PLANNING COMMISSION WORK SESSION AGENDA
Monday, August 22, 2016 - 6:00 PM
City Hall, Conference Room A, 169 SW Coast Highway, Newport, Oregon 97365

The meeting location is accessible to persons with disabilities. A request for an interpreter for the hearing impaired, or for other accommodations for persons with disabilities, should be made at least 48 hours in advance of the meeting to Peggy Hawker, City Recorder at 541.574.0613.

The agenda may be amended during the meeting to add or delete items, change the order of agenda items, or discuss any other business deemed necessary at the time of the meeting.

1. CALL TO ORDER

2. UNFINISHED BUSINESS

2.A. Preliminary discussion about the release of the 2016 flood insurance rate maps.

3. NEW BUSINESS

3.A. Code changes to height limits for vertical evacuation.

4. ADJOURNMENT

City of Newport

Community Development Department

Memorandum

To: Newport Planning Commission/Citizen Advisory Committee

From: Derrick Tokos, Community Development Director

Date: August 18, 2016

Re: Preliminary Release of New FEMA Flood Study and Insurance Rate Maps

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In June of 2014, the Planning Commission held a work session to review an early release of new Flood Insurance Rate (FIRM) Maps. The Federal Emergency Management Agency (FEMA), which produces the maps, was looking for local governments to provide their initial impressions, and the Commission asked that staff follow-up with them regarding changes they were proposing to make in the vicinity of the Big Creek Road/Harney Street Intersection, Nye Beach Turnaround, and SE 35th Street at the Neohla Point Townhouses.

The early release was to be followed by an official preliminary review set of the FIRM maps and flood study in September/October of 2014; however, the project was delayed and the preliminary maps and study were just released at the end of July. The maps and study are posted on the City website at:

http://newportoregon.gov/dept/cdd/FEMAFIRMMaps.asp.

If you have the time, please take a moment to review these documents in advance of the work session.

FEMA is mailing paper sets of the maps, and their staff is working to set up a meeting for our area in mid-September to discuss the revised flood hazard information, ordinance adoption, and other frequently asked questions and concerns. Our office is planning to send out letters to affected property owners, particularly those that have land that is being added to the floodplain. This will occur after the consultation meeting, once we have a better understanding of how the public comment process will work. FEMA is hoping to finalize the maps by the spring of next year. If that happens, we will need to have an ordinance adopting the maps and flood study in place by fall of 2017.

As background, FIRM maps establish the boundary of the 100-year floodplain. They also show the location of floodways, which represent areas of active flow, as opposed to standing water, during a 100-year event. Persons with property that fall within a 100-year floodplain must obtain flood insurance for the buildings and structures they own. Also, new development within a floodplain is subject to special building codes that are designed to ensure that the lowest floor area of the finished space is elevated at least one-foot above the 100-year base flood elevation, and that portions of the structure below that point are flood-proofed. Per our discussion in June, standards for development and redevelopment in the floodplain will have to be revised to include provisions that will protect habitat for endangered/threatened salmon. The deadline for getting the “habitat protection” provisions in place, on at least an interim basis, is March of 2018.

The version of the FIRM maps that the City is currently using were adopted in 2009. These maps are essentially a digitized version of the original paper maps prepared in 1982 with updates where parcel level map revisions were made over time, usually at the request of land owners. The 2009 flood study was unchanged, meaning it relied upon hydrologic analysis that was conducted as early as 1977.

The new draft maps are based upon an updated hydrologic analysis for coastal and estuary areas that has been performed by the State Department of Geology and Mineral Industries (DOGAMI). DOGAMI is FEMA’s contractor for this project. Highly accurate “Lidar based” elevation data has also used for the coastal work and mapping of inland tributaries. Hydrologic analysis for inland areas (i.e. rivers, streams, etc.) has not been updated, meaning those base flood elevations continue to draw from the 1970’s work.

Enclosed is a project summary that FEMA prepared in May of 2014 and sample images comparing the 2009 maps to the new maps. The Planning Commission reviewed this information in 2014. Also attached are maps of the new preliminary 100-year floodplain for the three areas the Commission asked us to address with FEMA. In Nye Beach, FEMA revised the map, scaling back the area of inundation in the vicinity of the Turnaround. They also adjusted the map so that the Neohla Point Townhouses will continue to be in the floodplain, as we provided them with photos showing the area being impacted by floods in the past. FEMA is still proposing to remove a number of residential properties from the floodplain adjacent to Big Creek, which is a concern in that the area is subject to flooding and if the properties aren’t within a mapped floodplain than the owners may not be aware that it is a potential issue and won’t obtain optional flood insurance.

Outside of these targeted areas, the map changes have little impact on Newport since most of our coastal development is on bluffs that are well above the 100-flood elevations. The new maps drop the base flood elevation of the bay from 13-feet to 12-feet (the early release maps had the elevation at 11.5 feet). This change is at least partially based upon actual tide gauge data, and results in a number of developed properties being pulled out of the 100-year floodplain. On balance, more properties are being removed from the floodplain than are being added and the accuracy of the new maps is much better than the 2009 version. Included in your packet are maps of north and south Newport showing the changes on a macro scale.

The purpose of this work session is to provide the Planning Commission and its Advisory Committee an overview of the work that FEMA and DOGAMI have performed, and to discuss issues and outreach that you would like to conduct during the preliminary review phase of the FEMA map adoption process.

<u>Attachments</u>

- FEMA Project Summary, May 2014
- Comparison of Existing and New Maps
- Maps of Newport Showing the New Preliminary 100-year Floodplain, including Detail Images of the Target Areas Discussed Above

FEMA

RiskMAP
Increasing Resilience Together

Lincoln County
FEMA Risk MAP Project

Flood Study Review Meeting

May 28, 2014

Newport

Project Team

Oregon Department of Geology and Mineral Industries (DOGAMI)

Providing the Science & Mapping

- *FEMA Cooperating Technical Partner*
- Lidar Acquisition
- Regulatory Flood Mapping
- Mitigation & Risk Analysis
- Hazard Viewer Website
- Community Awareness

FEMA Region X and the National Flood Insurance Program (FEMA NFIP)

Providing the Funding and Oversight

Oregon Department of Land Conservation and Development (DLCD)

Providing the Local Guidance

- *FEMA Cooperating Technical Partner*
- State-level NFIP Administration
- Planning
- Adoption/Implementation
- Mitigation Strategies

(FEMA Region X subcontractors)

- Quality Review

Flood Mapping Revision

Types of Revisions

1. **Survey-based detailed study of the Pacific Ocean producing new BFEs**
   - Results in coastal Zone VE and Zone AE
2. **GIS and lidar-based approximate river studies producing new BFEs**
   - Remains Zone A (BFE is not printed on FIRMs, but is available)
3. **Lidar-based re-delineation of existing BFEs**
   - Remains Zone AE (BFE still printed on FIRMs)

Flood Mapping Revision

Overview of Hydrologic Methods

	Description	Zone
Approximate River	Regional regression model produced by U.S. Geological Survey and Oregon Water Resources Department in 2005	Zone A
Detailed Coastal	• ~140-150 wave events modeled using Simulating WAves Nearshore by OSU/DOGAMI (based on 30 years of measured waves from NDBC) • 45 years of SWLs derived from synthesized time series of measured tides at Garibaldi and Newport • Wave runup on dune-backed beaches modeled using Stockdon et al. (2006), and on coastal engineering structures and bluff-backed beaches using TAW approach (van der Meer, 2002; NHC, 2005)	Zone VE and AE
Re-delineation of Detailed River	N/A	Zone AE

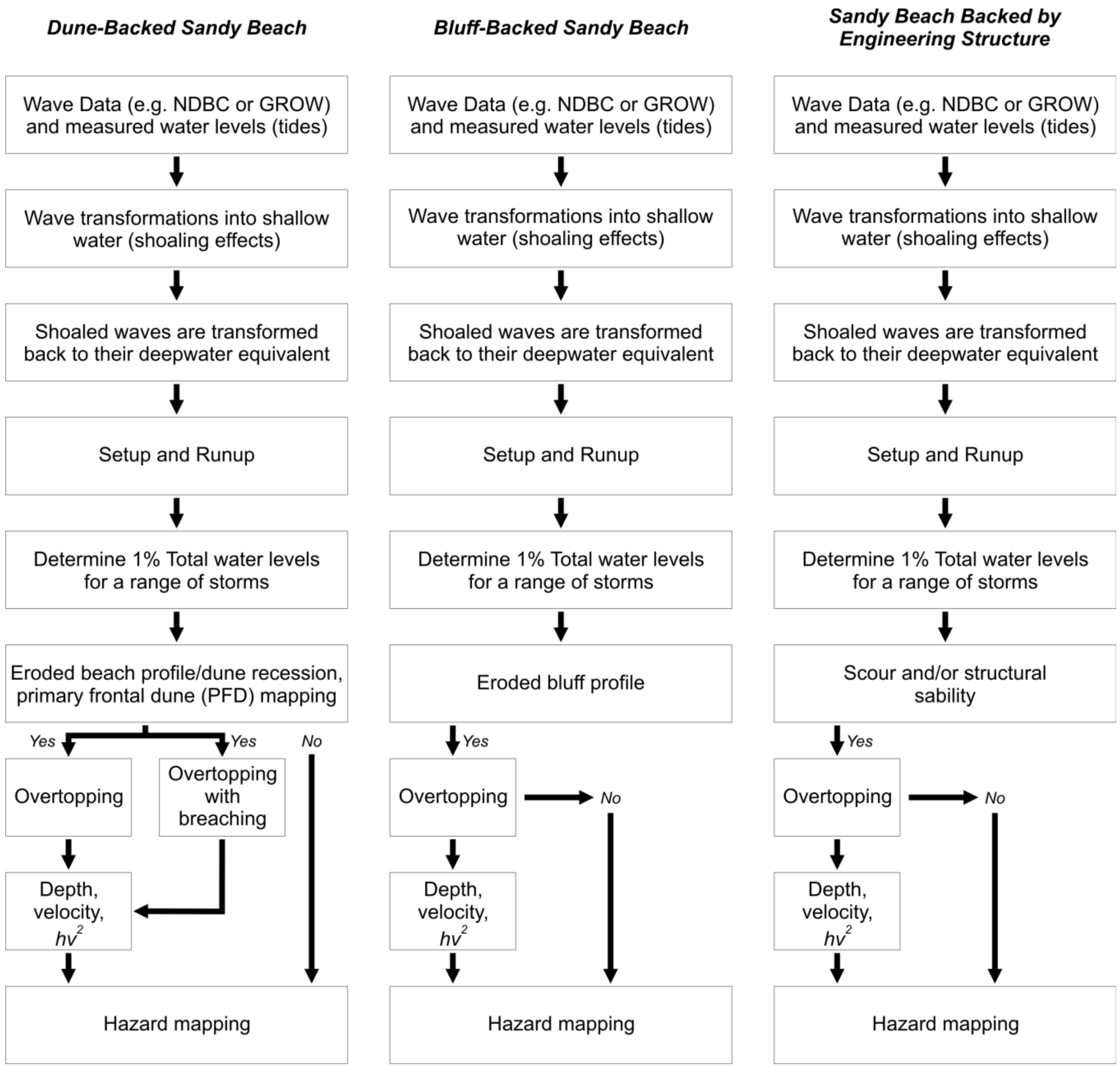
Overview of Hydraulic Methods

	Description	Zone
Approximate River	• Simple HEC-RAS models • Roughness is generalized • Based on lidar topography • No field survey • Structures are assumed or not modeled	Zone A
Detailed Coastal	• Geomorphic assessment of open coast performed • Morphological parameters defined at 85 transects, determined from RTK-DGPS and Lidar surveys above -1m (NAVD88), and bathymetric surveys of the nearshore (i.e. -1m to ~-25m) • Dune-backed beaches eroded using Kriebel and Dean (1993) approach, utilizing 1% storm conditions. Bluff-backed beaches not eroded. • Wave runup and overtopping determined at 86 coastal transects.	Zone VE and AE
Re-delineation of Detailed River	N/A	Zone AE

FEMA Coastal Flood Mapping – Why?

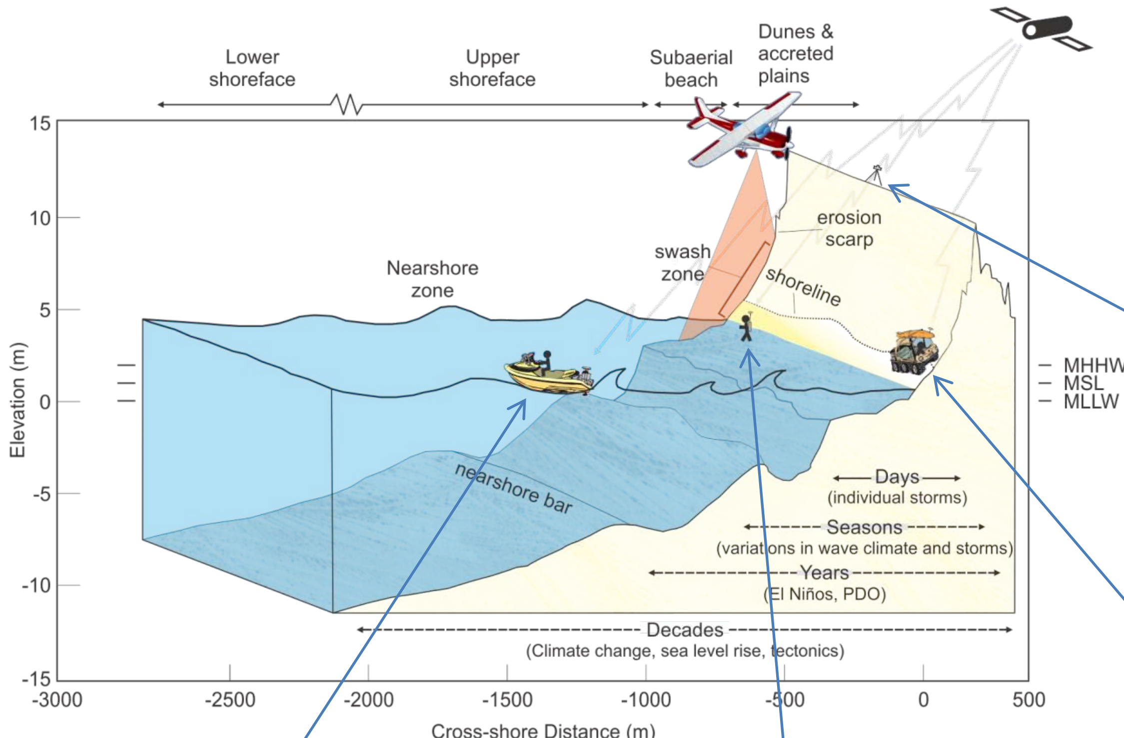
- New methodology, guideline, and/or policy (NHC, 2005)
- Changes in development and land use;
- Increase in tidal gage record length or historical storm set;
- Changes to stillwater elevations;
- Construction or removal of flood-control structures;
- Occurrence of one or more significant flood events;
- Availability of better topographic information;
- Construction of a shore protection structure;
- Changes to bathymetry and/or shoreline; and
- Identification of a Primary Frontal Dune.

Approach

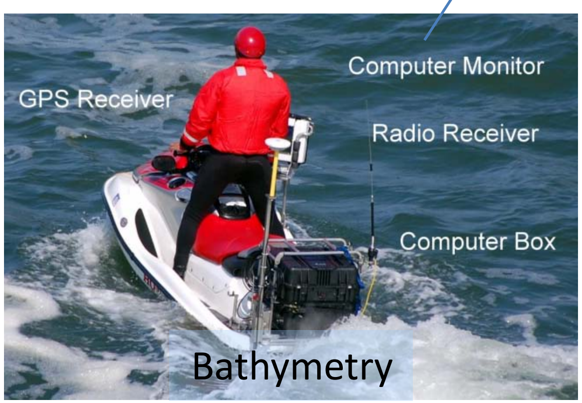


(after NHC, 2005)

