plains and wetlands, or they pass over coastal bluffs and passes prone to landslides.
- They are few in number, and hence may lack capacity for a sudden increase in traffic volume. Some communities or developed areas have only one or two of these collectors.
- They do not connect with other collectors. For example, the unincorporated community of Tierra del Mar is served mainly by a handful of east-west streets that extend from the developed foredune to Highway 101 but lack any north-south connection with each other. No alternate route is available if such a collector is blocked.
- In many cases, these lifeline collectors cross a low-lying bridge that is especially vulnerable to ocean flooding, earthquakes and tsunamis. Most of Neskowin, for example, is served by a single collector that crosses a bridge at Hawk Creek. The bridge deck is sometimes submerged during winter storms, and it is frequently battered by massive logs and debris. Most of these bridges perform multiple functions. In addition to carrying motor vehicles, they also serve as the main pedestrian and bicycle paths to Highway 101 and as river-crossing platforms for utilities such as water and sewer lines suspended beneath the bridge. Bridge failure during a hazard event thus may block vehicular travel, prevent the passage of pedestrians and cyclists, *and* break key utility connections.

Developed areas and communities in Tillamook County with these vulnerable lifeline collectors include the following (listed from north to south):

- Neahkahnie Beach
- Manzanita
- Nehalem Bay State Park
- Nedonna Beach
- Manhattan Beach
- Rockaway Beach
- Twin Rocks
- Watseco
- Cape Meares
- Oceanside
- Netarts
- Whalen Island Park
- Pacific City
- Robert W. Straub State Park
- Winema Beach
- Neskowin
- South Neskowin

The vulnerability of these lifeline collectors is a central concern in Tillamook County's effort to become more ready for and resilient to coastal erosion and related hazards.

11. Hazard Alleviation Techniques (HATs)

The preceding description of coastal erosion hazards and vulnerabilities leads to an obvious question: what can we do about them? That is, what measures can we take to reduce or eliminate impacts of hazardous events like beach erosion or flooding? Such measures are referred to as *hazard alleviation techniques* or HATs. Think of them as the tools that make up our toolkit for adapting to coastal hazards.

Outlined below are the main hazard alleviation techniques known to have been used in various places around the US and elsewhere. The list is long, but not all these would necessarily be effective or even possible to use in Tillamook County. For example, sand bypass systems are used on the east coast to move sand past inlets, which are common on barrier islands there. The much more rugged Oregon coast has no barrier islands and few inlets, so sand bypass is not likely to be useful for most conditions in Tillamook County.

Category 1: Hard (Structural) HATs

> "A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change."
>
> Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report* (A Summary of IPCC's Fourth Assessment Report (AR4)), p. 14. On-line at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Structures parallel to shore:

Bulkhead – A vertical retaining wall to impound sand or soil thus prevent sloughing or erosion of coastal property. See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;186&g=41

Revetment (including *riprap*) – A sloping rock face to protect beachfront property. See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;141&g=41

Sand bypass – A hydraulic or mechanical system to move sand around some obstacle, typically an inlet, from an accreting area to an eroding area.

Seawall – A vertical wall, often concrete, primarily to protect property against wave attack. See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;140&g=41

Sill – A low nearshore wall similar to a breakwater; it enables sand to build up behind it, creating a "perched beach." See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;189&g=41

Structures perpendicular to shore:

Groin – A short wall, usually one in a series, extending seaward from shore, intended to trap sand and reduce beach erosion. See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;188&g=41

Jetty – A stone or concrete wall extending from the shore seaward at the mouth of river. See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;514&g=41

Structures offshore:

Artificial reef – An offshore underwater mound or ridge intended to reduce or redirect wave impact. A variety of materials including derelict ships intentionally sunk offshore have been used to create such reefs.

Breakwater – A nearshore rock or concrete wall extending above the water's surface to reduce or redirect wave impact. See http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;187&g=41

Reef breakwater – A nearshore underwater mound or ridge intended to reduce or redirect wave impact. The most common type is made of rubble, but a variety of materials have been employed, including sand, thereby creating an artificial offshore sandbar. A variation on this theme is to enclose the sand in long geo-textile tubes called *sea bags*.

Category 2: Soft (Nonstructural) HATs

Beach nourishment – The replenishment of sand eroded from a beach by importing sand from some other location. Usually, the imported sand is pumped onto the beach from a barge anchored above an offshore source of sand known as a *borrow pit*. See NOAA's *Beach Nourishment: A Guide for Local Government Officials* at http://www.csc.noaa.gov/beachnourishment/html/human/law/history.htm

Buffer dune – A low artificial dune created along an eroding beach to dissipate wave energy and thereby reduce beach erosion. See "Navarre Beach: Providing Protection for the Panhandle," in *Coastal Voice*, the newsletter of the American Shore & Beach Preservation Association, September 2010, p. 13.

Dune management – The reshaping of a dune's height and shape with heavy equipment for purposes of flood control, view protection, or sand inundation prevention. See DLCD's *Dune Management Planning*.

