Reducing Earthquake-Tsunami Hazards in Pacific Northwest Ports and Harbors

SINCLAIR INLET PORT AND HARBOR COMMUNITY HAZARDS, VULNERABILITIES AND MITIGATION ACTIONS

Final Review Draft

January 3rd, 2005

Not for quotation without the

specific authorization of author

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ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS II
Sinclair Inlet Port and Harbor Community Participants ii
Other Regional Participants ii
Technical Advisors ii
Technical Advisors cont… iii
Sea Grant Project Team iii
Project Partners iii
TABLE OF CONTENTS IV
LIST OF TABLES VI
LIST OF FIGURES VI
SUMMARY VII
Building Community Resilience to Earthquakes and Tsunami vii
Earthquake and Tsunami Hazards Affecting Sinclair Inlet vii
Community Vulnerabilities viii
Proposed Actions to Increase Community Resilience ix
Next Steps x
I INTRODUCTION 1
Project Overview 1
How this Report is Organized 6
II BACKGROUND 7
1. Sinclair Inlet Port and Harbor Community 7
2. Sinclair Inlet Hazards 18
3. Specific Geographic Vulnerabilities 37
III VULNERABILITY ISSUES AND MITIGATION OPTIONS 46
1. Earthquake & Tsunami Disaster Response 46
2. Hazards & Vulnerability Assessment 53
3. Earthquake & Tsunami Awareness and Preparedness 57
4. Tsunami Warning Systems and Evacuation 65
5. Land, Water & Air Transportation Systems 67
6. Utilities 72
7. Occupied Structures 76
8. Shoreline Infrastructure 79
9. National Defense Facilities 82
10. Integrating Hazards Mitigation and Community Development 90
11. Hazardous Materials Releases and Spills 95

12. Debris Management.....*96*
13. Business Continuity.....*99*
IV MOVING TOWARDS SUSTAINABILITY.....100
Sustainable Communities.....*100*
What does it mean to be an earthquake- and tsunami-resilient port and harbor community?101
The Challenge in Sinclair Inlet.....*102*
V GLOSSARY.....103
VI BIBLIOGRAPHY.....104

LIST OF TABLES

Table 1: Sinclair Inlet Earthquake Scenarios 19
Table 2: Magnitude/intensity comparison 20

LIST OF FIGURES

Figure 1: Sinclair Inlet Area Map 9
Figure 2: Changes in Pacific Northwest UBC seismic zone maps 13
Figure 3: Schematic Diagram of Earthquake Hazards in the Pacific Northwest 18
Figure 4: Uplift on the Seattle Fault at Restoration Point, Bainbridge Island 18
Figure 5: Schematic of fault zone locations in the Puget Sound region 19
Figure 6: Evidence of subsidence found in Washington coastal marshes 24
Figure 7: Liquefaction Susceptibility Map 26
Figure 8: Geological Hazards Map 27
Figure 9: Major Fault Zones in Puget Sound 19
Figure 10: Salmon Beach after 1949 earthquake 25
Figure 11: Blackjack Creek estuary at Port Orchard 27
Figure 13: Merged Topography and Bathymetry 32
Figure 14: Essential Facilities & Hazardous Materials 35
Figure 15: Port Washington Narrows Area Map 33
Figure 16: Dyes Inlet Area Map 34
Figure 17: Sinclair Inlet Area Map 36
Figure 18: Bremerton Waterfront Area Map 37
Figure 19: SW Sinclair Inlet Area Map showing Port Orchard and Gorst 39

SUMMARY

Building Community Resilience to Earthquakes and Tsunami

Over the last two years a demonstration project designed to increase the community's resilience to earthquakes and tsunami has been underway in the Bremerton, Washington area. Washington Sea Grant Program, Oregon Sea Grant Extension and their community partners in the Sinclair Inlet Port and Harbor Community have undertaken three invitational workshops to: 1) document and understand the seismic (earthquake) and co-seismic (earthquake-caused) hazards, including tsunami, from which the community is at risk; 2) assess the vulnerability of local populations, businesses, buildings, infrastructure and natural resources to those hazards; and 3) to identify actions that could be taken to either reduce exposure to those risks, or mitigate their impacts.

Stakeholders representing local public and private marine enterprises, emergency response (fire, police and emergency management) officials, municipal planning, community development, public works and engineering departments, transportation lifelines and utilities companies, and citizens living in at-risk environments participated in these workshops. Providing expertise and technical assistance were university faculty, federal and state geological, ocean and coastal and emergency management agency scientists and technical staff.

A Geographic Information Systems (GIS) "atlas" was developed to illustrate specific geological hazards, and vulnerable sites and facilities. Posters, aerial photographs and data collection forms enabled participants to undertake detailed field exercises throughout the study area during the second workshop.

Earthquake and Tsunami Hazards Affecting Sinclair Inlet

The Sinclair Inlet Port and Harbor Community, comprising Kitsap County and the cities of Bremerton and Port Orchard, is at risk from three kinds of earthquakes and their associated co-seismic hazards: tsunami, landslides, and ground failure due to soil liquefaction.

The worst case scenario is a reprise of the ca. 900-930 A.D. Seattle Fault ground-rupturing earthquake. That event had a magnitude of 7+ and caused a tsunami that swept across low-lying shorelines in central Puget Sound and in all probability, the shores of Sinclair and Dyes Inlets. Such an event is rare, occurring on a time scale of thousands of years, but would be devastating to the port and harbor community should it recur. A preliminary computer model of a tsunami generated by an earthquake on the Seattle Fault shows strong currents and inundation affecting most parts of Kitsap County's shorelines.

Less rare is a multi-state regional earthquake along the Cascadia Subduction Zone off the coasts of Vancouver Island, Washington, Oregon and N. California, where the Juan

de Fuca oceanic plate subducts beneath the North American continental plate. The last Cascadia earthquake occurred on Jan 26, 1700 with a magnitude of 8+ and would have caused severe ground-shaking lasting several minutes throughout the region. While the tsunami that was generated affected the outer coast and the Strait of Juan de Fuca, it did not cause significant water level change or damaging currents inside central Puget Sound. Such "mega-thrust" earthquakes occur on a time scale of hundreds of years and we are "in the window" for a recurrence.

On February 28th. 2001 a magnitude 6.8 earthquake deep below the Nisqually Delta rocked the Puget Sound region, causing property damage in excess of $1 billion. Fortunately only one death – a heart attack victim – was attributed to the quake, and of 400 reported injuries only 4 were serious[1]. Such deep "Benioff Zone" earthquakes recur on the order of tens of years and several are experienced by most Puget Sound residents over their lifetime. They produce few after-shocks and no tsunami– unless a landslide occurs that displaces the water column, as happened in the Tacoma Narrows after the 1949 Olympia earthquake.

Community Vulnerabilities

Among the most vulnerable elements of the community are the marine enterprises, public port facilities, defense establishments and the hundreds of private residences lining the shorelines of Sinclair and Dyes Inlets; these entities either need, or are willing to pay the price for, a shore location. Located on filled ground, over-water, or at the foot of steep shoreline bluffs, the structures housing employees, customers, military personnel, visitors or residents are in harm's way for tsunami inundation and strong currents, landslides, and soil failure during and after strong groundshaking.

Older buildings–particularly unreinforced masonry (URM) structures–built before modern seismic codes were adopted are prone to collapse, including several on the Bremerton Naval Complex. A Seattle Fault or Cascadia earthquake would threaten military readiness by disrupting critical activities taking place in buildings and dry-docks at the Puget Sound Naval Shipyard.

Tourists and recreationists are vulnerable to tsunami when engaged in water contact activities–swimming, boating, fishing–or walking or picnicking along the shoreline when an earthquake strikes. High exposure occurs at the Bremerton Boardwalk Park, Lions Park on Port Washington Narrows, and along the Port Orchard waterfront, especially during the summer tourist season.

The community's transportation infrastructure–highway over-passes, bridges, ferry terminals, even the airport, are vulnerable where they have not been designed or retrofitted to withstand known seismic and co-seismic hazards. Other lifelines–communications, utilities–may be disrupted for days or weeks following a large regional

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[1] Nisqually Earthquake Clearinghouse Group. The Nisqually Earthquake of 28 February 2001–Preliminary Reconnaissance Report. University of Washington Seattle, WA. March, 2001.

earthquake.

The top-ranked vulnerability *issues* were those associated with:

- **loss of life** (shoreline residences exposed to tsunami, hazardous materials spills and fire; inadequate URM structures on Navy Base; lack of emergency preparedness in businesses and households; no tsunami evacuation signage in high use areas; inadequate emergency response system in a major seismic event; inadequate emergency communications system; threats to first reponders)
- **reduced military readiness** (vulnerable naval shipyard buildings and dry-docks; inadequate employee disaster training)
- **debris** (carried by tsunami run-up and currents blocking waterways and highways);
- **natural resources damages** (shellfish and salmon habitats; eelgrass beds; tidal wetlands)
- **transportation infrastructure** (damage to ferry docks, bridges, highway overpasses)
- **utilities** (damage to power-lines, gas pipelines, wastewater treatment), and
- **shoreline development** (residences in vulnerable shorelines, or at foot of steep bluffs; limited use of available planning, design and development tools; weak building codes)

Proposed Actions to Increase Community Resilience

Six stakeholders groups, organized along functional lines (e.g. emergency responders, land transportation and utilities, ports and waterway users, etc.), identified sixty-nine distinct vulnerability issues–serious hazard exposures affecting significant community interests and values. Guided by a "menu" of mitigation options prepared by staff and leavened by their imagination and community knowledge, the stakeholders created a list of over 180 individual actions that could be undertaken to increase the community's resilience to earthquake and tsunami hazards over the short term (within five years) and long-term (ten or more years). Staff took this "raw material" and reorganized the vulnerability issues and mitigation actions into the following set of thirteen groupings with the goal of minimizing redundancies and strengthening "orphaned" ideas:

- Disaster Response
- Hazards & Vulnerability Assessment
- Awareness and Preparedness
- Tsunami Warning Systems and Evacuation
- Transportation Systems
- Utility Systems
- Occupied Structures
- Shoreline Infrastructure
- National Defense Facilities

- Integrating Hazards Mitigation and Community Development
- Hazardous Materials
- Debris Management
- Business Continuity

For every mitigation action staff identified one or more entities capable of implementing the action – a county or city department, the port district, a federal research agency, a state transportation sub-agency, etc. These are *only suggestions* at this time; no commitments have yet been sought from any potential implementing entity.

Next Steps

This draft report is being circulated among project partners, stakeholders and technical advisors for their review over the summer of 2003. In the fall of this year Washington Sea Grant Program staff will convene one, or a series, of meetings with technical experts to clarify, correct or strengthen any sections of the report concerning the characterization, or mapping of seismic and co-seismic hazards affecting Sinclair Inlet, and the feasibility of mitigation actions involving further hazards research, e.g. tsunami modeling, seismographic data acquisition, etc.

Concurrently, meetings will be held with stakeholder groups, community service organizations and government officials to review the mitigation actions affecting their interests, enterprises or jurisdictions. After review by the Kitsap Emergency Management Department and further editing, a final report will be presented to the Kitsap Emergency Management Council for adoption.

I INTRODUCTION

Project Overview

The Need

Over the past decade, the threat of destructive earthquakes and tsunamis in the Pacific Northwest has been well documented by the scientific community. Such events pose significant threats to coastal communities, including a great potential for life loss and damage to development. Damage could result from numerous earthquake-related hazards, such as severe ground shaking, soil liquefaction, landslides, and tsunami inundation. Because of their geographic location, ports and harbors are especially vulnerable to these hazards. Ports and harbors are important economically and socially to communities and will also be vital as post-event, response/recovery transportation links. Oregon Sea Grant, Washington Sea Grant, the NOAA Coastal Services Center, and the US Geological Survey's Center for Science Policy have undertaken an initiative to increase the resiliency of Pacific Northwest ports and harbors to earthquake and tsunami hazards.

Project Components

Project products include a regional stakeholder issues and needs assessment[2], a model community-based mitigation planning process, a geographic information system (GIS)-based vulnerability assessment methodology, an educational website (http://ports-tsunamis.oregonstate.edu), a regional data archive, and a planned outreach effort.

A model planning process was developed and demonstration communities selected to "test" the model process. Yaquina Bay, a mid-sized commercial and recreational harbor comprising the ports of Newport and Toledo located on the central Oregon coast, was the initial demonstration site. The Sinclair Inlet port and harbor community[3] of Puget Sound in Washington was selected as the second demonstration site.

Why Now?

Just 15 years ago, the Pacific Northwest (PNW) was considered a relatively low risk zone for earthquake and tsunami hazards. Geologic and other evidence uncovered and evaluated since then suggest quite the opposite. Very large earthquakes with locally generated tsunami have been shown to occur along the Cascadia Subduction Zone

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[2] Wood, Nathan J., "Perceptions of Earthquake and Tsunami Issues in Pacific Northwest Port and Harbor Communities." October, 2002

[3] A *port and harbor community* is defined here as the governmental entities, industries, businesses, facilities, vessels, and people associated with the port and harbor by virtue of their activities or location on or adjacent to the harbor and the low-lying lands surrounding it. (Wood, et. al. 2002)

(CSZ) off the Washington, Oregon and northern California coasts. CSZ events are very large (Magnitude (M) 8 - 9+) and have a recurrence interval of about 500 years (+/-200 years), with the last event on January 26, 1700. Consequently, we are “in the window” for another Cascadia earthquake, though there is at present no way of predicting when it will happen.

More recent discoveries of active faults within the Puget Sound region have placed Seattle and Bremerton at “ground zero” for a devastating local earthquake along the Seattle Fault at some future time. The last major Seattle Fault event was about M7.5 and occurred about 1100 years ago. It caused local uplift of 20 feet along parts of Bainbridge Island, generated a tsunami that washed over low-lying shorelines, leaving tell-tale sand deposits in coastal marshes as far north as Cultus Bay on Whidbey Island. No recurrence interval has been estimated for such a Seattle Fault event.

Smaller, shallow crustal and deep intraplate earthquakes also occur, and more frequently, with the latest example being the Nisqually earthquake on February 28th., 2001 in southern part of Puget Sound. That event resulted in over $1 billion in damage. Kitsap County sustained some damage to its water system, and over 400 residences were affected. Almost half these homes reported chimney damage and over 100 had structural damage to walls and foundations. Despite this damage Sinclair Inlet got off lightly: no reported deaths, no serious, long-term, costly damage to infrastructure. We may not be so fortunate next time.

Why a Focus on Ports and Harbors?

Ports and harbors are important to many PNW coastal communities, supporting deep water shipping, commercial fishing and seafood processing facilities, recreational boating, marine industry, military bases, oceanographic research, tourism, and a wide variety of associated businesses that require, or otherwise benefit from a waterfront location. Their location makes them particularly vulnerable to multiple co-seismic hazards. They are sometimes surrounded by steep, landslide-prone topography, are often constructed on fill or other soil likely to liquefy during sustained ground-shaking, and they are subject to tsunami inundation and extreme current forces.

At the same time, ports and harbors are likely to be of immense importance in earthquake-tsunami disaster response and recovery operations. Because other transportation lifelines will be hard hit and take many months or even years to re-establish, ports and harbors are likely to play a key role in response and recovery operations. Closures of ports and major marine employment centers, even for a short time, due to earthquake damage, tsunami inundation or debris-choked waterways could seriously affect the local economy as well as the community’s capacity to recover from a seismic disaster.

Understanding the vulnerability of ports and harbors to earthquake-tsunami hazards and increasing their resiliency is thus an important goal for hazard preparedness and mitigation in the Pacific Northwest, as well as in other Pacific basin locations.

Within Sinclair and especially Dyes Inlets low-lying shoreline sites and view properties overlooking them have attracted, at first, weekend and seasonal vacation cabins, then, later, conversions to year-round primary residences. These structures and the populations they house are vulnerable to the same seismic and co-seismic hazards described above and, because of vulnerable accessways, present special challenges to first responders in a disaster.

Selecting the Washington Demonstration Community

In April, 2000, we invited a group of earthquake and tsunami experts[4] to a *Site Selection Scoping Workshop* at NOAA's Western Regional Center to help us choose a Washington demonstration community in which to test out the mitigation planning model being developed in the Yaquina Bay pilot study. We were looking for a port and harbor community that:

- would be representative of small to medium-sized Washington ports
- would face a typical suite of seismic and co-seismic hazards
- had a defined and modeled tsunami risk
- had made an investment in a geographic information system
- had local technical and planning capacity
- evidenced local political support

We learned from workshop participants about recent and on-going modeling of a tsunami generated by a shallow crustal earthquake on the Seattle Fault. This modeling effort would offer us an opportunity to move into Puget Sound and test our planning model in a setting quite different to that chosen in Oregon, yet still be exposed to the effects of a great Cascadia Subduction Zone earthquake.

Following a comprehensive and competitive review of interested small- to medium-sized ports in Puget Sound and along the Strait of Juan de Fuca, the Sinclair Inlet Port and Harbor Community was invited to become our Washington partner. The Port of Bremerton, the municipalities of Bremerton, Port Orchard and Kitsap County, and other waterfront stakeholders comprise this community. Resolutions supporting this partnership were passed by the Port of Bremerton Commission and the Kitsap Emergency Management Council.

Assessing Hazards and Vulnerabilities in Sinclair Inlet

The community hazards, risks and vulnerabilities, and mitigation actions identified to address them that appear in this report were developed and prioritized through a series of workshops held during 2001-2002.

Hazards Assessment Workshop, Kitsap Department of Public Works, May 23, 2001

Our technical advisors met with the "core" community team comprising city, county port and US Navy emergency management, public works and engineering staff, for this one-day invitational workshop. The goal was to identify the range of earthquake and tsunami hazards known to have imp[acted the area in the past and likely to do so again in the future. The workshop output was a set of worst case hazard scenarios for three kinds of earthquakes and the co-seismic hazards they would cause, including landslides,

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[4] These experts from universities, federal and state geologic and oceanic agencies, and private sector engineering firms would become our technical advisors for the duration of the demonstration project and are listed on page ii.

liquefaction and a locally-generated tsunami.

Over the course of the next five months University investigators, students and county community development staff developed a geographic information system (GIS) hazards and vulnerabilities *Atlas* for use as a decision-support tool in the first community workshop.

Vulnerability Assessment Workshop, Port Orchard City Hall, October 3, Kitsap Public Works October 4, 2001

This workshop was split into two parts: the first was a half-day event to brief the community participants on the hazards scenarios developed earlier and to familiarize them with the information assembled in the GIS *Atlas*; the second, a whole day affair, was designed to have participants undertake, with the help of facilitators, a community-wide risk and vulnerability assessment exercise.

The participants included: our technical advisors, the "core" community team and an invited group of local port and harbor stakeholders that included public and private marine enterprises, shoreline businesses, and local homeowners. In addition, staff from community development departments of city and county government; representatives of state agencies responsible for shorelines and growth management; Washington State Ferries engineering and operations staff and US Coast Guard officers with disaster management responsibilities; state highway engineers; were invited to participate. The participants' interests embraced the populations, structures and infrastructure, and the economic, cultural and environmental resources found around, over and beneath Sinclair and Dyes Inlets.

The workshop participants were grouped twice: first by geographic sub-areas and, second, by "function" – emergency responders, port and waterway users, land transportation and utilities, etc. The geographically-organized groups were trained, using the GIS *Atlas* and worksheets, to identify the range of hazard risks affecting their geographic area and to assess the vulnerability of populations, structures, infrastructure and natural resources at risk. The teams then went out into the field to put to work the experience they had gained in the desktop exercise. Each team had experts on tsunami and earthquakes to help interpret maps and explain on-site hazards.

Reassembled into functional groups, participants next were asked to take a community-wide look at risks and vulnerabilities that cut across geographic areas and affected their interests.

Finally, participants at the Vulnerability Assessment Workshop were asked to begin to identify options that might be used to mitigate those community-wide vulnerabilities.

Between workshops, staff refined and organized the "vulnerability issues" and "mitigation options" that participants had identified.

Hazards Mitigation Workshop, Island Lake, Poulsbo, February 8, 2002

At the final workshop staff reprised the hazards and vulnerabilities identified in previous workshops and presented a suite of mitigation strategies and actions that could be used to increase the resiliency of port and harbor communities. Local and state emergency management staff and other key "stakeholder agency" representatives—US Coast Guard, Washington State Ferries, Highways, US Geologic Survey—addressed the current preparedness and mitigation activities in their respective agencies.

Participants were again grouped into "functional" clusters to review, revise, augment and

then prioritize the “vulnerability issues” that staff had presented and suggested what additional mitigation actions should be used to address them. The six functional groups were able to identify 69 individual vulnerability issues and over 180 mitigation options. The output of the *Mitigation Workshop* became the “raw material” for the remainder of this report.

How this Report is Organized

The report begins with a brief description of the Sinclair Inlet Port and Harbor Community, its geography and economy. Next, we describe the various roles played by governmental agencies in Washington that enable local municipalities, businesses and households to become more resilient to earthquake and tsunami hazards. We then lay out the "worst case scenarios" for three kinds of earthquakes that threaten the Puget Sound region and the tsunamis that are likely to affect Sinclair and Dyes Inlets specifically. These scenarios, which were developed in the *Hazards Scenario Workshop*, produce a set of seismic, co-seismic and secondary hazards discussed in detail in the next section. In turn, these hazards interact with the built, natural and social environments that comprise the Sinclair Inlet Port and Harbor Community and present risk to the vulnerable structures, infrastructure, populations, institutions and natural resources found there. These risks and vulnerabilities are identified and discussed at the scale of the geographic area and sub-areas in which their effects are found – e.g. the downtown Bremerton waterfront, Gorst, Port Orchard, etc. – following the way they were discussed and examined "on the ground" in the *Vulnerability Assessment Workshop.*

Next, we lay out the community vulnerability issues and mitigation actions identified in the second phase of the *Vulnerability Assessment Workshop,* and refined and prioritized during the *Hazards Mitigation Workshop*. The form in which community vulnerabilities to earthquake and tsunami hazards are presented in this report differs from the way they were developed in the workshops. Workshop participants broke out into functionally organized groups to identify cross-cutting, community-wide vulnerabilities and to develop mitigation actions to address them. The results reflect those groupings: there were inevitable duplications and redundancies, and some issues simply didn't arise.

We have regrouped these community workshop results to capture broader contexts, expanded them to add detail, and supported them wherever possible with references to relevant geologic, hazards mitigation and emergency management literature. Those are gains, in our view; but there may have been losses in the reorganization, and for these the authors are solely responsible. The workshop participants' highest priority vulnerability issues are retained throughout. In this way we preserve the **community values** expressed by those with a stake in the Sinclair Inlet Port and Harbor Community.

We decided to keep all US Navy property issues under one section, "National Defense Facilities," even though there are redundancies with other sections of the report, e.g. Emergency Response, Waterborne Debris, etc. Since, for the most part, mitigation actions on USN bases are solely the responsibility of the Navy, it made little sense to list them under topics throughout the report. Also, in view of higher security concerns following the events of 9/11/01, this section could be excised from a public document easily and without compromising the integrity of the remaining sections of the report.

The report concludes with a review of some challenging ideas drawn from the recent writings of leading natural hazards management scholars and practitioners. We believe these ideas are relevant to stakeholders and decision-makers in the Sinclair Inlet Port and Harbor Community who are interested in taking the long view– that is, what the community's resiliency to earthquakes and tsunamis will be 50 years from now, and perhaps beyond.

II BACKGROUND

1. Sinclair Inlet Port and Harbor Community

Geography

Physical

The Sinclair Inlet Port and Harbor community comprises a large proportion of the Kitsap Peninsula, defined and surrounded by a complex system of inland waterways. Sinclair Inlet itself is a relatively shallow water-body (depths <50' MLLW) opening off Port Orchard, and connected to Dyes Inlet by Port Washington Narrows. Dyes Inlet comprises a N-S oriented series of narrow residential peninsulas and canals at south end of inlet, rarely exceeding 20' MLLW in depth, with an open bay to the north that reaches >100' MLLW in a few places. These relatively shallow tidal bodies result in disproportionately extensive intertidal wetlands compared to the rest of Puget Sound's much deeper–and steeper–Central Basin[5]. These tidelands form an important natural resource and valuable marine habitat, though most are closed to shell-fishing due to pollution.

The uplands are predominately low relief hills formed from glacial till and aligned approximately north-south by the ice flow of the Puget Lobe (ibid). To the west of Bremerton are found non-glacial bedrock outcroppings which define the western rim of the sediment-filled Seattle Basin, only recently discovered by geophysicists, and an important structure for understanding the seismicity of the region.

Population and Land Use

Bremerton, population 37,259, and Port Orchard, population 7,693, are the principal cities surrounding the port and harbor community; the latter is growing fast – up 54% from 4,984 in 1990. While Bremerton showed no growth over the last decade and, in fact lost 2% of its population in that period, development in rural Kitsap County pushed the county's population up 22%. Commercial and multi-family residential development is found along the shorelines of downtown Port Orchard, Bremerton and Gorst. With the exceptions of military reservations, port and marina facilities, and shoreline reaches given over to major highway corridors, most of the community's shorelines are occupied by single-family residences.

Transportation

West Bremerton and East Bremerton are connected by two highways that cross the steeply bluffed Port Washington Narrows. Transportation connections east to Seattle are by way of Washington State Ferries auto and passenger-only ferries from downtown Bremerton and an auto ferry from Southworth via Vashon Island and West Seattle, to Tacoma via State Highway 16, west to the Hood Canal, and north to the Olympic Penisula via State Highway 3 and the Hood Canal Bridge. The Puget Sound & Pacific Railroad which runs from Centralia via Shelton provides a critical rail connection to the

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[5] Burns, Robert. The shape and form of Puget Sound. Puget Sound Books. Washington Sea Grant. Seattle, Wash. 1985.

Bremerton Naval Complex and the Bangor Submarine Base. Bremerton National Airport a general aviation facility, located along State Highway 3 west of Gorst, has a single, instrument landing system-equipped 6,200 ft. runway.

Economy

Sinclair Inlet's economy is heavily reliant upon local defense establishments, but the area is serving increasingly as a "bedroom community" for part of Seattle's metropolitan workforce. As the costs of housing in the Seattle market have been driven up by urban growth, Kitsap County has seen an increasing number of families choosing to buy a home on the west side of Puget Sound, a ferry ride away from their Seattle-based jobs. Conversely, many PSNS workers commute from homes in Seattle. Ferry traffic between Bremerton and Seattle increased 9% over the last decade to 2,331,489 annual riders in 2001[6].

Bremerton and indeed Kitsap County have marine dominated economies comprising both government enterprises and private businesses. The influence of these entities ranges from local (e.g. a yacht club) to global (USN), as do their economic and social impacts. These enterprises own or operate major floating and land-based assets and their personnel have special vessel-handling and waterway skills that would be invaluable during on-water response and recovery operations.

Marine enterprises are water-dependent activities that require a location adjacent to navigable waterways in order to service, repair, store or operate vessels or floating equipment. Members of this group include Port of Bremerton, private marinas and yacht clubs, private ferry operations, and boatyards. (A partial listing appears below.)