Morphology

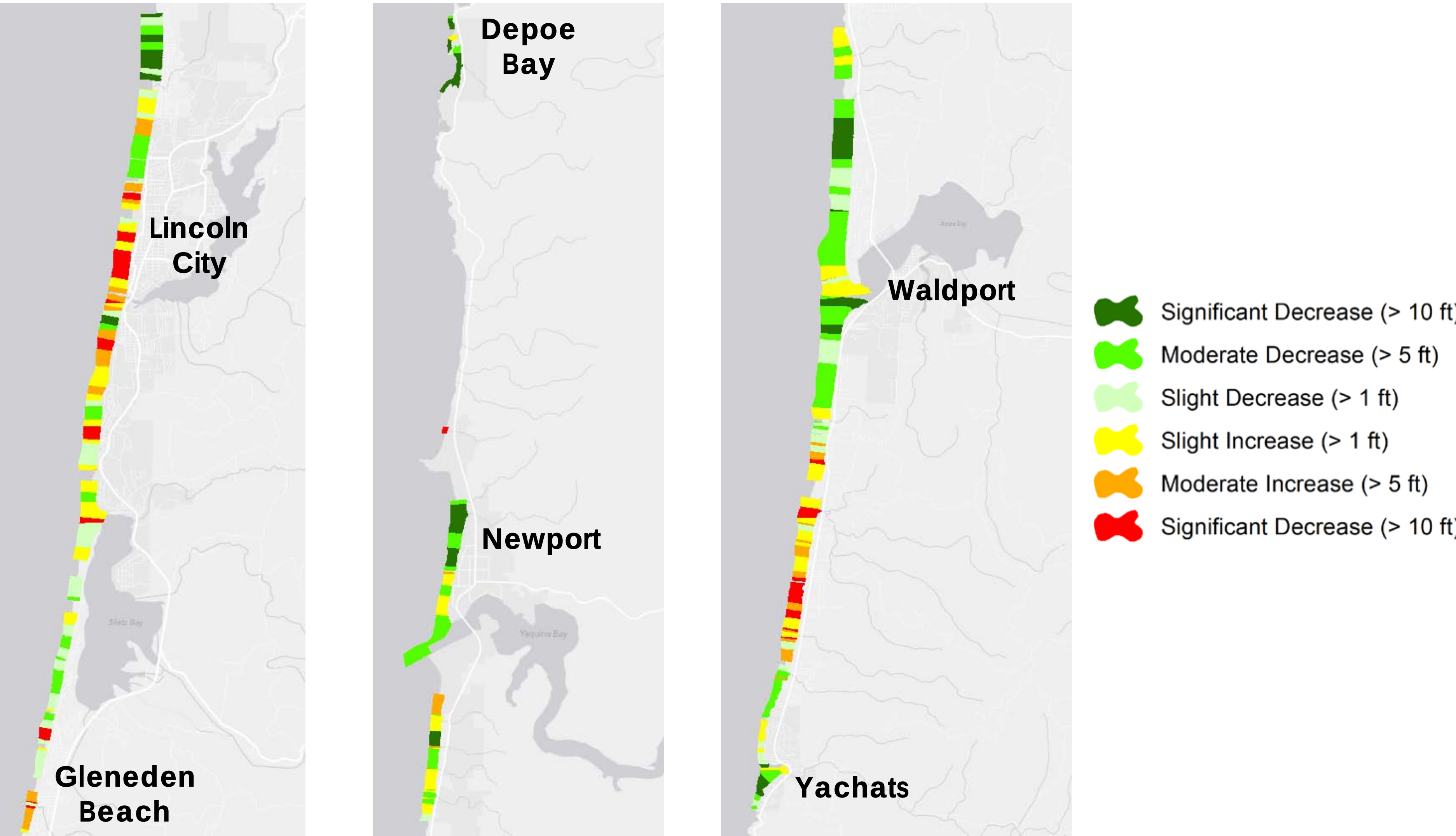


GPS Base Station



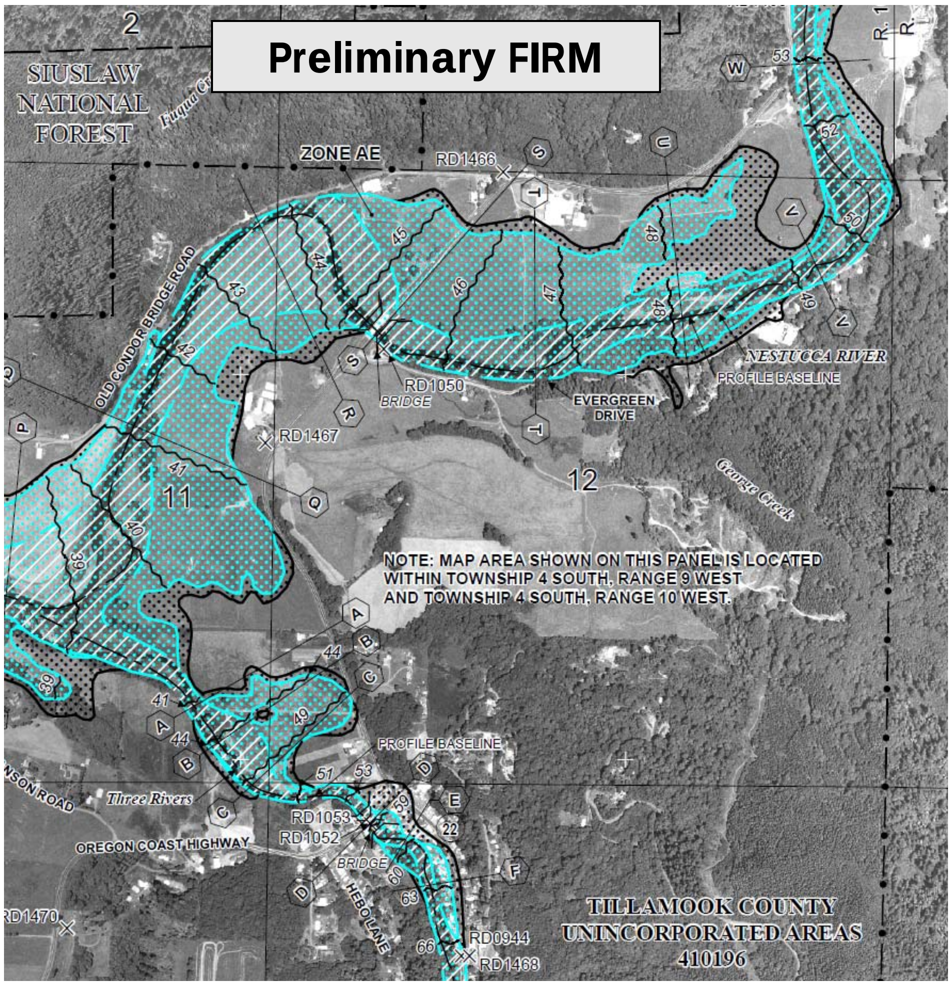
Coastal Zone Revisions

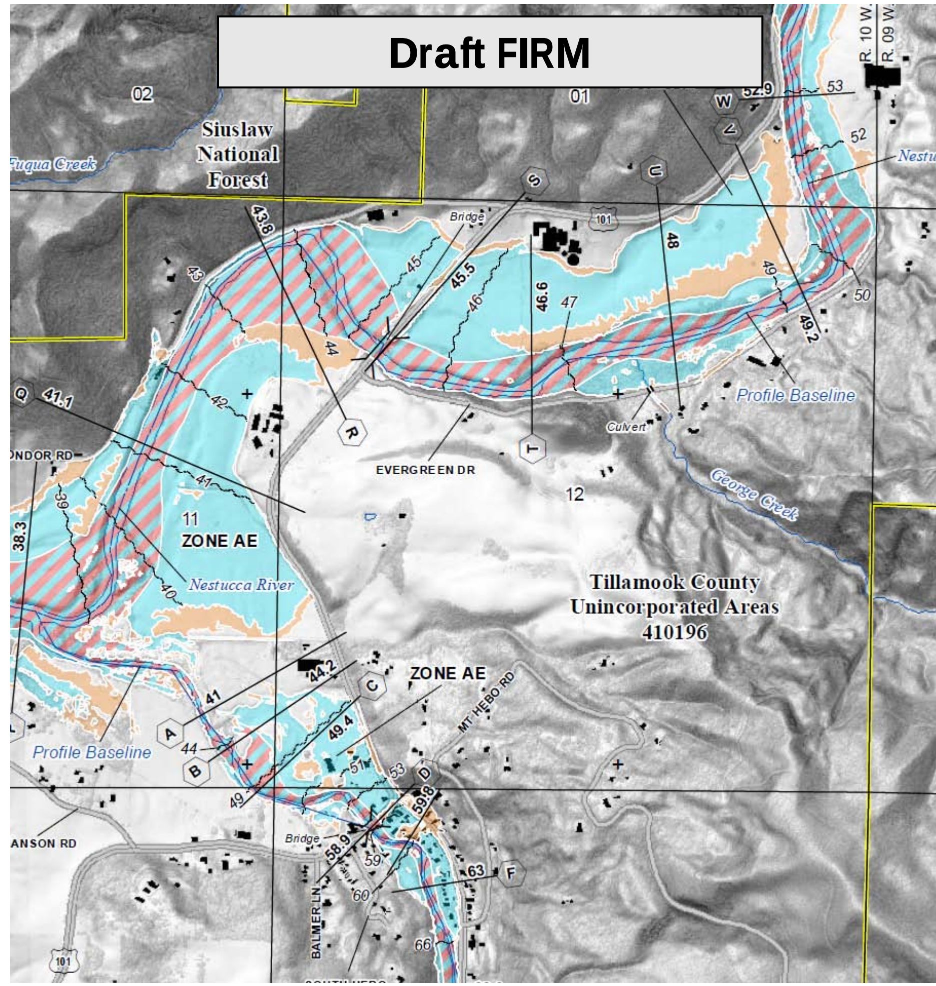
Base Flood Elevation Changes for Open Coast (Zone VE)



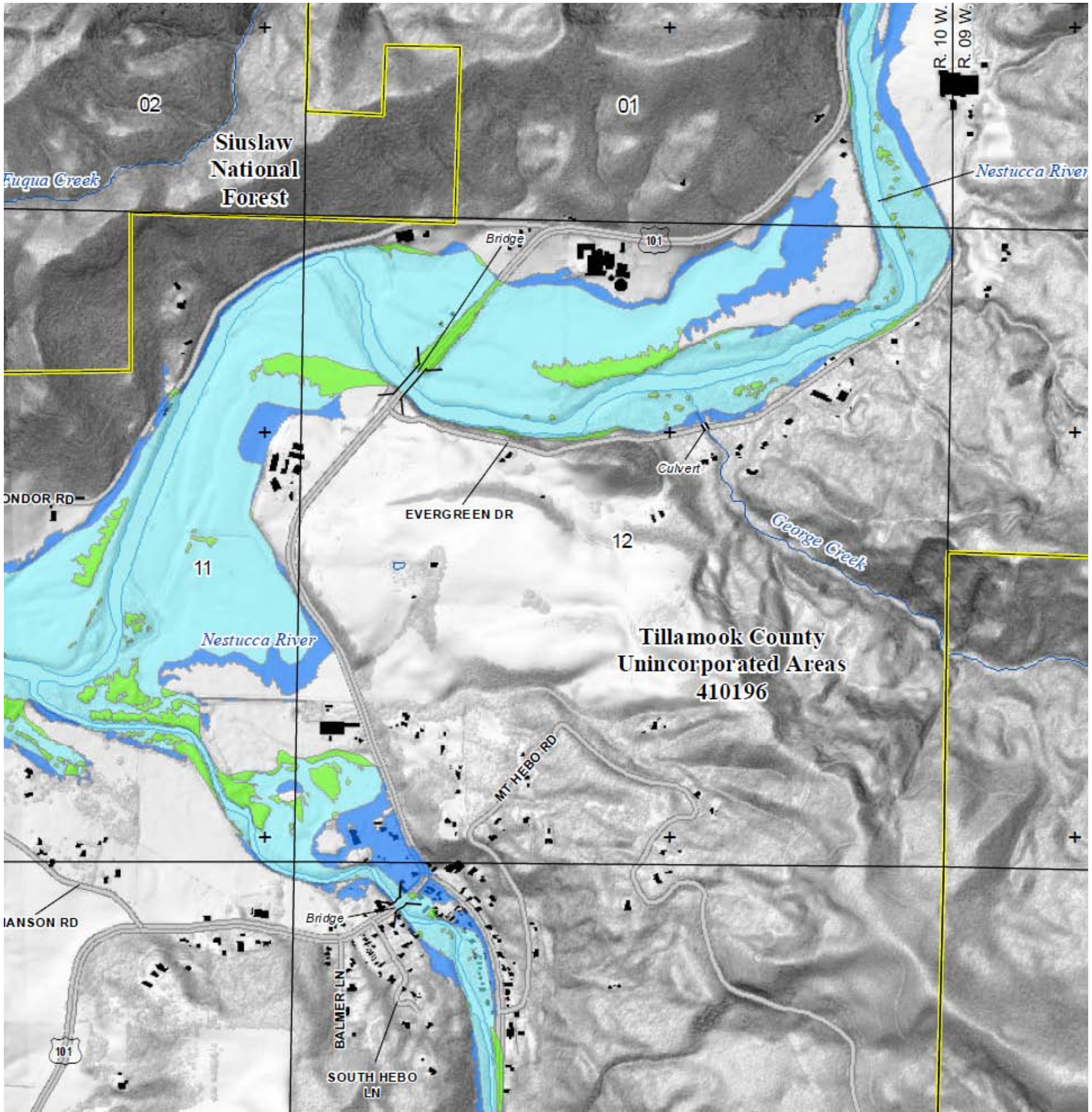
Flood Mapping Revision

Draft Maps





Flood Mapping Revision



Change Maps

Difference between preliminary and draft Special Flood Hazard Areas (SFHAs)

	Added
	No Change
	Removed

Flood Study Review

Change Statistics (Special Flood Hazard Area in Acres)

	Added	Removed	No Change	Effective	Revised	% Change
Lincoln City	25.6	66.7	391.7	458.4	417.3	-9.0%
Depoe	19.0	20.9	68.1	89.0	87.1	-2.1%
Siletz	6.9	9.3	54.2	63.5	61.1	-3.8%
Newport	82.0	161.6	1,352.2	1,513.8	1,434.2	-5.3%
Toledo	69.2	35.6	462.8	498.4	532.0	6.7%
Waldport	64.5	21.6	464.7	486.3	529.2	8.8%
Yachats	3.8	27.2	77.8	105.0	81.6	-22.3%
Lincoln County	4,405.5	4,601.7	30,201.7	34,803.4	34,607.2	-0.6%

Flood Study Review

Key Points of Review

1. Check to make sure mapping is consistent with your local knowledge of the flooding sources.
   - Is water going somewhere it physically can't go?
   - Has re-delineation created confusing floodways?
2. Are we missing important map features?
   - Roads, tide gates, levees, bridges, culverts
3. Is everything labeled correctly?
4. Most important – Do you understand the changes to the flood zones? Could you explain the basics to your constituents?

Review comments due by June 18, 2014.

Flood Study Key Contacts

Jed Roberts, DOGAMI (Flood Mapping Coordinator)

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Christine Shirley, DLCD (NFIP Coordinator)

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Steve Lucker, DLCD (Risk MAP Coordinator)

stephen.lucker@state.or.us

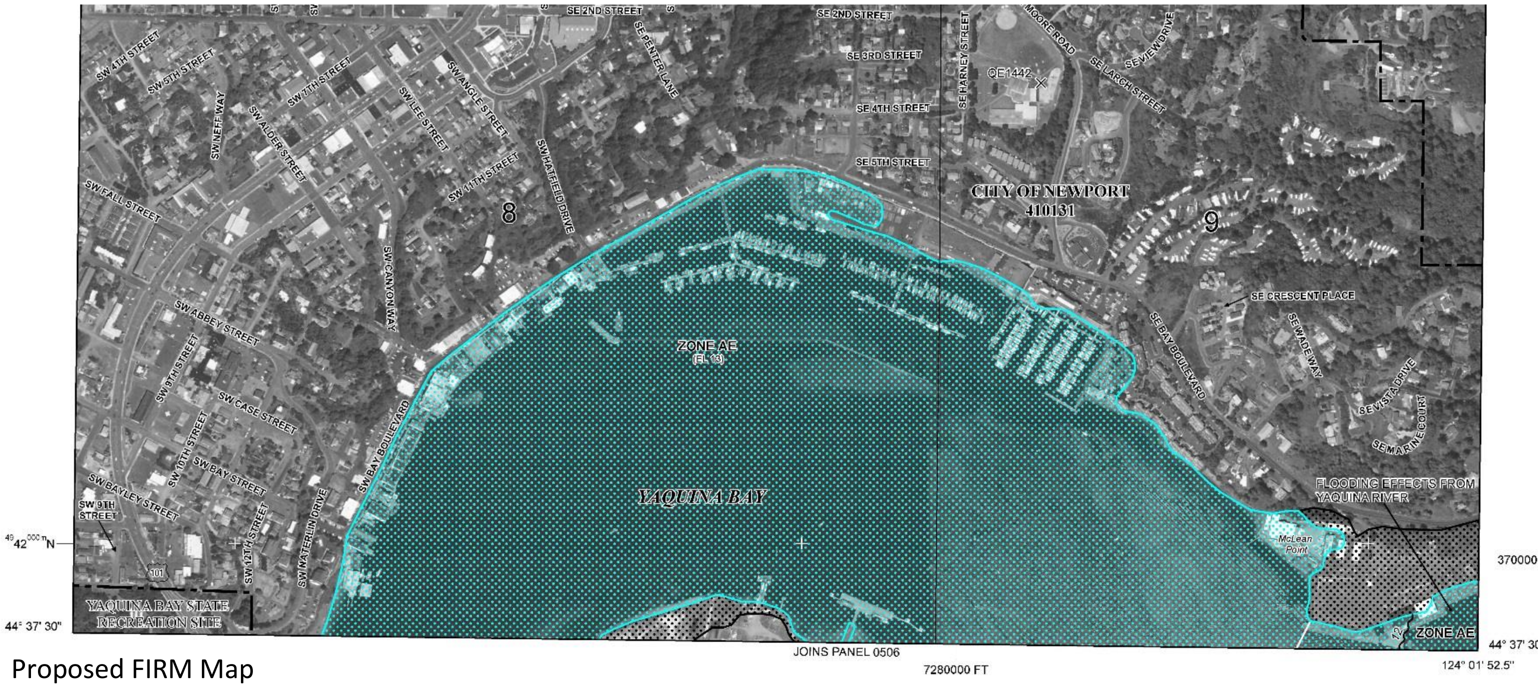
David Ratte, FEMA Region X (Regional Engineer)

david.ratte@fema.dhs.gov

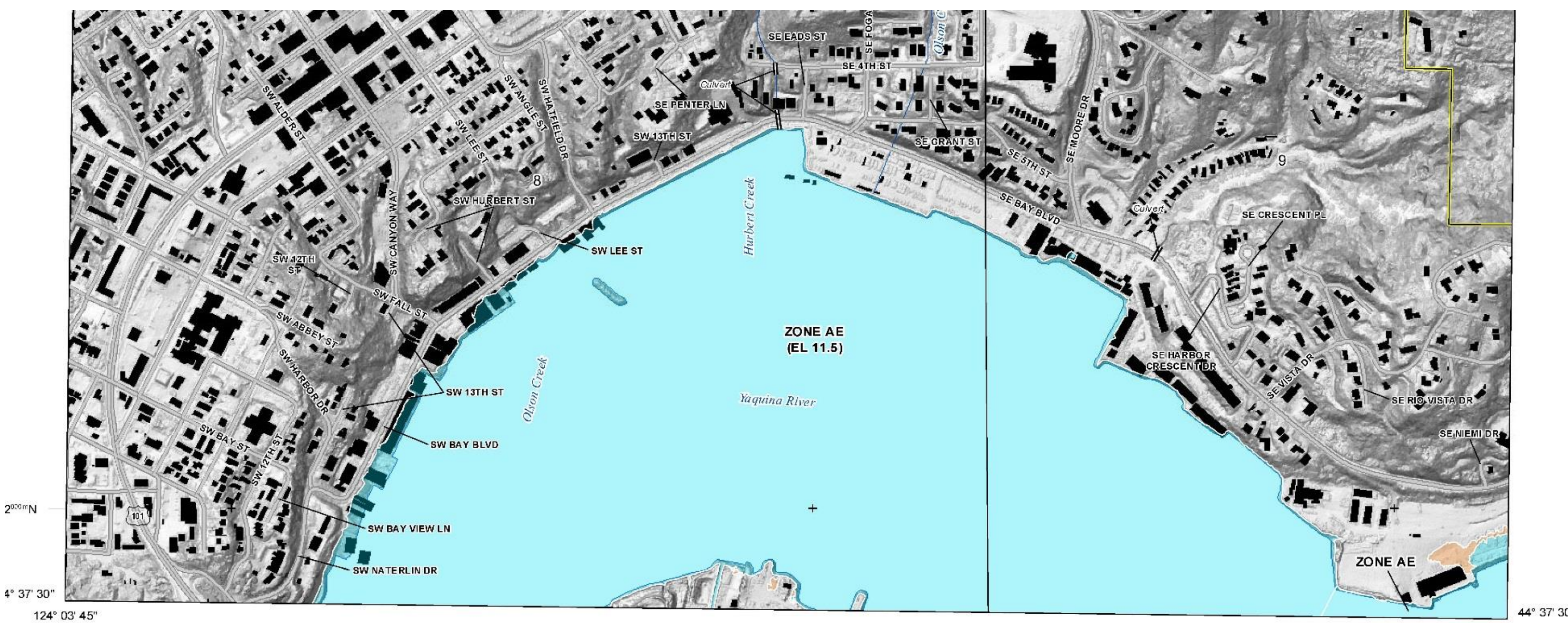
Amanda Siok, FEMA Region X (Risk Analyst)