Dune stabilization – The use of plantings (of European beach grass, for example) and, sometimes, dune fencing to reduce the effects of wind erosion. See "Invasion of New Beach Grass Could Weaken Shoreline Protect in *Science News,* September 26, 2007, at http://www.sciencedaily.com/releases/2007/09/070923203558.htm

Dynamic riprap (a.k.a. *cobble berm* or *rubble beach*) – A form of shore protection in which a cobble berm is placed on an eroding beach to dissipate wave impact. Cobble is essentially large gravel, with individual stones ranging from about 2 to 10 inches in diameter. See DOGAMI'S *Dynamic Revetment for Coastal Erosion in Oregon* at http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/DynamicRevetments.pdf

Category 3: Development HATs

Abandonment of building – To surrender a building to whatever damage or destruction may occur from a coastal hazard.

Increased elevation of building – To raise an existing building higher or to build a new structure to a specified height so as to avoid some hazard such as flooding or wave overtopping.

Making buildings movable – To design and build structures so that they can be moved to safer locations during times of increased risk from hazards such as ocean flooding.

Relocation of building – To move a building from a high-risk site to a site of lower risk.

Relocation of community – To move a community from a high-risk site to a site of lower risk.

Relocation of infrastructure – To move or re-route public facilities such as roads, sewers, water lines, and bridges to (a) make them less vulnerable to coastal hazards and (b) to ensure that critical facilities will be operable during hazard events.

Runoff and drainage controls – To design, build and manage coastal development so as to reduce runoff or drainage that contributes to coastal erosion.

Special building techniques – To design and build structures sited in higher-risk areas in such a way as to (a) increase the safety and integrity of the structure itself, and (b) to lessen risk that the structure's failure might cause harm or damage to others.

Category 4: Policy and Planning HATs

Compensatory mitigation – **Example**: A development permit applicant must pay fee to compensate for costs to public resulting from the development (typically, for costs of beach nourishment)

Conditions of development –

- *Floor elevation requirement*: Lowest habitable floor of development must be constructed at a specified elevation such as one foot above base flood elevation
- *Geological reconnaissance*: Development approval is contingent on a brief report from a qualified geologist who visits site and, based on observations, finds development to be appropriate
- *Geotechnical report*: Development approval is contingent on a detailed study from a qualified geologist who visits site and, based on scientific observations and field testing, finds development to be appropriate
- *Indemnification*: Applicant for a development permit must indemnify the government entity approving the development on a hazardous site – that is, hold the government harmless from any third-party litigation resulting from damage caused by the development
- *Land division standards* – **Example**: Land may not be partitioned or subdivided unless the newly created parcels or lots have building sites outside of active erosion or high risk areas
- *Liability waiver*: Applicant for a development permit must sign a waiver declaring that, in the event of any damage to that development resulting from a hazard event, he or she waives the right to sue the government entity that approved the development
- *Safe-site requirement*: Development may be approved only on that portion of a lot or parcel deemed suitable.

Conservation easement – **Example**: A property owner is paid by a public agency or nongovernmental organization to conserve land from certain types of use or development

Floodplain management – Development in flood-prone areas is regulated in accordance with FEMA floodplain management regulations

Hazard-area overlay zone – Areas at risk from hazards such as erosion or landslides are subject to hazards overlay zone, which sets standards and requirements based on type and degree of risk

Prohibition of development – New development is not allowed on sites determined to be at specified risk from hazard

Public education – Development officials prepare materials on coastal hazards and conduct programs to notify and inform key audiences

Public notification and review – Proposals for new development in specified areas must secure a coastal hazards permit through a review process that involves notification to interested persons and agencies, opportunity for public comment, notice of decision, and opportunity to appeal

Purchase of development rights (PDR) – Governments or nongovernmental organizations buy all rights to development of selected property for purposes of eliminating risk to development there or to facilitate hazard management of nearby property

Setback – Development is not permitted within a specified distance of some feature

Transfer of development rights (TDR) – A process in which the owner of a "receiving property" may buy development rights from a "sending property." The owner of the sending property thus gets reimbursed for a lost right to develop, while the owner of the receiving property gains a right to develop more intensively on his or her property. **Example**: Under current zoning, the owner of a vacant farm parcel has the legal right to build one dwelling. She sells that right to the owner of a rural residential parcel that, without the transfer, has a right to build only one dwelling. The transfer thus leaves the farm parcel protected from development and doubles the development potential of the rural residential parcel, all at no cost to taxpayers.

11.1 Choosing the Right HAT

We have quite a variety of tools to choose from: the toolkit for dealing with coastal hazards is large. To determine which hazard alleviation technique (HAT) is best for a given situation, we need to consider a multitude of factors:

Effectiveness – To what extent will the HAT that's being considered alleviate the coastal hazard?

Capital Cost – What will be the initial costs to build or put into effect the HAT?

Maintenance Costs – How much will the HAT cost to maintain over time?

Funding Availability – Does a reliable source of funding exist, both for the initial costs of the HAT *and* for its continued maintenance?

Materials Availability – Are essential materials such as suitable rock for riprap or sand for beach nourishment available at a reasonable price?

Durability (a.k.a. "design life") – To what extent is the HAT an enduring long-term solution to the problems presented by the hazard?

Environmental Impact – Are the likely effects of this HAT on environmental systems and natural resources consistent with local, state and federal standards and proportionate to the benefits of the HAT to development?

Public Access – Will the HAT ensure adequate public access to coastal resources?

Public Safety – Will the HAT ensure adequate safety for citizens residing or working in hazardous areas and for visitors to such areas?