United States Naval Facilities

Bremerton Naval complex (Puget Sound Naval Shipyard/Naval Station Bremerton)

Sinclair Inlet is the home of the Puget Sound Naval Shipyard (PSNS) and Naval Station Bremerton (NSB), important strategic assets of the U.S. Navy in the Pacific Northwest. The PSNS repairs and refurbishes all classes of navy vessels including those home-ported at Everett and the Bangor nuclear submarine base. NSB homeports aircraft carriers and support vessels. The civilian employment at this naval complex drives the local economy of Bremerton.

The Puget Sound Naval Shipyard was established in the 1890s and is presently the only one of its kind on the West Coast of the US. The shipyard population includes 8,400 civilian shipyard workers, 2,500 contractors, and active duty navy personnel, plus personnel attached to ships in for repair (up to 3,000 per carrier). The Naval Station homeport includes about 250 base personnel, plus crews of a carrier and fuel/ammunition support ships, when in port. The total shipyard population varies, but can reach 18,000.

Other Naval Facilities

Jackson Park located on the west shore of Dyes Inlet includes base housing for the Bremerton area and a Naval Hospital.

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[6] Puget Sound Regional Council. Ferry ridership data, 2002

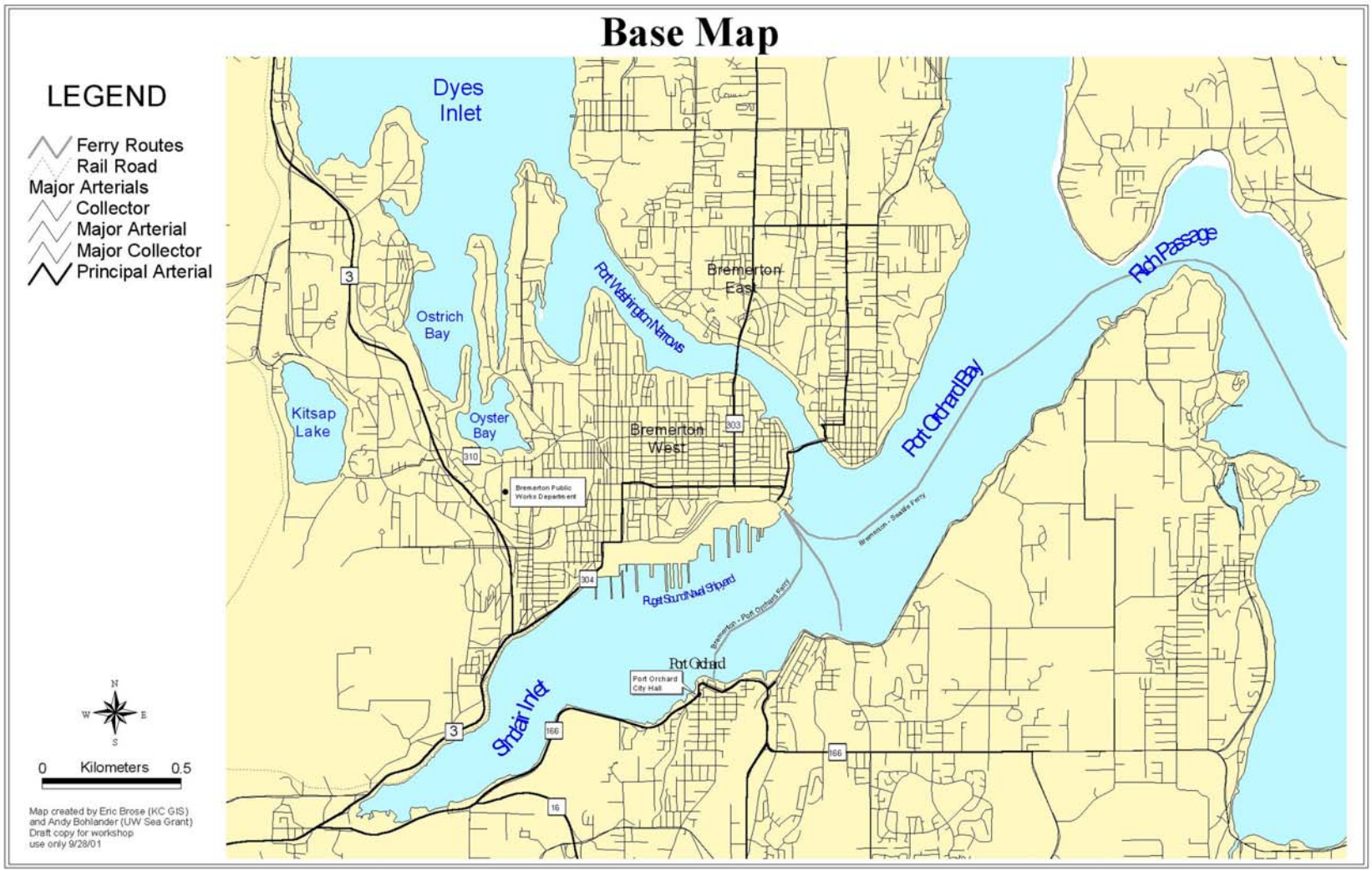

Figure 1: Sinclair Inlet Area Map

Transportation Facilities

Washington State Ferries

Horluck Transportation

Marinas & Boatyards

Port Orchard Marina

Suldan's Boatworks

Marinas & Boatyards, cont…

Kitsap Marina

Martins Marina

Port Washington Marina

Dockside Sales & Service

Port Orchard Marine Railway

Thompson Landing

Yacht Clubs

Port Orchard Yacht Club

Bremerton Yacht Club

Sinclair Inlet Yacht Club

Other Marine Business

Boat & Motor Dealers

Yacht brokers

Aquaculture

Bulk Fuel Storage and Distribution

Other Shoreline Businesses

A variety of non-marine businesses occupy waterfront sites around Sinclair and Dyes Inlet shorelines. Some are there because they need the parking or storage space that flat shoreline sites offer (they were once easy to fill). Auto dealerships, manufactured home sales, supermarkets, drive-up banks belong in this category. Other businesses, such as hotels and motels, restaurants, specialty retail stores and commercial offices are able to capitalize on the waterfront views to attract patrons or tenants, or to command higher rents. Technological change in transportation has left some formerly water-dependent business–e.g. bulk oil distribution terminals–on shoreline sites they no longer "need" but from which they have little incentive to move.

Governmental Responsibilities for Hazards Preparedness, Response, Recovery & Mitigation

Governmental agencies at regional, state and federal levels contribute in important ways to the capacity of local communities in Kitsap County to prepare for and respond to

seismic hazards. Through providing basic scientific information, funding for mitigation, technical assistance in hazards and vulnerability assessment, disaster response planning and in many other ways, these agencies underpin local efforts to minimize loss of life and property in a disaster.

Disaster Preparedness

Emergency Management Education and Training

Emergency management agencies at federal, state and local governmental levels conduct education and training programs. The Federal Emergency Management Agency (FEMA) runs a national Emergency Management Training Institute with course offerings in disaster response for emergency management professionals; disaster-resistant design for engineers, architects and building officials; business preparedness, recovery and mitigation for community economic development personnel and other "trainers". Distance learning modules permit local emergency management professionals and others to take courses without leaving their communities.

At the state level, the Washington Military Department, Emergency Management Division (WEMD) offers courses, disaster simulations and statewide drills for local government emergency managers, other state agency staff. WEMD's training section also develops public education materials and kits for individuals, families, neighborhoods, volunteer organizations, schools and businesses to prepare for emergencies and disasters, including earthquakes. Their "drop, cover and hold" drill is conducted annually, statewide.

Locally, Kitsap County Emergency Management Department offers training programs (K-PREP) for local schools and businesses to develop all-hazards emergency response plans and, through drills and table-top exercises, for employees to follow them.

Through the internet the public has growing access to training materials, posters, model plans and other useful preparedness information posted on the agency's website: www.kitsapdem.org

Disaster Response

KCEMD, a county-wide agency, has the responsibility for coordinating Kitsap cities' and the county's all-hazards response through the county's emergency operations center (EOC). The EOC coordinates police, fire and county sheriff departments response and is the primary link to state and federal emergency response resources through the Washington Emergency Management Division's (WEMD) EOC at Camp Murray.

In Washington State only *local* government officials can order an evacuation. Hence, the county Emergency Operations Center (EOC) is the primary unit effecting organized response in a disaster; the *state's* role is focussed on training, technical and financial assistance, regional coordination, and the all-important disaster declaration function that precedes federal assistance and response. WEMD's use of HAZUS[7] in earthquake loss estimation is credited with achieving such a rapid presidential disaster declaration

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[7] HAZUS or Hazards U.S., is a natural hazard loss estimation methodology developed by the Federal Emergency Management Agency (FEMA). Using Geographic Information Systems (GIS) technology, HAZUS allows users to compute estimates of damage and losses that could result from an earthquake. (http://www.fema.gov/hazus/)

following the February 28th., 2001 Nisqually Earthquake and paving the way for federal emergency aid to flow into the state.

Public transportation providers (highways, transit, ferries) have their own Emergency Operations Plans which are implemented when disasters strike.

Disaster Recovery

Following a request from the Governor for, and the granting of a Presidential disaster declaration, federal aid, technical assistance and resources begin to flow into the state, to augment state and local recovery operations, including:

- federal equipment, supplies, facilities, personnel, and other resources…
- medicine, food, and other consumable supplies, and other services and assistance to disaster victims
- any work or services essential to saving lives and protecting and preserving property or public health and safety, including -
- debris removal
- search and rescue, emergency medical care, emergency mass care, emergency shelter, and provision of food, water, medicine, and other essential needs, including movement of supplies or persons
- clearance of roads and construction of temporary bridges necessary to the performance of emergency tasks and essential community services
- provision of temporary facilities for schools and other essential community services
- demolition of unsafe structures which endanger the public

(Stafford Act, Section 403)

Mitigation Planning

Mitigation – *sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects* – occurs locally through the decisions of governmental agencies, business, schools, non-governmental organizations and households. Mitigation addresses all phases of a disaster in advance: taking actions to achieve better *preparedness*; planning for more rapid and coordinated *response;* and, having in place the mechanisms to speed the community's *recovery* following a disaster. Mitigation includes both protecting existing development from known hazards and managing future development to reduce exposure to hazards.

Science-based Hazards Information

Fundamental knowledge about the earth's crust and its overlying oceans comes in part from investments made in basic and applied science at our nation's geologic and oceanic agencies' research labs and field offices. The United States Geologic Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) are the most important in this regard. USGS seismologists, geologists and geophysicists study, monitor and map the region's geologic structure and faults, and produce earthquake risk maps to guide building codes. Their GIS-based HAZUS computer simulations can model, at the census tract scale, the damage done by an earthquake and estimate potential property and human losses.

NOAA's West Coast/AlaskaTsunami Warning Center monitors and provides warnings of tsunamis, sometimes hours in advance, when they are detected. When USGS scientists

uncovered evidence of past great earthquakes and tsunamis along the Cascadia Subduction Zone, NOAA's Pacific Marine Environmental Laboratory (PMEL) scientists and their collaborators in state agencies and universities developed computer models of those tsunamis from which they derived inundation maps to guide evacuation planning by local governments.

At the state level, Washington Department of Natural Resources Division of Geology and Earth Resources (WDNR-GER) augments geologic hazards mapping done by USGS with work of its own staff, including fine-scale liquefaction potential, landslide and tsunami inundation maps. WGER staff play vital public information roles during the damage assessment phase of a disaster, advising other agencies and the Governor with scientifically accurate interpretations of the event and its effects.

Washington Department of Ecology's Shorelands and Environmental Assistance Program in 1979 published the Washington Coastal Atlas, now on-line, to help guide local jurisdictions in the development of shoreline master programs. Slope stability maps identify landslide and other geologic hazards along the shorelines of all Puget Sound counties. (For Kitsap county shorelines go to: http://www.ecy.wa.gov/programs/sea/femaweb/kitsap.htm)

Local governments, especially counties, often have significant in-house GIS mapping capability; and, Kitsap County is no exception. Here, there are opportunities to overlay local information "layers" –land use, critical utilities and facilities, building footprints, etc.– with slope stability and soils layers developed by USGS or WDNR-GER to produce compelling hazards risk maps.

LIDAR–Light Detection and Ranging–is a new laser-driven altimeter that can accurately map topography through natural vegetative cover from an aircraft. A pilot lidar mapping project of Bainbridge Island, contracted by the Kitsap Public Utility District (KPUD) has uncovered features associated with fault strands within the Seattle fault zone, including a previously unrecognized fault scarp, an uplifted marine wave-cut platform, and tilted sedimentary strata. The USGS has conducted trenching studies across the fault scarp in an attempt to establish ages, displacements, and recurrence intervals of recent earthquakes on this active fault.[8]. Their findings suggest that the scarp is of recent origin–within the last 15,000 years–and that a "minimum of three surface-faulting-and-folding earthquakes (have occurred) since the recession of the Puget ice lobe…"[9].

The success of this pilot effort has led to the formation of a Puget Lidar Consortium comprising local, regional and federal governmental organizations–USGS, NASA, Puget Sound Regional Council, City of Seattle, Kitsap County, and KPUD.

(See: http://duff.geology.washington.edu/data/raster/lidar/index.htm). High-resolution (10 m) map images are complete for much of the central Puget Sound region as of March 2002.

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[8] Harding, David J. and Gregory S. Berghoff. "Fault Scarp Detection Beneath Dense Vegetation Cover: Airborne Lidar Mapping of the Seattle Fault Zone, Bainbridge Island, Washington State"

[9] Nelson, A.R., Johnson, S.Y., Pezzopane, S.K., Wells, R.E, Kelsey, H.M., Sherrod, B.L, Koehler, R.D. Iii, Bradley, L-A., Bucknam, R.C.; Laprade, W.T, Cox, J.W., And Narwold, C.F. "Postglacial and Late Holocene Earthquakes on the Toe Jam Strand of the Seattle Fault, Bainbridge Island, Washington." GSA Abstracts with Programs, v. n. p. ; presented at GSA Cordilleran Section Meeting, Vancouver, BC, 27-29 April 2000

Protecting Current Development–Structural Safety and Retrofitting

Building Codes are the primary vehicle for determining minimum structural and egress standards for new buildings and buildings that are being substantially remodeled and brought "up to code." The Washington State Department of Community, Trade and Economic Development (DCTED) provides administrative and staff support for the State Building Code Council (SBBC), a fifteen member group that adopts amendments to the State Building Code.[10] which governs seismic standards that buildings must meet.

QuickTime™ and a
GIF decompressor
are needed to see this picture.

Figure 2: Changes in Pacific Northwest UBC seismic zone maps. Source: http://www.geophys.washington.edu/CREW/Graphics/HAZMAPS/maps_ubc.html

The SBBC adopted the 1997 version of the Uniform Building Code which maps seismic zones (0 – 4) corresponding to the probabilistic ground-shaking estimates developed and updated by the US Geologic Survey. Currently, Kitsap County is in Zone 3, unchanged since 1949. (See Figure 2) Peak ground accelerations of 30-40% of gravity can be expected over a period of 50 years with only a 10% chance of them exceeding that value.

Ensuring that existing structures are resilient to seismic hazards is the responsibility of local building officials and building owners.

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[10] Chapter 19.27 RCW

Minimum seismic safety standards are designed to protect occupants from structural collapse, but the building may be badly damaged and unusable following an earthquake. Higher structural standards are applied to critical facilities—hospitals, emergency operations centers, etc.— to ensure continuity of use after an event.

Managing Future Development–Regulating Land & Water Uses

Land use is primarily a local government responsibility in Washington. However, there are two state statutes requiring counties and cities to plan for growth and address development in shorelines and other "critical areas." *The Shoreline Management Act*[11] (SMA) requires development of local *shoreline master programs* under guidelines[12] administered by the Washington Department Ecology. Enacted in 1971, well before prehistoric Cascadia Subduction Zone and Seattle Fault shallow crustal earthquake hazards had been documented, the SMA is silent on coastal seismic hazards. Ports and other water-dependent land and water uses are given preferential treatment in the act[13] when alteration of the natural shoreline is proposed. Single family homes are a preferred shoreline use and are exempted from the *shoreline substantial development permit* provisions of the act, as are shoreline bulkheads built to protect them. Consequently, the SMA has been ineffective in keeping populations and structures out of harm's way.

Kitsap County's *Shoreline Master Program*, last updated in 1999, does not explicitly address shoreline geologic hazards, but defers to the *Critical Areas Ordinance* for establishing setbacks and buffers (see below).

A copy of the Kitsap County Shoreline Master Program may be downloaded from the County's website: http://www.kitsapgov.com/dcd/shorelines/sh_county_info.htm

The state's *Growth Management Act*[14] (GMA) passed in 1990 when these hazards were better understood. The GMA requires local governments to designate "critical areas" and develop policies and regulations to protect them. "Geologically hazardous areas,"[15]

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[11] RCW 90.58

[12] New SMA Guidelines adopted by Dept. of Ecology in November 2000 were overturned on appeal to the Shorelines Hearings Board in 2001. Since the original Guidelines had been withdrawn by Dept. of Ecology when the new ones were adopted, there are now NO Guidelines in place for updating Shoreline Master Programs (SMPs). Local governments must rely instead exclusively on the statutory language of the SMA.

[13] "…uses shall be preferred which… unique to or dependent upon use of the state's shoreline. Alterations of the natural condition of the shorelines of the state, in those limited instances when authorized, shall be given priority for single family residences and their appurtenant structures, ports, shoreline recreational uses including but not limited to parks, marinas, piers, and other improvements facilitating public access to shorelines of the state, industrial and commercial developments which are particularly dependent on their location on or use of the shorelines of the state… [RCW 90.58.020]

[14] RCW 36.70A

[15] . "Geologically hazardous areas" means areas that because of their susceptibility to erosion, *sliding*, *earthquake*, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns" [RCW

"landslide hazard areas," and "frequently flooded areas" are three criteria used in defining critical areas; earthquakes fall in the first and second, and tsunami in the third of these. Each of these hazards is further refined in the rules adopted by Washington State Department of Community, Trade and Economic Development *Office of Community Development*, (DTED-OCD) to implement the act[16]. In the process of developing their policies and regulations to protect the functions and values of critical areas local governments must utilize "best available science"[17] (BAS). OCD provides technical assistance and training to local government officials in implementing all aspects of the GMA. Recently the office issued a report, *"Citations of Recommended Sources of Best Available Science for Designating and Protecting Critical Areas"* to guide local decision-makers. As tsunami inundation hazard maps and other science-based emergency management and planning products for Puget Sound shorelines are peer-reviewed and published, they will undoubtedly be added to this BAS citation listing.

The GMA is implemented through policies in the local Comprehensive Plan and development regulations. Kitsap County, like other local governments has adopted a *Critical Areas Ordinance* (CAO) that requires vegetated buffers and building setbacks around wetlands, geologically hazardous areas, and fish and wildlife habitat conservation areas; defines what development may occur within them; and, specifies what measures must be taken to limit potential risks to public health and safety.

A copy of the Kitsap Critical Areas Ordinance may be viewed at:
http://www.kitsapgov.com/dcd/cao/criticalareasord.pdf

36.70A.030 (9) emphasis added].

[16] Seismic hazard areas shall include areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting. [WAC 365-190-080 (4) (e)]

[17] RCW 36.70A.172

2. Sinclair Inlet Hazards

Over the last decade or so geologists, geophysicists and seismologists have made much progress in their understanding of the regional seismicity of the Pacific Northwest in general and Puget Sound in particular. What they have discovered is sobering: destructive *shallow crustal* earthquakes have occurred in central Puget Sound in the past; the latest, approximately 1,100 years ago left evidence of major uplift on a surface fault near Sinclair Inlet that caused a tsunami. The signature sand sheet left by that tsunami has been located on a bay at the south end of Whidbey Island and on low-lying spits in the Snohomish Estuary and at Seattle's West Point. Even larger, *subduction zone* earthquakes have occurred along the Cascadia Megathrust at uneven intervals hundreds of years long; their magnitude and effects are similar to the great Alaska earthquake of Good Friday, 1964. On a decadal time scale *deep intraplate (Benioff Zone)* earthquakes have been felt by almost everyone now living in the Puget Sound region.

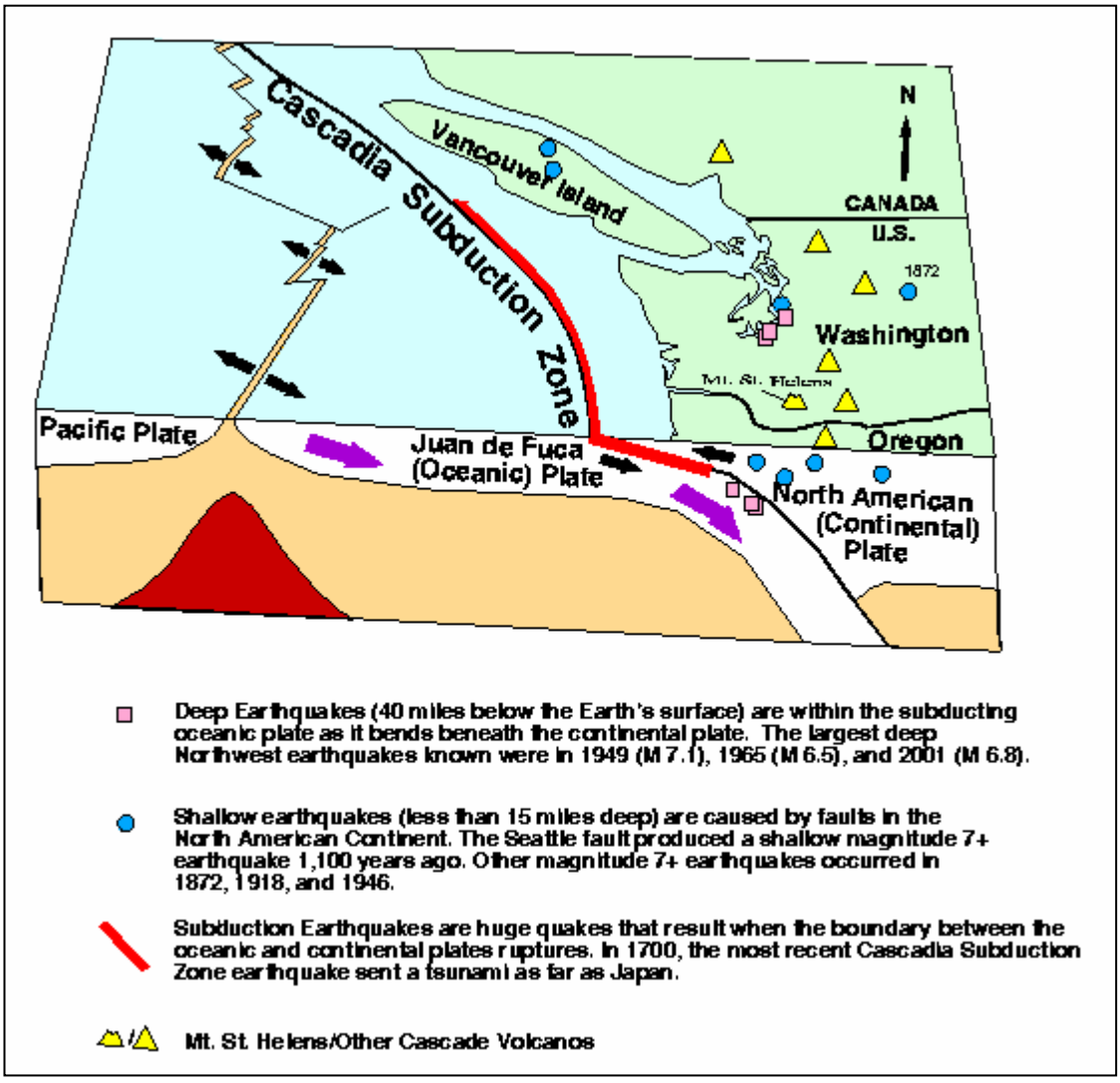


Figure 3: Schematic Diagram of Earthquake Hazards in the Pacific Northwest (Source: www.geophys.washington.edu/SEIS/PNSN/INFO_GENERAL/plates.gif)

Making plans for the Sinclair Inlet Port and Harbor Community to be come more resilient to these hazards requires that each of these regional earthquake threats be understood for what it is and addressed in the context of the time scale over which each occurs. Consequently, three hazard scenarios were presented to the community's stakeholders who took part in the vulnerability assessment and hazard mitigation works held in 2001-02.

Earthquake Scenarios

Event	Worst Case Magnitude	Last Occurrence	Frequency
Lower Plate (Benioff/Intraplate) Earthquakes	7.5	Nisqually, Feb. 28, 2001	10s of years
Plate Boundary (Subduction Zone/Interplate) Earthquakes	9.0	Cascadia, Jan. 26, 1700	100s of years
Upper Plate (Crustal) Earthquakes	7.5	Seattle Fault, A.D. 900	100s - 1,000s of years

Table 1: Sinclair Inlet Earthquake Scenarios

Benioff Zone Earthquakes

Benioff zone events are also known as lower plate or deep intraplate events. These earthquakes occur in the subducting Juan de Fuca plate at depths of 25-100 km. As the Juan de Fuca plate subducts under the North America plate, earthquakes are caused by the abrupt release of slowly accumulated strain. For the February 28, 2001, Nisqually earthquake, the hypocenter, or point beneath the surface at which the rupture starts, was at a depth of 52 kilometers (32 miles). The area of rupture was approximately 30 kilometers by 10 kilometers (18 miles by 6 miles) and slipped approximately one yard. The epicenter or point on the earth’s surface above the hypocenter, was just off the Nisqually delta in southern Puget Sound. The quake was felt as far north as Vancouver, British Columbia, as far south as Salem, Oregon, as far east as Spokane, Wash., and as far southeast as Salt Lake City, Utah. Most of the damage was sustained in the Olympia and Seattle areas.

Benioff zone earthquakes usually have dip-slip, or normal faulting, and no large aftershocks. These earthquakes are caused by mineral changes as the plate goes to deeper depths and is exposed to increased temperature and pressure. The mineral changes cause the plate to shrink and become more dense. Stresses build up, pulling the plate apart. Benioff Zone events are the most common earthquakes in Puget Sound, occurring on the order of 10s of years. Damaging Benioff Zone Earthquakes in Washington include:

- 1949: Olympia (M7.1, Depth 53km)
- 1965: Sea-Tac (M6.5, Depth 63km)
- 1999: Satsop (M5.5-5.8, Depth 41km)
- 2001: Nisqually (M6.8, Depth 52km)

- 2001: Matlock (M5.0, Depth 40km)

Subduction Zone Earthquakes

Subduction Zone events are also known as plate boundary, or interplate events. These earthquakes can be of very large magnitudes, and have been called “mega-earthquakes”. Although no large earthquakes have happened along the offshore Cascadia Subduction Zone since our historic records began in 1790, similar subduction zones worldwide do produce "great" earthquakes - magnitude 8 or larger. These occur because the oceanic crust "sticks" as it is being pushed beneath the continent, rather than sliding smoothly. Over hundreds of years, large stresses build which are released suddenly in great earthquakes. Such earthquakes typically have a minute or more of strong ground shaking, and are quickly followed by damaging tsunamis and numerous large aftershocks.

The Alaskan Mega-Thrust earthquake of 1964 was a great subduction zone event.