amanda.engstfeld@fema.dhs.gov

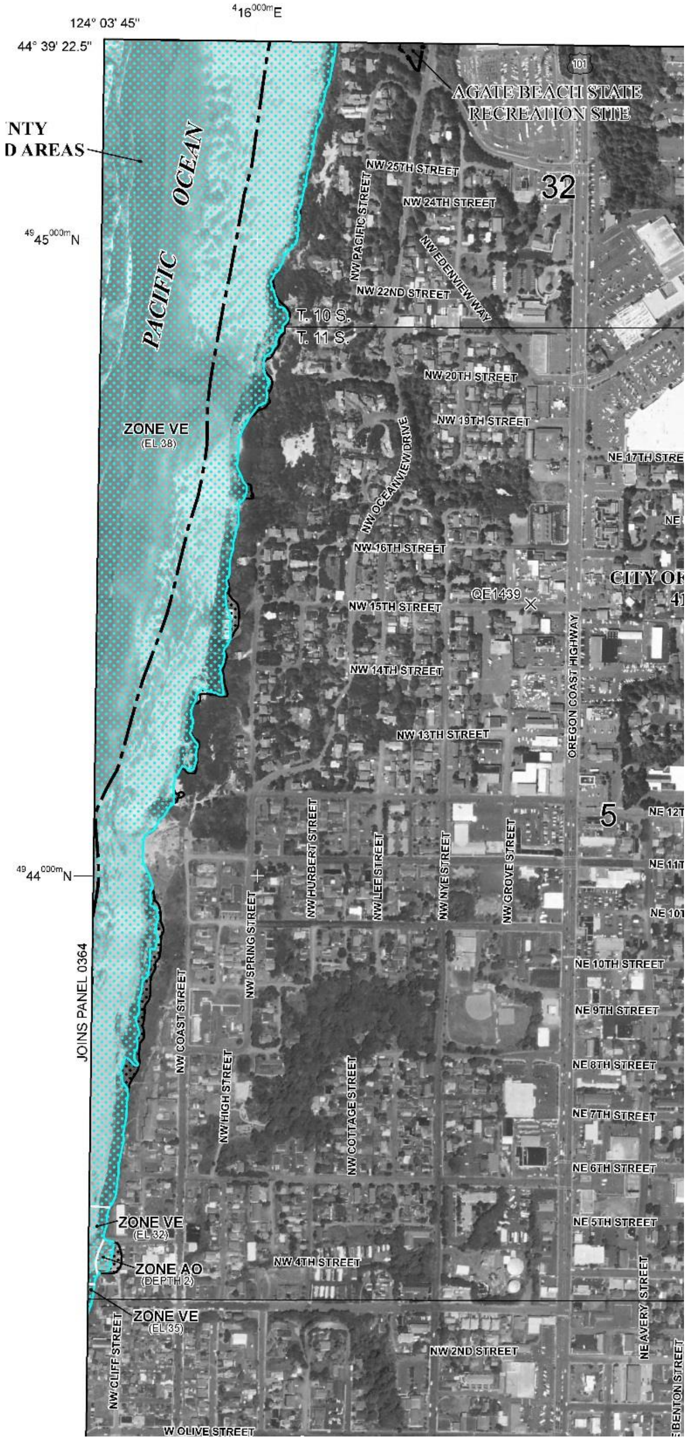
Existing FIRM Map



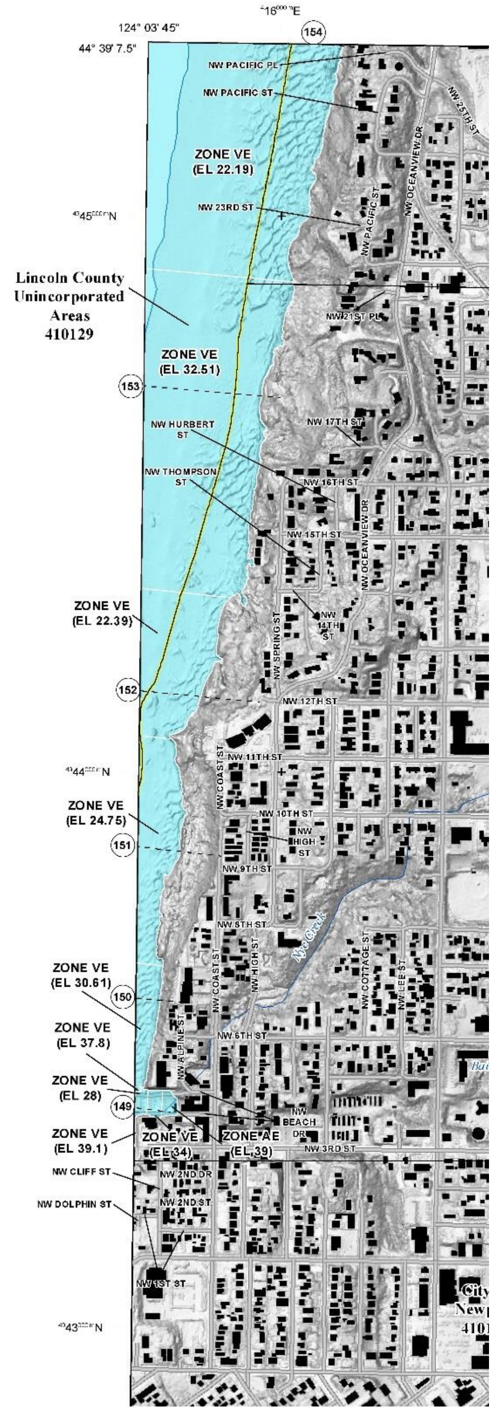
Proposed FIRM Map



Existing FIRM Map



Proposed FIRM Map



City of Newport
Community Development Department
169 SW Coast Highway Phone:1.541.574.0629
Newport, OR 97365 Fax:1.541.574.0644

FIRM Map Changes - Nye Beach Turnaround

Image Taken July 2013
4-inch, 4-band Digital Orthophotos
David Smith & Associates, Inc. Portland, OR

Feet: 0, 30, 60, 120

N

NEWPORT
City of Newport
Community Development Department
169 SW Coast Highway Phone:1.541.574.0629
Newport, OR 97365 Fax:1.541.574.0644

FIRM Map Changes - Harney / Big Creek Road

Image Taken July 2013
4-inch, 4-band Digital Orthophotos
David Smith & Associates, Inc. Portland, OR

0 75 150 300 Feet

N

NEWPORT OREGON
City of Newport
Community Development Department
169 SW Coast Highway Phone:1.541.574.0629
Newport, OR 97365 Fax:1.541.574.0644

FIRM Map Changes - Neohla Point Townhouses

Image Taken July 2013
4-inch, 4-band Digital Orthophotos
David Smith & Associates, Inc. Portland, OR

0 50 100 200 Feet

N

City of Newport
Community Development Department
169 SW Coast Highway Phone:1.541.574.0629
Newport, OR 97365 Fax:1.541.574.0644

North Newport
FIRM Map Changes

Aerial Image Taken 2009

0 1,000 2,000 4,000 Feet

N

City of Newport
Community Development Department
169 SW Coast Highway Phone:1.541.574.0629
Newport, OR 97365 Fax:1.541.574.0644

South Newport FIRM Map Changes

Aerial Image Taken 2009

0 1,000 2,000 4,000 Feet

N

City of Newport

Community Development Department

Memorandum

To: Newport Planning Commission/Citizen Advisory Committee

From: Derrick Tokos, Community Development Director

Date: August 18, 2016

Re: Amendments to Newport Municipal Code Related to Vertical Evacuation Structures

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At its August 15, 2016 regular meeting, the Newport City Council discussed whether or not the City should evaluate amending its building height limitations to allow for vertical evacuation structures in tsunami inundation areas in light of Oregon State University's July 6, 2016 announcement that they selected the Hatfield Marine Science Center as the location for their new Marine Studies Initiative building. The announcement noted that they intend to incorporate vertical evacuation features into the design of the building. While the City has a process in place for applicants to seek a variance to building height limits, the Council felt that this is an issue that might best be addressed legislatively given that the existing height limits were put in place before (a) the modern understanding of tsunamis and their potential impact on our community came to light and (b) vertical evacuation was developed as a tool for responding to tsunami risks. A legislative option could allow for the application of vertical evacuation technologies in a number of locations within the community. Considering the above, the Council directed staff to work with the Planning Commission on potential legislative amendments.

Chapter 14.10 of the Newport Municipal Code identifies height limitations of the various zoning districts and provides for certain exemptions to the height limits. Attached is draft language amending this section of the municipal code to allow portions of structures designed for vertical evacuation to exceed height limits for properties located within tsunami inundation areas. A general exemption such as this may be more desirable than a fixed height limit due to the fact that the design elevation of such a structure is likely to vary depending upon where it is located, the type of construction, etc. The draft language defines the tsunami inundation areas as those that have been mapped by the Oregon Department of Geology and Mineral Industries (DOGAMI). As a rule, it is important to call out your map source in this manner so that there isn't any ambiguity as to which properties are inside or outside of an inundation area.

This is an initial stab at code language that would address the issue, and I would appreciate your feedback as to its adequacy and whether or not there are other factors that should be considered. If you are interested in learning more about vertical evacuation structures and their potential application, the publication "Guidelines for Design of Structures for Vertical Evacuation from Tsunamis" published by FEMA, dated April 2012 is an excellent resource. I have included Chapters 4 and 5 of that document in your packet. A full copy of the publication can be viewed and downloaded from FEMA's website at:

http://www.fema.gov/media-library-data/1426211456953-f02dffee4679d659f62f414639afa806/FEMAP-646_508.pdf

If the Commission is comfortable that the proposed language is adequate for the city to initiate a legislative process to amend the Municipal Code than a motion can be made to that effect at the work session provided there is a quorum of Commission members present.

- Attachments

- Draft Amendments to Chapter 14.10 of the Newport Municipal Code
- Table A to the Zoning Ordinance (referenced in Chapter 14.10)
- Marine Studies Initiative Newport Building Siting Recommendations Executive Summary, dated July 6, 2016
- FEMA Guidelines for the Design of Structures for Vertical Evacuation from Tsunamis, dated April 2012 (Chapters 4 and 5 only)
- DOGAMI TIM Maps for North and South Newport

CHAPTER 14.10 HEIGHT LIMITATIONS

14.10.010 Height Limitations

A building, structure, or portion thereof hereafter erected shall not exceed the height listed in Table A for the zone indicated except as provided for in Sections 14.10.020, General Exceptions to Building Height Limitations and 14.10.030, Special Exceptions to Building Height Limitations.

14.10.020 General Exceptions to Building Height Limitations

A. The following types of structures or structural parts are not subject to the building height limitations of this Code as long as the square footage of said structure or structural part is no greater than 5% of the main building foot print as shown on the site plan, or 200 square feet, whichever is less: chimneys, cupolas, church spires, belfries, domes, transmission towers, smokestacks, flag poles, radio and television towers, elevator shafts, conveyors and mechanical equipment.

B. No structure or structural part excepted under Subsection (A) from the building height limitations of this Code, whether freestanding or attached to another structure or structural part, may exceed the maximum allowable height by more than 25% unless approved by the Planning Commission per section 14.10.030.

C. Standalone antennas, cell towers, electrical transmission towers, telephone or electric line poles and other public utility types of structures or structural parts, where allowed by this Ordinance, are limited in height to 50 feet in R-1, R-2, R-3, R-4, W-1, W-2, W-3 and C-2 zones; 100 feet in the P-1, C-1 and C-3 zones; 150 feet in the I-1, I-2 and I-3 zones. A taller structure or structural part referenced under this subsection may be allowed upon the issuance of a conditional use permit per Section 14.33 of this Code.

D. Portions of a structure designed for vertical evacuation from a tsunami where the property upon which the structure is located is within a tsunami inundation area as depicted on the maps titled "Local Source (Cascadia Subduction Zone) Tsunami Inundation Map Newport North, Oregon" and "Local Source (Cascadia Subduction Zone) Tsunami Inundation Map Newport South, Oregon" produced by the Oregon Department of Geology and Mineral Industries, dated February 8, 2013.

~~D~~E. No structure or structural part excepted under this section from the building height limitations of this Code may be used for human habitation.

14.10.030 Special Exceptions to Building Height Limitations

Any person seeking a special exception to the building height limitations of this Code shall do so by applying for an adjustment or variance as described in Section 14.33 of this Code, and consistent with Section 14.52, Procedural Requirements.**

*(*Amended by Ordinance No. 1839 (10-1-01).*
***Amended by Ordinance No. 1989 (1-1-10).)*

2-3-5
TABLE "A"

District	Minimum Lot Area (Sq. Ft.)	Minimum Width	Setback Requirements: Front/2nd Front[1]	Side	Rear	Lot Coverage In Percent	Maximum Building Height	Density In Sq. Ft. Per Unit
R-1/"Low Density Single-Family Residential"	7,500	65'	15' and 15' or 20' and 10'	5' & 8'	15'	54%	30'	7,500
R-2/"Medium Density Single-Family Residential"			15' and 15' or 20' and 10'					
Duplex on interior lot	7,500	50		5'	10'	57%	30'	3,750
Duplex on corner lot	5,000	50'		5'	10'	57%	30'	2,500
House	5,000	50'		5'	10'	57%	30'	5,000
R-3/"Medium Density Multi-Family Residential"	5,000	50'	15' and 15' or 20' and 10'	5'	10'	60%	35'	1,250[2]
R-4/"High Density Multi-Family Residential"[3]	5,000	50'	15' and 15' or 20' and 10'	5'	10'	64%	35'	1,250
C-1/"Retail and Service Commercial"	5,000	0'	0'	0'	0'	85-90%*	50'*	n/a
C-2/"Tourist Commercial"	5,000	0'	0'	0'	0'	85-90%*	50'*	n/a
C-3/"Heavy Commercial"	5,000	0'	0'	0'	0'	85-90%*	50'*	n/a
I-1/"Light Industrial"	5,000	0'	50' from Hwy. 101	0'	0'	85-90%*	50'*	n/a
I-2/"Medium Industrial"	20,000	0'	50' from Hwy. 101	0'	0'	85-90%*	50'*	n/a
I-3/"Heavy Industrial"	5 acres	0'	50' from Hwy. 101	0'	0'	85-90%*	50'*	n/a

* See Section 2-4-4   n/a - not applicable

[1] Front and second front yards shall equal a combined total of 30 feet. All garages shall be set back at least 20 feet from the access street.

[2] Amended by Ordinance No. 1642 (8-3-92).

[3] Density of hotels, motels, and nonresidential units shall be one unit per 750 square feet.

2-3-5 (con't)
TABLE "A"

District	Minimum Lot Area (Sq. Ft.)	Minimum Width	Setback Requirements: Front/2nd Front	Side	Rear	Lot Coverage In Percent	Maximum Building Height	Density In Sq. Ft. Per Unit
W-1/"Water Dependent"	0	0'	0'	0'	0'	85-90%*	40'*	n/a
W-2/"Water Related"	0	0'	0'	0'	0'	85-90%*	35'*	n/a
MU-1 thru MU-10 (Management Units)	0	0'	0'	0'	0'	100%	40'*	n/a
P-1/"Public Structures"	0	0'	0'	0'	0'	100%	50'	n/a
P-2/"Public Parks"	0	0'	0'	0'	0'	100%	35'	n/a
P-3/"Public Open Space"	0	0'	0'	0'	0'	100%	30'	n/a
(M-H)/"Mobile Home Overlay"	For mobile homes on individual lots, see underlying zone; for mobile home parks, see ORS 446.100 and OAR 814-28-060.							

* See Section 2-4-4 n/a - not applicable

Front and second yards shall equal a combined total of 30 feet. All garages shall be set back at least 20 feet from the access street.

Marine Studies Initiative Newport Building Siting Recommendation
Executive Summary
July 6, 2016

Marine Studies Initiative Newport Building Siting Committee*

Introduction

Through its Marine Studies Initiative (MSI), Oregon State University will be recognized as a global leader in 21st-century transdisciplinary education, research and outreach, and lead the development of inclusive global strategies for successful stewardship of the oceans and planet. The MSI will help to create a healthy future through research and teaching that emphasizes collaboration, experiential learning and research, engagement with society and problem solving.

To achieve this goal, the MSI will leverage and build upon OSU's existing strengths in the marine-related sciences and other academic disciplines, coastal community engagement and OSU's state-of-the-art research and teaching facilities, especially those at the Hatfield Marine Science Center (HMSC) in Newport, Oregon. By 2025, the goal is to have 500 full-time equivalent marine studies students resident in Newport, with 400 of those students being undergraduates and 100 as graduate students. The MSI will expand the collaborative, problem-solving and experiential learning environment in Newport with access to real-world scholars, agency scientists and engaging community issues. The MSI program will use existing classrooms, seawater teaching laboratories and facilities, and the Guinn Library at HMSC. MSI programming will improve overall "access to the sea" for OSU students, faculty and staff, thereby creating the foundation for experiential learning and research.

As part of the MSI, the University plans to construct an academic and research building in Newport. Given the importance of the MSI and the priority for safety in light of an eventual significant seismic event occurring along the coast, OSU has conducted a comprehensive evaluation of multiple potential site locations for this building. The primary purpose for this evaluation was to develop a recommendation on siting the building within the tsunami inundation zone at HMSC or on higher ground outside the inundation zone. The evaluation included two third-party reports about the HMSC site (Poland Report) and two alternative sites (Fortis Report), as well as information gathered from a public comment session in Newport, consultations with legislators, and input from a range of government officials and OSU faculty -- primarily from the College of Earth, Ocean and Atmospheric Sciences (CEOAS) and the College of Engineering (COE).

Regardless of the location selected for the MSI Newport building, Oregon State will meet the following building principles:

- The building will be designed to ensure that its structural integrity is maintained for the expected Cascadia Subduction Zone (CSZ) earthquake. This design will enable all occupants—including those with limited mobility—to survive a future seismic event, exit timely manner and, if required, safely follow a tsunami evacuation plan

- The building's design and safety features will serve as a national and global showcase and demonstrate state-of-the-art structural options for future buildings located in seismically active regions worldwide, as well as for earthquake and tsunami readiness.

- The building will have a design occupancy of not more than 350 people.

Overview of Seismic Hazards

All of the Newport-area sites considered are in a high seismic zone. The primary contributor to the seismic hazard is the Cascadia Subduction Zone. When a site is subjected to earthquakes and/or tsunamis, specific seismic hazards are considered: strong shaking, fault rupture, landslides, liquefaction, lateral spreading and tsunamis. All sites in the Newport-area will be subjected to a similar amount of strong shaking during a CSZ event. Some of the hazards, such as fault rupture and a tsunami event, can be avoided by site selection while other hazards, such as liquefaction and lateral spreading, can be prevented through design and construction measures.

Researchers have been able to identify 41 tsunamis associated with CSZ earthquakes of various sizes over the last 10,000 years. Based on the paleo seismic record, the average return interval for significant earthquakes (ranging from 7.4 to 9.2 in magnitude) within the CSZ is about 300 years. The last one occurred in 1700. In the last 10,000 years, the refereed literature indicates that there has been one event of magnitude 9.2. Recent OSU research indicates that there may have been a second event of this magnitude in the past 10,000 years, though this second event is currently not in the refereed literature.