Legality – Is the HAT consistent with local, state and federal laws regarding coastal hazards, coastal resources, and coastal zone management?

Design – If the HAT alters the built environment or natural environment, are such alterations consistent with local standards for design, appearance and visual impact?

Unfortunately, despite the significance of the eleven factors described above, many of them are given short shrift when it comes to deciding which HAT to use in a given situation. That's because such decisions often are made only when a catastrophic event such as an extreme winter storm suddenly reminds us about the hazards of coastal erosion. At that moment, short-term effectiveness tends to trump everything else. The result is likely to be selection of a "hard" structural HAT that may quickly reduce the immediate threat to beachfront properties but also creates long-term problems for entire community.

This tendency for most responses to coastal erosion to be short-term, reactive decisions is one of the key reasons to have an adaptation plan. Such a plan provides a forum in which we can consider all the factors listed above and thereby take long-term pro-active measures for dealing with coastal erosion – before the next big storm.

The table on the next page summarizes the main hazard alleviation techniques available and the key factors that should be considered when deciding which HAT to use.

Factors To Consider in Choosing Erosion Hazard Alleviation Techniques (HATs)											
	Effective-ness	Capital Costs	Maint. Costs	Funding Availability	Materials Availability	Durability	Environ. Impact	Public Access	Public Safety	Legality	Design
1. Hard (Structural) HATs											
Bulkhead											
Revetment											
Sand bypass											
Seawall											
Sill (for “perched beach”)											
Groin											
Jetty											
Artificial reef											
Breakwater											
Reef breakwater											
2. Soft (Nonstructural) HATs											
Beach nourishment											
Buffer dune											
Dune management											
Dune stabilization											
Dynamic riprap											
3. Development HATs											
Abandon structure											
Elevate structure											
Make structure movable											
Relocate structure											
Relocate community											
Modify or relocate infrastructure											
Control runoff and drainage											
Modify structure											
4. Policy and Planning HATs											
Compensatory mitigation											
Conservation easement											
Floor elevation COD (*Condition of Development*)											
Require geologic reconnaissance (COD)											
Require geotech report (COD)											
Indemnification (COD)											
Land div. standards (COD)											
Liability waiver (COD)											
Safe-site requirement (COD)											
Floodplain management											
Hazard-area overlay zone											
Prohibition of development											
Public notice and review											
Public education											
Purchase of developmt rights											
Setback											
Transfer of developmt rights											

Storm berm constructed at Navarre, Florida, in 2006 to protect the beach and shoreline properties
Paden E. Woodruff III, "Providing Protection for the Panhandle," in *Coastal Voice: The Newsletter of the American Shore & Beach Preservation Association, September 2010*, p. 16.

12. Funding and Technical Assistance

For a community preparing for and adapting to geologic hazards, the most difficult question often may be "How shall we pay for it?" NOAA answers that with what might be called guarded optimism:

> One of the biggest challenges to the implementation of climate change adaptation actions is funding. This will likely require creativity and networking and will be an ongoing effort. Currently, there is not a lot of funding directly targeted at climate change adaptation. But, there are a number of grant opportunities for restoration, conservation, hazard mitigation, infrastructure (e.g., installing new/updating existing), and community and economic development.[86]

This chapter describes some of those funding opportunities, sources and strategies (as well as some examples), beginning with the private sector and moving then to local, state and federal sources and programs. It also mentions several opportunities for technical assistance. In some cases, the distinction between "state" and "federal" programs is blurred, in that federal grants sustain certain state programs.

It is important to note the major distinction between *planning assistance* and *project assistance*. Planning assistance is funding and technical aid for communities to develop local plans for dealing with coastal hazards. Project assistance is funding and technical aid for specific hazard alleviation techniques such as building a seawall. Some state and federal agencies provide planning assistance but not project assistance. Others provide project assistance but not planning assistance. Few, if any, provide both. For example, NOAA and the Oregon Coastal Management Program, which administers several NOAA grant programs in this state, offer funding and technical assistance for plans such as this one, but have no funds or programs to develop local projects. In contrast, FEMA provides funding and technical assistance for a wide range of hazard alleviation projects – even relocation of entire communities.

In the past, hazard "mitigation" often consisted mainly of large public works projects such as dams and levees, and rapid emergency response to catastrophic hazards such as hurricanes. More recently, however, many state and federal agencies have been placing an increased emphasis on adaptation and preparedness planning. Today, sound local adaptation planning often is a prerequisite for the limited amount of state or federal project funding that is available.

12.1 Private Funding

In most cases today, adaptation to coastal erosion consists largely of sporadic actions by individual owners of beachfront properties seeking to protect their property from damaging erosion. These piecemeal efforts often are uncoordinated and unplanned –

[86] National Oceanic and Atmospheric Administration (NOAA). *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA Office of Ocean and Coastal Resource Management. 2010. P. 103. http://coastalmanagement.noaa.gov/climate/adaptation.html

hasty measures taken in response to damage from the last big storm. Typically, the solutions seized on are structural – riprap revetments, for example. The urgent need to protect beachfront structures tends to trump other considerations, such as the long term cumulative effects of such structures.

Private "homeowners insurance" (property insurance) often is assumed to be the main source of funding for recouping costs from coastal erosion. That assumption is rarely warranted, however, for two reasons.