Compelling evidence for great-magnitude earthquakes along the Cascadia subduction zone has recently been discovered. These earthquakes were evidently enormous (M8–9+) and recurred on average every 550 years. The recurrence interval, however, has apparently been irregular, as short as about 100 years and as long as about 1,100 years. The last of these great earthquakes struck Washington about 300 years ago.

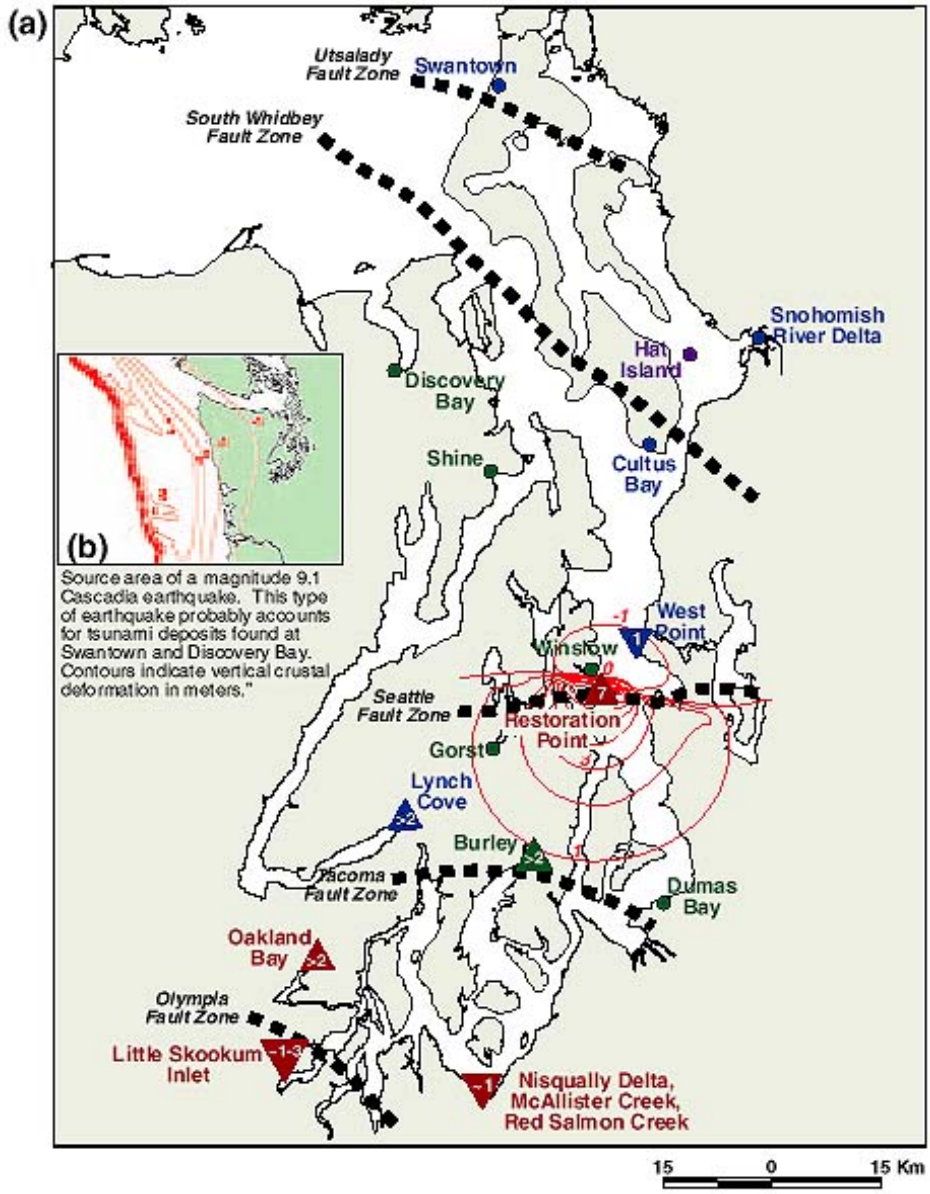
Crustal Earthquakes

Crustal earthquakes are also known as shallow, or upper plate events occuring within about 30 km of the surface. Recent examples occurred near Bremerton in 1997, near Duvall in 1996, off Maury Island in 1995, near Deming in 1990, near North Bend in 1945, just north of Portland in 1962, and on the St. Helens seismic zone (a fault zone running north-northwest through Mount St. Helens) in 1981. All these earthquakes were about M5–5.5. The North Cascades earthquake of 1872, is also thought to have been a shallow crustal event. It may rank as Washington’s most widely felt earthquake. Because of its remote location and the relatively small population in the region, though, damage was light.

Recent geological fieldwork on the Toe Jam Hill fault, a back-thrust to the Seattle fault on Bainbridge Island, reveals that cluster of, “…three, or possibly four,

Figure 4: Uplift on the Seattle Fault at Restoration Point, Bainbridge Island

earthquakes (took place) between 2500 and 1000 years ago. The most recent earthquake is probably the 1050-1020 cal BP (AD 900-930) earthquake that raised marine terraces and triggered a tsunami in Puget Sound." [18] (See Figure 4.) The intervals among these large ground-rupturing earthquakes on the Seattle Fault have been irregular – from as little as 250 to as many as 1,300 years, with much uncertainty surrounding the estimates. This cluster of earthquakes was preceded by a period of quiescence lasting 10 – 12 thousand years, confounding a precise determination of recurrence intervals for earthquakes on the Seattle Fault.



[18] Nelson, Alan R., Samuel Y. Johnson, Harvey M. Kelsey, Ray E. Wells, Brian L. Sherrod, Silvio K. Pezzopane, Lee-Ann Bradley, Rich D. Koehler, III, and Robert C. Bucknam. Late Holocene earthquakes on the Toe Jam Hill fault, Seattle fault zone, Bainbridge Island, Washington. Geological Society of America Bulletin, (in press).

Figure 5: Schematic of fault zone locations in the Puget Sound region (Source: NOAA-PMEL Puget Sound Tsunami Sources—2002 Workshop Report)

Other fault zones have been found in the Puget Sound region that are believed capable of producing shallow crustal earthquakes. (See Figure 5.) These include the North and South Whidbey Fault Zones, the Tacoma Fault Zone and the Olympia Fault Zone. A earthquake on any of these faults would affect the Sinclair Inlet area.

Earthquake Hazards

Groundshaking

Groundshaking occurs as a result of the seismic energy that is released in the form of waves during an earthquake. There are two basic kinds of seismic waves: body waves and surface waves. Body waves travel outward in all directions, including downward, from the quake's focus – that is, the particular spot where the fault first began to rupture.

Richter magnitude	MMI equivalent	Modified Mercalli Intensity Scale (MMI)
1.0–3.0	I	I. Not felt except by a very few under especially favorable conditions.
3.0–3.9	II–III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0–4.9	IV–V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0–5.9	VI–VII	VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0–6.9	VII–IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	VIII or higher	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Table 2: Magnitude/intensity comparison.

Magnitude and intensity measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environ-ment. The table above gives intensities that are typically observed at locations near the epicenter of earthquakes of different magnitudes. (Source: Down-loaded from http://neic.usgs.gov/neis/general/handouts/mag_vs_int.html and reproduced in Washington Geology Vol. 28, No. 3, May 2001.)

Surface waves, by contrast, are confined to the upper few hundred miles of the crust. They travel parallel to the surface, like ripples on the surface of a pond. They are also slower than body waves (Pendick, 2002).

Earthquakes are measured in two different ways – by their *intensity* or physical effects on structures and experienced by people, and by their *magnitude* or the total amount of energy released in the event. The scale used to measure intensity of an earthquake is the Modified Mercalli Intensity Scale; magnitude is measured with the Moment Magnitude Scale. (See Table 2.) Given the potential for a regional earthquake affecting the entire Puget Sound, it is reasonable to expect that the entire study are would be vulnerable to groundshaking in such an event. USGS maps the probability of groundshaking (horizontal ground accelerations) exceeding certain peak values over time periods of 50 to 2,500 years.

Groundshaking can result in any number of secondary hazards, which represent different risks to different areas in Sinclair and Dyes Inlets. The maps entitled, “Liquefaction Susceptibility” (Figure 7), and “Geologic Hazards" (Figure 8), are useful in identifying areas of artificial fill and soft and/or unconsolidated soils. The people and property in these areas, especially the older structures, are most likely to experience damages from groundshaking.

Amplification

Amplification refers to the increased levels of groundshaking during an earthquake due to local geological and soil conditions. Generally, loose sediments shake significantly more than dense bedrock. Large scale geological structures such as the Seattle Basin can “focus” earthquake energy and produce amplified ground-shaking over wider areas. Amplification is also associated with soils having liquefaction potential. Flat areas with loose sediments and rich soils are prime locations for human development, but these areas are also prone to amplification hazards. Most susceptible would be areas of unconsolidated soils, including artificial fill, found throughout the shorelines of Sinclair Inlet and, in particular, along the waterfronts of Bremerton, Port Orchard, Gorst, and parts of Dyes Inlet. Figures 7 and 8 are useful for identifying areas of artificial fill and soft and/or unconsolidated soils, which would likely experience more severe amplification during a major earthquake.

Uplift/Subsidence

Subsidence is the lowering of a portion of the earth's crust. During earthquakes, large areas of the surface can drop several feet almost instantaneously. Evidence of subsidence during major earthquakes along the Cascadia Subduction Zone exists in coastal marshes where cedar trees were killed when their roots were inundated by seawater following the 1700 A.D. Cascadia event (see Figure 6.). Vertical slip during earthquakes can result in uplift on one side of the rupturing fault and subsidence on the

other. There is evidence of approximately seven meters of uplift at Restoration Point on Bainbridge Island along the south side of the Seattle Fault during the ~950A.D. earthquake. To the north, approximately one meter of subsidence occurred. A recurrence of that magnitude crustal earthquake could produce similar vertical ground displacement.

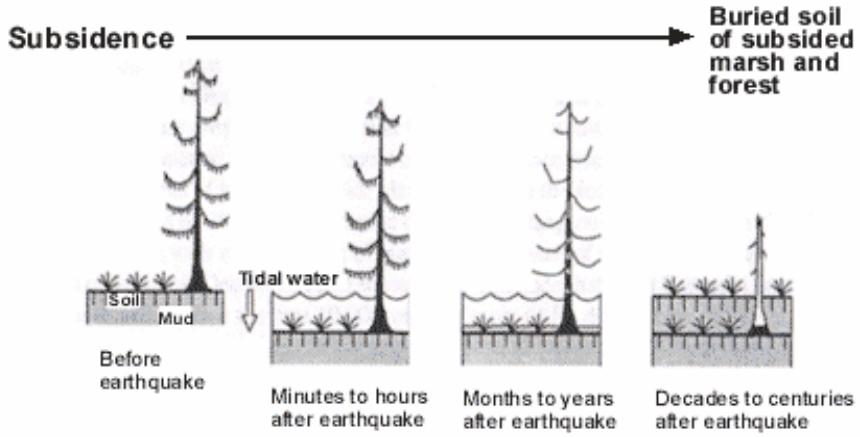


Figure 6: Evidence of subsidence found in Washington coastal marshes [19]

Liquefaction

Liquefaction occurs when groundshaking decreases the stability of saturated unconsolidated soil. The soil becomes a viscous fluid, creating problems with any structure from bridges to buildings and to buried pipes and tanks. Building foundations can slide or settle unevenly, bridges can collapse and empty underground fuel tanks can become buoyant and rise to the surface. Figure 7 and 8 are useful in identifying areas of artificial fill and soft and/or unconsolidated soils. These areas are most likely to experience liquefaction during or after a major earthquake-tsunami event.

Lateral spreading

Lateral spreading is defined as lateral displacement of gently sloping ground as a result of pore pressure build-up or liquefaction in a shallow underlying deposit during an earthquake. There is a strong correlation between liquefaction and lateral spreading. Therefore, it can be inferred that gently sloping areas that are susceptible to liquefaction are also vulnerable to lateral spreading. Where navigation channels have been dredged in loose sediments, the sidewalls of those channels are susceptible to this hazard. Again, Figures 6 and 7 are useful in identifying areas of artificial fill and soft and/or unconsolidated soils. These areas are most likely to experience liquefaction during or after a major earthquake-tsunami event.

Landslides

Landslides are a common hazard associated with earthquakes, winter storms and

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[19] Atwater, B.F., Tuttle, M.P., Schweig, E.S., Rubin, C.M., Yamaguchi, D.K., and Hemphill-Haley, E., 2003, Earthquake recurrence inferred from paleoseismology, in Gillespie, A.R., Porter, S.C., and Atwater, B.F., eds., The Quaternary Period in the United States: Amsterdam, Elsevier (in press).

human activity. The term “landslide” (or “mass wasting”) refers to the downslope movement of rock and soil, caused by one or a combination of the following factors: change in slope gradient; increasing the load the slope must bear; shocks and vibrations; change in water content; ground water movement; frost action; weathering of rocks; and, removal or changing the type of vegetation covering slopes[20]. Figure 8 identifies areas where landslides have occurred in the past, as well as those areas, which are most susceptible to sliding in future events.

[20] King County Office of Emergency Management. (Citation?), 2002

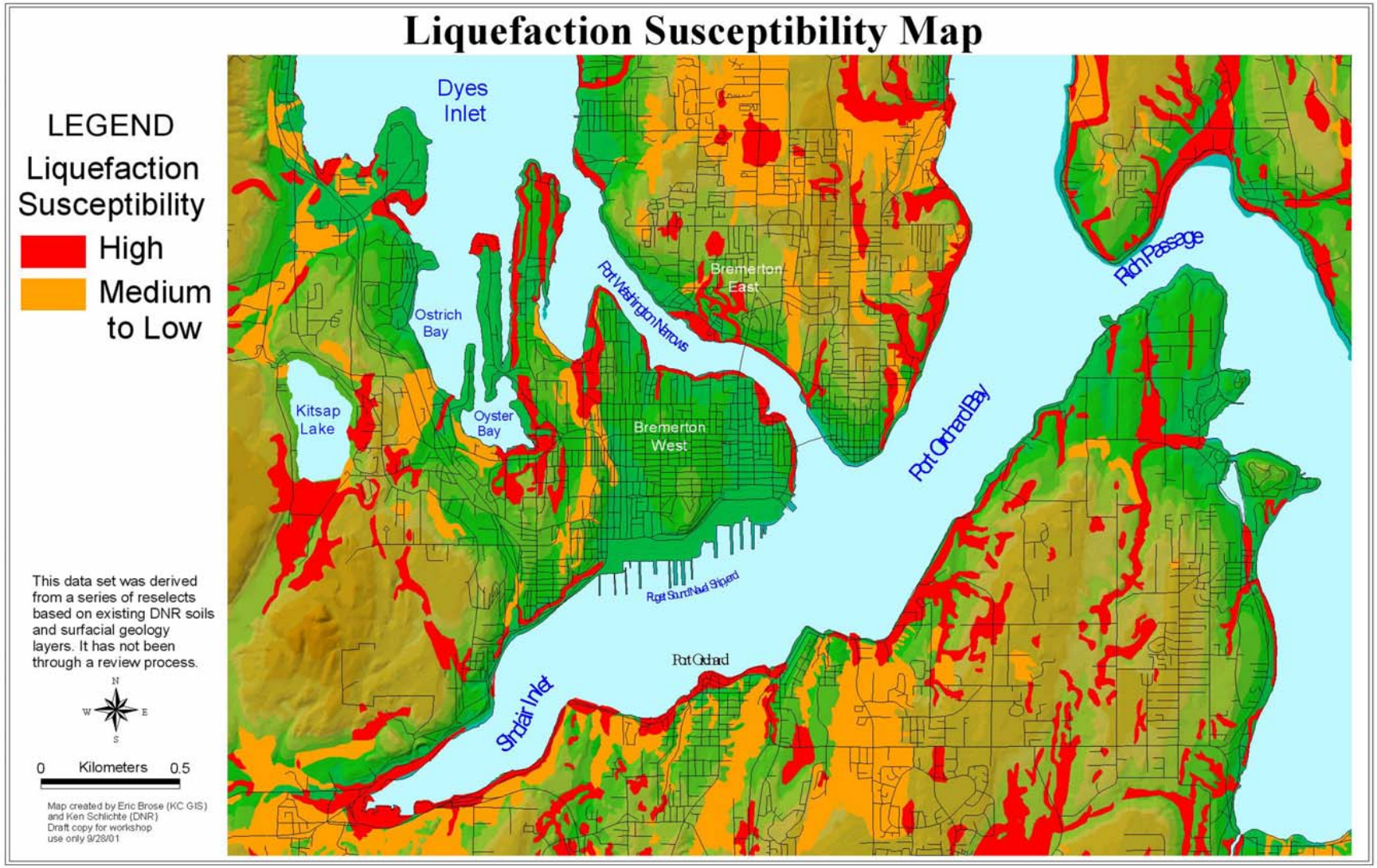

Figure 7: Liquefaction Susceptibility Map

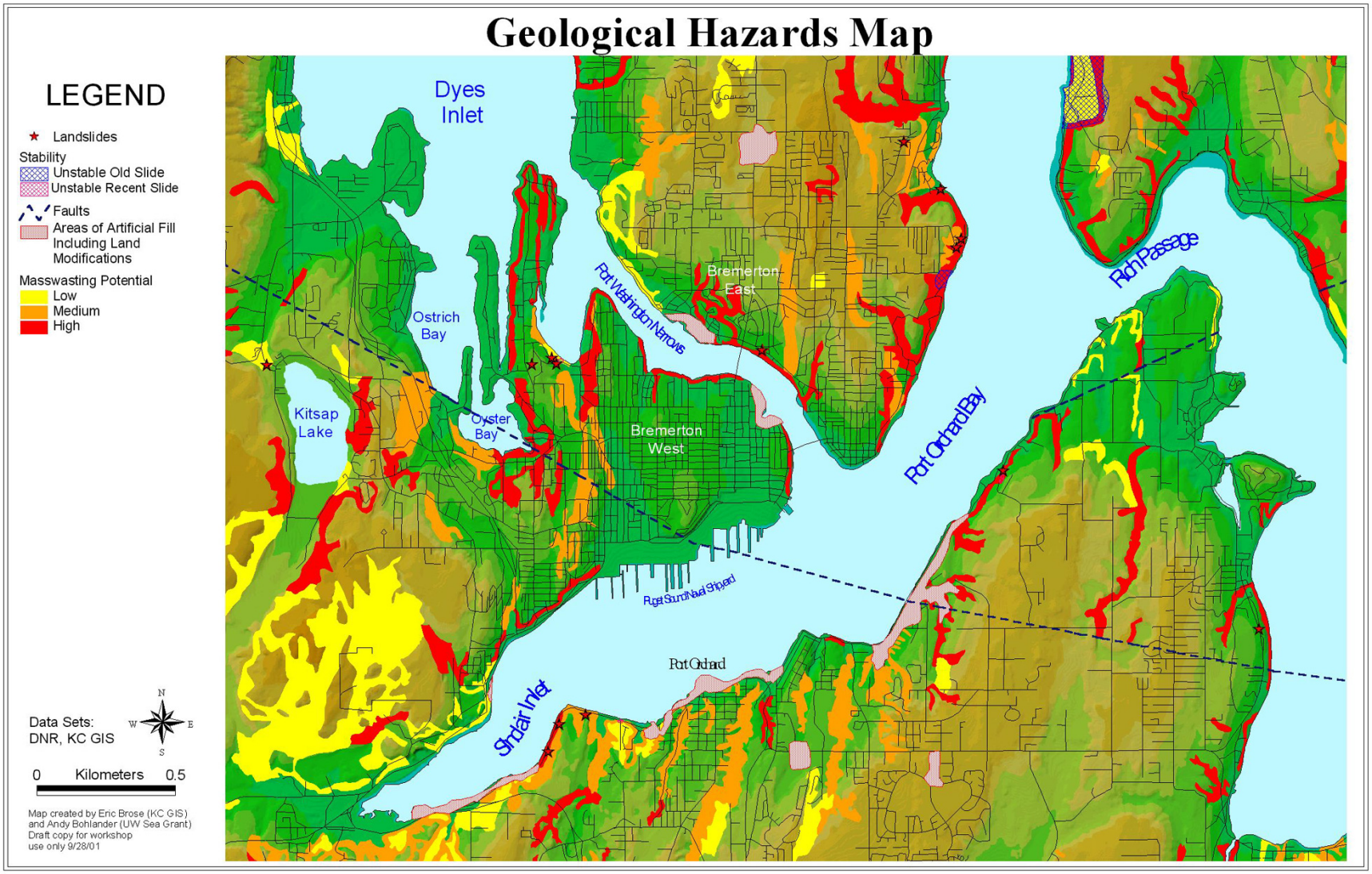

Figure 8: Geological Hazards Map

Tsunami Scenarios

Tsunamis are caused by submarine earthquakes, coastal and submarine landslides or rockslides, and volcanism. They also can be caused by asteroid and meteorite collisions with Earth. Destructive waves are generated when these geologic events cause large, rapid movements in the sea floor that displace the water column above. That swift change creates a series of high-energy waves that radiate outward like pond ripples. Tsunami waves can continue for hours. The first wave can be followed by others a few minutes or a few hours later, and the later waves are commonly larger.[21]

Earthquake-Generated Tsunami

Tsunami from earthquake sources in Puget Sound are extremely rare events though evidence of an occurrence, probably coinciding with the last Seattle Fault event in ca. 930 A.D., persists in marsh deposits – sand sheets deposited during tsunami run-up on the land – on Whidbey Island and elsewhere.[22] Recurrence of a crustal earthquake on the Seattle Fault would likely result in a damaging tsunami in Puget Sound affecting Sinclair and Dyes Inlets.

Landslide-generated Tsunami

Landslides can also produce tsunami. This trigger is particularly significant in Puget Sound, given the propensity for slope failure in the region. Landslides can take the form of indistinct slumping of rock and unconsolidated sediment, or rotation of material along planes of weakness in the rock. The latter often leaves a distinct scar or headwall in cliff lines[23].. Given the climatic conditions of the Puget Sound region, large landslides occur in the absence of seismic activity following periods of heavy, sustained rainfall. Tsunami generated by landslides in Puget Sound, while rare, are more common than those generated by ground-rupturing earthquakes described above; however, their effects are generally very localized. Since the time of European settlement, the region has experienced tsunami caused by earthquake-induced landslides as in case of the 1949 slide at Salmon Beach in the Tacoma Narrows. (See Figure 10.) The landslide occurred 3 days after the 1949 Puget Sound earthquake and generated a 6- to

Figure 10: Salmon Beach after 1949 earthquake (Image courtesy of USGS)

[21] Washington Department of Natural Resources Division of Geology and Earth Resources website: http://www.dnr.wa.gov/geology/hazards/tsunami.htm

[22] Atwater, B.F., and A.L. Moore, A tsunami about 1000 years ago in Puget Sound, Washington, Science, 258, 1614–1617, 1992

[23] Bryant, E.A. *Tsunami: The Underrated Hazard*. Cambridge University Press, Cambridge, 2001.

8-foot tsunami that hit Gig Harbor[24].

Although it is possible to identify landslide-prone areas, scientists have not yet been able to predict, with any degree of certainty, where, when, and how large these slides will be. Sinclair and Dyes Inlet are both characterized by steep slopes consisting of glacial sediment. Recent landslides are visible along the shores of the inlets, indicating the presence of the hazard. It is possible that a large landslide in this area could result in a local tsunami if it reached the water. Computer models of landslide-induced tsunami have been developed for isolated sites in Lake Washington and the Strait of Georgia, but there are no Puget Sound-wide maps created to depict this hazard[25]

Submarine landslides have also been recorded in Puget Sound. In 1894 a slide on the Puyallup River delta front in Commencement Bay that was not associated with a seismic disturbance probably produced a local tsunami. Submarine landslides are considered possible co-seismic hazards in the case of shallow crustal earthquakes, e.g. delta fronts collapsing following a Seattle Fault event. While there are no major river estuaries in Sinclair/Dyes Inlets, Blackjack Creek, east of Port Orchard has deposited a delta fan that geologists suspect could become unstable during strong ground-shaking. (See Figure 11)

Figure 11: Blackjack Creek estuary at Port Orchard. (Source: Washington Dept. of Ecology)

Tsunami Hazards

Tsunami Inundation

Inundation depth refers to the depth of the water on land at a particular location. The *inundation area* is the area that is flooded with water, and the *inundation line* is the inland limit of wetting measured horizontally from the edge of the coast defined by mean sea level.

Preliminary modeling[26] of such an event indicates likelihood of inundation within minutes of the onset of groundshaking along the entire south shore of Sinclair Inlet and at Gorst,

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[24] Walsh, T. *Puget Sound Tsunami/Landslide Workshop, Meeting Notes,* January 23-24, 2001 http://www.pmel.noaa.gov/tsunami/Ws20010123/

[25] NOAA/PMEL recently convened a workshop to address this lack of Puget Sound-wide tsunami probabilistic hazard maps. (Puget Sound Tsunami Sources Workshop, NOAA Sand Point, Seattle, Washington, June 10, 2002)

[26] Koshimura, Shunichi and Harold O. Mofjeld. "Inundation modeling of local tsunamis in Puget Sound, Washington, due to potential earthquakes" in International Tsunami Symposium 2001 Proceedings (pp. 861-873). Seattle. Wash. 2001.

and along the northern and southern shores of Dyes Inlet. The estimated inundation depths are up to 2 m at the shore 1 km east of Port Orchard, 4 m at the northern shore of Dyes Inlet. (See Figure 12). Inundation depths and current velocities cannot accurately be inferred from this model, however, and no inundation lines have been certified for mapping at this time.

Currents

Recent scientific studies have shown that even moderate tsunamis can produce large currents within harbors. *Harbor resonance* contributes to the continued reflection of waves from the edge of a basin, such as a harbor or narrow bay. These reflections cause fluctuations in the water level everywhere, which can increase the wave height inside the basin markedly.[27] Preliminary results of NOAA's tsunami modeling efforts suggest that: "Strong currents would be experienced along the Bremerton and Port Orchard waterfronts and at the narrow west end of the inlet at Gorst." These areas include the Puget Sound Naval Shipyard shoreline. (See Figure 12.)

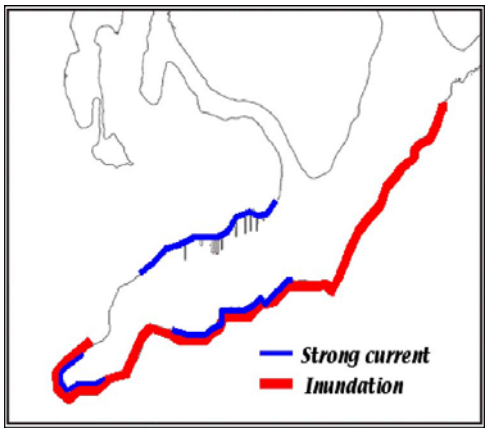

Figure 12: General indications of tsunami inundation and currents in Sinclair Inlet derived from Koshimura and Mofjeld (2001).