Earthquakes of different sizes generate different sizes of tsunamis. For simplicity, the Oregon Department of Geology and Mineral Industries (DOGAMI) has used the "t-shirt" sizes of S, M, L, XL and XXL to characterize the different sizes of tsunamis using estimated inundation line -- the inland limit of inundation due to the tsunami. According to DOGAMI, inundation depths at HMSC range from less than 1 foot in the "S" event to 27 feet in the "XXL" event. The XXL-line is associated with the largest tsunami in the past 10,000 years.

In 2015, the Governor's Task Force on Implementation of the Oregon Resilience Plan recommended that the L-line, the inundation limit associated with an L-size tsunami, be used for planning and design purposes in the state of Oregon. For this recommended design event, the inundation depth at HMSC for an L-size tsunami is six feet.

Student Housing to Be Located Outside of Tsunami Inundation Zone

Regardless of the location of the proposed MSI Newport building, all new OSU housing for marine studies students, as well as other students working at HMSC, will be constructed above the XXL inundation zone described by DOGAMI. Assuming that students spend about 9 to10 hours per day at their residence hall, the location of housing on higher ground reduces students' potential time spent in the tsunami zone by about 40 percent while also mitigating the potential impact that darkness might have on students should a seismic event occur at night. OSU is currently conducting due diligence on a site located outside the XXL tsunami inundation zone and proximal to HMSC, for use as student housing.

Overview of Site Characteristics

HMSC Site

The terrain in the South Beach area that includes the HMSC site is relatively flat and ranges from 15 to 18 feet above sea level. The area is underlain by a deep deposit of sand, whose density varies with location and depth. OSU leases the HMSC campus property from the Port of Newport. Over time, the City of Newport has invested $3.2 million to develop infrastructure to support the build out of the HMSC marine research and educational facilities.

Sites above Tsunami Inundation Zone – "Alternative Sites"

The two alternative sites identified by OSU are located south of the Yaquina Bay Bridge; are outside the tsunami inundation zone ("XXL-line") as identified by DOGAMI; and are within the City of Newport and/or the city's urban growth boundary. The sites are located between one to two miles away from HMSC; respectively provide 11 and 29 acres of developable land; and presently are heavily wooded with undulating terrain. One site includes infrequent deep ravines.

Summary Evaluation of Sites

Evaluation criteria of all prospective sites included the following factors:

1. Life Safety (seismic, inundation, evacuation, HMSC staff and visitor safety)

2. MSI Program Delivery

3. Cost of Development and Operations; and

4. Schedule

1. Life Safety Factors

<u>A. Seismic</u>

Both the HMSC site and the alternative sites will experience strong shaking of similar levels. In fact, it is possible that the alternative sites may experience greater shaking due to ground motion amplification. Structures at any of the sites can be designed to survive the strong shaking.

HMSC Site: Previous soil borings have been undertaken to determine the site's underlying sand characteristics. Without appropriate seismic design measures, significant liquefaction settlement is expected at the HMSC site, while it is anticipated the liquefaction settlement inland along the evacuation path may range from negligible to up to six inches. Liquefaction-induced lateral spreading, which may lead to cracks in the ground, is likely along the Yaquina Bay shoreline, but lateral spread is not expected to extend to Marine Science Drive (Fortis Report). Both liquefaction and lateral spreading hazards can be mitigated and are included in the construction cost estimates.

Alternative Sites: No signs of slope instability were observed and DOGAMI landslide maps show no indication of historic landslides having occurred at the sites. Based on anticipated subsoil conditions, modest ground motion amplification is anticipated and liquefaction at these locations, and lateral spread hazard are anticipated to be relatively low. Exploratory drilling will be required to better evaluate these hazards and guide the detailed design and construction processes (Fortis Report).

B. Inundation

DOGAMI and OSU College of Engineering inundation models show an estimated arrival time of 30 minutes for the tsunami to reach the proposed HMSC building site. Based on the Poland report recommendations, if the building were sited at HMSC, it should be designed to be repairable for the L-sized tsunami and horizontal evacuation strategies and capabilities should be designed for the worst case XXL-sized event. Inundation is not a concern for the alternative sites.

C. Evacuation *(Revision of July 1, 2016 Report)*

Throughout the world, the preferred method of evacuation planning for tsunamis stresses horizontal evacuation routes, preparations, procedures and training. HMSC conducts tsunami evacuation drills twice per year and a very high percentage of HMSC workers have a safety and survival pack ("go bags") nearby them at their place of work.

Evacuation modeling by the OSU College of Engineering shows that 100 percent of mobile evacuees can make it safely to Safe Haven Hill before the predicted arrival of a tsunami. The City of Newport and FEMA recently have completed a $900,000 project to improve the tsunami evacuation assembly area at Safe Haven Hill. Located at 70 feet above sea level, the top of Safe Haven Hill features a 2.33-acre area that includes approximately 50,000 square feet of cleared space. Based upon federal and engineering emergency space standards of 10-square-feet per person, the Safe Haven Hill evacuation area will serve 5,075 people. (See recommendation below regarding investments in hardening the evacuation route to Safe Haven Hill.)

Importantly, in addition to providing an emphasis on horizontal evacuation plans, the MSI building design process needs to consider building a seismically safe structure that includes features to vertically evacuate people with limited mobility to the upper levels and roof of the building or to the construction of a dedicated vertical shelter. Training and vertical evacuation drills to serve injured, disabled or elderly individuals should be emphasized and routinely conducted by OSU in coordination with other Newport-area community emergency planners. By doing so, OSU will provide additional life safety capacity to the existing HMSC staff and students, as well as visitors, other agency employees who work at HMSC, or others who work in the South Beach area.

Oregon State employed 356 people at HMSC in the winter of 2015; 436 people in the summer of 2015; and is expected to grow to 800 to 900 people by 2025.

Evacuation to higher ground is not required at the alternative sites.

D. HMSC Staff and Visitor Safety

The evacuation route from HMSC to Safe Haven Hill presently is clearly marked with blue tsunami evacuation signs. HMSC designed and implemented a tsunami interpretive trail on behalf of community partners, which each year educate thousands of visitors within the HMSC Visitor Center and the Oregon Coast Aquarium. HMSC is coordinating with South Beach peninsula stakeholders to fully supply two disaster caches at critical nearby evacuation sites.

2. *MSI Program Delivery*

Building at an alternative site would significantly compromise MSI program delivery and the ability to meet MSI program goals, due to the extensive spatial disconnect that would occur by separating the activities to occur within the MSI Building from OSU and agency researchers already working within HMSC, and by limiting users of the MSI building from ready access to core HMSC research facilities, including seawater labs. Further, MSI students would still spend the majority of their time at HMSC. Operationally, there would be added complications and likely costs in administering and maintaining offsite facilities. Finally, OSU would miss the opportunity -- and commitment made in the MSI building principles and during fund-raising -- to demonstrate state-of-the-art innovation in seismic and tsunami resilient engineering for local and global coastal communities.

3. *Cost*

<u>HMSC site</u>
OSU can build on leased land at no additional cost. Additional costs for providing seismic and tsunami safety will be included in the $50 million project cost. Construction on this site creates the opportunity to leverage additional public and private investments to support these safety features.

<u>Alternative Sites</u>
Construction costs at the alternative sites, including site infrastructure (utilities, roads, lighting, etc.), are estimated to be $1.5 to $3.5 million less than for the HMSC site. However, the alternative sites would also require additional one-time expenditures, including the purchase of land (estimated at $1 to $4 million) and required infrastructure (estimated at $1 to $3 million) to accommodate the off-site research building (shuttle, parking lot at HMSC, traffic flow improvements, facility vehicles, etc.). In addition, annual operating costs of the alternative sites would be approximately $500,000 to $700,000 due to the cost of shuttle services and building facilities and custodial support.

4. *Schedule from completion of architectural and engineering work*

<u>HMSC Site</u>
Construction is estimated at 16 months.

<u>Alternate Sites</u>
Construction ranges between 16-17 months, including possible infrastructure and site preparation work.

Additional Considerations

Faculty Input

Input regarding the siting of the MSI Newport building was sought from Oregon State faculty with relevant expertise. The initial input was provided in the form of letters from the Geology and Geophysics disciplinary group within the College of Earth, Ocean and Atmospheric Sciences

(CEOAS) and from faculty in the College of Engineering's School of Civil and Construction Engineering (COE). CEOAS Geology and Geophysics faculty urged the consideration of alternative sites located outside of the known tsunami flooding zones. COE faculty noted that Oregon State is in a unique position to provide evaluation in planning, design and construction, and education to reduce the coastal impact of a Cascadia Subduction Zone event. COE faculty urged OSU to design and construct the new Marine Studies facility beyond the conventional code requirements to serve as a model for earthquake and tsunami resilience.

COE and CEOAS faculty were asked by University leadership to review and comment on the two MSI building third-party reports: the Poland and Fortis reports. COE faculty did point out the requirement to address life safety at the three locations due to an earthquake citing that the MSI project would be new construction and would have to conform to seismic codes. The COE faculty discussion did not reveal any "red flags" or technical challenges which could not be overcome, and they noted that a well-designed building within the tsunami inundation zone would increase life safety opportunities for people already working within the surrounding area. COE faculty concluded that the new construction and plans to increase life safety should be integrated with the overall planning for the Newport campus.

CEOAS Geology and Geophysics faculty noted that the Poland Report concludes that a building that can withstand a large earthquake and tsunami and provide life safety for an extra-large event is feasible. They concluded that an alternative site "makes sense in terms of economic, hazard, life safety and longevity considerations." They also agreed with the recommendation for a new reinforced evacuation path to provide improved egress from existing facilities in and around HMSC. CEOAS Geology and Geophysics faculty concluded by recommending a long-term plan to relocate all existing OSU facilities to an alternative site above the tsunami inundation zone to substantively avoid the multiple natural hazards that exist at the HMSC site.

Community stakeholder input

Newport community stakeholder input is nearly unanimous in favor of building the MSI Newport building at HMSC. The Mayor and City Manager of Newport both stressed the investments made by the city and partners to improve the South Beach tsunami evacuation route and evacuation assembly area at Safe Haven Hill. Lincoln County Commissioners remarked that the risks of building at the HMSC site are mitigated by on-going advancement in structural design to withstand tsunamis including vertical evacuation features, and by the advancement in effective early detection and warning systems.

Leaders of three major OSU programs located at HMSC -- the Cooperative Institute for Marine Resources Studies (CIMRS); the Coastal Oregon Marine Experiment Station (COMES); and the

Marine Mammal Institute (MMI) -- stressed that building on the HMSC site will provide "an excellent example of how to build earthquake- and tsunami-safe buildings in coastal communities" and that the new building can "be engineered to increase survivorship for individuals working at South Beach by acting as an alternate on-location 'safe haven' for the disabled and injured."

Other HMSC faculty and staff emphasized the synergy of having the new MSI Newport building be built on the HMSC campus to gain the positive benefits of collaboration with existing personnel and facilities. HMSC faculty and staff also expressed concerns about potential damage to the tsunami evacuation route from the earthquake and the need for seismic retrofitting of existing OSU HMSC buildings.

HMSC Federal and State Agency plans (*Revision of July 1, 2016 Report)*

A survey of government agencies located on the HMSC campus, including the National Oceanic and Atmospheric Administration (NOAA); the U.S. Environmental Protection Agency (USEPA); the United States Department of Agriculture (USDA); the United States Fish and Wildlife Service (USFWS); and the Oregon Department of Fish and Wildlife (ODFW), indicated that the agencies were supportive of the MSI program, are aware of the potential seismic and tsunami hazards, and had no plans to leave the HMSC location. Each agency is involved in discussions of how to best prepare for seismic and tsunami hazards. NOAA leadership expressed interest in the potential for vertical evacuation in the new MSI building, especially for individuals who are mobility challenged and who may have difficulty reaching other higher ground locations in a timely manner.

Government agency and/or Commission Communications

Over the last two years, University officials have been in frequent contact with a wide variety of federal, state and local government officials and entities. Throughout the consideration of the capital project, both Governors Kitzhaber and Brown were kept fully aware that MSI plans provided for the construction of the building in the tsunami inundation zone. Through consideration of House Bill 5005, members of the Legislature's Joint Ways and Means Committee anticipated and enabled the construction of the project on the HMSC campus. In our evaluation, members of the Newport Building Siting Committee also recognize that the legislative history of the project's consideration does not require that the building be located on HMSC campus.

The committee acknowledges the importance of the natural hazard issues faced by all of Oregon's universities that are cited in a Feb. 1, 2016 letter sent by the chair and vice chair of the Oregon Seismic Safety Policy Advisory Commission (OSSPAC). While these resiliency issues are relevant to the location selected for the MSI Newport building, they predominantly apply to all of OSU's statewide operations. The Newport Building Siting Committee believes that Oregon State University should convene a seismic preparedness committee to evaluate and provide the University strategic recommendations on the following issues in the event of a major seismic event:

- Continuity planning for general university operations planning;
- Continuity planning for grant-funded research;
- Continuity planning for on-going student enrollment and tuition revenues;
- Continuity planning for research centers, experiment stations and extension centers along the coast and throughout the state that would be relied on after a seismic event.

In the event of a CSZ XXL-sized event, OSU might face liability for repair, recovery and cleanup of the campus facilities (both the existing and any new MSI Building). OSU's Risk Management intends to address this liability by extending existing insurance coverage to the new HMSC building. This coverage insures for costs associated with repair, recovery and cleanup of the campus facilities in the event of damage caused by either earthquake or flooding. OSU is currently protected from property damage caused by earthquake at a $100 million limit which specifically includes the Pacific Northwest earthquake zone and flood insurance at a $250 million limit. The premium amount charged to OSU for such property insurance for the new MSI building will not change because the property is inside or outside of the tsunami inundation zone. While OSU is working to avoid or mitigate personal injury and any loss of life in such a catastrophic event, we have also confirmed that OSU's liability is mitigated through insurance and negligence findings are less likely given OSU's dedication to meet or exceed industry standards for building and evacuation training.

A CSZ event might also have a significant impact on the surrounding community which might require a shutdown of the HMSC campus. This shutdown can occur regardless of the location of the new MSI building. Because of that possible shutdown, OSU is exposed to potential liability in the form of lost tuition, lost research grant revenue and obligations to continue to pay operating costs for the faculty and staff in salary and OPE. The financial model for MSI (which has a large number of assumptions in it) projects $12.8 million in revenues for fiscal year 2025. More than 90 percent of that revenue is projected to come from tuition from the student growth. Assuming OSU is still able to operate in Corvallis following a seismic event, OSU would presumably move Newport-based classes to facilities in Corvallis, and relocate what research activity that had not been lost into Corvallis labs. Because operating costs for the faculty and staff in salary and OPE would continue despite a shutdown of HMSC, presumably faculty and staff would move their work to Corvallis during restoration of the HMSC campus. In addition, OSU is also covered by a business interruption policy which covers lost tuition and research revenue and expenses, such as payment of salaries. OSU would look to its insurance provider to cover its revenue losses to the extent that mitigation efforts are not 100 percent successful.

In recent conversations, Jay Wilson, chair of the OSSPAC -- without expressing an opinion regarding precisely where the facility should be constructed -- expressed that he was pleased with the robust process OSU has followed. He said he understood OSU needs to balance function and seismic issues, and he expressed an assurance that through this process, President Ray can reach a thoughtful siting decision, whatever that decision may ultimately be.

During a February 2016 meeting with the Coastal Legislative Caucus, all legislators present were adamant in supporting construction of the facility on the HMSC campus. A number of members expressed deep concerns regarding the precedent – and possible impacts to the economic vitality of the coastal region – if OSU were to locate the facility outside of the tsunami inundation zone.

From numerous conversations involving OSU officials and a wide variety of political and governmental entities over the last two years, it is clear that construction within the inundation zone should be contingent upon the inclusion of design elements that will enable the building to withstand a significant seismic event, as well as provide for adequate evacuation infrastructure and plans from the HMSC campus.

Donor intent

The degree to which the primary donor is committed to locating the building at HMSC is not presently known. While the 2013 proposal to the primary donor was very explicit about building at the HMSC site, follow up will be needed with all donors if one of the alternative sites is selected. In the donor proposal, the building site at HMSC was specifically emphasized to:

1) Ensure that "students will have outstanding access to the full spectrum of research and educational facilities of the Marine Studies Campus and nearby natural habitats;"
2) "Build on Hatfield Marine Science Center's exceptional resources for education, research and outreach;" and
3) "Access the collaboration and innovation which is so deeply ingrained in the culture at Hatfield, where OSU researchers work in close proximity to and in collaboration with researchers in federal and state agencies."

As summarized in the section on program delivery, it may be possible to marginally meet these expectations at an alternative site, but it will be more difficult and operationally expensive to do so.

It was also clear within the donor proposal that "the facility will be designed with structural resiliency for seismic and tsunami events," and that "student housing facilities for the Marine Studies Campus will be located outside the hazard zone."

Summary Recommendations *(Revision of July 1, 2016 Report)*

Based on this comprehensive evaluation of the alternative sites and the HMSC location, it is recommended that OSU build the new MSI Newport building on the HMSC campus. This recommendation is based on due consideration of life safety while addressing program delivery, cost and schedule.

By building a seismically safe structure on the HMSC campus – with the ability to vertically evacuate people – OSU will deliver additional life safety capacity for existing HMSC employees and visitors. Building at the HMSC campus site will maximize the ability to meet the MSI programmatic goals due to new building's proximity to existing OSU and agency researchers, and access to core research facilities.

Even if the MSI building were built away from the HMSC campus, students would still spend the majority of their day time at HMSC, significantly negating the intended goal of keeping students out of the tsunami zone.

By building at the HMSC site, OSU will demonstrate state-of-the-art innovation in seismic and tsunami resilient engineering to local and global coastal communities.

Further, by building a seismically safe structure on the HMSC campus with the ability to vertically evacuate people, OSU will address life safety for those individuals with limited mobility or who are injured during a seismic event by providing training and vertical evacuation drills in coordination with other Newport-area community emergency planners. By doing so, OSU also will provide additional life safety capacity to the existing HMSC staff and students, as well as visitors, other agency employees who work at HMSC, or others who work in the South Beach area.

The building should be designed to allow individuals with limited mobility to be assisted in reaching the building's upper floors and roof.

In addition to this summary recommendation, the MSI Siting Committee also recommends:

- Improvement of evacuation route between the HMSC campus and Safe Haven Hill to mitigate risk from soil liquefaction. Hardening of the evacuation route with reinforced pavement will reduce the risk of cracking and faulting along the route, hence improving safe evacuation including for wheel chair access. The direct construction cost of this hardening is estimated at about $515,000.
- Hold the project budget to $50 million even if the building gross square footage is compromised to achieve the life safety benefits.
- A holistic evaluation by the University of seismic conditions at all OSU locations, including HMSC, and creation of a seismic safety improvement plan for each location. This effort will include implementing over the next decade recommendations in the Fortis Construction Inc. report as how to bring existing HMSC buildings up to appropriate standards.
- Continuation of ongoing and improved seismic safety and tsunami evacuation training for all HMSC visitors, students and employees in association with the local community. This preparation must address the needs of everyone, including those with limited mobility.