First, the standard homeowner policy typically *excludes* damage caused by earthquakes, flooding, landslide, mudslide, or earth movement. Separate policies are commonly available for flooding and earthquakes, but coverage usually is not available for landslides and mudslides. It is important for owners of coastal property to know that earthquake insurance does ***not*** cover a loss caused by landslides, erosion, or tsunamis, even if an earthquake causes them to happen. Coastal residents can get flood insurance through the National Flood Insurance Program that will protect against a tsunami.[87] Flood insurance obtained through that program, however, is limited to a maximum of $250,000 on a residential building. Many beachfront homes cost much more than that.

Second, the huge losses incurred by companies insuring Gulf Coast properties after 2005's hurricane Katrina caused many carriers to raise rates, increase deductibles, and exclude more "perils" from coverage. In some coastal areas, major carriers have stopped issuing new homeowners policies altogether. Others have declined even to renew existing policies.[88] One major carrier is said to have adopted a nation-wide policy of issuing no coverage for any property within 1,000 feet of the ocean, but we have been unable to verify that. In any case, property insurance in the post-Katrina era seems likely to be more expensive, more difficult to obtain, and less comprehensive in its coverage.

Such problems became so severe in Florida that the state established a not-for-profit "Citizens Property Insurance Corporation" that now is the largest home insurer in the state. The corporation describes itself this way:

> Citizens is a not-for-profit, tax-exempt government corporation whose public purpose is to provide insurance protection to Florida property owners throughout the state. The corporation insures hundreds of thousands of homes, businesses and condominiums whose owners otherwise might not be able to find coverage.[89]

One may argue that this is as far as an investigation of funding sources should go – that is, private property owners should pay all the costs to protect their individual properties from coastal erosion, either through private insurance or from their own pockets. That argument overlooks several significant questions of public policy, however.

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[87] Oregon Department of Consumer and Business Services, Insurance Division, "Insurance Tips," June 2009, at http://www.cbs.state.or.us/external/ins/consumer/consumer-tips/4845-5_earthquakes.pdf
[88] "5 years after Katrina, homeowners insurance costs more," *USA Today*, August 26, 2010.
[89] Citizens Property Insurance Corporation website, https://www.citizensfla.com/about/generalinfo.cfm

1. Do piecemeal actions of private property owners have significant public effects on coastal communities and natural resources?
2. Do costs of adapting to coastal erosion or repairing damage from it sometimes exceed the capacity of individual landowners to pay them?
3. If coastal erosion threatens not only beachfront dwellings but also a significant portion of a community's infrastructure, land and resources, should the public bear some or all the costs of hazard alleviation?

The answer to these questions will vary from one situation to another, but it surely is "Yes" in many cases. Adapting to coastal erosion thus is likely to require public support, and some form of local, state or federal funding.

12.2 Local Funding

Where a broader local funding base is needed, there are several options. Perhaps the most common source of project funding is the local improvement district or LID. With an LID, citizens with a common purpose, such as protecting their property from erosion, can form a district within which they generate revenue for the project by taxing themselves. In Oregon, the process for establishing such a district is prescribed by ORS Chapter 223. LIDs are solely for the purpose of funding "capital improvements," so this may not be a suitable funding mechanism for the numerous (and often superior) non-structural hazard alleviation techniques described in Chapter 11.

A related form of local project funding is the systems development charge or SDC. The SDC is a way of paying for off-site costs to a community generated by land development. The SDC process is prescribed by ORS 223.297 – 223.315. The statute strictly limits the way in which municipalities may spend revenue from SDCs. Generally, the funds are to be used for roads, sewers, water systems, storm drains, and parks. But ORS 223.299 (1)(a)(C) does provide that SDC revenues may be used for capital improvements related to "drainage and flood control." Whether this phrase encompasses hazard alleviation techniques for coastal erosion is uncertain. In any case, the SDC probably has little potential as a source of funding for hazard alleviation in most coastal communities, because it deals solely with capital improvements. As with LIDs, this requirement would limit its use to structural HATs. Also, the relatively small amounts of development in small coastal communities probably would not generate sufficient revenues.

Another potential local revenue source is the compensatory mitigation fee. This is a charge leveed on property owners to compensate for certain impacts of their development on the community. It does not appear to have been used in Oregon. We find it mentioned in the state of Hawaii's *Coastal Erosion Management Plan* with no explanation of its use or effectiveness. In that state, where the armoring of many miles of coastline has caused massive erosion of beaches, the revenue from the fee is to be used for the expensive and continuing process of "beach nourishment" (replenishment of sand). *Hawaii's Coastal Erosion Management Plan* describes the fee thus:

> **Compensatory Mitigation** If environmental impacts cannot be minimized, the concept of compensatory mitigation can be employed where the landowner contributes to the

state or county an amount related to the costs to develop or replenish similar beach resources elsewhere.[90]

The traditional local methods of fund-raising in Oregon, such as bonding and taxation, presumably can be used to fund coastal erosion adaptation projects and programs. We know of no municipality in Oregon that has passed bond measures specifically for that purpose.

In Oregon, most local adaptation planning is paid for through a combination of federal grants matched with local funding and in-kind services. Typically, the local planning or community development department provides local staffing, while state agencies such as DLCD's Oregon Coastal Management Program provide planning grants and technical assistance, which often originate with federal programs and agencies.