Depending on the source location of a tsunami and the severity of the event, portions of Dyes Inlet may also experience strong currents. The map, "Prism Merged Topography/Bathymetry" (Figure 13), shows that bathymetric features that form Sinclair and Dyes Inlets. A similar merged bathymetric and topographic coverage was used by NOAA scientists in the development of their tsunami model[28], which depicts strong currents in Sinclair and Dyes Inlets.

Secondary Hazards

Terrestrial and Waterborne Debris

Terrestrial (land-based) debris is typically a secondary hazard to ground-shaking from earthquakes. Examples of this type of debris are collapsed buildings, fallen utility lines, failed bridges, and rock and soil from landslides. Until it is removed, debris interferes with response and recovery operations by blocking roads and highways and access to buildings where people may be trapped. Debris removal is costly and time-consuming. Not only must the affected area be prepared to remove debris – e.g., have heavy equipment and personnel; they also must have areas designated for its disposal.

Waterborne debris includes floating vessels and structures torn loose from their moorings; cargoes or stockpiles of logs, lumber, wood chips, etc; and, flotsam from damaged piers and docks.

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[27] NOAA -PMEL's online "Tsunami Glossary" http://www.pmel.noaa.gov/tsunami-hazard/terms.html

[28] Koshimura and Mofjeld, op. cit.

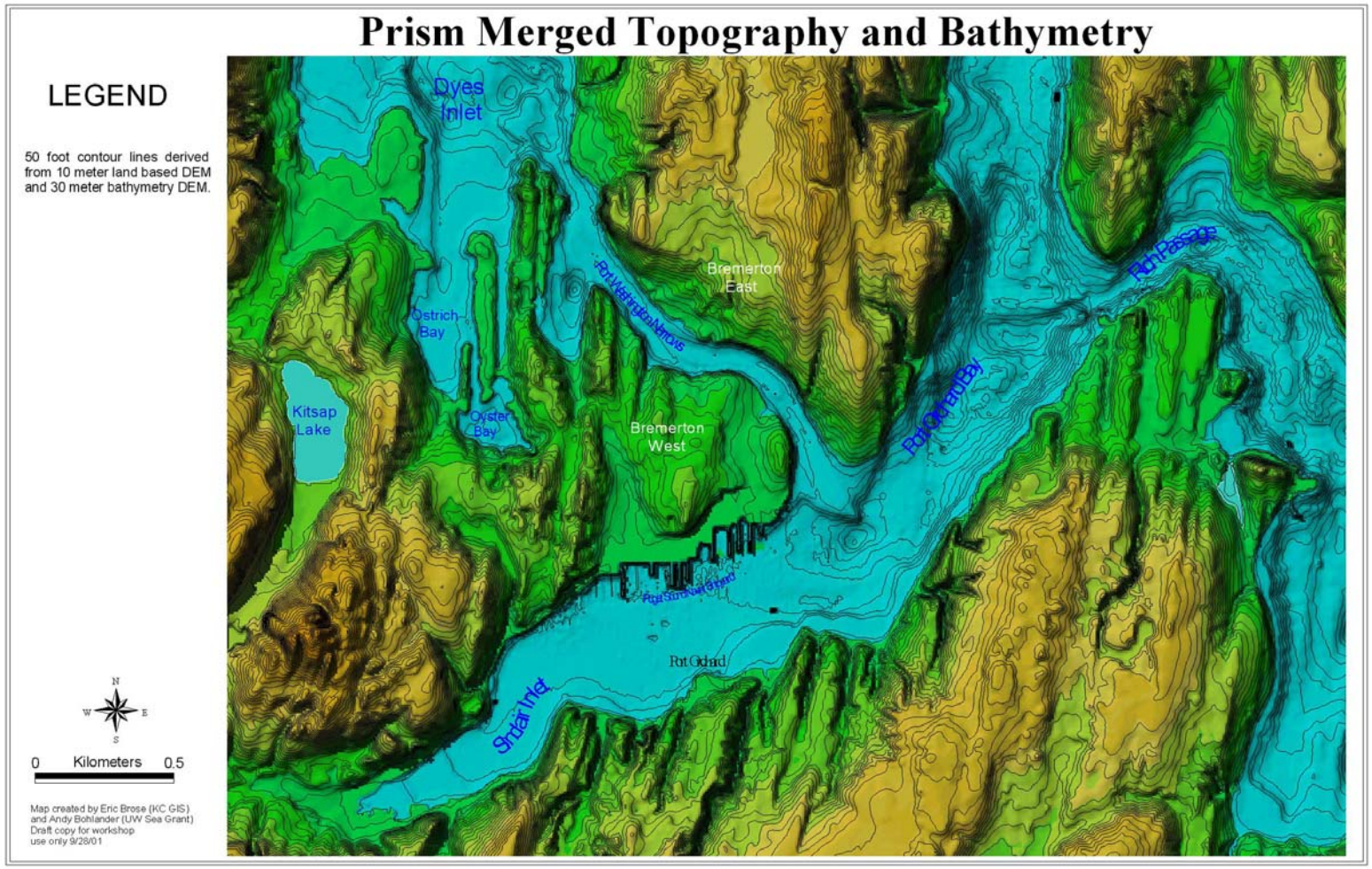

Figure 13: Merged Topography and Bathymetry

Where tsunami inundation brings swiftly moving water on to land, waterborne debris can be deposited in the uplands and terrestrial debris transported into waterways. In the process, debris can become a field of fast-moving projectiles, with the capacity to inflict

further damage and life loss. Waterborne debris is also subject to tidal currents and, if not contained, will be transported some distance from its point of origin, and present additional challenges to responders as well as potential contamination and damage at distant shoreline locations.

Sunken vessels and other foundered floating equipment present special hazards to navigation following an event. Navigation aids torn loose from their moorings may no longer serve their purpose and need to be removed.

Hazardous Materials

Hazardous materials (hazmats) include flammables, toxics, combustibles, explosives, radioactive materials and dangerous gases. An earthquake or tsunami could cause hazmat spills throughout the port and harbor community and have dire consequences for human populations and environmental resources. Spills should be contained and disposed of rapidly to limit exposing people and natural resources to harm.

Hazmats releases commonly occur as a result of damage to storage or transportation facilities caused by ground-shaking, ground failure –e.g. liquefaction– or wave impact. Tsunami can act as a vehicle to transport hazardous substances over wide areas. Many first responders will not have been trained in hazmat response methods, presenting a threat, not only to the responders, but to the greater community.

There are numerous sources of toxic and flammable materials in Sinclair and Dyes Inlet communities; those known are shown on the map, “Essential Facilities and Hazardous Materials” (Figure 14).

Fires

Fires are a common secondary hazard associated with earthquake and tsunami events. Tsunamis commonly create fire hazards by shorting out inundated electrical equipment, and spread fires from open flame sources (gas, fuels, etc.) to other locations in the harbor. Earthquakes can generate fires in a number of ways. For example, a severed gas line could result in a fire, an important issue for single family homes where gas leaks can often go unnoticed.

Scouring and deposition

Tsunamis produce strong currents that are capable of scouring and transporting sediment and causing shoaling of channels and fairways in harbors. Where they interact with the shoreline, tsunami waves and currents can undermine shore protection structures resulting in potential loss of containment of artificial fill and the structures it supports. Dredged slips and channels, shoreline rip-rap and sheet piling bulkheads are most vulnerable to this hazard, particularly where they may have been weakened by ground-shaking, liquefaction or lateral spreading.

Structural failure

There are many types of structural designs and materials used to construct buildings. Unreinforced masonry (URM) structures are the most vulnerable to ground-shaking and

are commonly found in older downtown commercial districts. These structures typically

Figure 14: Essential Facilities & Hazardous Materials

sustain the most damage during an earthquake due to failure of the external load-bearing masonry (usually brick) walls, and collapse of the roof and floor beams they support. More rigorous earthquake standards adopted in building codes over the years have made newer structures safer. Steel frame, reinforced concrete and wood frame buildings built to the latest earthquake-resistant standards are designed to protect the occupants from structural collapse, but they may be unusable after severe, prolonged ground-shaking.

Buildings of irregular shapes, with “soft” stories (having large, unbraced openings), or contiguous additions of different heights or construction types are also vulnerable to earthquake damage. Single family homes with split levels and unbraced “pony” walls between the first floor and foundation walls, or lacking wall-to-foundation tie-down bolts are vulnerable to collapse or displacement. Multi-story structures with “soft” first stories are particularly vulnerable to collapse.

Tsunami can also result in structural failure. Shoreline structures are not usually designed to tsunami-specific codes, because these codes are rarely in place. The location of the structure in relation to the water, as well as its orientation to the dominant currents will affect its overall vulnerability. For example, a building whose narrowest side faces the currents will likely sustain less damage because the currents can move around it with greater ease. A building whose widest side faces the currents will receive large amounts of energy from wave impact, resulting in greater damage. Buildings designed with break-away walls on the first floor allow passage of tsunami-driven water surges, reducing forces on vulnerable structures. Reinforced concrete structures generally fare well in tsunamis.

Non-structural damage

Though a modern building’s structure may withstand ground-shaking, its fixtures and contents may topple or break loose, causing injury or death, blocking egress and hampering response efforts. Free-standing bookcases, file cabinets and computers, suspended ceiling tiles and light fixtures, and the building’s exterior signs are items which, if not properly attached or anchored, are likely to be vulnerable to groundshaking.

3. Specific Geographic Vulnerabilities

Port Washington Narrows

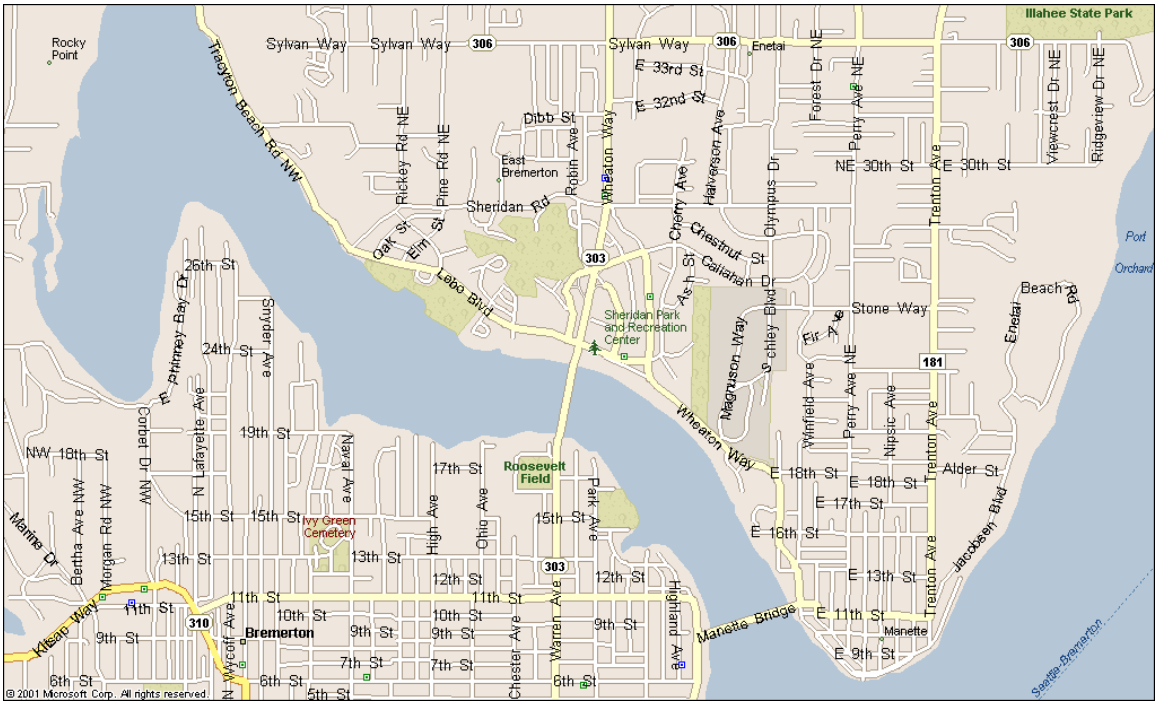

Figure 15: Port Washington Narrows Area Map

Port Washington Narrows is the channel that connects Port Orchard with Dyes Inlet, and separates West Bremerton from East Bremerton. Steep bluffs on both sides have experienced landslides in the past and are susceptible to earthquake-induced slides in the future. Crossing Port Washington Narrows and linking Bremerton with East Bremerton are the Manette and Warren Avenue Bridges. These bridges carry waterlines and other utilities as well as traffic. Underwater sewer lines also cross the Narrows in this transportation corridor. Each bridge provides roughly 80' of clearance for vessel passage. The Mannette Bridge was built in the 1940s and would not survive a major earthquake. Plans are in place to replace the bridge within the next few years. The Warren Ave. Bridge is of more recent vintage (year built?), but would be closed for structural inspection following a quake, resulting in temporary loss of service. Both bridges are state-owned and operated, and have a history of prompt closure during emergencies and periods of foul weather. The loss of both of these bridges necessitates a 20-mile detour for those commuting between Bremerton and East Bremerton. Both bridges were closed shortly after the Nisqually earthquake in February, 2001, but were quickly re-opened.

Three city parks are located along the Narrows: Bachmann Park at the southeastern entrance to the narrows; Evergreen City Park midway between the two bridges on the western shore; and Lebo Street Recreational Area (or Lion's Park) just north of the second bridge on the eastern shore. During the summer months, shoreline parks are crowded with people. If a tsunami occurred at this time, especially at high tide, losses

would be high.

Port Washington Narrows is an unrestricted waterway with up to 4-knot currents. Some moorage and anchorage opportunities are available in the numerous embayments along the narrows, but there is no anchorage directly in the waterway. Boating access is provided at boat ramps in two of the City parks and at the Tracyton Boat Ramp, operated by the Port of Tracyton, located at the northeast end of the channel. Port Washington Narrows Marina has 80 open boat slips at its facility on the west shore, north of the Warren Ave Bridge. Vessels being launched or retrieved at boat ramps, moored in marinas, or underway in the Narrows are vulnerable to tsunami hazards, particularly currents and floating debris.

Dyes Inlet

Figure 16: Dyes Inlet Area Map

Dyes Inlet is connected to Sinclair Inlet to the south through Port Washington Narrows. A number of north-south aligned bays, some with steep wooded bluffs, form the south end of Dyes Inlet. At its northern end Dyes Inlet has areas of low-lying shoreline facing more open water.

Oyster Bay is located in the southernmost portion of Dyes Inlet. It is primarily a residential area, and many homes abut the water. The population in this area is predominantly elderly. An assisted living home is located in a suspected high-risk inundation zone. Many of the structures built in this area are of older design (including brick and un-reinforced masonry structures).

Ostrich Bay is located in the southern portion of Dyes Inlet, northwest of Oyster Bay.

The navigable water in the area narrows significantly at the entrance to, and then widens again to form the main basin of Oyster Bay.

Chico Bay is located on the western portion of Dyes Inlet, northwest of Ostrich Bay, roughly 5 miles northwest of Bremerton

Phinney Bay is located on the western portion of Dyes Inlet, where the Port Washington Narrows ends.

Dyes Inlet is considered by anglers to be a prime fishing spot for Chum salmon in the Fall. Kayakers enjoy the waters of Ostrich, Phinney, Oyster or Chico bays and when the water is calm, paddle all of Dyes Inlet from Silverdale to Tracyton. Paddlers typically launch at the county park at Silverdale or at the Tracyton or Chico ramps. Kayakers and other recreational boaters and fishers would be at extreme risk in a tsunami. With little or no warning besides ground-shaking, which would likely go unnoticed on the water, these recreationists would be very exposed to tsunami hazards.

Dyes Inlet is an urbanized estuary that is subject to many point and non-point sources of pollution. Known point sources include periodic discharges of untreated human and industrial sewage into the inlet from pump stations and combined sewer overflows from the City of Bremerton, and the Jackson Park area of Ostrich Bay where heavy metals and toxic ordnance-related compounds from inadequate waste handling activities have leached into the marine sediments. Non-point sources include contaminated runoff from streets and streams, animal waste, spills or discharges from boats, discharge from storm sewers and failing septic systems. Because of such pollution sources, Dyes Inlet has been closed to the commercial harvest of shellfish since the 1960's.

Sinclair and Dyes Inlet are both special areas of concern for toxics, because they consistently exceed allowable state levels for mercury. Six Superfund sites are located in Puget Sound, two of which are Sinclair Inlet and Dyes Inlet[29]. It is possible these waters could be further harmed by the re-suspension of contaminants as a result of scouring of bottom sediments by tsunami currents following a major seismic event.

While the dominant shoreline land use in Dyes Inlet is single family residential, there are some significant parks, boating facilities, naval housing and hospital, and a major commercial center in Silverdale. These and other sites in Dyes Inlet are vulnerable to earthquake/tsunami hazards and include:

Old Mill Site: Kitsap County recently acquired seven acres of Dyes Inlet waterfront at the mouth of Clear Creek on the south side of Bucklin Hill Road. The property has 1150 feet of low bank gravel beach which more than triples the amount of public shoreline on Dyes Inlet.

Jackson Park Hospital: This site just south of Erlands Point is Navy property that includes base housing for the Bremerton area and the Naval Hospital and has a population of about 3000 people. At least one strand of the Seattle fault runs directly

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[29] People for Puget Sound, *Puget Sound in Washington*, 2000.

through the naval hospital site, making it extremely vulnerable to severe ground-shaking, tsunami inundation and seiches in Dyes Inlet. Predicting where a fault is going to surface is nearly impossible, and if it does surface directly under the hospital, there is little that could be done to prevent damage, besides moving the hospital.

Bremerton Yacht Club: Bremerton Yacht Club's reciprocal moorage is located in Phinney Bay on the south side of Port Washington Narrows. Its 250 feet of moorage is located on the east edges of their main North/South dock and can accommodate yachts up to 60 ft in length. The yacht club is privately-owned, and has only two full-time employees. The Vice-Commodore, a trained engineer, recently conducted a "risk/value analysis" of the facility, incorporating earthquakes and tsunami as threats. The purpose of this study was to evaluate potential risks to the Bremerton Yacht Club waterfront facilities, assign value to those risks, and determine the minimum monetary reserve with which to self-insure the yacht club against catastrophic loss. The results of this report are confidential, but it was determined that the yacht club was highly vulnerable in the event of a major earthquake or tsunami.

Madrona Point/Marine Drive Surrounds: Madrona Point, a waterfront residential community, is an isthmus connected to Bremerton by a single roadway located only a few feet above the mudflats at its narrowest point. Many homes in the area have boathouses and/or piers and docks. Only one power line serves the community and that is located at the water's edge near the mudflats. Consequently, the area is vulnerable to isolation and loss of power following a major earthquake and tsunami.

Silverdale: Silverdale is a growing community located along a low-lying shoreline at the northern end of Dyes Inlet. Proposed development plans include a new conference center[30]. It is possible that further development on low-lying sites here will be at risk to tsunami inundation.

Sinclair Inlet

[30] Erb, George. *Kitsap County Expects 5 Plans For Event Centers*. Puget Sound Business Journal, Industry Wrap-ups, July 16, 2001. http://www.bizjournals.com/seattle/stories/2001/07/16/newscolumn4.html)

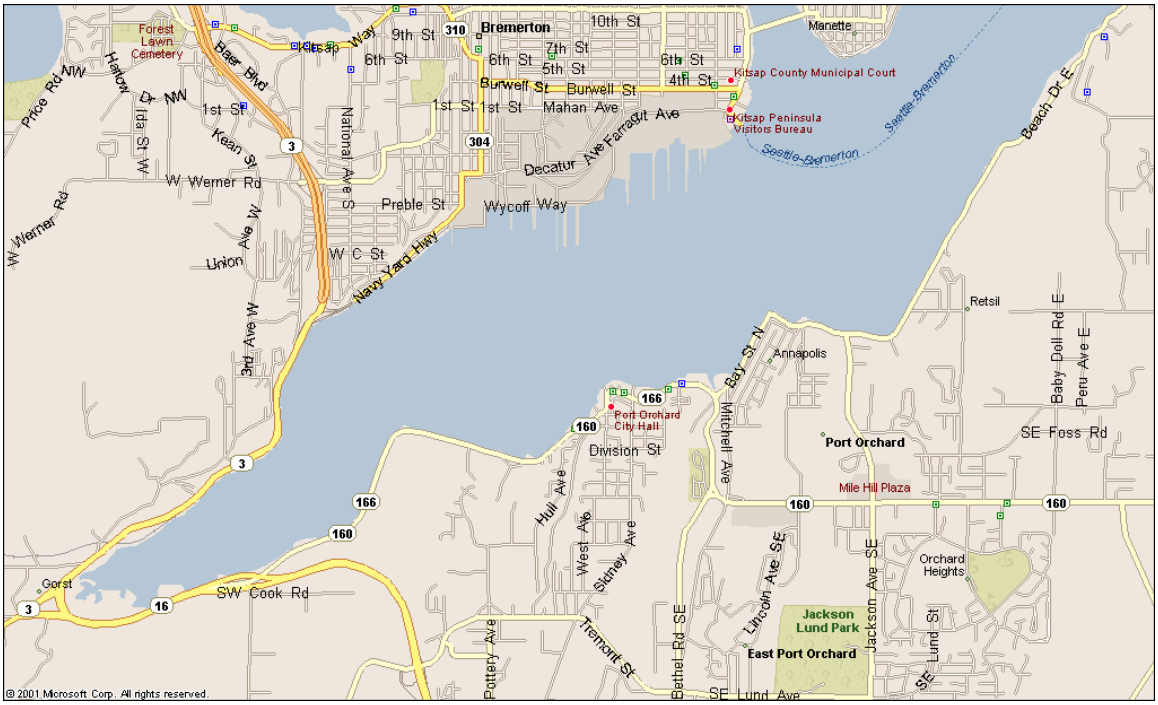

Figure 17: Sinclair Inlet Area Map

Bremerton Waterfront

Figure 18: Bremerton Waterfront Area **Map**

The downtown Bremerton Waterfront plays a significant role in the cultural and economic vitality of the larger Sinclair Inlet community. First, the Bremerton Transportation Center

accommodates terminal facilities for the larger of the two cross-Sound Washington State Ferry routes serving the area, as well as passenger-only services to both Seattle and Port Orchard. Second, a short-stay marina operated by the Port of Bremerton provides small craft access to downtown and to waterfront visitor amenities, including the USS Turner Joy, a vessel of recent historic importance, and the downtown waterfront boardwalk. Third, the Blackberry Festival and other community events take place along the Boardwalk, drawing large crowds. Finally, a major convention center is planned for a site immediately north of the Ferry Terminal and adjacent to the Boardwalk.

Most of the waterfront infrastructure was constructed to current Zone III seismic standards and would fare well in all but the worst case scenario earthquakes. Tsunami hazards were not considered when these structures were designed and they may be vulnerable to strong currents and inundation during a tsunami, however.

USS Turner Joy

The Turner Joy is fastened at the stern to a large concrete and steel pile dolphin via a hard truss-like steel connector that would probably fail in strong ground-shaking, , allowing tsunami currents to swing the vessel by its bow lines, perhaps damaging other vessels and structures.

Bremerton Transportation Center

The Washington State Ferry terminal facilities are new (199?) and designed to latest building code and engineering standards, but are vulnerable to a tsunamigenic Seattle Fault earthquake coinciding with high tide – a highly improbable event. The passenger-only ferry terminal float/bridge connection was designed to accommodate water levels up to +15ft. MLLW. A tsunami occurring at high water could overtop this level and damage the bridge structure. Floating dock anchorage at the Horluck Transportation Port Orchard ferry slip may be vulnerable to tsunami currents and inundation.

Lateral spreading and scouring/redeposition of liquefiable soils and bottom sediments could lead to shoaling of ferry slips. Bathymetry may change due to slumping, and thereby prevent ferries docking. Floating debris, sunken vessels, collapsed highway bridges and shoaling could obstruct navigation channels following a tsunami. While ferries are docking or docked, battering of/from dolphins and wing-walls, and failure of the loading ramp during severe ground-shaking could occur.

Waterfront Boardwalk Park

Because of the tourist amenity it provides and the events it hosts, the Boardwalk Park draws large crowds. While there, these populations are in harm's way and must cross low-lying ground to reach safety. Given the uncertainty surrounding the current generation of tsunami modeling, the Boardwalk may or may not be subject to inundation following an earthquake on the Seattle Fault. The city has proposed a waterfront conference center on a downtown municipal parking lot adjacent to the waterfront and possibly susceptible to tsunami inundation. Bremerton's proposal includes a privately developed hotel. The Bremerton City Council on July 2, 2001 passed a resolution endorsing the plan[31].

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[31] Erb, George. *Kitsap County Expects 5 Plans For Event Centers*. Puget Sound Business Journal, Industry Wrap-ups, July 16, 2001.

Bremerton Naval Complex

Sinclair Inlet is the home of the Puget Sound Naval Shipyard and Naval Station Bremerton (NSB), important strategic assets of the U.S. Navy in the Pacific Northwest. The PSNS repairs and refurbishes all classes of navy vessels including those home-ported at Everett and the Bangor nuclear submarine base. NSB homeports aircraft carriers and support vessels. The civilian employment at this naval complex drives the local economy of Bremerton.

The Puget Sound Naval Shipyard was established in the 1890s and is presently the only one of its kind on the West Coast of the US. The shipyard population includes 8,400 civilian shipyard workers, 2,500 contractors, and active duty navy personnel, plus personnel attached to ships in for repair (up to 3,000 per carrier). The Naval Station homeport includes about 250 base personnel, plus crews of a carrier and fuel/ammunition support ships, when in port. The total shipyard population varies, but can reach 18,000.

The shipyard and naval station are located directly on Sinclair Inlet and thus subject to both earthquake and tsunami hazards. Many of the low-lying portions of the PSNS are located only a few feet above extreme high water (pier elevations +18'-19' MLLW). These low-lying areas are virtually all fill over former tidal marshes and flats and thus potentially vulnerable to amplified ground-shaking, liquefaction, and lateral spread.

While the PSNS facilities have fared well in recent deep Benioff earthquakes ~M7, their performance in a Seattle Fault event is likely to be poor, putting shipyard workers and vessels under repair at considerable risk and compromising military functionality. Loss of key professional workers in support roles due to location in at-risk buildings could shut down the shipyard following an earthquake. (Continuity of shipyard operations is considered at risk also because of potential problems with regional transportation continuity.)

Structures: Many buildings on both the shipyard and naval station are old and constructed of unreinforced masonry (URM) –15 on the Naval Shipyard and 12 on the Naval Station. The number of URM's is approximate, some are load-bearing URM causing concern, others are non-loadbearing (i.e. steel or timber frame). Many of the other Navy buildings were constructed prior to the current seismic codes, and are thus vulnerable to seismic hazards. The large shipyard machine shop is among the most vulnerable.

Planned seismic upgrades—structural (buildings) and nonstructural (e.g., securing of interior lighting fixtures) have gone unfunded or have been deferred. Emergency lighting/power problems exist in many buildings, as illustrated by the 2001 Nisqually earthquake.