Finally, the MSI Newport Building and any related seismic improvements and safety efforts should capture a full learning experience for OSU students, as well as the community at large.

*MSI Newport Building Siting Committee membership:
Ron Adams, Interim Provost and Executive Vice President
Scott Ashford, Dean, College of Engineering
Anita Azarenko, Associate Vice President designate, Capital Planning, Development & Facilities Operations
Jack Barth, MSI Executive Director
Steve Clark, Vice President for University Relations and Marketing
Robert Cowen, HMSC Director
Lori Fulton, Manager of Capital Administration
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Gabrielle Serra, Director, Federal Relations

Guidelines for Design of Structures for Vertical Evacuation from Tsunamis

Second Edition

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Chapter 4
Vertical Evacuation Options

A *vertical evacuation refuge from tsunamis* is a building or earthen mound that has sufficient height to elevate evacuees above the level of tsunami inundation, and is designed and constructed with the strength and resiliency needed to resist the effects of tsunami waves. Vertical evacuation refuges can be stand-alone or part of a larger facility. They can be single-purpose refuge-only facilities, or multi-purpose facilities in regular use when not serving as a refuge. They can also be single-hazard (tsunami only) or multi-hazard facilities.

> In concept, vertical evacuation options are applicable to new or existing structures, but it will generally be more difficult to retrofit an existing structure than to build a new tsunami-resistant structure using these criteria.

In concept, these options are applicable to new or existing structures, but it will generally be more difficult to retrofit an existing structure than to build a new tsunami-resistant structure using these criteria. This chapter describes the features of different vertical evacuation options that are available, and provides guidance to assist in choosing between various options.

It should be stressed that evacuation to high ground is always preferred where access to nearby high ground exists. This provides the option for refugees to move to even higher ground if the tsunami inundation is greater than anticipated, something that may not be possible in an evacuation building or earthen mound because of the height limitation of the refuge.

4.1 Vertical Evacuation Considerations

Vertical evacuation structures can be intended for general use by the surrounding population, or by the occupants of a specific building or group of buildings. Choosing between various options available for vertical evacuation structures will depend on emergency response planning and needs of the community, the type of construction and use of the buildings in the immediate vicinity, and the project-specific financial situation of the state, municipality, local community, or private owner considering such a structure.

4.1.1 Single-Purpose Facilities

> Vertical evacuation facilities can be single-purpose, multi-purpose, or multi-hazard facilities.

The tsunami hazard assessment and inundation study may show that the best solution is to build new, separate (i.e., stand-alone) facilities specifically designed and configured to serve as vertical evacuation structures. Potential advantages of single-purpose, stand-alone facilities include the following:

- They can be sited away from potential debris sources or other site hazards.
- They do not need to be integrated into an existing building design or compromised by design considerations for potentially conflicting usages.
- They are structurally separate from other buildings and therefore not subject to the potential vulnerabilities of other building structures.
- They will always be ready for occupants and will not be cluttered with furnishings or storage items associated with other uses.
- Single-purpose, stand-alone structures will likely be simpler to design, permit, and construct because they will not be required to provide normal daily accommodations for people. They can have simplified prototypical structural systems, resulting in lower initial construction costs.

One example of a single-purpose facility is a small, elevated structure with the sole function of providing an elevated refuge for the surrounding area in the event of a tsunami. A possible application for such a facility would include low-lying residential neighborhoods where evacuation routes are not adequate, and taller safer structures do not exist in the area.

4.1.2 Multi-Purpose Facilities

A coastal community may not have sufficient resources to develop a single-purpose tsunami vertical evacuation structure or a series of structures, so creative ways of overcoming economic constraints are required. Possible solutions include co-location of evacuation facilities with other community-based functions, co-location with commercial-based functions, and economic or other incentives for private developers to provide tsunami-resistant areas of refuge within their developments. The ability to use a facility for more than one purpose provides immediate possibility for a return on investment through daily business or commercial use when the structure is not needed as a refuge.

Multi-purpose facilities can also be constructed to serve a specific need or function in a community, in addition to vertical evacuation refuge. Examples include elevated man-made earthen berms used as community open spaces. In downtown areas or business districts, they can be specially constructed private or municipal parking structures incorporating tsunami resistant design. On school campuses, vertical evacuation facilities could serve as gymnasiums or lunchrooms on a daily basis. In residential subdivisions, they can be used as community centers.

4.1.3 Multi-Hazard Considerations

Communities exposed to other hazards (e.g., earthquakes, hurricanes) may choose to consider the possible sheltering needs associated with these other hazards, in addition to tsunamis. This could include allowances for different occupancy durations, consideration of different post-event rescue and recovery activities, and evaluation of short- and long-term medical care needs.

Designing for multiple hazards requires consideration of the load effects that might be unique to each type of hazard. This can pose unique challenges for the resulting structural design. For example, the structural system for vertical evacuation structures exposed to near-source-generated tsunamis will likely need to be designed for seismic hazards. Such a structure might include break-away walls or open construction in the lower levels to allow water to pass through with minimal resistance. Open construction in the lower levels of a multi-story structure are contrary to earthquake engineering practice to avoid soft or weak stories in earthquake-resistant construction. Proper design and construction will need to include special consideration by the structural engineer of these and other potential conflicting recommendations.

4.2 Vertical Evacuation Concepts

To provide refuge from tsunami inundation, vertical evacuation solutions must have the ability to receive a large number of people in a short time frame and efficiently transport them to areas of refuge that are located above the level of flooding. Potential vertical evacuation solutions can include areas of naturally occurring high ground, areas of artificial high ground created through the use of soil berms, new structures specifically designed to be tsunami-resistant, or existing structures demonstrated to have sufficient strength to resist anticipated tsunami effects.

> Vertical evacuation structures can be soil berms, parking garages, community facilities, commercial facilities, school facilities, or existing buildings.

Nonstructural systems and contents located in the levels below the inundation depth should be assumed to be a total loss if the design tsunami occurs. If the building is required to remain functional in the event of a disaster, the loss of lower level walls, nonstructural systems, and contents should be taken into account in the design of the facility and selection of possible alternative uses.

4.2.1 Existing High Ground

Naturally occurring areas of high ground may be able to be utilized or modified to create a refuge for tsunami vertical evacuation. Large open areas offer easy access for large numbers of evacuees with the added advantage of avoiding the possible apprehension about entering a building following an earthquake. In addition, most coastal communities have educated their populations to "go to high ground" in the event of a tsunami warning. The topography of the existing high ground should be evaluated for the potential of wave runup or erosion. Some modification of the existing topography may be required to address these issues.

4.2.2 Soil Berms

If natural high ground is not available, a soil berm can be constructed to raise the ground level above the tsunami runup height, as shown in Figure 4-1. Although care must be taken to protect the sides of the soil berm from the incoming and outgoing tsunami waves, this option can be relatively cost-effective in comparison to building a stand-alone structure. The height of the berm must be sufficient to avoid becoming inundated, and the slope of the sides must allow for ingress. A maximum ramp slope in the range of one foot vertical rise to four feet horizontal run (1 in 4) is recommended. Soil berms have the added benefit that they are immune to damage from large debris strikes such as shipping containers, barges and ships, making them suitable for locations near port facilities (Figure 4-1).

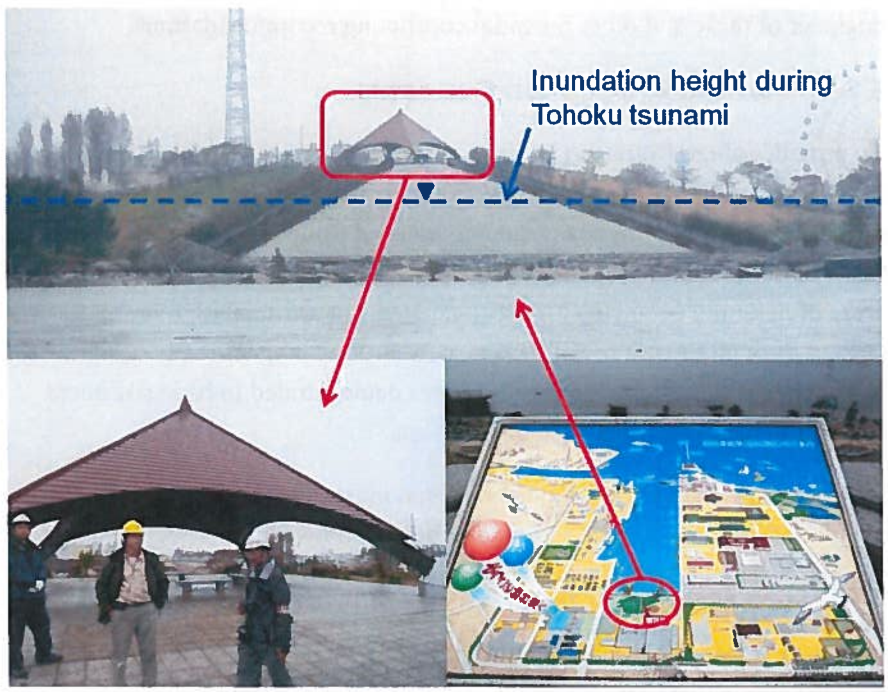

Figure 4-1 Soil berm combined with a community park at Sendai Port, Japan. Concrete lining on the ocean face can deflect incoming waves while sloped sides provide for quick access. Graphic in the lower right side illustrates where the evacuation berm is located in Sendai Port.

4.2.3 Multi-Story Parking Garages

Parking garages are good candidates for use as vertical evacuation structures. Similar to the example shown in Figure 4-2, most parking garages are open structures that will allow water to flow through with minimal resistance. They can also be open for pedestrian access at any time of the day or night. Interior ramps allow ample opportunity for ingress, and easy vertical circulation to higher levels within the structure. Parking garages can also be used to provide additional community amenities on the top level, including parks, observation decks, and sports courts. They are also obvious revenue-generating facilities, especially in areas that attract large numbers of tourists.

Parking garages, however, tend to be constructed using low-cost, efficient structural systems with minimal redundancy. If designed with higher performance objectives in mind, and if subjected to additional code review and construction inspection by local jurisdictions, parking garages could be effective vertical evacuation structures.

Figure 4-2 Cast-in-place reinforced concrete parking garage in Biloxi, Mississippi after Hurricane Katrina. Open structural systems allow water to pass through with minimal resistance, and interior ramps allow for easy ingress and vertical circulation.

4.2.4 Community Facilities

Vertical evacuation structures could be developed as part of other community-based needs such as community centers, recreational facilities, sports complexes, libraries, museums, and police or fire stations. One such example is shown in Figure 4-3. When not in use as a refuge, facilities such as these can be useful for a variety of functions that enhance the quality of life in a community. When choosing alternative uses for a vertical evacuation facility, consideration should be given to potential impacts that other uses might have on the vertical evacuation function. Potential negative impacts could include clutter that could become debris that disrupts ingress. Limited access after regular operating hours would make it difficult to use a facility for evacuation from a tsunami that could occur at any time of the day or night. Priority should be given to uses with complementary functions, such as accommodations for large numbers of people and 24-hour access.

4.2.5 Commercial Facilities

Vertical evacuation structures could be developed as part of business or other commercial facilities including multi-level hotels, restaurants, or retail establishments, as shown in Figure 4-4. For example, if the refuge area is part of a hotel complex, meeting rooms, ballrooms, and exhibit spaces that are located above the tsunami inundation elevation could be used to provide refuge when the tsunami occurs. The apartment building shown in Figure 4-5 was used successfully as a vertical evacuation structure during the Tohoku tsunami. Exterior stairs provided 24 hour access to the upper floors designated as the evacuation refuge.

Figure 4-3 Sports complex. Designed for assembly use, this type of structure can accommodate circulation and service needs for large numbers of people.

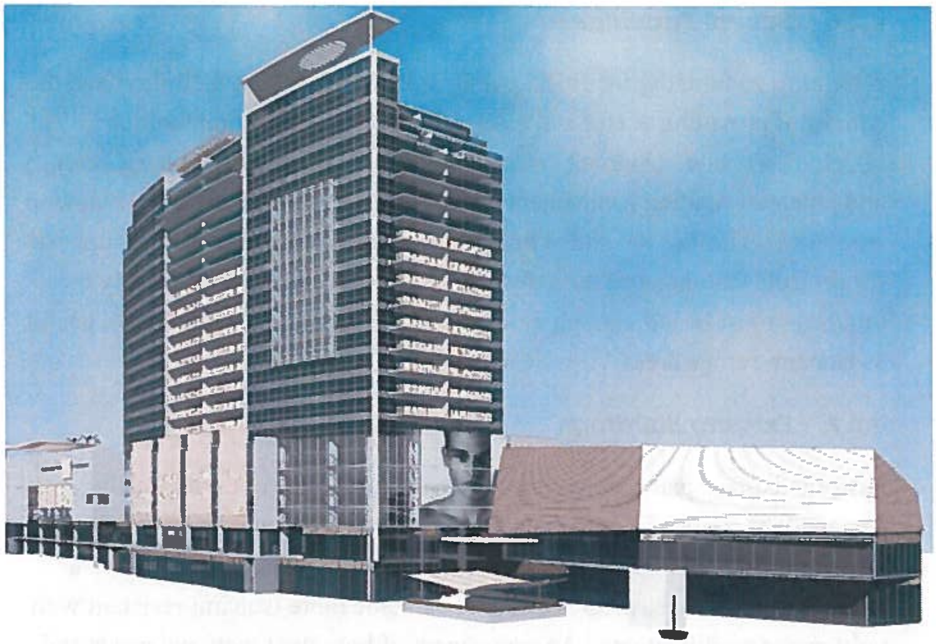

Figure 4-4 Hotel and convention complex. Meeting rooms, ballrooms, and exhibit spaces located above the tsunami inundation elevation can be used to provide areas of refuge.

Figure 4-5 Residential apartment building in Kamaishi, Japan, with designated refuge area at or above the fourth level.

4.2.6 School Facilities

Similar to community facilities, public and private school facilities have the benefit of providing useful and essential services to the communities in which they reside. Ongoing construction of schools provides an opportunity and potential funding mechanism for co-located tsunami vertical evacuation structures. This has the added benefit of possible additional public support for projects that increase the safety of school-age children. Obviously these buildings must be tall enough or sited on high ground so that they are useful as tsunami refuge areas.

4.2.7 Existing Buildings

Historic damage patterns suggest that many structures not specifically designed for tsunami loading can survive tsunami inundation and provide areas of refuge. It is possible that some existing structures could serve as vertical evacuation structures or could be made more tsunami-resistant with only minor modifications. An assessment of both the functional needs and potential structural vulnerabilities would be required to determine if an existing building can serve as a vertical evacuation structure.

In some situations, providing some level of protection is better than none. An example of this concept is shown in Figure 4-6. In a tsunami evacuation map for Waikiki, it is noted that "structural steel or reinforced concrete buildings of six or more stories provide increased protection on or above the third floor", and are identified as potential areas of refuge.

Figure 4-6 Evacuation map for Waikiki, Hawaii, indicating use of existing buildings for vertical evacuation.

Chapter 5
Siting, Spacing, Sizing, and Elevation Considerations

Tsunami risk is unique in that some communities may be susceptible to far-source-generated tsunamis (longer warning time), near-source-generated tsunamis (shorter warning time), or both. Far-source-generated tsunamis generally allow sufficient warning time so that emergency response plans can be based on evacuation out of the inundation zone. Near-source-generated tsunamis may not allow sufficient time for evacuation, so emergency response plans may need to include vertical evacuation refuge. This chapter provides guidance on how to locate vertical evacuation refuges within a community, and how to determine the size of a vertical evacuation structure.

Vertical evacuation structures should be located such that all persons designated to take refuge can reach the structure within the time available between tsunami warning and tsunami inundation.

5.1 Siting Considerations

Vertical evacuation structures should be located such that all persons designated to take refuge can reach the structure within the time available between tsunami warning and tsunami inundation. Travel time must also take into consideration vertical circulation within the structure to levels above the tsunami inundation elevation. Structures located at one end of a community may be difficult for some users to reach in a timely fashion. Routes to the structure should be easily accessible and well-marked.

Location of vertical evacuation structures within a community should take into account potential hazards in the vicinity of a site that could jeopardize the safety of the structure, and should consider that natural behaviors of persons attempting to avoid coastal flooding.

5.1.1 Warning, Travel Time, and Spacing

The West Coast and Alaska Tsunami Warning Center (WC/ATWC) in Alaska, and the Pacific Tsunami Warning Center (PTWC) in Hawaii monitor potential tsunamis, and warn affected populations of an impending tsunami. Table 5-1 summarizes approximate warning times associated with the distance between a tsunami-genic source and the site of interest. A far-source-generated tsunami originates from a source that is far away from the site, and could have 2 hours or more of advance warning time. A near-source-generated tsunami originates from a source that is close to the site, and could have 30 minutes or less of advance warning time. Sites experiencing near-source-generated tsunamis will generally feel the effects of the triggering event (e.g., shaking caused by a near-source earthquake), and these effects will likely be the first warning of the impending tsunami. A mid-source-generated tsunami is one in which the source is somewhat close to the site of interest, but not close enough for the effects of the tsunami generating event to be felt at the site. Mid-source-generated tsunamis would be expected to have between 30 minutes and 2 hours of advance warning time.

Table 5-1 Tsunami Sources and Approximate Warning Times

Location of Source	*Approximate Warning Time (t)*
Far-source-generated tsunami	t > 2 hrs
Mid-source-generated tsunami	30 min < t < 2 hrs
Near-source-generated tsunami	t < 30 min

Recommended maximum spacing of vertical evacuation structures depends on warning time, ambulatory speed, and the surrounding population density.

Consideration must be given to the time it would take for designated occupants to reach a refuge. To determine the maximum spacing of tsunami vertical evacuation structures, the critical parameters are warning time and ambulatory capability of the surrounding community. Once maximum spacing is determined, size must be considered, and population becomes an important parameter. Sizing considerations could necessitate an adjustment in the number and spacing of vertical evacuation structures if it is not feasible to size the resulting structures large enough to accommodate the surrounding population at the maximum spacing. Sizing considerations are discussed in Section 5.2.

The average, healthy person can walk at approximately 4-mph. Portions of the population in a community, however, may have restricted ambulatory capability due to age, health, or disability. The average pace of a mobility-impaired population can be assumed to be about 2-mph.

Assuming a 2-hour warning time associated with far-source-generated tsunamis, vertical evacuation structures would need to be located a maximum of 4 miles from any given starting point. This would result in a maximum spacing of approximately 8 miles between structures. Similarly, assuming a 30 minute warning time, vertical evacuation structures would need to be located a maximum of 1 mile from any given starting point, or 2 miles between structures. Shorter warning times would require even closer spacing. Table 5-2 summarizes maximum spacing of vertical evacuation structures based on travel time associated with a mobility-impaired population.

Table 5-2 **Maximum Spacing of Vertical Evacuation Structures Based on Travel Time**

Warning Time	*Ambulatory Speed*	*Travel Distance*	*Maximum Spacing*
2 hrs	2 mph*	4 miles	8 miles
30 min	2 mph*	1 mile	2 miles
15 min	2 mph*	½ mile	1 mile

* Based on the average pace for a mobility-impaired population

5.1.2 Ingress and Vertical Circulation

Tsunami vertical evacuation structures should be spaced such that people will have adequate time not only to reach the structure, but to enter and move within the structure to areas of refuge that are located above the anticipated tsunami inundation elevation.