12.3 State Funding and Technical Assistance

Most adaptation planning in the United States occurs through state-level programs funded partly through federal grants. In Oregon, the key agencies and programs are these:

Oregon Department of Land Conservation's Ocean and Coastal Management Program. DLCD and the OCMP administer Oregon's federally approved Coastal Zone Management (CZM) Program. The state thus receives a variety of federal funds (described in the next section) for various coastal programs, some of which deal with coastal erosion.

Oregon Parks and Recreation Department. OPRD is charged with "protecting and preserving the recreation, scenic and natural resource values found on Oregon's ocean shore." It is the lead agency in administering permits for shoreline protective structures. It has no grant or technical assistance programs for coastal erosion adaptation.

Oregon State University, through its Sea Grant program (see next section), provides both technical and limited financial assistance to coastal communities. OCMP, OPRD and OSU/Sea Grant all played a significant part in providing resources and technical assistance to Tillamook County for development of this plan.

Oregon Partnership for Disaster Resilience. Since 2000, OPDR at the University of Oregon's Community Service Center has been leading a statewide planning initiative to build capacity for the development of state, regional, and local mitigation plans and projects. Natural hazard mitigation planning occurs in partnership with Oregon Emergency Management, Department of Land Conservation and Development, Department of Geology and Mineral Industries, FEMA Region X, and local governments throughout Oregon. See http://opdr.uoregon.edu/mitigation

[90] Hawaii Department of Land and Natural Resources, *Coastal Erosion Management Plan – COEMAP,* 2000, p. 25, at http://hawaii.gov/dlnr/occl/documents-forms/policies-plans/coemap.pdf/view

University of Oregon. In Oregon, a unique program for technical assistance to small and rural communities is the University of Oregon's RARE Program. RARE recently sent out this announcement about its program for 2011:

> The Resource Assistance for Rural Environments (RARE) Program is currently recruiting non-profit and governmental organizations for the 2011 - 2012 program year. The mission of the RARE Program is to increase the capacity of rural communities to improve their economic, social, and environmental conditions, through the assistance of trained graduate-level participants, from across the US, who live in and serve the communities for 11 months. RARE participants assist communities in the development and implementation of projects for achieving a sustainable natural resource base and improving rural economic conditions. The RARE program is now in its 17th year, over the years it placed more than 300 volunteers and served nearly every Oregon county.
>
> For more information about RARE, including the benefits and the costs of the program, please visit our web site at: http://csc.uoregon.edu/rare.

Some states provide tax credits or grants to owners of coastal properties who remodel their homes to make them more resistant to flood or wind damage. Some require insurance carriers to offer lower premium rates to homeowners who remodel their homes so as to meet higher code standards for wind and flood hazards.

12.4 Federal Funding and Technical Assistance

CZMA: For Oregon, the main source of grants and technical assistance for coastal erosion adaptation planning has been the federal Coastal Zone Management Act (CZMA), administered by the NOAA's Office of Ocean and Coastal Resource Management (OCRM)). OCRM describes the CZMA grant programs as follows:[91]

> **Coastal Management Programs:** OCRM awards four types of funding to the nation's 34 state and territory state coastal zone management programs, to protect, restore, and responsibly develop coastal communities and resources.
>
> - **Administrative Grants:** Under Section 306 of the Coastal Zone Management Act (CZMA), OCRM provides 1:1 matching funds to states to administer their coastal zone management programs.
> - **Coastal Resource Improvement Program:** Under Section 306A of the CZMA, state coastal zone management programs may choose to spend up to half of their Section 306 funds on small-scale construction or land acquisition projects that enhance public access to the coast, facilitate redevelopment of urban waterfronts, or preserve and restore coastal resources.[92]
> - **Coastal Zone Enhancement Grants:** Under Section 309 of the CZMA, OCRM provides zero match Coastal Zone Enhancement Program funds to state coastal zone management programs to enhance their programs in one or more areas of national significance.
> - **Coastal Nonpoint Pollution Control Program (Technical Assistance):** Congress appropriates 1:1 matching funds to help state coastal zone management programs

[91] OCRM website, "Coastal Management Programs," http://coastalmanagement.noaa.gov/funding/welcome.html

[92] 306A grants once were used to fund a variety of projects in Oregon, but in recent years, no grants have been available.

implement their Coastal Nonpoint Pollution Control Programs under Section 310 (Technical Assistance) of the CZMA.

Section 309 of the CZMA offers states an opportunity to enhance their current coastal management programs nine coastal zone enhancement areas. One of the nine areas is "Coastal Hazards." A Section 309 grant administered by the Oregon Coastal Management Program paid for development of this framework plan.

Sea Grant: Sea Grant is a nationwide network of 32 university-based programs that work with coastal communities. Sea Grant is administered through the National Oceanic and Atmospheric Administration(NOAA). For information about the Sea Grant program at Oregon State University, see http://seagrant.oregonstate.edu/ OSU Sea Grant does offer some small grants, mostly for research.