Infrastructure: Utilities, streets, cranes, rail lines, piers and seawalls are vulnerable to liquefaction and lateral spread of filled areas in the shipyard. Most crane rails are supported on piles and much of the utility distribution system is housed in concrete utility tunnels and trenches. Piers are vulnerable at connecting points with land. Sheet pile and other seawalls and bulkheads could fail and allow upland fill material to spread laterally into waterways. Historically the dry docks have performed well during major intraplate

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http://www.bizjournals.com/seattle/stories/2001/07/16/newscolumn4.html

earthquakes (1949, 1965, and 2001), but their performance during a major crustal event has not been established.

Port Orchard Waterfront

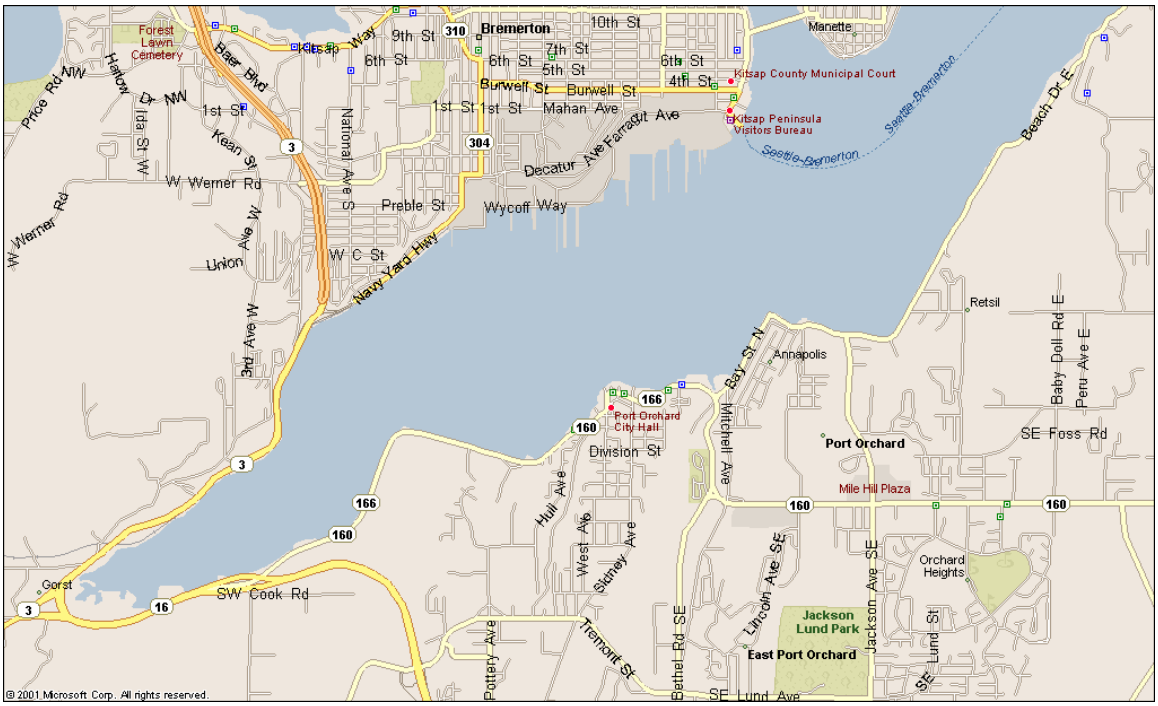

Figure 19: SW Sinclair Inlet Area Map showing Port Orchard and Gorst

The Port Orchard waterfront abuts the city's downtown retail core and plays a major role in the city's recreation and tourism sector, in particular through the Port of Bremerton's 400-slip Port Orchard Marina. A private foot-passenger ferry connects Port Orchard to the Bremerton Transportation Center and the Seattle Ferry. Most of the waterfront has been modified through filling of intertidal wetlands and shoreline armoring. Consequently, many structures on or near the waterfront are built on fill over bay sediments and are susceptible to amplified ground-shaking and liquefaction during earthquakes. Preliminary tsunami modeling shows the likelihood of strong tsunami currents and inundation along this part of Sinclair Inlet leading to structural damage of pile-supported over-water structures from high water levels and floating debris, and flooding of low-lying areas of downtown. Utility lines–sewer and water mains–are located in areas with high liquefaction potential and could fail during ground-shaking, resulting in loss of water-pressure for fire suppression and sewage spills.

Port Orchard Marina

Much of this structure was rebuilt following a disastrous rain-on-snow storm event in December, 1996 which sank many of the facility's pontoon-supported covered moorage sheds. Designed to withstand a 100-year windstorm, the rebuilt structure would likely weather tsunami currents, but would be vulnerable to battering from floating projectiles–vessels and floats torn from their moorings elsewhere in Sinclair Inlet. Short-stay vessels moored along the 3,500ft. floating breakwater would be particularly vulnerable.

A fuel dock located adjacent to the shoreline is fed by buried tanks on land and

protected by both automatic and manual shut-off valves. Fuel spills would most likely be limited, therefore, to that quantity in the lines below the shut-off valves. If the tsunami occurred at or near high water, there would be some risk of pontoons and moorage docks floating free of the pilings supporting them, and being carried away by the currents. A municipal sewage pumping station is located adjacent to the shoreline and might be vulnerable to amplified ground-shaking and liquefaction.

Downtown Port Orchard

Past land use decisions have resulted in many non-water dependent uses being housed in structures located on waterfront parcels, including a large car dealership, a former supermarket, a bank, offices, apartments, a motel and several restaurants. Many of these structures and the businesses they house are vulnerable to ground-shaking, liquefaction and tsunami inundation. Bay Street businesses in the downtown core may also be at risk, but their precise elevation, structural condition and the boundary of filled tidelands upon which they may be built have not been determined. Un-reinforced masonry (URM) buildings are known to be prevalent along the waterfront.

Blackjack Creek Delta

Sediment carried into Port Orchard by Blackjack Creek at the east end of the Port Orchard waterfront has resulted in the formation of a steep delta front that could fail in an earthquake and produce a potentially dangerous tsunamigenic submarine landslide.

Gorst Waterfront

Day-time populations are at risk from a variety of seismic and co-seismic hazards affecting the Gorst floodplain and filled wetlands. Tsunami modeling shows substantial tsunami wave run-up and inundation, coupled with strong currents at this narrow funnel at the west end of Sinclair Inlet where several businesses and highway infrastructure are at risk. A car dealership, technical school, modular home sales yard and other small businesses including a gas station, and fire supply store would add heavy floating objects to the debris stream.

Waterborne debris deposition and strong currents could damage highway interchanges and road beds, shutting down an important regional transportation node. Landslide-prone slopes above SR 166 could fail in an earthquake shut off access to Port Orchard. A basaltic outcropping above SR 3 could produce a rockfall during severe ground-shaking and block this major regional highway route. This hazard has not been mapped or validated, however.

III VULNERABILITY ISSUES AND MITIGATION OPTIONS[32]

1. Earthquake & Tsunami Disaster Response

Community Importance

A Seattle Fault earthquake followed quickly by a local tsunami would create a set of disastrous effects never before encountered by post European settlement populations in Kitsap County. Community lifelines – highways, bridges, ferries, power-lines – will be severed for days if not weeks or months following the event due to landslides, flooding, structural failure, and debris. Only the most modern, earthquake-resilient buildings will remain occupiable, and most older structures will have sustained heavy damage or been destroyed. The number of deaths and injuries from structural collapse, falling debris, tsunami inundation and floating debris propelled by strong currents will be high and tragic.

Workshop participants called into question the adequacy of existing emergency response capacity to cope with such a disaster. Local jurisdictions do not have the number of trained personnel or resources needed to respond. Existing medical care facilities have insufficient beds to accommodate large numbers of injured persons, and access to these facilities may be compromised. The County has not designated open spaces (e.g. parks, parking lots, structures), or estimated numbers of personnel (e.g. doctors, EMTs, laborers), and resources (e.g. mobile medical care units, beds, cots, shelters, tents) needed to respond to massive demands for medical care when medical care facilities will have suffered damage resulting in decreased functionality.

The Kitsap County emergency communications system, which exhibited some problems during the Nisqually earthquake in 2001, is vulnerable and needs major upgrades to be functional following a Seattle Fault event.

Hazardous materials spills and debris – both on land an in the water – will over-tax the capacity of agencies to contain, remove and dispose of them. Fires are a common occurrence following earthquakes and tsunamis. Spilled flammable materials will likely ignite and spread fire over large areas.

Local businesses lack emergency response plans, and employers and employees have not been trained how to respond in a disaster. Many local residents, and most tourists and visitors will be isolated from their homes and families after a major event. These individuals will rely primarily on local emergency response professionals and local agencies for temporary shelter and medical assistance.

In such a region-wide disaster mutual aid agreements with surrounding jurisdictions will

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[32] Please Note: The mitigation actions that appear below are, for the most part, recommendations made by participants at the "Sinclair Inlet Earthquake/Tsunami Hazards Mitigation Workshop" held in Silverdale, Wash. on February 8, 2002. These actions have not been reviewed by elected officials and do not constitute the official positions of Kitsap County, the Cities of Bremerton or Port Orchard, the Port of Bremerton or any of the state or federal agencies whose representatives participated in the workshops. Similarly, Washington Sea Grant Program neither endorses those actions nor attests to the scientific validity of the findings of the workshops except where they are attributed to peer-reviewed, published research.

be unlikely to provide additional response capacity since local emergency personnel will be over-taxed responding to their own communities' needs. Consequently, Bremerton, Port Orchard and Gorst will be "on their own" for some time following a large earthquake-tsunami event.

1.1 Response Capacity and Procedures

Issue: Inadequate emergency response system capacity

Inadequacies in the current emergency response system could increase the risks associated with an earthquake-tsunami event.

Findings

The overall capacity of the emergency response system to meet the needs of local communities is questionable. The County currently has not designated open spaces (e.g. parks, parking lots, structures), or estimated numbers of personnel (e.g. doctors, EMTs, laborers), and resources (e.g. mobile medical care units, beds, cots, shelters, tents) needed to respond to increased medical needs and decreased functionality of medical care facilities.

Many doctors and other health care professionals live in vulnerable residential areas – low-lying waterfront homes subject to inundation,or atop steep bluffs susceptible to landslides – or areas separated from critical medical facilities by vulnerable highway bridges. If these responders are isolated, the response capacity of the medical system is compromised.

Local fire stations may be vulnerable to structural damage from ground-shaking. If fire station doorways collapse, trucks and equipment can be damaged or trapped. Loss of even a few fire response vehicles could seriously undermine the communities' ability to respond to widespread fire, or many smaller localized fires.

Police cruisers are needed to mobilize law enforcement services, and to spread warnings and information. Damage to these vehicles could hinder important low-tech communications efforts.

Existing Mitigation Actions

None identified, though many of these issues may have been addressed in Emergency Operations Plans (EOPs) of individual response agencies (Police, Fire, KEMD, etc.)

Recommended Actions

Objective

To improve emergency response procedures in Sinclair and Dyes Inlets, resulting in safer, more resilient communities.

Mitigation Actions

Short-Term:

1.1 1 Develop agreements with local schools, community centers, churches, etc. to determine where people can be moved, in what numbers, and what resources will be available at each site. (KEMD)

1.1 2 Plan for a percentage of medical and HAZMAT responders being unavailable and, in planning for this contingency, have reservists online for rapid response. (KEMD, local Fire Depts., USN)

1.1 3 Maintain and update a roster of every doctor, nurse, EMT, and qualified HAZMAT responder available for emergency response. (KEMD)

1.1 4 Maintain a minimum of one (1) fire response vehicle outside of each fire station in the County at all times. Facilities that are deemed to be more vulnerable to structural damage from groundshaking should keep at least two (2) vehicles outdoors at all times. (local Fire Depts.)

1.1 5 Create redundancy in emergency response routes, and develop contingency plans in the event that a road, bridge, ferry, airstrip, railway, or other transportation artery were blocked or destroyed. (Local Fire & Police Depts, KEMD.)

1.1.6 Conduct frequent training programs for all first responders and medical personnel. (WEMD, KEMD, local Fire & Police Depts.)

1.1.7 Encourage, or require first responders to store emergency equipment (e.g. first aid supplies, food, water, blankets) in a safe location inside their homes and/or in their vehicles. (WEMD, KEMD, local Fire & Police Depts.)

1.1.8 Evaluate and, if warranted, implement an improved address system to allow easier access for emergency vehicles similar to one adopted by Bainbridge Island .

1.1.9 Evaluate and, if warranted, establish a list of boat owners and emergency personnel pickup points in Kitsap County similar to that implemented by Bainbridge Island Harbor Commission. (Coast Guard Auxillary; Power Squadrons; Port of Bremerton)

Long-term:

None identified

1.2 Inadequate Resources

Issue: Inadequate numbers of responders and resources

There may be inadequate numbers of response professionals and support facilities to handle expected needs during and following an earthquake-tsunami disaster

Findings

Shortage of emergency personnel and resources will hinder rapid and effective response, resulting in prolonged exposure of local populations and property to post-event hazards, increasing the loss of life and property.

During a regional-scale event, outside resources may be largely unavailable, and the community will be forced to rely on its own resources for recovery. Consequently, reliance on mutual aid agreements for access to outside resources and assistance can actually increase the level of risk associated with earthquakes and tsunami.

Programs such as Los Angeles' Community Emergency Response Team (CERT), and Seattle Disaster Aid & Response Teams (SDART)[33]. are helpful in augmenting

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[33] http://www.cityofseattle.net/projectimpact/pages/resources/SDART-over-rec.htm

professional responders through trained volunteers operating autonomously at the block or community level. SDART's overall purpose is to enable neighborhoods to be self-sufficient for a minimum of 72 hours following a major disaster. This will be accomplished by:

- Organizing block groups into six disaster response teams: communications, damage assessment, first aid, safety & security, light search & rescue, and sheltering & special needs.
- Utilizing the skills and knowledge the neighborhood currently possesses

CERT has been adopted by FEMA as a model for all-hazards community preparedness and response and is taught through the Emergency Management Institute.[34]

Existing Mitigation Actions

KEMD has a robust disaster preparedness educational system in place. For example, it conducts Kitsap Practices Responsible Emergency Preparedness (K-PREP) programs for neighborhoods, schools and businesses to assist with citizen preparedness efforts.

Individual response agencies' EOPs may address also some of these issues, however.

Recommended Actions

Objective

To ensure that there are adequate numbers of response professionals and support facilities to handle expected needs during and following an earthquake-tsunami disaster

Mitigation Actions

Short-term:

1.2.1 Develop mutual aid agreements with neighboring jurisdictions, as well as more distant cities, for transportation and deployment of response personnel – medical, hazmat. (KEMC)

1.2.2 Develop an Emergency Responders Plan to guide the allocation of resources, identify high-risk high-need areas, and assess all available local personnel and resources. (WEMD, KEMD, local Police and Fire Depts.)

1.2.3 Encourage community-based action by continuing to host community-based disaster seminars and distributing educational literature on how to cope with an emergency. (KEMD, utility companies)

1.2.4 Continue Kitsap Practices Responsible Emergency Preparedness (K-PREP) programs for neighborhoods, schools and businesses to assist with citizen preparedness efforts. (KEMD)

1.2.5 Encourage local communities to initiate community-based response teams like Los Angeles' Community Emergency Response Team (CERT), and Seattle Disaster Aid & Response Teams (SDART).

Long-term:

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[34] http://www.cert-la.com/

None identified

1.3 Emergency Communication Systems

Issue: Vulnerable emergency communications system and infrastructure

The existing emergency communications system lacks redundancy and robustness, which could hinder rapid and effective response efforts, resulting in increased risk to persons and property, and a decreased ability for local communities to recover.

Findings

Communications among agencies with preparedness, response and recovery responsibilities, and with the larger port and harbor community will be essential in administering quick and effective emergency assistance. The existing means of communication in a disaster may fail, and a lack of redundancy could result in first responders being sent into dangerous situations under inappropriate circumstances.

Damage to response centers may hinder the recovery of local communities, in that emergency services may operate at less-than 100% functionality.

Damage to or loss of communications capacity may occur during or after an earthquake-tsunami event. A number of problems exist in the current emergency communications system:

- The area currently lacks a mobile 911 capability, which could result in failed communications and increased risk exposure to responders and residents.
- Dead spots still exist in Kitsap County, and while the current 800mhz system is new, it is still inadequate. The 800mhz system exhibited some problems during the Nisqually earthquake in 2001, both in Kitsap and other counties in Puget Sound.
- Power outages can shut down phone service.
- The current 911 center is falling apart and in need of replacement. During a disaster, there will inevitably be an influx of calls to report fires, accidents, and medical emergencies. The ability to take these calls and effectively dispatch emergency personnel could be compromised if communications centers are damaged or inoperable.
- Methods of communicating with the public in a major disaster may be inadequate. Emergency managers may wish to issue certain directives and guidance to local residents. If television and phone lines are down, it may be difficult to get valuable information to the public.

Existing Mitigation Actions

The Navy is in the process of switching over to a land mobile system and is standardizing its hardware and software.

Recommended Actions

Objective

To diversify and create redundancy in the existing emergency communications system to ensure that response strategies can be implemented quickly, efficiently, with the

minimum amount of risk to persons and property.

Mitigation Actions

Short-term:

1.3.1 Provide satellite phones for first responders (police, fire, Coast Guard, etc.), to minimize problems associated with congested public lines and cellular disruptions. (Cities/County/USCG)

1.3.2 Invest in portable repeaters, and develop contingency plans for where and how to distribute them during a major event. This could involve some mutual aid agreements with neighboring cities/counties, including the City of Seattle. (KEMD)

1.3.3 Conduct inter-agency focus groups to discuss and develop ideas and plans for a newer, more robust communications system. This would help to familiarize responders with other agencies and their personnel, as well as facilitate better coordination in overall response efforts and communications. (WEMD/KEMD/cities' police and fire chiefs/County Sheriff)

1.3.4 Conduct ATC-21 visual assessments of all important communications sites and equipment, determining areas of concern, and prioritizing action. (KEMD/Cities' Public Works and Engineering Depts.)

1.3.5 Develop mutual aid agreements with neighboring cities to enhance mobile 911 capacity. (KEMD)

Long-term:

1.3.6 Establish permanent repeater sites throughout the County to eliminate all dead spots that threaten clear and reliable communications.(KEMD)

1.3.7 Construct a new, resilient 911 center in Bremerton with supplemental emergency operations center (EOC) capability, to serve as the nexus for county-wide communications during and after an event. (KEMD)

1.4 Threat to First Responders

Issue: Vulnerable First Responders

First responders will be placed in harm's way during a major seismic event; their numbers will be inadequate to respond to multiple secondary hazards including debris, fires, HAZMAT spills and dangerous structures; and well-meaning volunteer responders may add complexity to their jobs.

Findings

In the event of a major disaster, first responders (e.g. police, fire, emergency personnel, doctors, etc.) are placed in highly volatile situations. It is essential that as many responders as possible be available to fight fires, treat injuries, remove debris, respond to hazardous materials releases, and provide assistance to stranded populations. Lack of adequate numbers of response professionals would result in increased risks to life and property. If first responders are stranded or injured, there will be less qualified persons available to assist in recovery efforts.

It is likely that emergency response personnel and resources will be taxed beyond their

capabilities in a major earthquake-tsunami event. Threats exist that could result in the loss of additional responders during response efforts. Loss of these individuals and resources would contribute to further debilitating local emergency response capacity.

First responders (e.g. police and fire fighters) may be untrained in assessing the structural integrity of damaged buildings, which could result in situations where they enter buildings that are unsafe and vulnerable to subsequent damage following an earthquake.

The number of fire fighters available at any one time may be insufficient to respond to widespread localized fires. During a disaster, large numbers of local (and non-local) residents may attempt to volunteer to assist in the response effort. Lack of a mechanism to coordinate and dispatch volunteers can result in volunteers hindering response efforts, rather than helping. These individuals can be damaging to the overall response effort if they are not properly managed.

Existing Mitigation Actions

None identified. Individual response agencies' EOPs may address some of these issues, however.

Recommended Actions

Objective

To take actions that will minimize the risks to which responders and emergency managers are exposed, during and after a major event.

Mitigation Actions

Short-term:

1.4.1 Continue to enhance first responder training at all levels: responders, managers, and administration. (Local Fire and Police Depts., KEMD)

1.4.2 Continue to train on weapons of mass destruction, HAZMATS and Incident Command System training into overall training programs. (Local Fire and Police Depts., KEMD)

1.4.3 Continue to enhance redundancy in first responder communications. (Local Fire and Police Depts., KEMD)

1.4.4 Enhance volunteer dispatch system utilized for Search and Rescue and Ham Radio Operators by including Medical Reserve Corps and Citizen Corps volunteers. (Local Fire and Police Depts., KEMD)

1.5 Fire Prevention & Suppression

Issue: High fire risk after an earthquake-tsunami event

A major earthquake-tsunami event could result in widespread localized fires. These fires represent a threat to local populations, homes, and businesses.

Findings

Risks of fire following an earthquake-tsunami event are caused by several factors:

Ignition sources include electrical shorts, power outages over-stressing power lines that

sag into trees, residential fireplaces, or reactive mixtures of spilled chemicals. Fuels include combustible debris, HAZMAT spills, leaking or severed gas and petroleum pipelines, and dry vegetation. Periods of drought can enhance the danger of fires in the area. Combustible vegetation can accumulate at the base of steep slopes and act as fuel-loading areas. Structures at both the base and top of steep slopes are particularly vulnerable to fires and access may be difficult. Steep slopes can allow fires to spread higher rapidly, threatening residences at the top.

Tsunami inundation can spread flammable liquids and combustible debris, threatening low-lying residences, and other waterfront structures.

There may be inadequate numbers of response professionals, vehicles and water supply to deal with widespread localized fires. Local fire stations may be vulnerable to structural damage from ground-shaking.

Existing Mitigation Actions

None identified. Individual response agencies' EOPs may address some of these issues, however.

Recommended Actions

Objective

To develop redundancy in the existing fire response capacity to minimize the potential threat of fires to low-lying residences and other structures following an earthquake-tsunami event.

Mitigation Actions

Short-term:

1.5.1 Conduct training courses for local businesses and residents in fire safety and response. (Local Fire Depts.)

1.5.2 Encourage businesses and residents to have a redundant supply of fire extinguishers of the correct type. (KEMD, Local Fire Depts.)

1.5.3 Educate locals in appropriate landscaping techniques to minimize the accumulation of combustible vegetation and maximizing defensible space; and in when and how to safely shut off the natural gas supplies to their homes. (Cooperative Extension Service Master Gardener Program, local Fire Depts.)

1.5.4 Encourage automatic shut-off valves in schools, and for local natural gas pipelines. (Local municipal building depts.)

1.5.5 Identify and map high-risk areas (e.g. remote areas, steep slopes, fuel loading areas) in GIS. (Kitsap Dept. of Community Development)

2. Hazards & Vulnerability Assessment

Community Importance

In order for community stakeholders to take individual and collective actions to increase their resiliency to earthquake and tsunami hazards they need access to information about the likelihood and magnitude of future events and their probable impacts on the

local built, social and natural environments. At present there are gaps in knowledge concerning both the seismic hazards the community faces and it's vulnerability to them. Consequently, efforts to prepare for future events and to mitigate their impacts wherever possible proceed with only partial information.

Three areas of uncertainty in particular became apparent during the course of this study: seismicity of the Seattle Fault; tsunami inundation and currents; location of vulnerable structures and infrastructure; and hazardous materials location and security.

2.1. Seismic and Tsunami Hazards Mapping

Issue: Inadequate mapping and documentation of earthquake and tsunami hazards

Neither earthquake nor tsunami hazards in the Puget Sound region are sufficiently well documented at the local level to give port and harbor communities clear guidance on what scenarios to prepare for.

Findings

In the case of Sinclair Inlet, three earthquake scenarios factor into this calculus: Benioff, Cascadia Subduction Zone and local (Seattle Fault) crustal events. Of these, the first is best understood, in part because of the frequent recurrence of these deep intra-plate earthquakes (e.g. Nisqually, Feb. 28, 2001) and in part because of their having been monitored on the growing regional network of seismic monitoring instruments. In the case of the second, while the paleogeologic record of past Cascadia events is well-documented, much uncertainty surrounds their impacts in Puget Sound. The eastward limits of the "lock zone" between the upper and lower plates is insufficiently understood to assess the amount of energy released that would affect the Puget Sound region were the fault to rupture again. The Seattle Fault event is the least well understood in terms of its probability of recurrence and the westward limits of the fault zone. Only one ground-rupturing tsunamigenic event (c. 950 A.D.) has been identified to date. (Need to update this information if new evidence exists.)

Tsunami from earthquake sources in Puget Sound are extremely rare events though evidence of an occurrence probably coinciding with the last Seattle Fault event persists in marsh deposits on Whidbey Island and elsewhere. Tsunami generated by landslides are more common, but their effects are generally very localized. Submarine landslides have been recorded in Puget Sound, and they are considered possible co-seismic hazards in the case of shallow crustal earthquakes, e.g. delta fronts collapsing following a Seattle Fault event. Preliminary modeling of a tsunami generated by an event on the Seattle Fault , similar to that of 950 A.D. suggests "…inundation mainly occurs along the southern shore of Sinclair Inlet and the northern and southern shore of Dyes Inlet. The estimated inundation depths are up to 2 m at the shore 1 km east of Port Orchard, 4 m at the northern shore of Dyes Inlet…" (Koshimura and Mofjeld, 2001). Strong currents would be experienced along the Bremerton and Port Orchard waterfronts and at the narrow west end of the inlet. This model has not resulted in production of certified inundation maps, however.

Existing Mitigation Activities

Kitsap EMD's Mitigation Action Plan Category V, item #2, Earthquake Mitigation Strategy: "identify and study ground motion, landslide, and primary liquefaction community-wide. Include new data from most recent earthquake studies affecting Kitsap

County." This strategy is being implemented, in part, through item # *3, Geologic Mapping Mitigation Strategy* which recommended "that Kitsap County participate in the collaborative USGS-UW Geologic mapping effort. The US Geological Survey and the University of Washington, under the umbrella of the USGS Earthquake Program, have proposed a cooperative project for geologic hazard mapping over the Seattle Fault. This project would include a combination of remote sensing of landforms using airborne laser mapping, Light Detection and Ranging (LIDAR), Geologic mapping, Landslide Hazard mapping and expansion of the Strong Motion Sensor Network."

This work is largely complete. LIDAR has increased the level of topographic detail available and has permitted several "new" local faults to be identified and then investigated "on the ground" using trenching methods. Landslide and liquefaction zones have been mapped as part of this project in collaboration with Kitsap County Dept. of Community Development GIS section.

Recommended Actions

Objective

To have earthquake and tsunami hazards mapped at a scale and level of detail necessary to support site-specific planning for hazard reduction in the port and harbor community.