Increased travel times may need to be considered if obstructions exist, or could occur, along the travel or ingress route. Unstable or poorly secured structural or architectural elements that collapse in and around the entrance, or the presence of contents associated with the non-refuge uses of a structure, could potentially impede ingress. Allowance for parking at a vertical evacuation refuge may decrease travel time to the refuge, but could complicate access when the potential traffic jams are considered.

Stairs or elevators are traditional methods of ingress and vertical circulation in buildings, especially when designated users have impaired mobility. Ramps, such as the ones used in sporting venues, however, can be more effective for moving large numbers of people into and up to refuge areas in a structure. Estimates of travel time may need adjustment for different methods of vertical circulation. Disabled users may need to travel along a special route that accommodates wheelchairs, and those with special needs may require assistance from others to move within the structure.

When locating vertical evacuation structures, natural and learned behaviors of evacuees should be considered. Most coastal communities have educated their populations to "go to high ground" in the event of a tsunami warning. Also, a natural tendency for evacuees will be to migrate away from the shore. Vertical evacuation structures should therefore be located on the inland side of evacuation zones and should take advantage of naturally occurring topography that would tend to draw evacuees towards them. Figure 5-1 illustrates an arrangement of vertical evacuation structures in a community based on these principles.

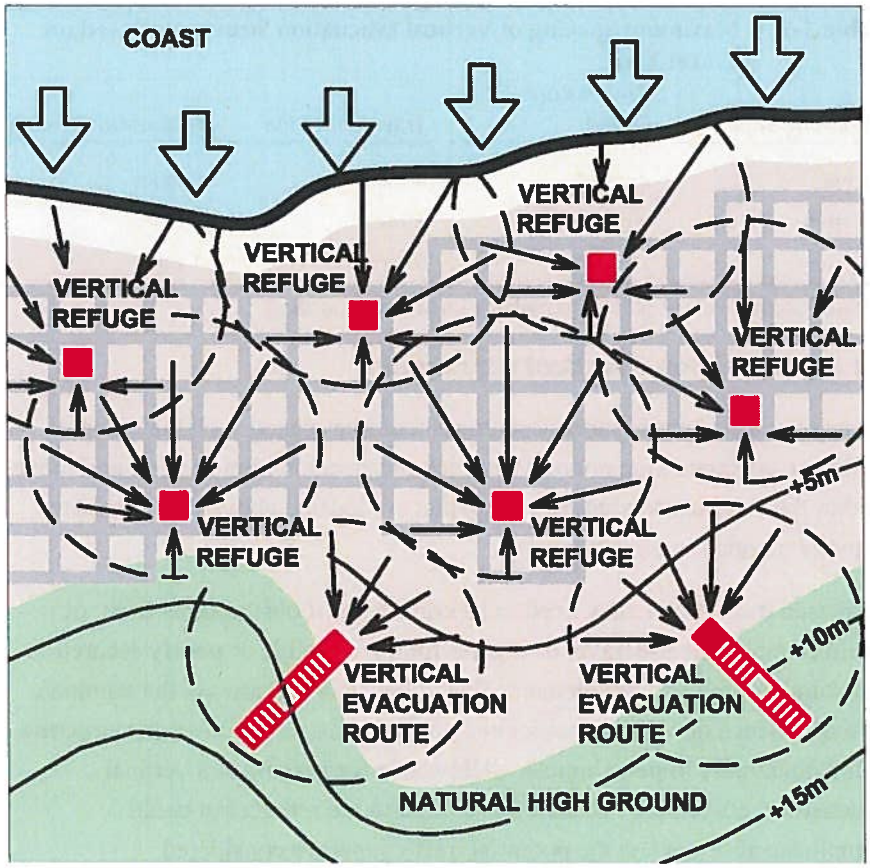

Figure 5-1 Vertical evacuation refuge locations considering travel distance, evacuation behavior, and naturally occurring high ground. Arrows show anticipated vertical evacuation routes.

5.1.3 Consideration of Site Hazards

Potential site hazards include breaking waves, sources of large waterborne debris, and sources of waterborne hazardous materials.

Special hazards in the vicinity of each site should be considered in locating vertical evacuation structures. Potential site hazards include breaking waves, sources of large waterborne debris, and sources of waterborne hazardous materials. When possible, vertical evacuation structures should be located away from potential hazards that could result in additional damage to the structure and reduced safety for the occupants. Due to limited availability of possible sites, and limitations on travel and mobility of the population in a community, some vertical evacuation structures may need to be located at sites that would be considered less than ideal. Figure 5-2 illustrates adjacent site hazards that could exist in a typical coastal community.

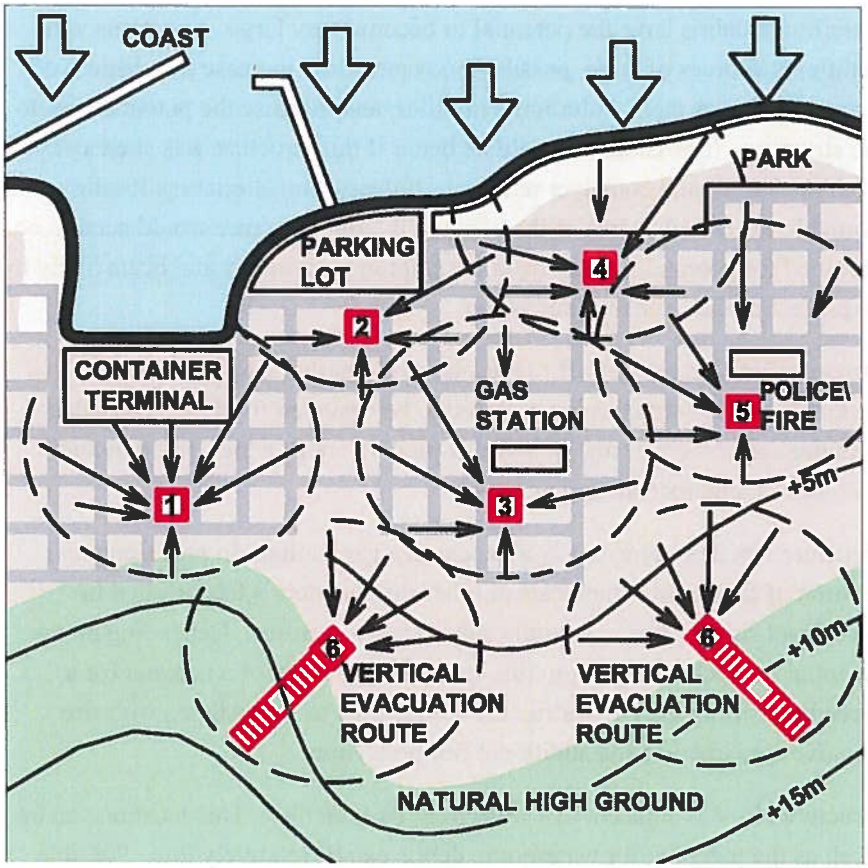

Figure 5-2 Site hazards adjacent to vertical evacuation structures (numbered locations). Arrows show anticipated vertical evacuation routes.

Wave breaking takes place where the water depth is sufficiently finite. In the design of usual coastal structures (e.g., breakwaters, seawalls, jetties), critical wave forces often result from breaking waves. In general, tsunamis break offshore. In the case of very steep terrain, however, they can break right at the shoreline, which is known as a collapsing breaker.

Forces from collapsing breakers can be extremely high and very uncertain. Location of vertical evacuation structures within the tsunami wave-breaking zone poses unknown additional risk to the structure. While the possibility of tsunami wave breaking at an on-shore location is not zero, it is considered to be very rare. For these reasons, recommended sites for vertical evacuation structures are located inland of the wave-breaking zone, and wave breaking forces are not considered in this document.

In Figure 5-2, vertical evacuation structures are located some distance inland from the shoreline. Structure No. 1 is located adjacent to a harbor and container terminal. Impact forces from ships, barges, boats, and other waterborne debris have the potential to become very large. Locations with additional sources of large, possibly buoyant debris increase the chances of impact by one or more waterborne missiles, and increase the potential risk to the structure. If possible, it would be better if this structure was sited away from the harbor and container terminal. If there is no alternative location available to serve this area of the community, this structure would need to be designed for potential impact from the shipping containers and boats likely to be present during tsunami inundation.

Structure No. 2 is located off to the side of the harbor and adjacent to a parking lot. This structure would need to be designed for debris consistent with the use of the parking lot and surrounding areas, which could include cars, trucks, and recreational vehicles.

Structure No. 3 is immediately adjacent to a gas station. In past tsunamis, ignition of flammable chemicals or other floating debris has resulted in significant risk for fire in partially submerged structures. Depending on the potential for fuel leakage from this station in the event of a tsunami (or a preceding earthquake), this structure would need to be designed with fire resistive construction and additional fire protection.

Structure No. 4 is adjacent to a waterfront park facility. This location can be ideal, as the potential for waterborne debris can be relatively low. Possible hazards could include debris from park structures, naturally occurring driftwood, or larger logs from downed trees. This area has a higher potential for tourists and visitors unfamiliar with the area. It would require additional signage to inform park users what to do and where to go in the event of a tsunami warning.

Structure No. 5 is adjacent to an emergency response facility. Co-locating at such facilities can provide opportunities for direct supervision by law-enforcement and monitoring and support of refuge occupancies by other emergency response personnel.

At two locations, Structure No. 6 is intended to aid evacuees in taking advantage of naturally occurring high ground.

5.2 Sizing Considerations

Sizing of a vertical evacuation structure depends on the intended number of occupants, the type of occupancy, and the duration of occupancy. The number of occupants will depend on the surrounding population and the spacing and number of vertical evacuation structures located in the area.

Duration of occupancy will depend on the nature of the hazard and the intended function of the facility.

5.2.1 Services and Occupancy Duration

A vertical evacuation structure is typically intended to provide a temporary place of refuge during a tsunami event. While tsunamis are generally considered to be short-duration events (i.e., pre-event warning period and event lasting about 8 to 12 hours), tsunamis include several cycles of waves. The potential for abnormally high tides and coastal flooding can last as long as 24 hours.

A vertical evacuation structure must provide adequate services to evacuees for their intended length of stay. As a short term refuge, services can be minimal, including only limited space per occupant and basic sanitation needs. Additionally, a vertical evacuation structure could be used to provide accommodations and services for people whose homes have been damaged or destroyed. As a minimum, this would require an allowance for more space for occupants, supplies, and services. It could also include consideration of different post-event rescue and recovery activities, and evaluation of short- and long-term medical care needs. Guidance on basic community sheltering needs is not included in this document, but can be found in FEMA 361, *Design and Construction Guidance for Community Shelters* (FEMA, 2000a).

Choosing to design and construct a vertical evacuation structure primarily for short-term refuge, or to supply and manage it to house evacuees for longer periods of time, is an emergency management issue that must be decided by the state, municipality, local community, or private owner.

5.2.2 Square Footage Recommendations from Available Sheltering Guidelines

Square footage recommendations are available from a number of different sources, and vary depending on the type of hazard and the anticipated duration of occupancy. The longer the anticipated stay, the greater the minimum square footage recommended.

A shelter for mostly healthy, uninjured people for a short-term event would require the least square footage per occupant. A shelter intended to house sick or injured people, or to provide ongoing medical care, would require more square footage to accommodate beds and supplies. For longer duration stays, even more square footage is needed per occupant for minimum privacy and comfort requirements, and for building infrastructure, systems, and services needed when housing people on an extended basis.

Table 5-3, Table 5-4 and Table 5-5 summarize square footage recommendations contained in International Code Council/National Storm Shelter Association, ICC-500, *Standard on the Design and Construction of Storm Shelters* (ICC/NSSA, 2007), FEMA 361 *Design and Construction Guidance for Community Shelters* (FEMA, 2000a), and American Red Cross Publication No. 4496, *Standards for Hurricane Evacuation Shelter Selection* (ARC, 2002).

Table 5-3 Square Footage Recommendations – ICC-500 *Standard on the Design and Construction of Storm Shelters* (ICC/NSSA, 2007)

Hazard or Duration	*Minimum Required Usable Floor Area in Sq. Ft. per Occupant*
Tornado	
Standing or seated	5
Wheelchair	10
Bedridden	30
Hurricane	
Standing or seated	20
Wheelchair	20
Bedridden	40

Table 5-4 Square Footage Recommendations – FEMA 361 *Design and Construction Guidance for Community Shelters* (FEMA, 2000a)

Hazard or Duration	*Recommended Minimum Usable Floor Area in Sq. Ft. per Occupant*
Tornado	5
Hurricane	10

Table 5-5 Square Footage Recommendations – American Red Cross Publication No. 4496 (ARC, 2002)

Hazard or Duration	*Recommended Minimum Usable Floor Area in Sq. Ft. per Occupant*
Short-term stay (i.e., a few days)	20
Long-term stay (i.e., days to weeks)	40

The number of standing, seating, wheelchair, or bedridden spaces should be determined based on the specific occupancy needs of the facility under consideration. When determining usable floor area, ICC-500 includes the following adjustments to gross floor area:

- Usable floor area is 50 percent of gross floor area in shelter areas with concentrated furnishings or fixed seating.
- Usable floor area is 65 percent of gross floor area in shelter areas with un-concentrated furnishings and without fixed seating.
- Usable floor area is 85 percent of gross floor area in shelter areas with open plan furnishings and without fixed seating.

5.2.3 Recommended Minimum Square Footage for Short-Term Refuge from Tsunamis

For short-term refuge in a tsunami vertical evacuation structure, the duration of occupancy should be expected to last between 8 to 12 hours, as a minimum. Because tsunami events can include several cycles of waves, there are recommendations that suggest evacuees should remain in a tsunami refuge until the second high tide after the first tsunami wave, which could occur up to 24 hours later.

Recommended minimum square footage is 10 square feet per occupant.

Based on square footage recommendations employed in the design of shelters for other hazards, the recommended minimum square footage per occupant for a tsunami refuge is 10 square feet per person. It is anticipated that this density will allow evacuees room to sit down without feeling overly crowded for a relatively short period of time, but would not be considered appropriate for longer stays that included sleeping arrangements. This number should be adjusted up or down depending on the specific occupancy needs of the refuge under consideration.

5.3 Elevation Considerations

In order to serve effectively as a vertical evacuation structure, it is essential that the area of refuge be located well above the maximum tsunami inundation level anticipated at the site. Determination of a suitable elevation for tsunami refuge must take into account the uncertainty inherent in estimation of the tsunami runup elevation, possible splash-up during impact of tsunami waves, and the anxiety level of evacuees seeking refuge in the structure. Unfortunately a number of designated evacuation structures in Japan were inundated during the Tohoku tsunami, leading to loss of life of many of the refugees. To account for this uncertainty, the magnitude of tsunami force effects is determined assuming a maximum tsunami runup elevation that is 30% higher than values predicted by numerical simulation modeling or obtained from tsunami inundation maps. Because of the high

Recommended minimum refuge elevation is the maximum anticipated tsunami runup elevation, plus 30%, plus 10 feet (3 meters).

consequence of potential inundation of the tsunami refuge area, it is recommended that the elevation of tsunami refuge areas in vertical evacuation structures include an additional allowance for freeboard above this elevation.

The recommended minimum freeboard is one story height, or 10 feet (3 meters) above the tsunami runup elevation used in tsunami force calculations. The recommended minimum elevation for a tsunami refuge area is, therefore, the maximum tsunami runup elevation anticipated at the site, plus 30%, plus 10 feet (3 meters). This should be treated as an absolute minimum, with additional conservatism strongly encouraged.

5.4 Size of Vertical Evacuation Structures

Given the number and spacing of vertical evacuation structures, and the population in a given community, the minimum size can be determined based on square footage recommendations for the intended duration and type of occupancy. Consideration of other functional needs, such as restrooms, supplies, communications, and emergency power, should be added to the overall size of the structure.

Given the maximum tsunami runup elevation anticipated at the site, the minimum elevation of the area of refuge within a vertical evacuation structure can be determined based on minimum freeboard recommendations.

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Local Source (Cascadia Subduction Zone) Tsunami Inundation Map
Newport North, Oregon

2013

Tsunami Inundation Map Linc-06
Tsunami Inundation Maps for Newport North, Lincoln County, Oregon
Plate 1

Introduction

The Oregon Department of Geology and Mineral Industries (DOGAMI) has been identifying and mapping the tsunami inundation hazard along the Oregon coast since 1994. In Oregon, DOGAMI manages the National Tsunami Hazard Mitigation Program, which has been administered by the National Oceanic and Atmospheric Administration (NOAA) since 1995. DOGAMI's work is designed to help cities, counties, and other sites in coastal areas reduce the potential for disastrous tsunami-related consequences by understanding and mitigating this geologic hazard. Using federal funding awarded by NOAA, DOGAMI has developed a new generation of tsunami inundation maps to help residents and visitors along the entire Oregon coast prepare for the next Cascadia Subduction Zone (CSZ) earthquake and tsunami.

The CSZ is the tectonic plate boundary between the North American Plate and the Juan de Fuca Plate (Figure 1). These plates are converging at a rate of about 1.5 inches per year, but the movement is not smooth and continuous. Rather, the plates lock in place, and unreleased energy builds over time. At intervals, this accumulated energy is violently released in the form of a megathrust earthquake rupture, where the North American Plate suddenly slips westward over the Juan de Fuca Plate. This rupture causes a vertical displacement of water that creates a tsunami (Figure 2). Similar rupture processes and tsunamis have occurred elsewhere on the planet where subduction zones exist: for example, offshore Chile in 1960 and 2010, offshore Alaska in 1964, near Sumatra in 2004, and offshore Japan in March 2011.

CSZ Frequency: Comprehensive research of the offshore geologic record indicates that at least 19 major ruptures of the full length of the CSZ have occurred off the Oregon coast over the past 10,000 years (Figure 3). All 19 of these full-rupture CSZ events were likely magnitude 8.9 to 9.2 earthquakes (Witter and others, 2011). The most recent CSZ event happened approximately 300 years ago on January 26, 1700. Sand deposits carried onshore and left by the 1700 event have been found 1.2 miles inland; older tsunami sand deposits have also been discovered in estuaries 6 miles inland. As shown in Figure 3, the range in time between these 19 events varies from 110 to 1,150 years, with a median time interval of 490 years. In 2008 the United States Geological Survey (USGS) released the results of a study announcing that the probability of a magnitude 8-9 CSZ earthquake occurring over the next 30 years is 10% and that such earthquakes occur about every 500 years (WGCEP, 2008).