Other Sea Grant programs have offered small grants to coastal communities for adaptation planning. Virginia Sea Grant, for example, will offer $50,000 in matching grants to three or four coastal communities in 2011 to help them develop adaptation plans. See http://www2.vims.edu/seagrant/res-funding_docs/2011_CCA_announcement.pdf

FEMA: The Federal Emergency Management Agency (FEMA) administers the Pre-disaster Hazard Mitigation[93] Act of 2010 (Public Law 111-83). Congress recently reauthorized $580 million for FEMA to operate the *Pre-disaster Hazard Mitigation Program* for fiscal years 2011, 2012, and 2013. FEMA describes the grants for this program in these words:[94]

> The Pre-Disaster Mitigation (PDM) program provides funds to states, territories, Indian tribal governments, communities, and universities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event.
>
> Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations. PDM grants are to be awarded on a competitive basis and without reference to state allocations, quotas, or other formula-based allocation of funds.

It is unclear whether FEMA's PDM program offers any funding for coastal hazard adaptation planning.

FEMA's *Community Rating System (CRS)* provides incentives and guidelines for establishing planning performance standards in coastal communities:[95]

> The CRS offers reduced premium rates for communities that implement adequate land use and loss control measures, facilitate accurate risk ranking, promote flood

[93] "Mitigation" is a term of art that sometimes includes adaptation. Federal agencies such as FEMA often use *mitigation* broadly. It should not be assumed that programs with the word *mitigation* in their title or purpose statement contain no provisions for adaptation planning or implementation.
[94] FEMA, "Pre-Disaster Mitigation Grant Program," http://www.fema.gov/government/grant/pdm/index.shtm
[95] FEMA, "Community Rating System," at http://www.fema.gov/business/nfip/crs.shtm

insurance awareness, and encourage measures for the management of natural and beneficial floodplain functions and erosion hazards. Communities may receive additional credit for implementing eligible mitigation activities. This could include changes in the shoreline setback, or development of mitigation plans that place stricter development and building guidelines on structures in the coastal V zone.

For CRS participating communities, flood insurance premium rates are discounted in increments of 5%; i.e., a Class 1 community would receive a 45% premium discount, while a Class 9 community would receive a 5% discount (a Class 10 is not participating in the CRS and receives no discount). The CRS classes for local communities are based on 18 creditable activities, organized under four categories:

1. Public Information,
2. Mapping and Regulations,
3. Flood Damage Reduction, and
4. Flood Preparedness.

FEMA also offers the *Flood Mitigation Assistance (FMA)* program, which provides mitigation assistance grants and mitigation insurance coverage to eligible states and communities:

FEMA provides FMA funds to assist States and communities implement measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program.[96]

USACE: The US Army Corps of Engineers (USACE) traditionally has focused on public works related to commercial navigation, hydropower, and flood and coastal storm damage reduction. In recent years, it has placed increasing emphasis on sustainability and climate change mitigation. Its mission statement with regard to sustainability includes a provision for "engaging in regional and local sustainable planning efforts to achieve sustainable communities."[97] It is unclear whether any USACE funding is available to local governments for coastal hazard adaptation planning.

The Corps has conducted an "overall assessment" of erosion, including coastal erosion hazards, for the entire state of Alaska.[98] It also has spent many tens of millions of dollars to relocate several communities in Alaska threatened by rapid sea level rise.

EPA: The Environmental Protection Agency (EPA) manages some programs that offer funding and technical assistance for local hazard adaptation efforts. For example, the Long Island Sound Study (LISS) "received a Partner Start-up Grant from the U.S.

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[96] See http://www.fema.gov/government/grant/fma/index.shtm

[97] USACE, :Sustainability," at http://www.usace.army.mil/sustainability/Documents/Sustainability_fact_sheet_20100901.pdf

[98] *US Corp of Engineers' Alaska Baseline Erosion Assessment: Study Findings and Technical Report, March 2009,* http://www.poa.usace.army.mil/en/cw/planning_current%20projects%20info/Alaska%20Baseline%20Erosion%20Assessment%20(BEA)%20Main%20Report.pdf

Environmental Protection Agency's Climate Ready Estuaries Program to develop an adaptation plan for the Town of Groton, Connecticut."[99] See "Adaptation Planning" on EPA's website at http://www.epa.gov/climatereadyestuaries/adaptation.html

Other Federal Agencies: The US Department of Agriculture, Natural Resources Conservation Service, US Army Corps of Engineers, Bureau of Land Management, and US Geological Survey all have programs and, in some cases, grants for erosion control. Most of those programs, however, focus on controlling soil erosion and management of watersheds. We are unaware of any provisions in these programs that would advance local adaptation planning for coastal erosion hazards.

The plethora of federal programs and agencies makes it difficult to assess which programs may offer grants or technical assistance suitable for coastal hazard adaptation planning in any given community's. It seems clear, however, that the most likely sources reside in NOAA and FEMA.

[99] See http://www.cakex.org/case-studies/845

12.5 International Sources of Funding and Technical Assistance

The **ICLEI** is an international body originally known as the "International Council for Local Environmental Initiatives." It later changed its name to "Local Governments for Sustainability," but it continues to use the ICLEI acronym. The organization has a proven track record in helping local governments deal with adaptation planning for climate change. The following description is quoted from Terri L. Cruce's *Adaptation Planning – What U.S. States and Localities are Doing*, Pew Center on Global Climate Change, August 2009, p. 21.