Mitigation Actions

Short –term:

2.1.1 Undertake peer review of draft hazard maps produced for this demonstration project (WGER)

2.1.2 Develop more accurate digital elevation models of the shoreline and adjacent uplands subject to tsunami inundation (USGS, WGER)

2.1.3 Undertake multi-beam bathymetric survey – especially in nearshore– to develop a 2-meter resolution bathymetric model (NOAA-PMEL)

2.1.4 Continue tsunami inundation modeling using more accurate bathymetric and shoreline digital elevation models and produce certified tsunami inundation and currents maps for Sinclair and Dyes Inlets shorelines (NOAA-PMEL)

2.1.5 Assess hazards associated with steep submarine slopes, especially the Blackjack Creek, Port Orchard, delta front (USGS, NOAA-PMEL)

Long-term:

2.1.6 Continue to refine probabilistic peak ground acceleration maps (USGS)

2.1.7 Continue to deploy instrumentation (strong motion seismographs) to produce detailed local shake maps following the next major seismic event (USGS, UW)

2.1.8 Continue to update geologic hazard mapping and analyses in Kitsap County (WGER, Kitsap DCD)

2.1.9 Continue to update tsunami hazard mapping and analyses, as needed, as geologic hazard mapping and tsunami modeling and mapping technology are improved (NOAA-PMEL)

2.2 At-risk Structures and Infrastructure

Issue: Inadequate mapping and documentation of at-risk structures and infrastructure

There is no single, accessible mapped source of information about vulnerable structures and infrastructure within the study area

Findings

Shoreside buildings and over-water facilities in the study area have not been digitally mapped, or mapped in a consistent fashion, to permit inclusion in a GIS[35]. Furthermore, neither the types of structures nor their condition is known in a systematic fashion. Consequently it is not possible to produce a robust GIS-based vulnerability assessment for Sinclair Inlet Port and Harbor Community.

Existing Mitigation Activities

Several strategies in *Kitsap EMD's Mitigation Action Plan* address the need for a more robust vulnerability assessment for structures and community infrastructure. *Category V, Item 1, Earthquake Mitigation Strategy:* is to "Design and implement an ongoing community-wide public seismic risk assessment program."

KEMD has a "training the trainers" program in Rapid Visual Appraisal based on FEMA's ATC-21 report[36].

A parcel layer exists for Kitsap County and the incorporated cities in the study area. This project produced hazards layers for liquefaction and geologic hazards (landslides), and adopted existing layers for essential facilities, hazardous materials storage and congested roads.

Recommended Actions

Objective

To map and document at the parcel scale the type and condition of at-risk structures and infrastructure in the study area.

Mitigation Actions

Short–term:

2.2.1 Create a building footprint GIS layer for the study area with the initial priority being URM structures and essential facilities (ferry terminals, jails, hospitals, schools, etc.) in or near high hazard shoreline areas. Link to Assessors records and other databases that contain valuation, condition, number of stories and structural type information that would be useful for vulnerability assessment. (Kitsap DCD, with Bremerton Pub. Works

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[35] This demonstration study lacked sufficient resources to undertake the effort to produce such GIS layers from the various CAD files available in city engineering departments and project consultants' offices.

[36] Applied Technology Council (ATC). (1988). *Rapid visual screening of buildings for potential seismic hazards: a handbook.* ATC-21 Report, Federal Emergency Management Agency, Earthquake Hazard Reductions Series 41, Washington, DC.

Dept. and Port Orchard Eng. Dept.)

2.2.2 Continue and expand training for individual building owners to undertake Rapid Visual Appraisals of at-risk structures using FEMAs' ATC-21 report (KCEMD)

Long–term:

2.2.3 Complete building footprint GIS layer for all industrial, commercial, and multi-unit housing zones. (Kitsap DCD, with Bremerton Pub. Works Dept. and Port Orchard Engineering Dept.)

2.3 Hazmat Locations and Security

Issue: Incomplete mapping of hazmats

Not all sources of stored hazmats have been identified and mapped.

Findings

As with underground and above ground storage tanks (see 8.3.1 below), there are numerous unidentified sources of hazardous materials in the Sinclair community, many but not all of which are mapped.

Existing Mitigation Activities

None identified

Recommended Actions

Objective

To enhance awareness of the location and composition of hazardous materials and preparedness for addressing spills during and after seismic events.

Mitigation Actions

Short term:

2.3.1 In addition to Tier II reports, enact a city/county ordinance to identify all hazardous material (Kitsap Emergency Management Council)

2.3.2 Expand this study's mapping and archiving of HAZMAT information; include the potential for dangerous mixtures/combinations, based on adjacent/proximate storage facilities (Kitsap Dept. of Community Development)

2.3.3 Update fire code(s) for the proper and secure storage of all hazardous materials (Cities and County)

3. Earthquake & Tsunami Awareness and Preparedness

Community Importance

"There is no substitute for mitigation and preparedness. Not only is impact likely to be reduced, but the psychological consequences associated with injury and damage is also lessened… People do best when they have the knowledge, resources and opportunities

to take mitigation and response actions on their own behalf."[37]

Workshop participants placed the highest priority on mitigation options that would save lives.

3.1 Waterfront Residents

Issue: Residents' hazards awareness and preparedness

Waterfront residents are highly vulnerable to earthquake-tsunami hazards, but are poorly informed about how to prepare for, and what to do during and after these events.

Findings

A large proportion of Sinclair and Dyes Inlets' shorelines are zoned residential and occupied by waterfront homes. Waterfront residents are highly vulnerable to earthquake-tsunami hazards, including, groundshaking, liquefaction, landslides, and inundation. In the event of a major tsunami, populations in low-lying areas may become isolated due to washed out roads, and damage to transportation infrastructure. Waterborne debris and projectiles put live-aboards and low-lying homes at risk to structural damage.

Elderly residents, children, and doctors and other health care professionals living in low-lying areas represent particularly high levels of community risk. Local residents may not have emergency materials in place in their homes. Lack of basic first aid kits and skills could result in the inability of residents to treat minor injuries, placing a greater burden on local medical response personnel and resources, which would likely already be stressed.

People living at or near the water's edge need to know what to do before, during and after a major event. Given the high demands placed on emergency resources, it is also important that these shoreline residents be capable of being self-sufficient for the initial 72 hours of a disaster.

One of the primary concerns of local residents will be locating their family and friends to ensure their safety. Parents will be looking for their children, and vice versa. They will need to know when and how to go about finding these individuals.

There is a need for a robust communications system that would supplement the existing system and be reliable in the event that traditional means of communication are inoperable. Waterfront residents may be isolated from emergency personnel and services, and they will need a reliable means of communicating their needs to responders.

Existing Mitigation Activities

Kitsap County has a variety of public education programs for earthquake awareness and response:

Category X - 2. Multi-hazard Public Education Mitigation Strategy: Examine and support ongoing programs for a multi-jurisdictional approach for public education, public awareness and the promotion of public participation.

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[37] The H. John Heinz III Center for Science, Economics and the Environment, "Human Links to Coastal Disasters." Washington D.C., 2002. p.77

However, none deals specifically with tsunami threats in Sinclair and Dyes Inlets.

Cascade Natural Gas has flyers and website materials for consumers on appropriate earthquake response[38].

Recommended Actions

Objective

Increase the resiliency of local waterfront residents to earthquake-tsunami hazards, and ensure that these populations can be self-sufficient for the initial 72 hours of a major earthquake-tsunami event.

Mitigation Actions

Short-term:

3.1.1 Continue to promote the use of NOAA weather radios for Emergency Alert System (EAS) messages.

3.1.2 Utilize the existing EAS to break into television and radio broadcasts when life threatening situations exist. (KEMD)

3.1.3 Communicate with Coast Guard about assistance with post-event water transportation and access (KEMD)

3.1.4 Enlist local media to assist in the communities' efforts to educate the public re: what to do and where to go in the event of a major earthquake or tsunami, i.e. *drop, cover and hold until the ground-shaking stops, then head for higher ground and stay there until emergency management officials declare it is safe to return.* (KEMD)

3.1.5 Through K-PREP continue to enhance the public's awareness of earthquakes and incorporate the latest information on tsunami hazards into the curriculum.

3.1.6 Design and install tsunami hazard mitigation signs to direct people to evacuation routes and centers in the event of a major earthquake (KEMD)

3.1.7 Continue to recommend that schools have food, water, and emergency supplies in case of earthquake or tsunami. Continue to educate the teachers and administrators through the K-PREP school program on what to do before, during, and after disasters; incorporate earthquake and tsunami education into school curricula (KEMD) (Move to "Existing Mitigation Actions?")

3.2 Tourists and Visitors

Issue: Visitors and tourists hazards awareness and preparedness.

Tourists and visitors are especially vulnerable to earthquake and tsunamis because of their lack of awareness of local area hazards, and unfamiliarity with local geography, evacuation routes, transportation options, and emergency services and shelters.

Findings

The waters and shorelines of Sinclair and Dyes Inlets attract tourists and visitors who

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[38] http://www.cngc.com/_docs/EarthquakeNews_revised2.pdf

come to boat, kayak, fish and take in local urban attractions. The Bremerton Boardwalk and Port Orchard waterfront are prime local tourist destinations; local marinas and yacht clubs host visiting vessels; and, there are many shoreline parks throughout the area that attract visitors and tourists during the summer months. For example, Lion's Field is a very popular recreational area located adjacent to the water on low-lying fill.

Anyone who is unfamiliar with the local geography, high-risk areas, emergency services and shelters, transportation, etc., needs to know what to do during and after a major earthquake and tsunami. There are currently no signs or interpretive displays to alert these visitors to the seismic hazards they are exposed to, nor what to do, or where to go in event of a major earthquake.

Oregon Department of Geology and Mineral Industries (DOGAMI) has designed and installed at coastal viewpoints panels interpreting the Cascadia Subduction Zone, plate tectonics and the resulting seismic hazards affecting the Oregon Coast. They are usually co-located with tsunami warning and evacuation signs.

Tourists will want to contact family and friends outside of the immediate area to ensure them that they are safe. Many tourists may be without ground transportation to get them to safety or their local accommodations. They will also be attempting to make plans to get out of the area ASAP and return to their homes.

Existing Mitigation Activities

Kitsap County has established evacuation plans that incorporate primary and alternative routes (e.g., contingency plan includes close-down procedures for Warren Avenue and Mannette Bridges).

Recommended Actions

Objective

To enhance the safety of tourists and visitors during and after earthquake-tsunami events.

Mitigation Actions

Short-Term:

3.2.1 Enhance existing evacuation plans to include tsunami. Utilize best available science to establish likely tsunami inundation areas and add a conservative safety factor, e.g. 200% of modeled inundation depths, to account for current tsunami modeling limitations. (KEMD/KDCD)

3.2.2 Develop or adopt interpretive signs that illustrate earthquake and tsunami hazards and the appropriate responses during and following an event; install signage in high-use visitor areas such as the Bremerton and Port Orchard waterfronts, as well as in low-lying business centers, e.g. downtown Port Orchard, and Gorst. (Consider use of tsunami hazard zone signs from WSDOT and interpretive panels similar to "Oregon Geology" panels found along the Oregon Coast.) (KEMD/Bremerton & Port Orchard Public Works and Engineering Depts./Port of Bremerton)

3.2.3 Develop informational brochures to be placed at port-related businesses (e.g. ferry terminals, marinas), and hotels/motels, to educate and inform visitors and tourists. (KEMD/local Chambers of Commerce)

3.2.4 Plan to utilize emergency radio and television break-ins (this strategy was

successful in Japan during major earthquake and flooding disasters). (KEMD)

3.2.5 Provide an efficient means of post-disaster communications for visiting populations. (KEMD/Telecommunications Utilities)

3.2.6 Provide a reliable means of emergency transportation for visiting populations. (KEMD/Kitsap Transit/local taxi companies)

3.2.7 Enlist local media coverage to assist in the communities' efforts to educate the public re: what to do and where to go in the event of a major earthquake or tsunami. (KEMD)

3.3 Waterfront Businesses Employees and Customers

Issue: Employee hazards awareness and preparedness

Employees in shipyards, boatyards and marinas work at or below water level in facilities that are vulnerable to ground-shaking and tsunami inundation and currents. These employees have insufficient awareness of the extreme hazards affecting these low-lying areas during and following major earthquake-tsunami event. They are not well prepared to save their own lives or direct others to safety.

Findings

Bremerton and indeed Kitsap County have marine dominated economies comprising both government enterprises and private businesses. The influence of these entities ranges from local (e.g. a yacht club) to global (USN), as do their economic and social impacts. Closures of major marine employment centers even for a short time due to earthquake damage, tsunami inundation or debris-choked waterways could seriously affect the local economy as well as the community's capacity to recover from a seismic disaster.

Marine enterprises are water-dependent activities that require a location adjacent to navigable waterways in order to service, repair, store or operate vessels or floating equipment. Members of this group include Port of Bremerton, private marinas and yacht clubs, private ferry operations, and boatyards. These enterprises are located in over-water structures and on adjacent shorelines in low-lying filled areas. They are vulnerable to both land- and water-based hazards including amplified ground-shaking, soil liquefaction and lateral spreading; and, tsunami waves, currents and run-up hazards. These businesses can themselves generate substantial quantities of floating debris that can inflict death and injury, damage adjacent structures, and clog waterways, city streets and highways. Hazardous materials stored on-site present fire and pollution risks.

Mitigation workshop participants concluded that life safety is the top issue for this set of waterway users. However, present levels of business and industry personnel training and resources are inadequate to deal with an earthquake-tsunami event. Even at the PSNS, where emergency training plans are in place, earthquake and (especially) tsunami hazard and response strategy awareness among most workers is probably low.

Local businesses lack emergency response plans, and employers and employees have not been educated in how to respond in a disaster.

Workers, customers, and marina tenants need to understand how the building or vessel they are in at the time the event occurs is likely to respond to ground-shaking and liquefaction, tsunami currents and extreme high or low water levels, and make evacuation plans consistent with that likely performance. Vessels in dry-docks could

become unstable;and ramps may separate from docks in marinas, especially at low water. Live-aboards present special problems for evacuation from marinas and moorages, including personnel living aboard US Navy subs and USN Reserve vessels. Businesses may be forced to be self-sufficient for the initial 72 hours of a disaster.

Inadequate PA warning systems in place at the Bremerton Transportation Center and marinas in Bremerton and Port Orchard impose heavy reliance on ferry and other waterfront employers (when they have specific assignments) for instructions to passengers and drivers on how they should respond to earthquake and tsunami hazards.

Existing Mitigation Activities

Kitsap County has a variety of education programs for earthquake awareness and response, but none dealing with tsunami threats.

Recommended Actions

Objective

To reduce loss of life and injury to waterfront business employees and customers during and following an earthquake and/or tsunami

Mitigation Actions

Short-term:

3.3.1 Target the K-PREP Business program to ports and marine businesses to encourage the development of emergency response plans that include tsunami hazards and evacuation plans for each facility and workplace on the waterfront; educate and train employees to follow them.. (KEMD/WSF/USN/Port of Bremerton/private marine enterprises)

3.3.2 Provide signs that illustrate earthquake and tsunami hazards and appropriate responses in case of an event (consider tsunami hazard zone signs from WDOT) (KEMD)

3.3.4 Develop and install standardized warning systems for waterfront workplaces and public-use areas, facilities, etc. (e.g. recorded, one-button messages) and undertake education & publicity on their activation and meaning. (KEMD/Port of Bremerton/USN/WSF/private marine enterprises)

Issue: Augmenting response and recovery operations

Marine enterprises generally do not have the emergency response training and equipment that will be needed to effectively deal with the early stages of a seismic disaster before professional first responders can reach isolated sites. Nor do they have in place plans and procedures for using their waterways skills and waterborne equipment to aid in disaster recovery.

Findings

Marine enterprises, as a group and individually could and should be active in response and recovery operations following an earthquake and/or tsunami. It is likely that professional responders will be unable to access key areas and facilities after an event due to blocked roads, bridge failures, and flooding. Therefore, on-site expertise in

response and recovery will be needed for waterfront businesses to respond to their own and their customers needs during the first hours after an event.

Marine enterprises have special waterways skills and own or operate major floating and land-based equipment – barges, tugs, cranes, etc. – that would be invaluable during response and recovery operations. However, no plans or procedures have been developed to fully utilize these resources; no heavy marine equipment inventory exists; and, no organization has taken on the responsibility to coordinate marine firms' response to a disaster.

Existing Mitigation Activities

None identified.

Recommended Actions

Objective

Enhance the capacity of marine enterprises to augment professional first responders during the early phases of a disaster, to recover quickly and, collectively, to provide assistance in waterway clearance and debris removal

Mitigation Actions

Short-term:

Encourage local business organizations and unions to educate and train workers in emergency response strategies, including basic First Aid and CPR.

3.3.5 Undertake personnel training programs that will enable marine enterprises to:

- Protect life and property under their direct control
- Assist their customers and port district constituents caught on site
- Secure assets on site
- Assess capacity to function
- Clear debris
- Get back on-line ASAP for recovery efforts (KEMD/Port of Bremerton/USN/WSF/private marine enterprises)

3.3.6 Identify and inventory work boats and heavy equipment likely to survive an earthquake-tsunami (Port of Bremerton/USN/WSF/private marine enterprises)

3.3.7 Develop plans and procedures to integrate marine enterprises' capacities with the professional emergency management community that include agreements to:

- Provide work-boats (e.g. USN and USN contractors' tugboats) and heavy floating equipment for rescue and debris removal work
- Allocate AOE (supply ships) to local areas for emergency supplies, food, medicine, etc.)

(KEMD/Port of Bremerton/USN/WSF/private marine enterprises)

3.4 Vessel passengers and crews

Issue: On-water safety and preparedness

Vessels caught underway, or loading/unloading passengers at docks and marinas are particularly vulnerable to tsunami waves and currents. Many vessels will be disabled, capsized or sunk, placing passengers and crews at risk of drowning or being crushed by debris.

Findings

Access to Bremerton and Port Orchard for many commuters and visitors is by ferry and at any moment two or more of these vessels may be at dockside or underway in Bremerton, Port Orchard or Rich Passage. Sinclair and Dyes Inlets are popular waters for recreational boaters and fishermen aboard sail and motorized vessels, canoes, or kayaks. Depending on time of day and season, large numbers of people may be aboard recreational and commercial vessels underway when a local earthquake generates a tsunami.

Not only will it be difficult to warn these individuals of danger, they will have little or no time to react: if they do not feel ground-shaking, their first indication of danger will be the onset of tsunami waves and currents. Boats close to shore, or in the immediate vicinity of a terminal or marina will be most vulnerable due to debris in the water, collision with fixed or floating structures and vessels, and the risk of fire and hazmat spills. Smaller vessels may capsize, putting passengers and crew at risk of drowning, or severe injury or death from being crushed by large floating debris. Emergency responders may have difficulty accessing individuals stranded in/on the water for some time–perhaps hours–following the event.

Washington State Ferries have tsunami-specific emergency operation plans that call for cessation of loading during an earthquake and immediately backing out to deep water. PA warning systems in place at Ferry Terminal and marinas in Bremerton and Port Orchard are, for the most part, inadequate for guiding people to safety, and may be inoperable, or inaccessible. Passengers about to board ferries need clear, audible directions from trained personnel to guide them to safety.

Recommended Actions

Objective

To reduce loss of life and vessels during and following a tsunami event

Mitigation Actions

Short-term:

3.4.1 Engage the local USCG Auxilliary, Power Squadron's and yacht clubs in developing tsunami hazards awareness and response training (USCG/KEMD/NOAA-PMEL)

3.4.2 Implement a redundant PA system at the ferry terminal. Consider use of bullhorns as back-up. (WSF/Bremerton Public Works)

4. Tsunami Warning Systems and Evacuation

Community Importance

A "Tsunami-Ready Community[39]" would have systems in place to warn residents of an approaching tsunami, and have evacuation routes marked leading to safe areas on high ground outside the tsunami hazard zone. In event of a local tsunami, immediate evacuation will be the only option available to populations living, working or recreating in low-lying shoreline areas around Sinclair and Dyes Inlets. The Alaska Tsunami Warning Center issues warnings of teletsunamis approaching the coast from across the Pacific, giving hours of notice to coastal residents, but there are no systems currently in place to give immediate warnings of a local tsunami inside Puget Sound. The only warning will be ground-shaking occurring minutes before the first tsunami wave reaches the shoreline. With little warning time, every second gained is a life-saving advantage.

4.1 Tsunamis Warning Systems

Issue: Rapid on-set of tsunami waves and currents following a local earthquake

Warning systems developed for tele-tsunami and deployed in the NE Pacific may be adaptable for local circumstances in event of a Seattle Fault earthquake-induced tsunami.

Findings

Sinclair Inlet's relative isolation from the Pacific Ocean makes it vulnerable to local tsunami only. Tsunami warning systems such as DART (Deep-ocean Assessment and Reporting of Tsunamis) being deployed in the Northeast Pacific and off Chile give several hours notice of tsunamis underway by detecting their passage and "signature" through transducers on the ocean floor. Up-linked via buoys to satellites, this information is delivered to NOAA's Alaska/West Coast Tsunami Warning Center and passed on to emergency managers in affected states. In this fashion, warnings will no longer be triggered by the occurrence of large Pacific Rim earthquakes alone; an actual teletsunami will be detected at sea before making landfall.

With sufficient automation, such systems deployed in inland waters might be configured to provide a few minutes warning, perhaps through NOAA Weather Radio, to employees, customers and visitors at waterfront workplaces and public facilities, enabling them to move quickly to higher ground.

A tsunami warning system in Sinclair Inlet would provide only a little lead time–a few minutes at most–in which to respond. But even that short a time could save the lives among those trained to respond quickly and appropriately to the warning.

Existing Mitigation Activities

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[39] The TsunamiReady program is voluntary preparedness program that prepares communities to respond to tsunamis. The communities must follow strict requirements for warning reception and dissemination, public outreach and education, awareness, administrative planning and communication. Ocean Shores in Grays Harbor County was Washington's first "TsunamiReady" community, designated in June, 2001. Their completed application form can be viewed at: www.pmel.noaa.gov/its2001/Separate_Papers/Tsunami_Ready_Form.pdf

Kitsap County has a variety of education programs for earthquake awareness and response, but none dealing with tsunami threats.

Recommended Actions

Objective

To investigate the feasibility of local tsunami warning systems

Mitigation Actions

Short-term:

4.1.1 Assess West Coast and Alaska tsunami warning system results for their applicability to Puget Sound tsunami (NOAA-PMEL)

Long-term:

4.1.2 If feasible, deploy modified DART system buoys or shore-linked transducers in Puget Sound (NOAA-PMEL)

4.1.3 Develop standardized warning system for tsunami (e.g. sirens and NOAA weather radio) and supporting education program. (NOAA-PMEL/NOAA-NWS)

4.2 Tsunami Hazard Zones and Evacuation Routes

Issue: Uncertainty about areas susceptible to tsunami inundation

The absence of mapped tsunami inundation lines inside Puget Sound makes it difficult for local officials to properly respond to the safety needs of locals and tourists caught in areas exposed to tsunami hazards

Findings

Having mapped tsunami inundation lines permits emergency management officials to address fundamental questions about how to save lives from these violent events: How high above normal water levels is safety to be found? Is directing visitors to a nearby area only a few feet above high tide a better evacuation strategy than sending them to a more distant site at higher elevation?

The “best available science” to guide local officials’ decisions was presented by NOAA-PMEL Tsunami Inundation Modeling Effort (TIME) scientists to attendees at the Vulnerability Assessment workshop in October 2001. The Koshimura-Mofjeld tsunami modeling study for a Seattle Fault earthquake, while only a preliminary step in more refined future tsunami modeling in Puget Sound, provided some direction.

Scientists testified that as tsunami models are refined using finer scale topographic and bathymetric digital elevation models and land cover information, surprises can arise: modeled inundation depths and local run-up distances can change significantly from those derived from coarser models. For these reasons modeling alone is insufficient to establish inundation lines on maps; paleo-geological evidence–e.g. tsunami sand sheets–is necessary to document where tsunami have occurred in the past. While some tantalizing sand features were demonstrated in the intertidal wetlands at Gorst, peer-reviewed research has not been done to definitively declare a tsunami caused them.

Existing Mitigation Activities

None identified. Kitsap County's Hazard Vulnerability Analysis identified a theoretical risk of tsunami, but lacked the more conclusive evidence of occurrences in the past that are now available.

Recommended Actions

Objective

Enhance existing evacuation plans to include tsunami

Mitigation Actions

Short-Term:

4.2.1. Utilize best available science to define a conservative danger zone to be evacuated immediately following a large earthquake, e.g. 200% of modeled inundation depths and run-up distances, to account for current tsunami modeling limitations. (NOAA-PMEL/KEMD/KDCD)

4.2.2 Designate evacuation routes that lead to areas of increasing elevation, avoiding "islands" of terrain less than, say 300% of modeled inundation.

5. Land, Water & Air Transportation Systems

Community Importance

Roadways, waterways, railroad and airports will likely be damaged or blocked after a Seattle Fault or Cascadia Subduction Zone earthquake. Damage to these important but vulnerable lifelines and critical transportation routes would hinder response and recovery efforts; restoring them is a high community priority.

5.1 Highways, Bridges and Railroads

Issue :The loss or long-term closure of highways, roads, railways and bridges

Loss or long-term closure of surface transportation systems would severely impact all response and recovery initiatives. Access to hospitals would be limited, as would access to fires and HAZMAT spills by emergency personnel after an earthquake or tsunami. Loss of BNSF RR links would compromise Naval Shipyard operations.

Findings

Roads, bridges and railroads are vital lifelines in the Sinclair Inlet port and harbor community.

Roads: SR16 connects Bremerton with Tacoma via the Narrows Bridge to the north. SR3 is the major east-west link to Shelton and Olympia, and north via the Hood Canal floating bridge to the communities of the upper Olympic Peninsula.

The SR16/3 interchange in Gorst is a significant regional transportation node. Temporary loss of this facility would severely influence response and recovery efforts in the Sinclair Inlet community. There is a high risk of road closures due to landslides at several locations on SR 166 between Gorst and Port Orchard.

Road standards exist for new roads, but all existing roads need to be improved.

Bridges: Crossing Port Washington Narrows the Mannette and Warren Avenue Bridges link Bremerton with East Bremerton. These bridges carry waterlines and other utilities as well as traffic on SR 303.

The Mannette Bridge was built in the 1940s and would not survive a major earthquake. It is due to be replaced within the next few years. The Warren Ave. Bridge is of more recent vintage (year built?), but would be closed for structural inspection following a quake, resulting in temporary loss of service.

Railroads: The Puget Sound & Pacific Railroad is used primarily by the Navy and has similar vulnerabilities to SR 3 and 16, which it parallels near Gorst. Recent investigations of the Tacoma Fault Zone have raised concern about the vulnerability of the track where it crosses this faulted zone in the vicinity of Allyn.

Existing Mitigation Activities

Bridges: New building codes are being designed to withstand M8 events. Bridge Retrofit Program is underway: Phase I: Involves superstructure tie-down and is complete for all bridges in the area. Phase II: Involves structural improvements to all columns; this has begun and will take a few more decades to complete. Phase III: Involves improvements to bridge substructure; a plan has been developed but it will many decades before Phase III is started. Mannette Bridge is not in current 5-yr WDOT plan.

Kitsap County has established evacuation plans that incorporate primary and alternative routes (e.g., contingency plan includes close-down procedures for Warner Avenue and Mannette Bridges)

Roads: Potential problems have been identified, but low funding slows the implementation of any improvements. Right now, WSDOT can only respond to immediate problems. (Referred to as "putting out fires" by workshop participants.)

Recommended Actions

Objective

Increase the resiliency and redundancy of key highways and bridges linking Bremerton and Port Orchard to the rest of the Puget Sound region.