CSZ Model Specifications: The sizes of the earthquake and its resultant tsunami are primarily driven by the amount and geometry of the slip that takes place when the North American Plate snaps westward over the Juan de Fuca Plate during a CSZ event. DOGAMI has modeled a wide range of earthquake and tsunami sizes that take into account different fault geometries that could amplify the amount of seawater displacement and increase tsunami inundation. Seismic geophysical profiles show that there may be a steep splay fault running nearly parallel to the CSZ but closer to the Oregon coastline (Figure 1). The effect of this splay fault moving during a full-rupture CSZ event would be an increase in the amount of vertical displacement of the Pacific Ocean, resulting in an increase of the tsunami inundation onshore in Oregon. DOGAMI has also incorporated physical evidence that suggests that portions of the coast may drop 4 to 10 feet during the earthquake; this effect is known as subsidence. Detailed information on fault geometries, subsidence, computer models, and the methodology used to create the tsunami scenarios presented on this map can be found in DOGAMI Special Papers 41 (Priest and others, 2009) and 43 (Witter and others, 2011).

Map Explanation

This tsunami inundation map displays the output of computer models representing five selected tsunami scenarios, all of which include the earthquake-produced subsidence and the tsunami-amplifying effects of the splay fault. Each scenario assumes that a tsunami occurs at Mean Higher High Water (MHHW) tide; MHHW is defined as the average height of the higher high tides observed over an 18-year period at the Yaquina Bay (Central Coast Model) tide gauge. To make it easier to understand this scientific material and to enhance the educational aspects of hazard mitigation and response, the five scenarios are labeled as "T-shirt sizes" ranging from Small, Medium, Large, Extra Large, to Extra Extra Large (S, M, L, XL, XXL). The map legend depicts the respective amounts of slip, the frequency of occurrence, and the earthquake magnitude for these five scenarios. Figure 4 shows the cumulative number of buildings inundated within the map area.

The computer simulation model output is provided to DOGAMI as millions of points with values that indicate whether the location of each point is wet or dry. These points are converted to wet and dry contour lines that form the extent of inundation. The transition area between the wet and dry contour lines is termed the Wet/Dry Zone, which equates to the amount of error in the model when determining the maximum inundation for each scenario. Only the XXL Wet/Dry Zone is shown on this map.

This map also shows the regulatory tsunami inundation line (Oregon Revised Statutes 455.446 and 455.447), commonly known as the Senate Bill 379 line. Senate Bill 379 (1995) instructed DOGAMI to establish the area of expected tsunami inundation based on scientific evidence and tsunami modeling in order to prohibit the construction of new essential and special occupancy structures in this tsunami inundation zone (Priest, 1995).

Time Series Graphs and Wave Elevation Profiles: In addition to the tsunami scenarios, the computer model produces time series data for "gauge" locations in the area. These points are simulated gauge stations that record the time, in seconds, of the tsunami wave arrival and the wave height observed. It is especially noteworthy that the greatest wave height and velocity observed are not necessarily associated with the first tsunami wave to arrive onshore. Therefore evacuees should not assume that the tsunami event is over until the proper authorities have sounded the all-clear signal at the end of the evacuation. Figure 5 depicts the tsunami waves as they arrive at a simulated gauge station. Figure 6 depicts the overall wave height and inundation extent for all five scenarios at the profile locations shown on this map.

Cascadia Subduction Zone Setting

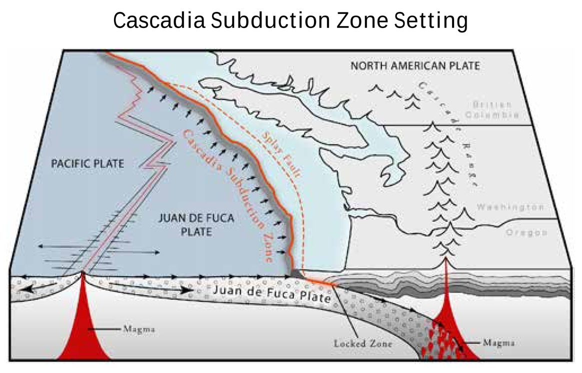
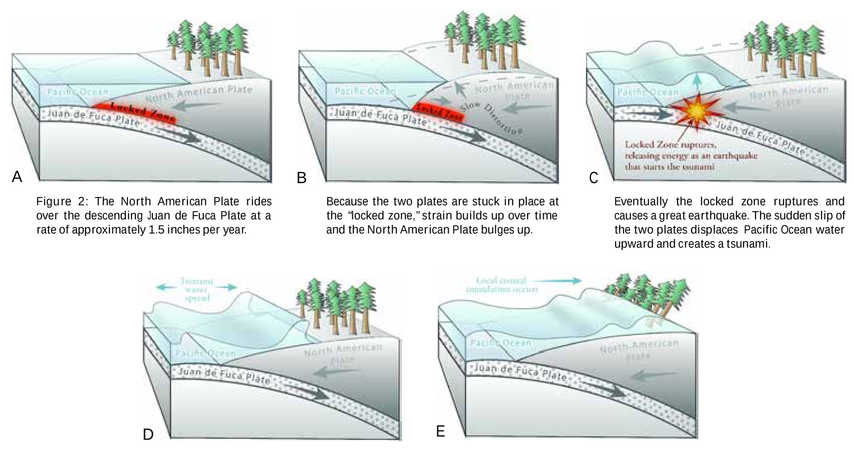


Figure 1: This block diagram depicts the tectonic setting of the region. See Figure 2 for the sequence of events that occur during a Cascadia Subduction Zone megathrust earthquake and tsunami.

How Tsunamis Occur



A: Figure 2: The North American Plate rides over the descending Juan de Fuca Plate at a rate of approximately 1.5 inches per year.

B: Because the two plates are stuck in place at the "locked zone," strain builds up over time and the North American Plate bulges up.

C: Eventually the locked zone ruptures and causes a great earthquake. The sudden slip of the two plates displaces Pacific Ocean water upward and creates a tsunami.

D: Displaced and uplifted Pacific Ocean water rushes in all directions.

E: Along the Oregon coast, tsunami waves run up onto the land for several hours.

Occurrence and Relative Size of Cascadia Subduction Zone Megathrust Earthquakes

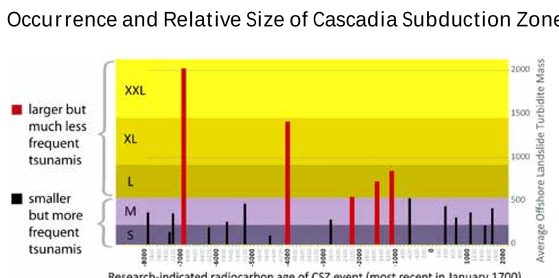


Figure 3: This chart depicts the timing, frequency, and magnitude of the last 19 great Cascadia Subduction Zone events over the past 10,000 years. The most recent event occurred on January 26, 1700. The 1700 event is considered to be a "medium sized" event. The data used to create this chart came from research that examined the many submarine landslides, known as "turbidites," that are triggered only by these great earthquakes (Witter and others, 2011). The loose correlation is "the bigger the turbidite, the bigger the earthquake."

Buildings within Tsunami Inundation Zones

	Entire Map Area	Newport	Unincorporated Areas
Total Buildings	5,098	4,901	197
Buildings within Tsunami Zones*			
Small	173	162	11
Medium	290	278	12
Large	376	361	15
Extra Large	698	672	26
Extra Extra Large	786	760	26
Percent of Buildings within Tsunami Zones			
Small	3.4%	3.3%	5.6%
Medium	5.7%	5.7%	6.1%
Large	7.4%	7.4%	7.6%
Extra Large	13.7%	13.7%	13.2%
Extra Extra Large	15.4%	15.5%	13.2%

*Building counts shown are based on polygon centroids and are cumulative within the map area.

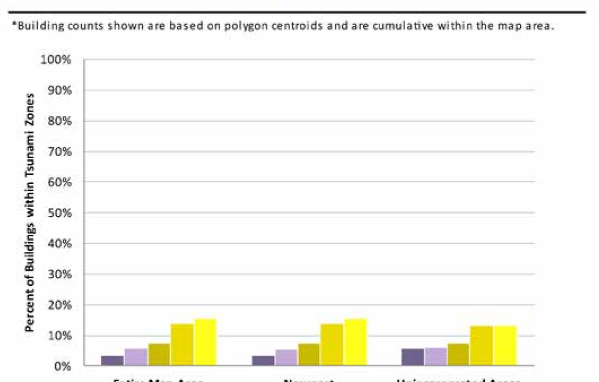


Figure 4: The table and chart show the number of buildings inundated for each "tsunami T-shirt scenario" for cities and unincorporated portions of the map.

Estimated Tsunami Wave Height through Time for Simulated Gauge Station

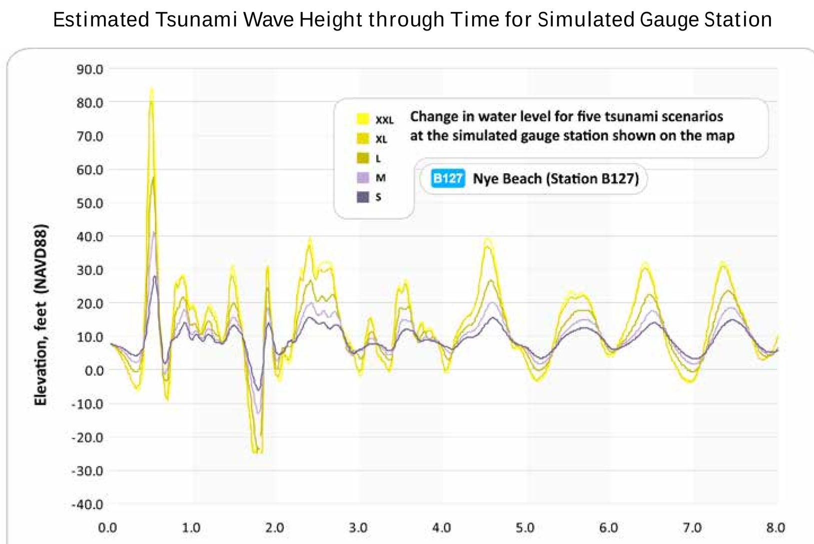


Figure 5: This chart depicts the tsunami waves as they arrive at the selected reference point (simulated gauge station). It shows the change in wave heights for all five tsunami scenarios over an 8-hour period. The starting water elevation (0.0 hour) takes into account the local land subsidence or uplift caused by the earthquake. Wave heights vary through time, and the first wave will not necessarily be the largest as waves interfere and reflect off local topography and bathymetry. Any absence of data indicates periods for which tsunami inundation has not yet reached or has receded from the station location and dry land is exposed.

Maximum Wave Elevation Profiles

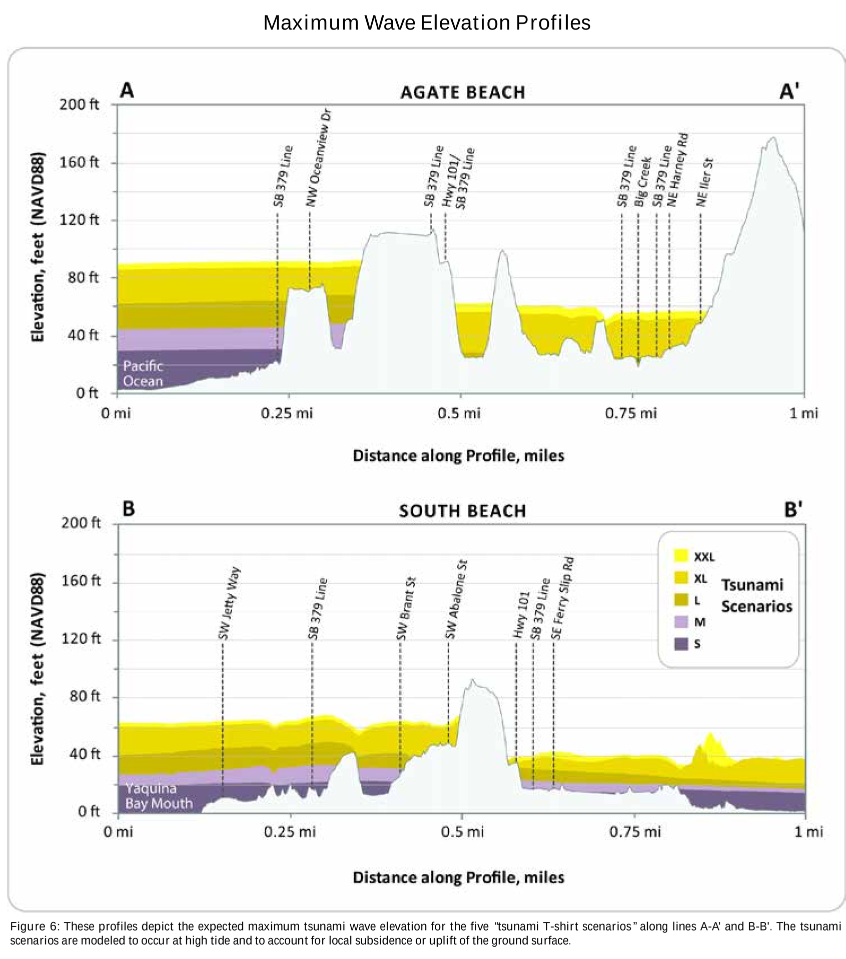
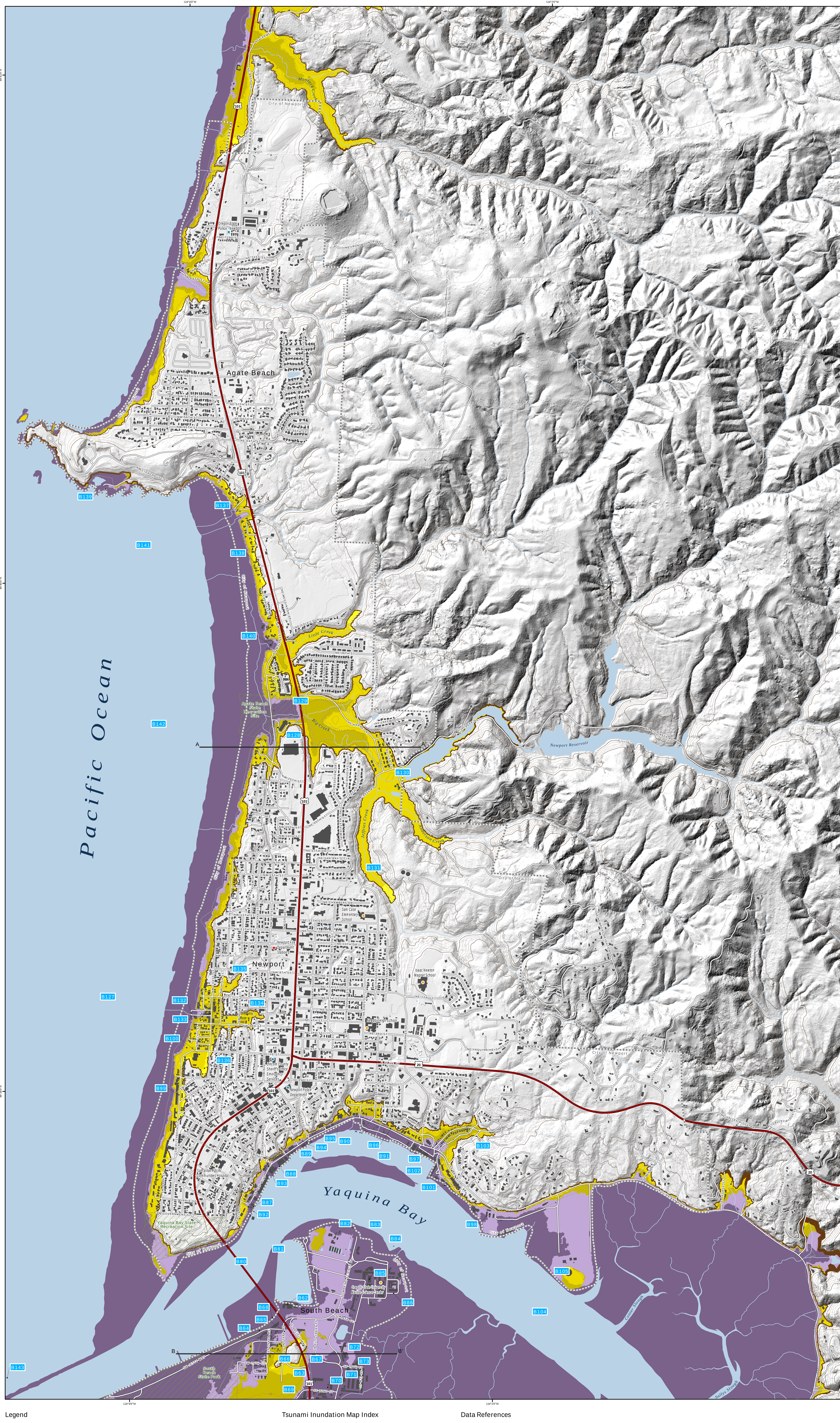


Figure 6: These profiles depict the expected maximum tsunami wave elevation for the five "tsunami T-shirt scenarios" along lines A-A' and B-B'. The tsunami scenarios are modeled to occur at high tide and to account for local subsidence or uplift of the ground surface.



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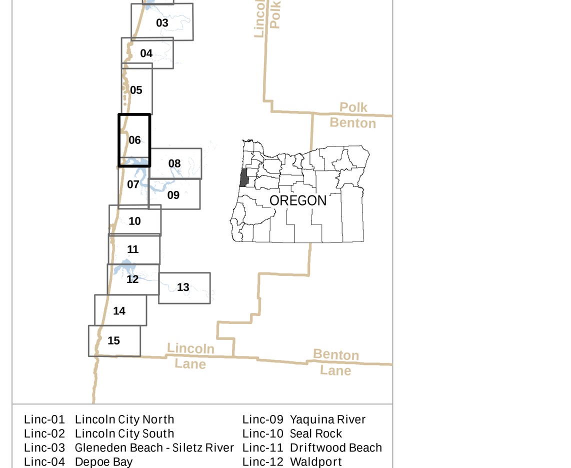

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Andree V. Pollock, Assistant Director, Geologic Survey and Services
Rachel L. Smith, Project Operations Manager
Ian P. Madin, Chief Scientist

Local Source (Cascadia Subduction Zone) Tsunami Inundation Map
Newport South, Oregon

2013

Tsunami Inundation Map Linc-07

Tsunami Inundation Maps for Newport South, Lincoln County, Oregon

Plate 1

Introduction

The Oregon Department of Geology and Mineral Industries (DOGAMI) has been identifying and mapping the tsunami inundation hazard along the Oregon coast since 1994. In Oregon, DOGAMI manages the National Tsunami Hazard Mitigation Program, which has been administered by the National Oceanic and Atmospheric Administration (NOAA) since 1995. DOGAMI's work is designed to help cities, counties, and other sites in coastal areas reduce the potential for disastrous tsunami-related consequences by understanding and mitigating this geologic hazard. Using federal funding awarded by NOAA, DOGAMI has developed a new generation of tsunami inundation maps to help residents and visitors along the entire Oregon coast prepare for the next Cascadia Subduction Zone (CSZ) earthquake and tsunami.