> ICLEI U.S.A.'s Climate Program assists over 575 member cities in 49 states in their efforts to reduce greenhouse gas emissions and protect the climate from further human impacts. In 2006, ICLEI collaborated with the University of Washington's Climate Impacts Group and King County, Washington, to develop a guidebook for state and local governments to approach adaptation. *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* describes ICLEI's Five Milestones for Adaptation Methodology. Over the last three years, some ICLEI USA member cities completed climate resiliency or adaptation plans, leveraging the ICLEI methodology, including Keene, New Hampshire; Homer, Alaska; and Miami-Dade County, Florida. ICLEI has recently refocused its Climate Resilient Communities (CRC) program, which was initiated in 2005, to better serve its member cities that understand the need to take on adaptation in addition to mitigation. The CRC program is striving to improve local governments' access to and understanding of relevant climate science and impacts data; support better integration of parallel mitigation and adaptation planning efforts; and tools and methods to guide its members through an adaptation planning process that includes analyzing likely climate impacts at the local government level, setting priorities, selecting appropriate options, and implementing effective adaptation actions. An Advisory Group of 22 member cities has been working with the CRC Program since March 2009 to provide it with deeper insight into the adaptation needs of local governments across the U.S., which guides the Program's agenda and efforts. These 22 members include cities that have completed their initial adaptation plans and are focused on implementing their recommendations, such as King County Washington and Keene NH, as well as cities that are in-progress (e.g. New York City), and some that are highly motivated and trying to get started." See www.icleiusa.org/adaptation

13. Findings

With regard to the data and information presented in this document, *Adapting to Coastal Erosion Hazards in Tillamook County: Framework Plan*, *2011*, we find the following:

1. The problem of coastal erosion in Tillamook County has become acute in multiple areas along the county's coastline. The dune-backed and bluff-backed beaches that make up much of the county's shoreline are especially vulnerable to erosion. This coastal erosion causes or contributes to several significant hazards and problems:
   - It poses a serious risk of wave overtopping, ocean flooding, landslides, bluff failure, and sand inundation to vulnerable shorefront properties.
   - It poses a significant risk to key coastal resources, such as beaches, dunes, freshwater wetlands, and wildlife habitats.
   - It increases demand for costly shorefront protective structures that often accelerate beach erosion, limit public access to beaches, limit emergency access to beaches, and displace large areas of sandy beach.
   - It increases public costs for emergency management, for liability, and to protect and maintain infrastructure and public facilities.
   - It makes some areas more vulnerable to damage from climatic and geologic hazards such as tsunamis and earthquakes.
   - It increases private costs to protect and maintain coastal properties.
   - It increases risks to persons who reside in, work at, or visit hazardous areas along the coast.

2. Coastal erosion is increasing and will continue to increase and perhaps even accelerate. One of the most significant factors in coastal erosion, relative sea level, has been increasing and is likely to increase further. The evidence in support of the increase is substantial and comes from multiple authoritative studies and sources. A second key factor, deep-water storm-wave height, has been increasing, but whether the wave heights will continue to grow remains unknown. Another key factor in coastal erosion is the El Niño Southern Oscillation (ENSO), which has been observed to accelerate erosion along Tillamook County's coast, as demonstrated most notably during the winter of 1997-1998. The long-term trend for strength and frequency of El Niño events is unknown.

3. The climatological and geologic events and forces that cause or contribute to coastal erosion in Tillamook County will continue to occur. Current scientific methods and data, however, are not sufficient to make precise forecasts of the timing or extent of these events and forces. Despite that uncertainty, however, current scientific methods and data are sufficient to estimate the probability that key climatological and geologic events and forces will occur in specified places in the future.

4. Tillamook County lacks the resources or expertise to make the estimates described in Finding 3 above. However, the state's Department of Geology of Mineral Industries

(DOGAMI), the Department of Land Conservation and Development's Ocean and Coastal Management Program (OCMP), Oregon State University (OSU), the United States Geological Survey (USGS) and other key state, federal and academic agencies do have the necessary resources and expertise. The county refers to the most recent scientific methods and data currently available from the leading state, federal, and academic agencies as the "best available science."

5. DOGAMI has monitored coastal erosion in Tillamook County for the past decade and has used the resulting data to prepare deterministic maps for the entire shoreline of the county. These maps show where erosion will occur under certain conditions.

OSU and DOGAMI also have been exploring probabilistic methods to assess likely future erosion. These methods aim to quantify relative uncertainties in future erosion associated with climate change effects and morphology of the beach. That effort has produced a series of maps for the Neskowin area that identify areas at varying degrees of risk from erosion over different periods of time ranging as far into the future as 2100. These maps will be used as the basis for an adaptation sub-plan for the community of Neskowin.

Taken together, the data and maps described above constitute the "best available science" regarding coastal erosion and related hazards in Tillamook County. These data and maps thereby meet the requirement of Statewide Planning Goal 2, *Land Use Planning*, to "To establish a land use planning process and policy framework as a basis for all decision and actions related to use of land and to assure an adequate factual base for such decisions and actions."

The high cost of coastal erosion . . .

"In the United States, coastal erosion is responsible for approximately $500 million per year in coastal property loss, including damage to structures and loss of land. To mitigate coastal erosion, the federal government spends an average of $150 million every year on beach nourishment and other shoreline erosion control measures. Despite these efforts, a 2000 Heinz Center study found that erosion may claim one out of four houses within 500 feet of the U.S. shoreline by mid-century."