Mitigation Actions

Short-term

5.1.1 Hire a County Engineer to conduct seismic assessments of all lifelines that are considered critical to these communities (e.g. Warren Avenue Bridge, Manette Avenue Bridge, Highway 16/3 interchange, ferry terminal, etc.), and make recommendations for replacements, reconstruction, or retrofits. (Kitsap County)

5.1.2 Undertake geotechnical analyses to pinpoint potential problems and recommend improvements. (WSDOT/Kitsap County, Bremerton, Port Orchard Public Works/Engineering)

5.1.3 Use the port-to-port model (King/Pierce Counties) to map best alternative land routes between key locations in Kitsap County (KMED)

Long-term:

5.1.4 Replace Mannette Bridge (WSDOT)

5.1.5 Introduce newer, more advanced road technologies, e.g. fiber mesh, to improve resilience (WSDOT)

5.1.6 Study existing zoning and its long-term impacts on transportation and critical access needs for hazard response and recovery (may imply down-zoning some areas to reduce future density) (Kitsap County DCD)

5.1.7 Include hazards and critical access issues into criteria for funding transportation improvements and bridge replacement (WSDOT)

5.1.8 As modeling efforts refine the tsunami inundation risks in Sinclair Inlet, plan and implement a system of dikes to protect critical transportation lifelines throughout the area. (WSDOT/Kitsap County)

5.2 Ferry Services

Issue: Interruption/loss of ferry service

Interruption or loss of ferry service would sever a critical community lifeline and hamper recovery efforts following a tsunami.

Findings

Washington State Ferries is a critical community lifeline connecting Bremerton to Seattle and the metropolitan core of the Puget Sound region using a fleet of auto and high-speed passenger-only vessels. Working families increasingly seek affordable housing in South Kitsap County and commute by ferry to jobs in Seattle, while Seattle-based PSNS workers commute in the reverse direction. A privately run passenger-only ferry links Port Orchard with the Washington State Ferry terminal in Bremerton, obviating a long drive around Sinclair Inlet.

Following a seismic disaster the ferry system will play a critical role in recovery operations, re-supplying the community, transporting recovery workers, vehicles and equipment from outside the area, and reuniting families separated at the time of the disaster

Tsunami is the most dangerous seismic hazard affecting the functioning of the ferry service and the safety of its passengers and employees. Ferries are most vulnerable to tsunami waves and currents during arrival or when they are docked at the downtown Bremerton ferry terminal or the Port Orchard city dock, or when underway in a narrow channel such as Rich Passage.

Existing Mitigation Activities

Washington State Ferries has an emergency operational plan that requires the cessation of loading when ground-shaking begins and backing out to deep water–at least half a mile from shore–as soon as possible. Passengers would be unloaded as soon as practicable. The boats would then possibly be put into service as emergency marine transport, as a floating emergency control center for the ferry service or as foot transport to get stranded commuters home to their families.
<www.thesunlink.com/news/2000/february/0207a1b.html>

Recommended Actions

Objective

Restore, first, emergency local ferry services, then regional service as quickly as possible following an earthquake and/or tsunami to aid in response and recovery efforts.

Mitigation Actions

Short-term:
5.2.1 Review and upgrade as necessary existing WSF and private ferry system's emergency operating procedures to address known tsunami hazards (WSF)

5.2.2 Plan for alternate regional ferry routes, e.g. Agate Pass. (WSF)

5.2.3 Use the "Port-to-Port" model (undertaken by King/Pierce Counties) to map best alternative water routes between key locations in Kitsap County. (KMED)

5.2.4 Plan for use of small emergency boats for use as ferries, or to "lighter" goods and people to/from larger ferries after an event. (KMED, Port of Bremerton, Horluck Transportation, USCG, Power Squadrons, Yacht Clubs, USN)

5.2.5 Undertake studies to assess the feasibility of using smaller docks for ferries in the event of a disaster. (KMED, WSF, Horluck Transportation, Port of Bremerton, USN)
Long-term:
5.2.6 Delineate redundant local ferry routes and harden alternative landings in Sinclair Inlet (KMED, WSF, Horluck Transportation, Port of Bremerton, USN)

5.3 Navigation Infrastructure

Issue: Disruptions to Navigation

Blocked navigation channels, lost or displaced navigation aids and alteration of bathymetry following an earthquake and tsunami would disrupt important transportation lifelines and severely hamper response and recovery efforts.

Findings

Local waterways serve important national, regional and local functions including national defense, transportation services and recreation and tourism. Military vessels of varying size and draft depend on access to the Puget Sound Naval Shipyard from the Pacific Theater of naval operations; Washington State and private ferries serve as a marine highway connecting the Kitsap Peninsula to Seattle and central metropolitan Puget Sound; and, numerous boating families–many from the eastern side of Puget Sound – moor their vessels in Sinclair Inlet's marinas and yacht clubs, sail local waters, and help support local economies.

Navigation infrastructure is vulnerable to a variety of co-seismic and secondary hazards. Near the shoreline, lateral spreading of liquefiable soils and the movement of sediment by tsunami currents could change local bathymetry and block access to docks and piers. In narrow Rich Passage uplift along the Seattle Fault zone is possible during a ground-rupturing earthquake and the resulting tsunami currents could be fast and turbulent. Vessels traveling through this busy channel could encounter uncharted hazards and collision risks.

One of the two bridges crossing Port Washington Narrows is particularly vulnerable to severe ground shaking and could fail, blocking navigation to and from Dyes Inlet. Finally, for a considerable period of time after a tsunami–perhaps months–the waterways would

be clogged with floating debris and sunken vessels.

Existing Mitigation Activities

None identified.

Recommended Actions

Objective

To quickly restore navigational access to communities and defense facilities on Sinclair Inlet following an earthquake and tsunami

Mitigation Actions

Short-term:

5.3.1 Evaluate and assess potential bathymetric changes in channels linking Sinclair Inlet to Puget Sound (especially Rich Passage) and plan alternate ferry routes, e.g. Agate Pass. (NOAA-PMEL, WSF, KEMD).

5.3.2 Plan for immediate re-surveying of critical channels following a ground-rupturing earthquake. (NOAA-NOS, USN)

5.3.3 Through integrated emergency planning, organize port and waterway user groups to be active in debris removal operations following a tsunami. (Members of this group include Port of Bremerton, private marinas and yacht clubs, power squadrons, Coast Guard Auxiliary, ferry operators, the US Navy and its civilian contractors.) (KMED, Port of Bremerton)

5.3.4 Plan for post-event retrieval and replacement of displaced aids to navigation – buoys, lights, channel markers, etc. (USCG, WSF)

5.4 Bremerton National Airport (PWT)

Issue: Partial or complete closure of Bremerton's airport would hamper its capacity to support response and recovery operations following an earthquake.

Findings

Bremerton National Airport is a general aviation facility with a single, instrument landing system-equipped 6,200 ft. runway. While it has no scheduled airline operation, the airport is capable of handling the kinds of cargo and med-evac operations that would be necessary to support response and recovery in the wake of a major disaster.

Even though the airport has withstood the last three major intraplate earthquakes, a Cascadia or Seattle Fault-rupturing event would subject its soils, hard surfaces and structures to far greater stresses than encountered in recent history.

The airport may have been built, in part, on wetland deposits, making it vulnerable to soil liquefaction and enhanced groundshaking. Damage to its single runway, taxiway, or aprons would result, at least, in temporary closure until engineering inspections had been carried out, and possible imposition of aircraft weight restrictions, until repairs could be completed. In the worst case the airport could be closed for a longer period.

Existing Mitigation Activities

None identified.

Recommended Actions

Objective

To increase the resiliency of Bremerton National Airport to earthquake hazards.

Mitigation Actions

Short term:

5.4.1 Review geotechnical reports, corings and other data on soils and geologic conditions underlying the airport, and, if necessary, undertake additional geo-technical investigations to remove gaps in information. (Port of Bremerton)

Long-term:

5.4.2 As airport maintenance and improvement projects (e.g. runway/taxiway resurfacing) are undertaken, consider modifying any incompetent bearing soils, or taking other remedial measures to increase airport resiliency. (Port of Bremerton)

6. Utilities

Community Importance

6.1 Underground Pipes

Issue: Vulnerable sewer, water, natural gas and fuel pipes

Pipelines located in liquefaction areas or crossing different soils boundaries are vulnerable to failure during severe ground-shaking, releasing their contents into surface streams or marine waters.

Findings

Water mains: Two water mains cross Port Washington Narrows between East and West Bremerton. Water mains located in liquefaction areas likely to break, resulting in road washouts and diminished fire suppression capabilities.

Loss of potable water will immediately impact human populations and the longer-term community recovery process.

Waterfront Sewers and Pumping Stations: Areas along the Bremerton and Port Orchard waterfronts use gravity sewers and pump stations to lift sewage to the treatment plant. In both areas, waterfront pumping stations are built to current seismic standards and cut-off valves prevent back-flows into adjacent marine waters. Where sewer pipes cross liquefaction zones they are liable to break in severe ground-shaking, resulting in loss of sewage capacity. Full lines below the cut-off valves would discharge into Sinclair Inlet.

Natural gas lines: Many of the single-family homes and businesses in the study area rely on natural gas for their heating needs. Although automatic shut-off valves will stop the flow, residual gas in the lines may result in explosions and fires.

No Cascade Natural Gas representatives participated in either of the workshops; consequently, there is little information available about the company's vulnerabilities or mitigation plans. However, gas pipelines do appear to cross liquefaction-prone soils in

Gorst, and, perhaps, Port Orchard waterfront. Recent investigations of the Tacoma Fault Zone have raised concern about the vulnerability of the gas pipoelines where they cross this fault.

First responders may enter buildings where gas leaks have occurred or pipes have been damaged, increasing the risk of injury/death to responders.

Fuel Pipelines: No major fuel pipelines moving product long distances were identified during the workshops. The principal concerns are lines connecting on-site fuel storage tanks to self-serve, or manned pumps at marinas, which pass through poorly consolidated soils in filled shoreline areas, such as adjacent to downtown Port Orchard.

Existing Mitigation Activities

Kitsap County is developing a mitigation plan for its utility systems:

4. Earthquake Mitigation Strategies: *Assess community-wide utility infrastructure with regard to earthquake risk, including public and private utilities (power and telephone systems).*

Puget Sound Energy, Natural Gas Companies, Public Utility Districts, Private Communications Businesses, Water Purveyors, and Sewer Districts would be identified as the lead agencies or businesses, where appropriate, in relation to the service provided, to implement this strategy.

- *This program will need to be tied to, and an active participant in, a regional GIS Mapping Project*.

To our knowledge this has not been completed.

7. Water System Earthquake Hazard Mitigation Strategy: *Implement a community-wide water main and water delivery system risk assessment. Formulate alternatives to mitigate risk.*

- *Lead agencies for this strategy would be the Public Utility Districts, Water*
- *Purveyors, City Utilities and public/private system owners or operators, where*
- *appropriate.*
- *In addition to Local operational budgets, this project would require matching*
- *grant funds.*
- *Coordinate the risk assessment with the identification of fire hydrants and*
- *perform risk analysis for fire protection.*

To our knowledge this has not been completed.

Recommended Actions

Objective

To enhance the resilience of Kitsap County's sewer, water, natural gas and fuel pipelines.

Mitigation Actions

6.1.1 Upgrade telemetry systems to pinpoint water line problems. (Water purveyors)

6.1.2 Improve redundancy from reservoir to lines so that if one line is lost, the whole community is not impacted. (Water Purveyors)

6.1.3 Install automatic shut-off valves on all lines. (Water purveyors, building owners, Cascade Natural Gas, City and County Public Works Depts., Port of Bremerton, private marinas)

6.1.4 Upgrade pipe as it is replaced over the years, and conduct more geotechnical analyses of critical facilities and pipelines. (Water Purveyors, Cascade Natural Gas, building owners, City and County Public Works Depts.)

6.2 Electrical Power

Issue: Damage to power-lines and substations

During an earthquake or tsunami power-lines and distribution stations may be damaged, resulting in an interruption or loss of service.

Findings

Most of Central Kitsap County's energy needs are met by Puget Sound Energy (PSE) and power it purchases from the Bonneville Power Administration (BPA). The current demand for the area is roughly 4600 megawatts, 2300 of which are provided from PSE sources, and 2300 of which come from BPA. PSE runs a submarine cable from Des Moines to Central Kitsap County. The cable is exposed at points along the shorelines of Vashon Island and at Command Point and is vulnerable in the event of a major earthquake or tsunami. BPA runs a land-based transmission line from Hood Canal to Central Kitsap via Gorst. This line may be vulnerable to severe ground-shaking during a major earthquake.

Local electrical utilities operate on an N-1 capacity, meaning that, when one line goes down, power can be re-routed through another line. However, when lines are overloaded they tend to heat up and sag, resulting in localized fires and loss of power. Loss of multiple power lines in the Bremerton area would likely result in widespread outages, producing additional stress on response efforts, and endangering more local residents.

Few homes and businesses in Sinclair Inlet have on-site generators. Sustained power outage can hinder the ability of local businesses to resume services. Loss of power for three days—longer in a large Seattle Fault event—will make some emergency equipment inoperable. Sudden power losses/surges can damage computer systems, resulting in loss of internet capabilities, communications, and business records, and can generate sparks and cause appliances to "blow-up", resulting in an increased risk of fires. Response equipment that cannot be operated with batteries or generators may be rendered useless.

"Fried" appliances and use of fire and candlelight for illumination and heat can cause fires, stressing the resources of local fire departments.

Workshop participants felt that technology is rapidly changing, and were unsure what electrical networks would look like in 50 years.

Existing Mitigation Activities

KEMD identified the need for developing mitigation actions for vulnerable power facilities:

4. Earthquake Mitigation Strategies: Assess community-wide utility infrastructure with regard to earthquake risk, including public and private utilities (power and telephone systems).

To our knowledge this has not been completed.

Recommended Actions

Objective

To ensure that Kitsap County's energy supply is resilient to hazard events.

Mitigation Actions

Short Term:

6.2.1 Identify alternate sources of energy to increase supply redundancy. (Puget Sound Energy [PSE])

6.2.2 Conduct geotechnical analyses of all critical transmission lines, towers and substations. (PSE)

6.2.3 Pursue alternative energy solutions to reduce dependence on the primary electrical grid. (PSE, County and City Community Development Depts., Non-Governmental Organizations)

Long Term:

None identified.

6.3 Telecommunications

Issue: Failure/over-loading of telecommunications systems

An earthquake or tsunami could physically damage the communications network and result in system overload, disrupting critical communications during response and recovery

Findings

Methods of communicating with the public in a major disaster may be inadequate. Emergency managers may wish to issue certain directives and guidance to local residents. If television and phone lines are down, it will be difficult to get valuable information to the public.

No representatives from local telecommunications providers attended the workshops. Consequently, no information was obtained regarding local telecommunications systems and their vulnerabilities**.** However**,** during the recent Nisqually earthquake both cellular and landline phone systems were jammed and therefore could not be relied upon should a similar event occur. (See also Issue 1.3)

Existing Mitigation Activities

KEMD identified the need for developing mitigation actions for vulnerable telecommunications systems:

4. Earthquake Mitigation Strategies: Assess community-wide utility infrastructure with regard to earthquake risk, including public and private utilities (power and telephone

systems).

To our knowledge this has not been completed.

The Navy is in the process of switching over to a land mobile system and is standardizing its hardware and software.

Recommended Actions

Objective

To improve the reliability, resilience and redundancy of telecommunications systems in Kitsap County

Mitigation Actions

Short Term:

6.3.1 Utilize Joint Information Center plan to disseminate key messages when necessary. (KEMD, Media)

6.3.2 Improve coordination of communication networks (KMED, Telecomms)

6.3.3 Improve collaboration with the general media - radio, TV, print (KMED).

7. Occupied Structures

Community Importance

During an earthquake people die, not from ground-shaking, but as a result of falling debris or building collapse. Structural safety is therefore of paramount importance in protecting lives. Building codes accomplish this for new construction and for structures undergoing alteration or change in use, but current, more stringent standards are not applied retroactively to older non-conforming structures.

Damage to vulnerable structures can result in large numbers of injuries at times when medical response capabilities will be over-taxed. Furthermore, debris from collapsed structures can block transportation routes and delay response.

Shoreline workplaces and residences may be uninhabitable following a major earthquake or tsunami, resulting homelessness, interruptions of businesses and loss of marine support services critical to response and recovery.

Fire trucks will be needed for rescue and fire suppression operations. Police cruisers will be needed to mobilize law enforcement services, and to spread warnings and information. Loss of, or damage to these vehicles due to structural collapse could hinder critical response and recovery activities as well as low-tech communications efforts such as use of patrol car loudspeakers.

7.1 Unreinforced Masonry Buildings

Issue: Collapse of un-reinforced masonry buildings and other non-resilient structures

There is the potential for significant loss of life due to partial or complete collapse of un-reinforced masonry buildings and other non-resilient structures, resulting from

earthquake-induced ground-shaking. (See also Issue 1.1)

Findings

Many older buildings in the Sinclair Inlet port and harbor area are of un-reinforced masonry (URM) construction. The absence of structural continuity between load-bearing masonry walls and the floors and roofs they support makes these structures particularly vulnerable to ground-shaking.

Other kinds of structures can be susceptible to earthquake damage, depending on when they were built (then-current seismic zone), their configuration (asymmetry in plan or vertical section, first floor wall openings, etc.), adjoining structures, and many other design and site factors.

Local fire stations may be vulnerable to structural damage from ground-shaking. If fire station doorways collapse, trucks and equipment can be damaged or trapped. Loss of even a few fire response vehicles could seriously undermine the communities' ability to respond to widespread fire, or many smaller localized fires.

URM buildings can be retrofitted to withstand ground-shaking in all but the worst case scenarios. However, owners cannot be compelled to undertake structural retrofit unless they propose to undertake any changes requiring a building permit, or change type of occupancy.

Existing Mitigation Activities

Item 8. Public Safety Earthquake Hazard Mitigation Strategies: Promote public seismic risk retrofit for commercial sector and residential sector to include foundation bolting, tie downs, and necessary bracing actions.

Recommended Actions

Objective

To encourage voluntary compliance with current building standards and increase the resilience of vulnerable structures, thereby saving lives and speeding recovery of businesses

Mitigation Actions

Short-term:

7.1.1 In cooperation with private property owners and tenants, conduct ATC-21 vulnerability assessments of the built shoreline environment to identify at-risk buildings in need of more detailed engineering studies (KEMD/City and County Engineering and Public Works Depts.)

7.1.2 Conduct detailed seismic assessments of all *critical facilities*, and proceed with replacements, reconstruction, or retrofits, until all critical facilities are sufficiently resilient. (KEMD/City and County Engineering and Public Works Depts.)

7.1.3 Conduct public workshops on the importance of retrofitting older structures (KEMD/City and County Engineering and Public Works Depts.)

7.2 Shoreline Residences

Issue: Shoreline residences vulnerable to earthquake hazards and tsunami

inundation

Waterfront homes are vulnerable to earthquake-tsunami hazards, including ground-shaking, liquefaction, landslides, and inundation.

Findings

Waterfront homes are frequently built in hazard areas – on steep slopes, at the top or foot of bluffs, on fill, in low-lying shorelines. While little can be done to prevent landslides, soil liquefaction, flooding and inundation, some measures can be undertaken to mitigate the effects of groundshaking on structures and their contents.

The most common causes of homes being red-tagged (uninhabitable, unsafe to enter) following an earthquake are exterior walls being shifted off foundations, and toppling of unbraced “cripple” or “pony” walls that connect floors to foundation walls. These hazards can be mitigated by actions such as bolting load-bearing walls to foundations and installing bracing.

Existing Mitigation Activities

Item 8. Public Safety Earthquake Hazard Mitigation Strategies: Promote public seismic risk retrofit for commercial sector and residential sector to include foundation bolting, tie downs, and necessary bracing actions.

Recommended Actions

Objective

Increase the resilience of shoreline residences through education and voluntary programs

Mitigation Actions

Short-term:

7.2.1 Continue to use a variety of outreach methods, such as brochures, flyers, notes in utility bills, etc. to educate public on seismic hazards. (KMED)

7.2.2 Publicize the need for simple earthquake hazard retrofits, such as tie-downs for water tanks, bolting houses to foundations, etc. (KEMD, media, neighborhood organizations, home improvement stores, e.g. Lowes, Home Depot, etc.)

7.2.3 Develop training guides and local home retrofit demonstration programs to educate local residents about low-cost, high-benefit retrofits. (KEMD, home improvement stores)

7.2.4 Encourage state and local government to develop and enforce stricter building codes to ensure that future construction is more resilient to seismic hazards. (Neighborhood organizations, KEMD)

7.3 Over-water pile-supported structures

Issue: Structural failure during tsunamis

Vulnerability of over-water pile-supported structures to tsunami hazards in particular, threatens life and property, and disruption of marine businesses.

Findings

Over-water pile-supported structures are vulnerable to multiple hazards. Severe ground-shaking can cause direct structural damage; during a tsunami, heavy floating debris–larger vessels, logs, etc.–can damage piles and cause structural weakening or collapse; and, extreme high water levels can impact and damage structures directly or indirectly through lifting large buoyant debris against floor decks.

Most waterfront infrastructure was constructed to current Zone III seismic standards and would fare well in all but the worst-case scenario earthquakes. Tsunami hazards were not considered when these structures were designed, however. Current engineering standards for coastal structures are possibly inadequate to protect against the effects of tsunami inundation and currents and the impacts from large items of floating debris.

Overlapping governmental regulations hamper coastal engineering solutions (e.g. ESA permit reviews).

Existing Mitigation Activities

None identified

Recommended Actions

Objective

Increase the resilience of over-water pile-supported structures to tsunami water levels and currents, thereby saving lives and enterprises.

Mitigation Actions

Short-term:

7.3.1 As tsunami modeling for Sinclair and Dyes Inlets becomes more accurate and the extreme range of water levels and currents are better defined, review design standards for new construction. (Building and Public Works Depts. in cities and Kitsap County)

7.3.2 Conduct vulnerability assessments of pile-supported over-water structures to determine which facilities are at risk. (Port of Bremerton, private marina operators, yacht clubs, individual building owners)

7.3.3 Review insurance policies in effect on buildings and contents for earthquake and flooding coverage.

Long-term:

7.3.3 As facilities are upgraded or replaced, incorporate best scientific information on tsunami water levels into design standards. (Port of Bremerton, private marina operators, yacht clubs, individual building owners)

8. Shoreline Infrastructure

Community Importance

Docks and dry-docks, passenger terminals, piers and floats, together with the structures that protect them from waves and currents, comprise the essential infrastructure to support water-dependent businesses, recreational water access, regional water transportation systems, naval operations and ship repair in Sinclair Inlet. Damage to or failure of these facilities following an earthquake and/or tsunami would cripple the

activities they support, sever lifelines and compromise the response and recovery operations that depend on access to water.

8.1 Shore Protection Structures

Issue: Land loss, flooding and erosion

There is a potential for collapse of sheet pile and other seawalls resulting in slumping and erosion of material they retain and loss of land and structures they are designed to protect.

Findings

Even though they are built to withstand “design” windstorms and wind-driven waves, seawalls may be vulnerable to strong tsunami currents and heavy floating debris they tear loose and transport. Bulkheads may fail due to inadequate toe-protection, or size of rock in rip-rap.

Soils behind shore protection structures are usually composed of unconsolidated fill material and are particularly vulnerable to liquefaction and lateral spreading if those structures fail.

Existing Mitigation Activities

None identified

Recommended Actions

Objective

Identify and upgrade vulnerable shore protection structures so as to increase the resilience of shore-side facilities and activities they protect.

Mitigation Actions

Short-term:

8.1.1 Evaluate the potential for soil liquefaction and damage to seawalls (USN, Port of Bremerton, City of Bremerton)

Long-term:

8.1.2 Wherever possible, stabilize soils vulnerable to liquefaction; upgrade or replace deficient seawalls. (USN, Port of Bremerton, City of Bremerton).

8.2 Docks and Floats

Issue: Loss of access to and from vessels at dockside and in marinas

During tsunami, extreme water levels–both high and low–threaten access to and from docks and floats, stranding boaters and workers alike.

Findings

Piling holding floating docks in place may have insufficient length above water to accommodate tsunami inundation, particularly at high tide levels, allowing docks and finger piers to float free. At extreme low water levels ramps could separate from the

floats to which they provide access, stranding personnel and boaters on docks or aboard their tied-up vessels.

In areas of high tsunami current velocities the lateral loads on floating dock systems may exceed the design standards

Existing Mitigation Activities

None identified

Recommended Actions

Objective

Improve resilience of floating dock systems to tsunami inundation and currents

Mitigation Actions

Short-term:

8.2.1 As tsunami modeling for Sinclair and Dyes Inlets becomes more accurate and the extreme range of water levels and current velocities better defined, assess which facilities are at risk. (USN, Port of Bremerton, private marina operators)

Long-term:

8.2.2 As facilities are upgraded or replaced, incorporate best scientific information on tsunami water levels into design standards for piling, ramps and anchoring systems. (USN, Port of Bremerton, private marina operators)

8.3 Storage tanks

Issue: HAZMAT spills, fires and loss of fuel to support recovery operations

Findings

Storage tanks–both underground and above ground–are susceptible to ground-shaking, liquefaction, tsunami inundation and currents. Improperly anchored underground tanks may “pop-up” due to liquefaction of surrounding soils, particularly when empty; rigid pipe connections may fail; above ground tanks may be carried off-site by tsunami currents. The results are loss of fuels, lubricants and other products, HAZMAT spills and fires, and compromised response and recovery operations.

Existing Mitigation Activities

None identified

Recommended Actions

Objective

To reduce HAZMAT spills and fires and conserve fuels and other liquid products important for response and recovery operations.

Mitigation Actions

Major HAZMAT sites have been identified, but many smaller facilities, e.g. Port of

Orchard Marina underground fuel storage tanks, may have not been mapped.

Short-term:

8.3.1 Using Dept. of Ecology's underground storage tank database and other sources, update and enhance the Kitsap County GIS Hazmat layer to include shore-side storage tanks, especially those in liquefaction zones. (Kitsap County DCD GIS Division)

Long-term:

8.3.2 As storage tanks reach the end of their useful life, replace them using best available scientific information to resist ground-shaking intensity, liquefaction potential and tsunami water levels. (Port of Bremerton, private marinas, USN Bremerton)

9. National Defense Facilities

Community Importance

Sinclair Inlet is the home of the Puget Sound Naval Shipyard and Naval Station Bremerton (NSB), important strategic assets of the U.S. Navy in the Pacific Northwest. The PSNS repairs and refurbishes all classes of navy vessels including those home-ported at Everett and the Bangor nuclear submarine base. NSB homeports aircraft carriers and support vessels. The civilian employment at this naval complex drives the local economy of Bremerton.

The Puget Sound Naval Shipyard was established in the 1890s and is presently the only one of its kind on the West Coast of the US. The shipyard population includes 8,400 civilian shipyard workers,2,500 contractors, and active duty navy personnel, plus personnel attached to ships in for repair (up to 3,000 per carrier). The Naval Station homeport includes about 250 base personnel, plus crews of a carrier and fuel/ammunition support ships, when in port. The total shipyard population varies, but can reach 18,000.