The CSZ is the tectonic plate boundary between the North American Plate and the Juan de Fuca Plate (Figure 1). These plates are converging at a rate of about 1.5 inches per year, but the movement is not smooth and continuous. Rather, the plates lock in place, and unreleased energy builds over time. At intervals, this accumulated energy is violently released in the form of a megathrust earthquake rupture, where the North American Plate suddenly slips westward over the Juan de Fuca Plate. This rupture causes a vertical displacement of water that creates a tsunami (Figure 2). Similar rupture processes and tsunamis have occurred elsewhere on the planet where subduction zones exist: for example, offshore Chile in 1960 and 2010, offshore Alaska in 1964, near Sumatra in 2004, and offshore Japan in March 2011.

CSZ Frequency: Comprehensive research of the offshore geologic record indicates that at least 19 major ruptures of the full length of the CSZ have occurred off the Oregon coast over the past 10,000 years (Figure 3). All 19 of these full-rupture CSZ events were likely magnitude 8.9 to 9.2 earthquakes (Witter and others, 2011). The most recent CSZ event happened approximately 300 years ago on January 26, 1700. Sand deposits carried onshore and left by the 1700 event have been found 1.2 miles inland; older tsunami sand deposits have also been discovered in estuaries 6 miles inland. As shown in Figure 3, the range in time between these 19 events varies from 110 to 1,150 years, with a median time interval of 490 years. In 2008 the United States Geological Survey (USGS) released the results of a study announcing that the probability of a magnitude 8-9 CSZ earthquake occurring over the next 30 years is 10% and that such earthquakes occur about every 500 years (WGCEP, 2008).

CSZ Model Specifications: The sizes of the earthquake and its resultant tsunami are primarily driven by the amount and geometry of the slip that takes place when the North American Plate snaps westward over the Juan de Fuca Plate during a CSZ event. DOGAMI has modeled a wide range of earthquake and tsunami sizes that take into account different fault geometries that could amplify the amount of seawater displacement and increase tsunami inundation. Seismic geophysical profiles show that there may be a steep splay fault running nearly parallel to the CSZ but closer to the Oregon coastline (Figure 1). The effect of this splay fault moving during a full-rupture CSZ event would be an increase in the amount of vertical displacement of the Pacific Ocean, resulting in an increase of the tsunami inundation onshore in Oregon. DOGAMI has also incorporated physical evidence that suggests that portions of the coast may drop 4 to 10 feet during the earthquake; this effect is known as subsidence. Detailed information on fault geometries, subsidence, computer models, and the methodology used to create the tsunami scenarios presented on this map can be found in DOGAMI Special Papers 41 (Priest and others, 2009) and 43 (Witter and others, 2011).

Map Explanation

This tsunami inundation map displays the output of computer models representing five selected tsunami scenarios, all of which include the earthquake-produced subsidence and the tsunami-amplifying effects of the splay fault. Each scenario assumes that a tsunami occurs at Mean Higher High Water (MHHW) tide; MHHW is defined as the average height of the higher high tides observed over an 18-year period at the Yaquina Bay (Central Coast Model) tide gauge. To make it easier to understand this scientific material and to enhance the educational aspects of hazard mitigation and response, the five scenarios are labeled as "T-shirt sizes" ranging from Small, Medium, Large, Extra Large, to Extra Extra Large (S, M, L, XL, XXL). The map legend depicts the respective amounts of slip, the frequency of occurrence, and the earthquake magnitude for these five scenarios. Figure 4 shows the cumulative number of buildings inundated within the map area.

The computer simulation model output is provided to DOGAMI as millions of points with values that indicate whether the location of each point is wet or dry. These points are converted to wet and dry contour lines that form the extent of inundation. The transition area between the wet and dry contour lines is termed the Wet/Dry Zone, which equates to the amount of error in the model when determining the maximum inundation for each scenario. Only the XXL Wet/Dry Zone is shown on this map.

This map also shows the regulatory tsunami inundation line (Oregon Revised Statutes 455.446 and 455.447), commonly known as the Senate Bill 379 line. Senate Bill 379 (1995) instructed DOGAMI to establish the area of expected tsunami inundation based on scientific evidence and tsunami modeling in order to prohibit the construction of new essential and special occupancy structures in this tsunami inundation zone (Priest, 1995).

Time Series Graphs and Wave Elevation Profiles: In addition to the tsunami scenarios, the computer model produces time series data for "gauge" locations in the area. These points are simulated gauge stations that record the time, in seconds, of the tsunami wave arrival and the wave height observed. It is especially noteworthy that the greatest wave height and velocity observed are not necessarily associated with the first tsunami wave to arrive onshore. Therefore evacuees should not assume that the tsunami event is over until the proper authorities have sounded the all-clear signal at the end of the evacuation. Figure 5 depicts the tsunami waves as they arrive at a simulated gauge station. Figure 6 depicts the overall wave height and inundation extent for all five scenarios at the profile locations shown on this map.

Cascadia Subduction Zone Setting

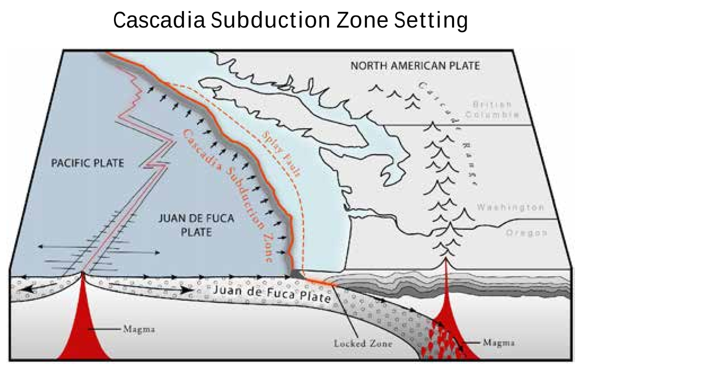
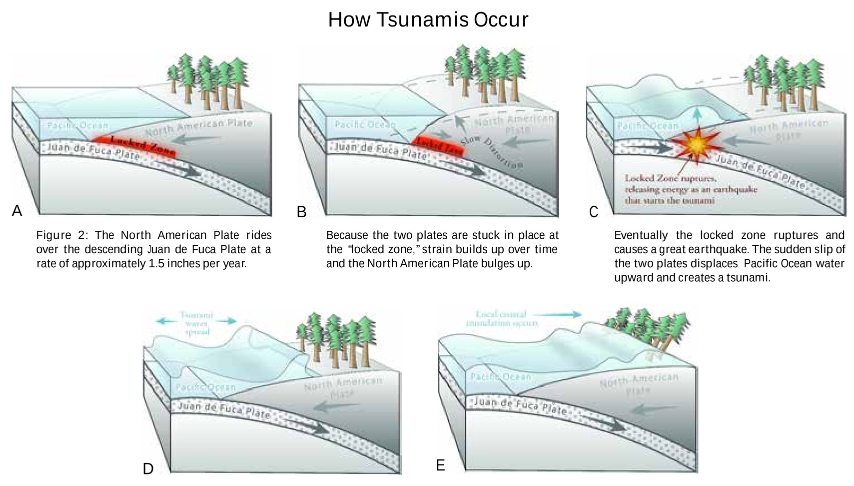


Figure 1: This block diagram depicts the tectonic setting of the region. See Figure 2 for the sequence of events that occur during a Cascadia Subduction Zone megathrust earthquake and tsunami.

How Tsunamis Occur



A — Figure 2: The North American Plate rides over the descending Juan de Fuca Plate at a rate of approximately 1.5 inches per year.

B — Because the two plates are stuck in place at the "locked zone," strain builds up over time and the North American Plate bulges up.

C — Eventually the locked zone ruptures and causes a great earthquake. The sudden slip of the two plates displaces Pacific Ocean water upward and creates a tsunami.

D — Displaced and uplifted Pacific Ocean water rushes in all directions.

E — Along the Oregon coast, tsunami waves run up onto the land for several hours.

Occurrence and Relative Size of Cascadia Subduction Zone Megathrust Earthquakes

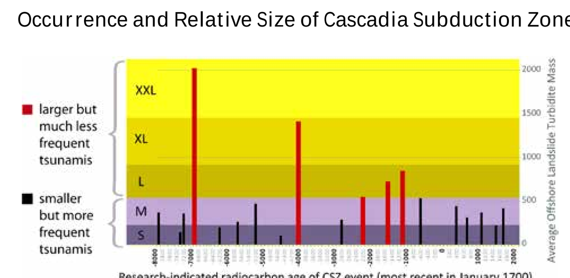


Figure 3: This chart depicts the timing, frequency, and magnitude of the last 19 great Cascadia Subduction Zone events over the past 10,000 years. The most recent event occurred on January 26, 1700. The 1700 event is considered to be a "medium sized" event. The data used to create this chart came from research that examined the many submarine landslides, known as "turbidites," that are triggered only by these great earthquakes (Witter and others, 2011). The loose correlation is "the bigger the turbidite, the bigger the earthquake."

Buildings within Tsunami Inundation Zones

	Entire Map Area	Newport	Unincorporated Areas
Total Buildings	2,311	1,480	831
Buildings within Tsunami Zones*			
Small	286	251	35
Medium	629	554	75
Large	863	769	94
Extra Large	1,034	846	188
Extra Extra Large	1,068	862	206
Percent of Buildings within Tsunami Zones			
Small	12.4%	17.0%	4.2%
Medium	27.2%	37.4%	9.0%
Large	37.3%	52.0%	11.3%
Extra Large	44.7%	57.2%	22.6%
Extra Extra Large	46.2%	58.2%	24.8%

*Building counts shown are based on polygon centroids and are cumulative within the map area.

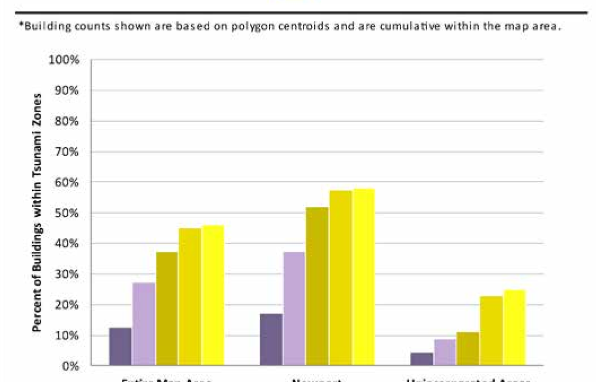


Figure 4: The table and chart show the number of buildings inundated for each "tsunami T-shirt scenario" for cities and unincorporated portions of the map.

Estimated Tsunami Wave Height through Time for Simulated Gauge Station

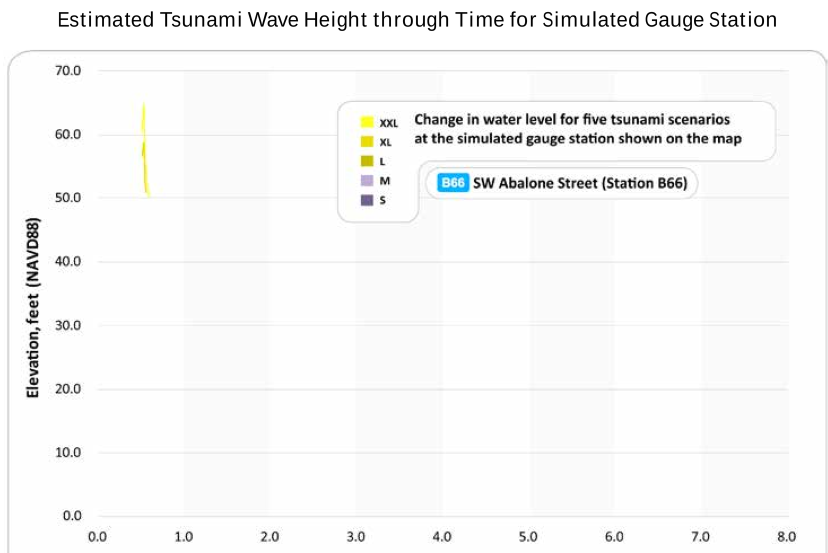
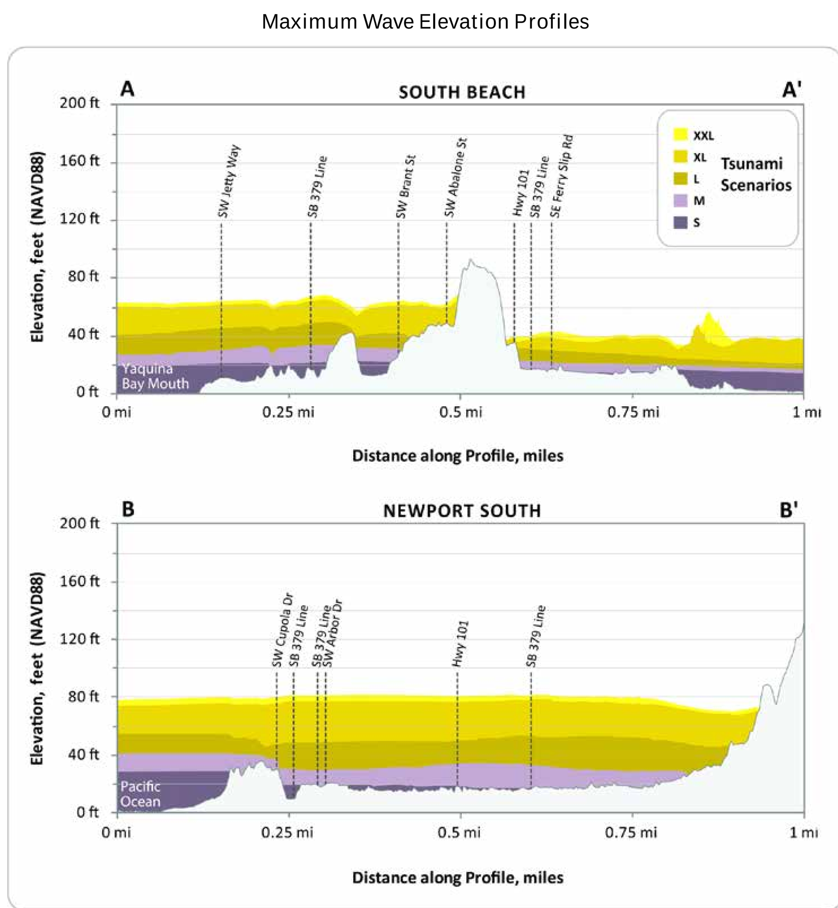


Figure 5: This chart depicts the tsunami waves as they arrive at the selected reference point (simulated gauge station). It shows the change in wave heights for all five tsunami scenarios over an 8-hour period. The starting water elevation (0.0 hour) takes into account the local land subsidence or uplift caused by the earthquake. Wave heights vary through time, and the first wave will not necessarily be the largest as waves interfere and reflect off local topography and bathymetry. Any absence of data indicates periods for which tsunami inundation has not yet reached or has receded from the station location and dry land is exposed.

Maximum Wave Elevation Profiles



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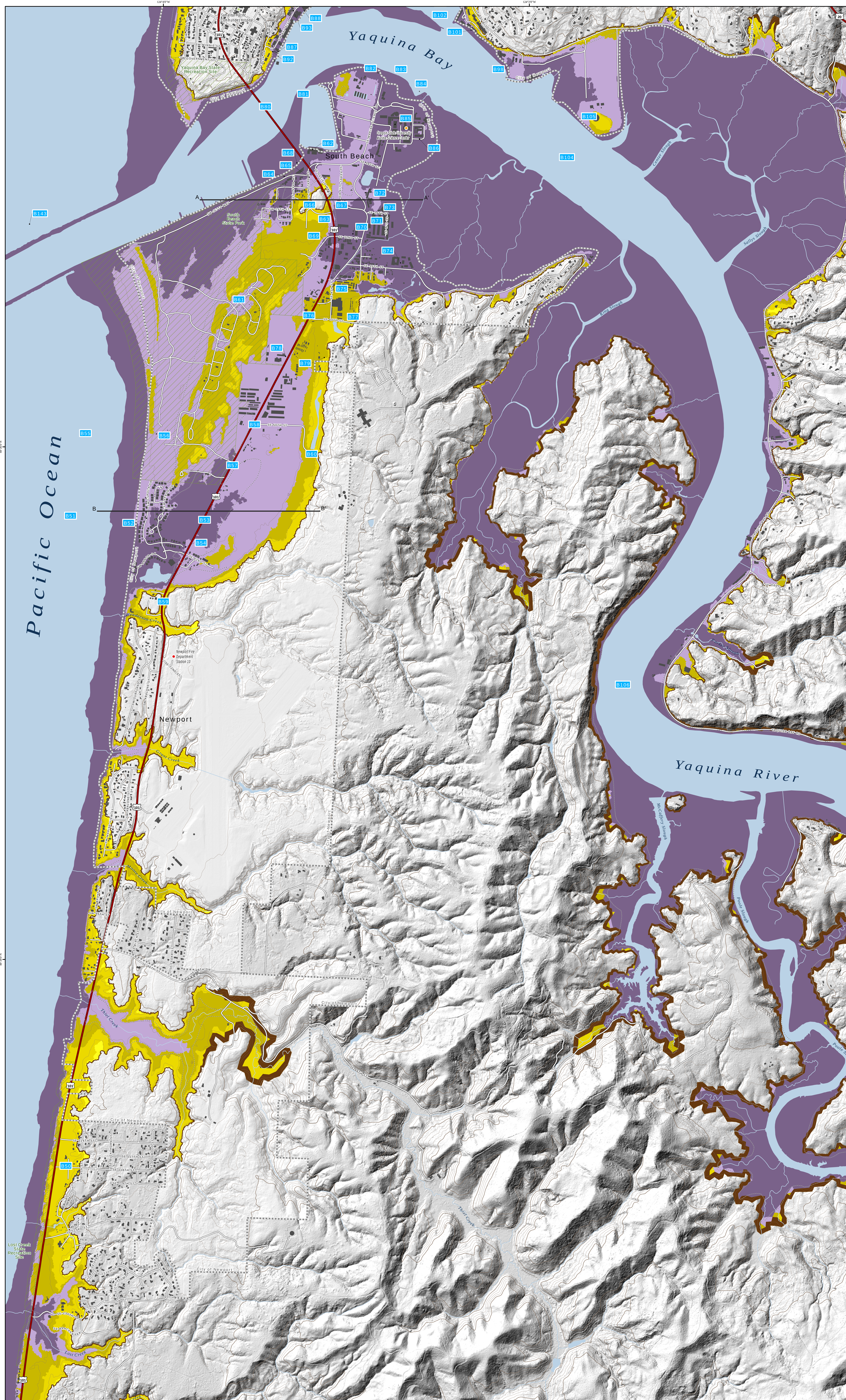

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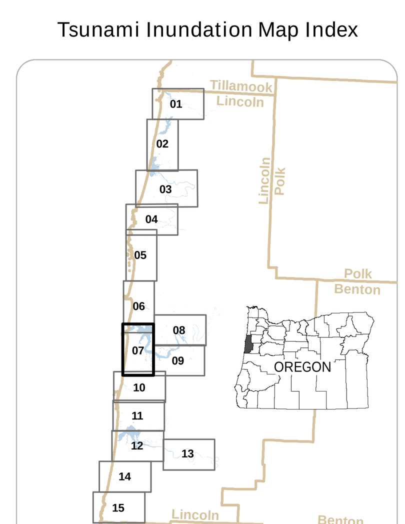

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