NOAA Ocean and Coastal Management website, "Coastal Hazards," at http://coastalmanagement.noaa.gov/hazards.html

14. Policies

1. The Coastal Erosion Hazards Adaptation Plan
Tillamook County hereby adopts this plan, ***Adapting to Coastal Erosion Hazards in Tillamook County: Framework Plan*, *2011***, which shall become effective on *[date to be determined]*. The county shall apply, maintain, implement, and from time to time, amend this framework plan as needed to ensure its effectiveness. The area subject to this plan shall be that portion of Tillamook County within the "planning area" defined by Statewide Planning Goal 17, *Coastal Shorelands,* and described in Section 2.4 of this plan.

2. Community Sub-Plans
Tillamook County shall work with its unincorporated communities to develop and implement community sub-plans as needed to respond to specific local coastal erosion hazards. The framework plan is intended to help the individual communities with that task in several ways:

- By providing a sound policy foundation on which to base community plans for adapting to and preparing for local erosion hazards;
- By extracting from a broad range of complex scientific and technical reports the key points and critical information most relevant to coastal erosion hazards in Tillamook County;
- By providing the detailed factual base and background information necessary to develop effective community plans for dealing with erosion hazards;
- By coordinating the planning done by individual communities, service providers, and first responders in adapting to and preparing for coastal erosion hazards;
- By enabling individual communities to make successful requests for funding and technical assistance from key agencies such as the Federal Emergency Management Agency;
- By informing property owners, businesses, service providers and the general public about the risks and consequences of coastal erosion hazards;
- By informing property owners, businesses, service providers and the general public about effective methods for adapting to and preparing for coastal erosion hazards;
- By clearly expressing the county and state's strong support for community adaptation planning efforts.

3. Consistency of Plans
Community sub-plans for adapting to and preparing for coastal erosion hazards are intended to augment and complement the framework plan described in Policy 1 above and shall be consistent with it.

4. The Erosion Hazard Area
Within the area subject to this plan, Tillamook County shall inventory and map lands at significant risk from coastal erosion and related hazards. The lands so identified shall be described as the "Erosion Hazard Area." The Erosion Hazard Area shall be based on

information, data and maps from DOGAMI, OSU and other key agencies as described in Finding 5 above. In addition to using the above-referenced DOGAMI and OSU maps and studies, the county should review new scientifically credible coastal erosion information as it becomes available for potential inclusion within the county coastal erosion program

5. Land Use Standards and Criteria

Tillamook County shall develop and adopt land use regulations and standards that establish risk assessment and risk reduction measures for development within the Erosion Hazard Area. Such regulations may include, but are not necessarily limited to, measures such as:

- Requirements for site-specific engineering geologic assessments or reports for development in specified areas;
- Content standards for engineering geologic reports which specifically address the full range of coastal hazards, including erosion hazards;
- Building setbacks based on estimated erosion rates for new development within the Erosion Hazard Area;
- Authority to impose conditions of approval on new development as necessary to ensure the protection of new and existing development and significant coastal natural resources;
- Limitations on and/or design standards for new land divisions in the Erosion Hazard Area;
- Requirements for applicants for new development within the Erosion Hazard Area to waive liability and hold the county harmless for damages from coastal hazards;
- Requirements for applicants for new development within the Erosion Hazard Area to indemnify the county against third party damages from coastal hazards; and
- Limitations or prohibitions on certain types of development (e.g. essential facilities, places of public assembly, special occupancy structures) within the Erosion Hazard Area
- Provisions regarding existing development threatened by coastal erosion.

6. Review and Revision of Plan

Tillamook County shall work with the Department of Geology and Mineral Industries (DOGAMI) and Department of Land Conservation and Development (DLCD) to periodically review and, as needed, revise this coastal erosion hazards framework plan to ensure that it is based on the best available scientific information.

7. Application of Framework Plan

This framework plan neither repeals nor replaces any provisions of Tillamook County's acknowledged comprehensive plan and land-use regulations. In the event of a conflict between policies of this framework plan and provisions of the county's acknowledged comprehensive plan or land-use regulations, the more restrictive policy or provision shall apply.

8. Financial and Technical Assistance
Tillamook County should continue to seek technical assistance and funding for climate adaptation planning from likely sources such as NOAA, FEMA, and the ICLEI-US Climate Resilient Communities (CRC) Program. The county also should encourage use of local funding measures such as local improvement districts and conservation easements for appropriate hazard alleviation techniques.

9. Linking the County's Hazard Plans
Tillamook County will investigate and consider ways to better integrate or perhaps combine its adopted 2005 Hazard Mitigation Plan and this Coastal Erosion Hazard Framework Plan.

10. Beachfront and Shoreline Protective Structures
Beachfront and shoreline protective structures, such as revetments and seawalls, intended for the protection of private property shall be constructed, maintained and repaired by the owner of the protected property. Tillamook County shall not incur any costs to build, maintain or repair any private beachfront or shoreline protective structure.

11. Lifeline Roads
Tillamook County shall identify key "lifeline" collector roads and streets as described in Chapter 10 of this plan. The county should use appropriate signage, parking restrictions, bridge and roadway maintenance, structural improvements, law enforcement and other suitable measures to ensure that lifeline roads will be maintained in peak operating condition during hazard events.