Jackson Park is Navy property on the west shore of Dyes Inlet that includes base housing for the Bremerton area and the Naval Hospital and has a population of about 3000 people.

Overall Findings

The shipyard and naval station are located directly on Sinclair Inlet and thus subject to both earthquake and tsunami hazards. The elevation of low-lying areas is only a few feet above high tide levels– pier elevations +18'-19' MLLW. These low-lying areas are virtually all fill over former tidal marshes and flats and thus potentially vulnerable to amplified groundshaking, liquefaction, and lateral spreading.

While the PSNS facilities have fared well in recent deep Benioff earthquakes ~M7, their performance in a Seattle Fault event is likely to be poor, putting shipyard workers and vessels under repair at considerable risk and compromising military functionality. Many buildings on both the shipyard and naval station are old and constructed of unreinforced masonry (URM); many of the other Navy buildings were constructed prior to the current seismic codes, and are thus vulnerable to seismic hazards. There are also numerous buried utilities, crane rails on ties, retaining structures, piers, wharves and dry docks potentially vulnerable to seismic and/or tsunami hazards.

At least one strand of the Seattle fault runs directly through the Jackson Park Naval

Hospital site, making it extremely vulnerable to that hazard (severe groundshaking, uplift/subsidence). Predicting where a fault is going to surface is nearly impossible, and if it does surface directly under the hospital, there is little that could be done to prevent damage, besides moving the hospital.

Overall Goal

To increase the resiliency of US Navy assets and personnel to rare but potentially devastating earthquakes and tsunami.

9.1 Puget Sound Naval Shipyard Employee Safety

Issue: Employee disaster preparedness

Low awareness of seismic hazards and appropriate response by shipyard workers puts their lives at risk and the shipyard in jeopardy of losing its functionality following a majoe seismic event.

Findings

Earthquake and, especially, tsunami hazard and response strategy awareness among most shipyard workers is probably low, despite training plans being in place. Awareness of key personnel is higher. Shipyard evacuation needs better coordination on-base and with city, as demonstrated by the gridlock that occurred after workers were released after the Nisqually quake; problem exacerbated by shift changes.

Existing Mitigation Activities

Employee training plans in place.

Coordination with county on response is in place.

Recommended Actions

Objective

Equip shipyard personnel with the knowledge and skills needed to minimize their risk of death or injury from earthquake and tsunami hazards in their workplace.

Mitigation Actions

Short-term:

9.1.1 Assess the need for increased training level of base personnel.

9.1.2 Research how Boeing handles its industrial facility training as an example.

9.1.3 Develop a tsunami response plan to build awareness and response capacity.

9.1.4 Determine what can be done to better institutionalize evacuation and related plans

9.1.5 Include earthquake and tsunami response training in staff orientation and refresher training programs.

9.1.6 Add pertinent information to the video that all personnel have to view when obtaining a badge at the Pass and ID office.

Issue: Seismically deficient buildings and dry docks

Potential for significant loss of life due to partial or complete collapse of the unreinforced masonry buildings (URMs) and other seismically deficient buildings and dry docks.

Findings

There are fifteen unreinforced masonry buildings (URMs) on the Naval Shipyard and twelve on the Bremerton Naval Station. The large shipyard machine shop is among the most vulnerable. Many of the other Navy buildings were constructed prior to the current seismic codes, and are thus vulnerable to seismic hazards.

Loss of key professional workers in support roles due to location in at-risk buildings could shut down the shipyard following an earthquake.

Emergency lighting/power problems exist in many buildings, as illustrated by the 2001 Nisqually earthquake.

Planned seismic upgrades—structural (buildings) and nonstructural (e.g., securing of interior lighting fixtures) have gone unfunded or have been deferred.

Continuity of shipyard operations at risk due to questions of post-event building usability and potential problems with regional transportation continuity.

Current Mitigation

Seismic studies have been completed for most of the Navy's core buildings that are suspected of being vulnerable.

FEMA Tier 2 seismic studies are currently underway for vulnerable core shipyard buildings to better establish repair/upgrade methods and provide budget cost estimates so funding can be pursued.

The shipyard recently seismically upgraded one occupied and two vacant historic URM buildings, which allowed for the vacating and demolition of three other seismically-deficient buildings, two of which are URM construction. (Funding was through the Congressionally-approved Military Construction (MILCON) program). Two other seismically-deficient URM buildings will be demolished by FY04 and FY05 MILCON projects.

The shipyard and naval station are proceeding with repairs to various buildings that were damaged from the 2001 earthquake, utilizing repair funds provided by special legislation.

Recently PSNS/NSB has partnered with FEMA to undertake a pilot demonstration project promoting the use of HAZUS–MH. This updated HAZUS decision- support tool is designed to support mitigation planning through local- and state-level risk assessments, and to estimate losses to federal facilities during earthquakes. The shipyard is also partnering with USGS and UW to install a “real-time” seismic instrument, which will provide shipyard management valuable information for emergency response operations.

Recommended Actions

Objective

To provide a safer working environment for shipyard personnel located in seismically vulnerable facilities and thereby maintain or quickly re-establish military readiness following a seismic disaster.

Mitigation Actions

Short-term:

9.1.7 Evaluate the potential seismic hazards (liquefaction, ground amplification, structural damage, etc.) affecting the shipyard and naval station.

9.1.8 Continue to accomplish seismic repairs/upgrades within local funding authority.

Long-term:

9.1.9 Increase vulnerability awareness of potential sources of funding (i.e. Congress).

9.1.10 Pursue MILCON funding to (1) seismically upgrade core buildings and (2) construct new facilities to replace seismically-deficient buildings that are not cost-effective to upgrade to current seismic codes.

9.2 Puget Sound Naval Shipyard Infrastructure

Issue: Infrastructure shortcomings

Infrastructure including utilities, crane rails on ties, retaining structures, piers, wharves and dry docks are potentially vulnerable to seismic and/or tsunami hazards.

Findings

Workshop participants were concerned about the Puget Sound Naval Shipyard infrastructure. Not only is this infrastructure critical to the functioning of the Naval Yard, but it could also be tapped for community response and recovery initiatives.

Utilities, streets, cranes, rail lines, piers and seawalls, etc. are vulnerable to liquefaction and lateral spread of filled areas in the shipyard. Most crane rails are supported on piles and much of the utility distribution system is housed in concrete utility tunnels and trenches. In general, the Navy relies on the community for all essential utilites (water, sewer, gas and electrical power), but there are emergency power generators in place to support critical shipyard power loads.

Piers are vulnerable at connecting points with land. Sheet pile and other seawalls and bulkheads could fail and allow upland fill material to spread laterally into waterways.

Historically the dry docks have performed well during recent major intraplate earthquakes (1949, 1965, and 2001), but their performance during a major crustal event has not been established.

Existing Mitigation Activities

Dry docks have been evaluated for seismic load conditions (0.15-0.2g) and hydrostatic pressures on the dry dock caissons from tsunami waves. Historically the dry docks have performed well during major deep intraplate earthquakes (1949, 1965, and 2001).

Seismic loads are considered when developing ship blocking plans.

Periodic inspections are done to monitor condition of piers.

Fender piles and "camel" logs are utilized to breast ships alongside piers and minimize the intrusion of small craft and debris that could get under the pier deck and cause damage to the pier structure and suspended utility piping.

The shipyard is pursuing funding to replace the structurally-deficient creosote fender pile with environmentally-friendly pile, i.e. pre-cast concrete. The first retrofit has been funded and is scheduled to start in Summer 2004

Most crane rails are supported on piles and much of the utility distribution system is housed in concrete utility tunnels and trenches. Some vulnerabilities have been identified, however, and further research is needed to assess the degree of risk and identify potential mitigation efforts.

Recommended Actions

Objective

9.2.1 Increase the resilience of Puget Sound Naval Shipyard infrastructure designed to older seismic standards.

Mitigation Actions

Short-term:

9.2.2 Assess whether further analysis of dry dock vulnerability is warranted; i.e. dynamic analysis to current criteria.

9.2.3 Identify potential hazards, and develop personnel training and temporary construction methods that limit potential for damage.

9.2.4 Undertake further evaluation to determine the potential for liquefaction and earthquake/tsunami damage and develop mitigation measures.

9.2.5 Identify infrastructure items that are necessary for post-earthquake response and recovery, as well as those infrastructure items that have the highest earthquake/tsunami loss of life potential, and upgrade those items as funding becomes available.

9.2.6 For some of the facilities that are undergoing FEMA Tier 2 studies, possible mitigation measures being considered include adding micropiles to existing building footings and soil compaction grouting at strategic locations**.**

Long-term:

9.2.7 Stabilize soils vulnerable to liquefaction, if possible, and/or upgrade or replace deficient seawalls to current seismic codes.

9.2.8 Design and construct replacement structures to current seismic codes.

9.3 USN Emergency Response Capacity

Issue: Vulnerable Emergency Response Capacity

Response capacity is compromised by vulnerable buildings, transportation routes and personnel and supplies.

Findings

The Shipyard and Naval Station Bremerton fire stations are highly vulnerable to major earthquakes. Loss of fire/EMT emergency response capacity within the shipyard due to probable collapse of both URM fire stations. However, loss of the Navy's Emergency Command Center (ECC) is a low probability since it is housed in a relatively new facility that was designed to latest seismic standards at the time of construction (1980's).

Key medical response and recovery facilities are in URM or otherwise seismically unstable buildings, e.g., the Chico fire station and facility management offices, and the older sections of the hospital.

Insufficient medical response capacity is present within the shipyard to handle expected injuries resulting from a major earthquake in the area.

Limited transportation access to and from the Chico Annex facilities and Naval Hospital, with steep areas possibly vulnerable to landsliding puts part of area-wide response capability in question.

Existing Mitigation Activities

The Navy is pursuing MILCON funding to construct a new consolidated fire station at the Bremerton naval complex, thereby vacating the two existing seismically-deficient facilities. The Naval Station is also considering upgrade or replacement of their Jackson Park fire station.

Naval Fire Department has mutual aid agreement with City of Bremerton.

NESCOM (Police Communications) will be moving in about one year from a seismically-deficient building to a seismically-upgraded building.

Bremerton Naval complex building inspections are conducted routinely on a weekly basis.

Recommended Actions

Objective

Increase the resilience of naval station facilities housing key response units.

Mitigation Actions

Short-term:

9.3.1 Assess the vulnerability of the power plant that houses the Emergency Command Center on Naval Station Bremerton.

9.3.2 Keep at least one fire engine outside firehouses at all times.

Long-term mitigation:

9.3.3 Implement fire station upgrade/replacement projects.

9.3.4 Consider relocation of Emergency Command Center or upgrade power plant building's seismic resistance, as necessary

Issue: Communications capability

A communications facility siting decision compromises response in event of a major earthquake.

Findings

A Navy regional communication facility (Navy/MC Internet, etc.) is slated to occupy a Naval Station building that is located in low-lying areas with liquefiable soil.

Existing Mitigation Activities

Naval Station has done an initial assessment of the site conditions.

Recommended Actions

Objective

Ensure resilience of new communications facility structure against known seismic hazards.

Mitigation Actions

Short-term:

9.3.5 Evaluate the potential seismic hazards (liquefaction, ground amplification, structural damage, etc.) of communication facilities and develop mitigation measures.

Long-term:

9.3.6 Stabilize soil, if possible. Design and construct replacement structures to current seismic codes, if necessary.

9.4 Waterborne Debris

Issue: Waterborne debris damage and waterway access

Findings

Waterborne debris and projectiles from both onsite and offsite sources, driven by tsunami currents would threaten floating and fixed over-water structures and hamper recovery operations from and on water. Based on NOAA model, there is very low probability that projectiles would put upland facilities at risk. Pier decks are 18-19 foot above sea level.

Existing Mitigation Activities

Fender piles and "camel" logs are utilized to breast ships alongside piers and minimize small craft and debris that could get under the pier deck and cause damage to the pier structure and suspended utility piping. As a result of 9/11, the Navy has installed offshore floating security barriers (i.e. boom-mounted fences). Depending on the adequacy of the anchor system, they could help collect waterborne debris…or potentially add to the projectile problem. So far, they have withstood some high winds and 3-4 foot seas, but they should be assessed for the tsunami scenario.

Higher capacity fendering systems will further reduce vulnerability of projectile damage.

The shipyard is pursuing funding to replace the structurally-deficient creosote fender pile with environmentally-friendly pile (i.e. precast concrete). The first retrofit has been funded and is scheduled to start in Summer 2004.

Objective

Reduce vulnerability of floating and fixed over water structures and vessels to waterborne debris.

Mitigation Actions

Short-term:

9.4.1 Identify on-site and off-site sources of debris, and the potential for on-site damage from these sources.

9.4.2 Develop water use plan that limits sources of on-site debris; i.e. remove non-essential waterfront craft, securely tie-down waterfront craft, etc.

9.4.3 If deemed necessary, anchor offshore log booms to shield the piers from off-site sources of debris.

Long-term:

9.4.4 Design and construct replacement waterfront structures taking into account the potential for waterborne debris and projectiles.

9.5 Hazardous Materials Spills

Issue: Hazardous materials release and contamination

Findings

Potential for hazardous material incidents at the Bremerton naval complex during or following an earthquake and tsunami disaster would pose human health risks to recovery operations.

The hazardous/flammable material warehouse was constructed a few years ago in accordance with applicable seismic criteria.

Existing Mitigation Activities

Industrial waste treatment facility is being moved closer to waste generation area, eliminating use of present pipeline buried in liquefiable soils. The new facility has been designed to current seismic criteria and construction will begin in late 2003.

Recommended Actions

Objective

Achieve increased safety and resilience to seismic hazards in the handling, transportation and storage of hazardous materials.

Mitigation Actions

Short-term:

9.5.1 Evaluate the potential for hazardous material spills and develop response and mitigation strategies.

Long-term:

9.5.2 Seismically upgrade or replace the hazardous waste temporary storage facility.

9.6 Coordination with Local Emergency Management Officials

Issue: Community support function

Findings

Plans for the Naval Station/PSNS serving as a Base Support Installation (BSI) for Kitsap County need to be updated to include earthquake and tsunami disaster.

Existing Mitigation Activities

Navy has state/federal coordination mechanisms in place – local EMD is the "state" representative and in-charge person

Objective

Have plans and procedures in place to utilize local naval facilities, personnel and equipment to augment local civilian disaster response and recovery capacities.

Mitigation Actions

Short-term:

9.6.1 Develop BSI plan: work with the county EMD to identify potential roles and sites for the naval facilities to serve as a post-event BSI for transportation of goods and materials across Navy piers, by rail, use of cranes, MARAD crane ships, etc.

Long-term:

9.6.2 Harden key facilities to serve BSI functions identified in plan.

9.7 Navigational Access

Issue: Seismic uplift in navigation channels

Findings

Vessel access to the Bremerton naval complex is through Rich Passage, a narrow channel connecting the main basin of Puget Sound with Port Orchard. During a large Seattle Fault earthquake, uplift would likely occur in this waterway causing changes to channel bathymetry. A tsunami would produce strong currents in Rich Passage, moving sediments and possibly further altering channel morphology. For the deepest draft naval vessels these conditions could compromise their deployment during a national emergency.

Recommended Actions

Objective

Have in place plans for redundant waterway access from Puget Sound to the PSNS.

Mitigation Actions

None identified (See: Section 5.3 Navigation Infrastructure," above)

10. Integrating Hazards Mitigation and Community Development

Community Importance

> "Human beings, not nature, are the cause of disaster losses. The choices that are made about where and how human development will proceed actually

determine the losses that will be suffered in future disasters."[40]

The safety of homes and businesses is in part a community's and in part an individual's responsibility. The community, acting through its governmental institutions, can play many important roles in enhancing the safety of its citizens. In particular, providing accurate information about hazards helps private parties make prudent locational decisions about their residences and businesses.

Through regulation, local government can limit exposure of development to hazards: zoning, critical area buffers, floodplain delineations and shoreline designations are some of the land use planning tools available to steer new development away from unacceptable hazard areas. However, excluding all development from hazardous shoreline areas has not been a politically acceptable mitigation strategy in Washington State.

Property owners, developers and local government planning officials seek a degree of predictability as to where and what kind of development will be permitted on or near the shoreline. Multiple layers of regulation have been created through a plethora of environmental quality and land-use planning statutes enacted since the early 1970s that frustrate predictable outcomes to land-use decision-making.

The State Growth Management Act mandates efficient use of land and public services, and leads to development becoming more concentrated in existing urban areas in order to reduce the costs of sprawl. FEMA's floodplain regulations, the state Shorelines Management Act and federal wetlands protection under the Clean Water Act, as well as recent regulatory measures to protect salmon habitat under the Endangered Species Act, all tend to propel new development away from the immediate shoreline. Mitigation of earthquake and tsunami hazards adds another ingredient to the planning mix.

10.1 Reducing Exposure to Hazards

Issue: Vulnerable shoreline development

Development on or near shorelines is vulnerable to landslides, tsunami inundation and other co-seismic hazards

Findings

Waterfront properties are some of the most valuable real estate on Sinclair and Dyes Inlets, and are commonly used for residential and commercial purposes. Residential shoreline parcels, for the most part, comprise long narrow lots that were originally developed as small weekend cabins, but later remodeled to become permanent residences. Few undeveloped parcels remain.

Located at or near the top, or at the foot of steep slopes, or near water level, most shoreline development lies in harm's way. Landslides and tsunami inundation are the two most common hazards. It is difficult to reduce the exposure to such hazards in already developed areas. Re-zoning commercial and residential properties to less vulnerable uses such as parks and recreation areas is fraught with political risk; and,

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[40] Mileti, Dennis. 1999. Disaster by design: a reassessment of natural disasters in the United States. Washington DC. Joseph Henry Press.

community buy-outs of waterfront property from private parties is cost-prohibitive.

Currently, there are mitigation requirements for commercial uses under critical areas and shoreline management codes, whereas residential uses are, for the most part exempt from these. Furthermore, mitigation requirements are impossible to apply retroactively.

With respect to tsunami hazards there are seven characteristics that make a port and harbor community resilient to tsunami; five address where development is allowed and how it is designed and constructed:

- Avoid new development in tsunami run-up areas to minimize future tsunami losses
- Locate and configure new development that occurs in tsunami run-up areas to minimize future tsunami losses
- Design and construct new buildings to minimize tsunami damage
- Protect existing development from tsunami losses through redevelopment, retrofit, and land reuse plans and projects
- Take special precautions in locating and designing infrastructure and critical facilities to minimize tsunami damage

Workshop attendees identified a number of planning and community development issues and mitigation options which, if addressed would move the Sinclair Inlet Port and Harbor Community towards possessing these resilient characteristics.

Existing Mitigation Activities

Buffers and building setbacks are required in geologically hazardous areas under the Kitsap County Critical Areas Ordinance. KEMD's Hazard Mitigation Plan, *Cat IV: Law & Regulatory Issues*, addresses Critical Areas in three ways relevant to this issue:

2. Identify components in Critical Areas Ordinances that are not being fully implemented. Utilize site visits and develop a program to enhance enforcement of compliance with the Ordinances.

- *Approach the Critical Areas Ordinance to include maximization of regional solutions and program implementation.*
- *The Lead agency would be the Departments of Public Works, the Community Development Departments, Regional GIS, and the Department of Emergency Management and current code enforcement staff.*

This strategy would require each jurisdiction to internally review their current enforcement methodology and determine an independent course of action in identification of the deficiencies unique to the jurisdiction and then propose individual remediation strategies.

3. Critical Area Building Code: Explore the feasibility of implementing a Critical Area Building Code for single family homes.

- *Review Remodeling Code in risk areas for opportunities to implement mitigation measures for land shift and other identified risks.*

    a. Enhance code restrictions as needs are identified.

    b. Take the code enhancement recommendations back to the Hazard Mitigation Steering Committee for additional recommendations on an annual basis.

    c. Work with Departments of Community Development for additional recommendations.

    d. Contact the United States Geological Survey Agency (USGS) for additional information and recommendations.

The lead agencies would be the Community Development Departments. Regional GIS would be the first step in making sure the information was uniformly available to all parties and thereby allowing better enforcement.

Note: Identification of the Critical Areas Ordinances implementation implies a certain current enforcement in the cities and the County. There are a number of issues unique to each entity's CAO, which would require a review and discussion to determine the problems with full implementation. Each jurisdiction would have to internally review their current enforcement methodology and determine their deficiencies and than determine who and how they were going to increase implementation.

5. Earthquake Code Mitigation Measures: Review current codes and recommend adoption of most current Seismic Safety Codes where they are not already implemented.

The lead agency for this mitigation strategy would be the Community Development Departments.

Recommended Actions

Objective

To increase the resilience of future waterfront development to seismic and co-seismic hazards

Mitigation Actions

Short-term:

10.1.1 Identify vulnerable areas and update maps with new information based on best available science. (KCDCD) (See action 1.1.1, above.)

10.1.2 Update local codes to provide protection beyond the minimum state and federal standards, if warranted, based on local conditions. (KCDCD, city community development departments.)

10.1.3 Use existing ordinances and protection measures, such as those implemented for frequently flooded areas, to address the tsunami and earthquake vulnerability issues. (KCDCD)

10.1.4 Re-zone more hazard-prone areas not suitable for residential or commercial uses to recreational use areas. (KCDCD, city community development departments.)

10.1.5 Review adequacy of Critical Areas buffer requirements and building setbacks for geological and flood hazard-prone areas. (KCDCD, city community development departments.)

10.1.6 Where appropriate, use small-scale “buy outs” for portions of sites a private individual cannot use, for public recreational purposes such as a community trail. (City and county parks departments.)

10.1.7 Evaluate inconsistencies between development rules and regulations in adjacent jurisdictions. (KCDCD)

Long-term:

10.1.8 Promote the concept of an earthquake- and tsunami-ready community. (KEMD)

10.1.9 Evaluate the unintended consequences of locating facilities serving special needs populations (nursing homes, long-term care facilities, etc.) in high hazard areas. (KCDCD)

10.1.10 Conduct literature research to determine what kinds of development patterns achieve both density and shoreline/wetland protection goals. (KCDCD)

10.1.11 Encourage State legislation to develop and implement a "Critical Facilities Ordinance", similar to Oregon’s OR Senate Bill 379: ORS 455.446-447. This legislation should have some provision to regulate the placement and construction practices for buildings considered essential, or critical to an emergency response effort. Provisions could require that no critical facility be built: in the flood plain, on slopes greater than 15 degrees, abutting any shorelines, on areas of artificial fill, etc. This sort of guidance in facility siting could result in more resilient and more reliable response centers. (KEMD).

10.2 Buyers’ Hazards Awareness

Issue: Uninformed shoreline residential real estate buyers

Shoreline property buyers lack awareness of site-specific earthquake and tsunami hazards and the danger they pose to life and property

Findings

At time of sale the buying public is overwhelmed with information and there are concerns that people buy property without awareness of potential seismic hazards.

Critical areas –geologic hazards, frequently flooded areas– are mapped and this information is available to the public, developers, and planners. However critical areas for tsunami hazards have not been established, nor is information about co-seismic hazards–amplification, liquefaction, etc.–yet available on official maps. (See action 1.1.1, above.)

Existing Mitigation Activities

Ongoing earthquake hazard and response education efforts on part of (KEMD).

Recommended Actions

Objective

To raise the level of awareness of shoreline property buyers concerning the general and site-specific seismic and co-seismic hazards they face

Mitigation Actions

Short-term:

10.2.1 Increase educational outreach to inform the public of the risks involved in locating buildings in hazard-prone areas. (Board of Realtors, KEMD, City and County Building and Public Works Depts.)

10.2.2 Use a variety of outreach methods, such as brochures, flyers, notes in utility bills, etc. to educate public on seismic hazards. (KMED, Puget Energy, Cascade Natural Gas, water purveyors)

10.2.2 Integrate earthquake and tsunami education materials with other hazard awareness education to avoid "information overload." (KEMD)

Long-term:

None identified.

11. Hazardous Materials Releases and Spills

Community Importance

There are numerous sources of toxic and flammable materials in the Sinclair community, many but not all of which are mapped (see Issue 1.3 above)). For example, the Bremerton Naval complex currently stores, short-term, a number of hazardous materials. These materials range from flammables to toxics. Small quantities of HAZMATs–solvents, paints, lubricants, etc.–are found in use in boatyards, marinas and wherever vessels are being worked on. An earthquake or tsunami could cause hazardous material spills throughout the community with potentially dire consequences for human populations and environmental resources.

There is a community concern that release of hazardous materials can contaminate local water supplies, cause explosions, fires, and dangerous fumes, and result in negative health effects on local populations. These populations will rely on hazardous materials responders to contain and dispose of hazardous materials quickly.

Large releases of hazardous materials could exceed the capacity of local agencies to respond to, contain, and dispose of and would necessitate outsourcing for additional responders. In a large-scale regional event, additional responders from other communities and agencies may be unavailable.

Kitsap County's "Hazard Vulnerability Analysis" addresses hazardous materials hazards and acknowledges that,

> *"Kitsap County fire agencies do not have hazardous materials response teams, which could place the community at risk in the event of a major spill. However, at present, the State of Washington and private industry along with the military will support the County when necessary."*

11.1 Bremerton Naval Complex HAZMATS

Issue:

There is the potential for the release of hazardous materials at Bremerton naval complex during or following an earthquake and tsunami disaster, which could put local populations and the environment at risk.

(See also Issue 9.5, above.)

Findings

The existing methods of containment may be inadequate to withstand intense ground-shaking during a major earthquake. Tsunami inundation could result in flooding of low-lying buildings. Hazardous materials stored or used in these buildings could be dislodged and the water could act as a vehicle for transporting these materials to locations outside of the Bremerton naval complex and/or contaminating the waters of Sinclair Inlet.

Existing Mitigation Activities

Navy Fire Department conducts routine weekly building inspections for life safety threatening deficiencies

In event of disaster where mutual aid agreement with City of Bremerton is activated, Navy firefighters trained in HAZMATs and familiar with all base buildings are teamed with City firefighters

Navy Fire Department regularly conducts both shoreside and shipboard HAZMAT trainings

Recommended Actions

Objective

To reduce or eliminate the threat of hazardous material releases at the Bremerton Naval complex, and other storage facilities throughout the study area.

Mitigation Actions

Short-term:

11.1.1 Conduct an assessment of existing containment facilities, assess needs for retrofitting, and develop better containment strategies. (USN)

11.1.2 Develop a coordinating mechanism to organize and maintain a database of all personnel and resources available to respond to hazardous materials release and plan for "inter-military cooperative response" in the event of a large-scale release. (USN, KEMD, US Coast Guard)

Long-term: None identified

12. Debris Management

Community Importance

During an earthquake debris from collapsed or damaged buildings can block access to first responders and impede recovery efforts. If a tsunami is generated, terrestrial debris, stockpiled buoyant materials, vehicles, outdoor containers, stored vessels, or even small buildings in low-lying areas subject to inundation can be swept by strong

currents into adjacent water-bodies. While moving, these objects become projectiles capable of inflicting death and injury to anyone in or on the water, and causing structural damage to vessels and shore-side buildings.

Debris sloshing back and forth in waterways could represent a threat to vessels that were not damaged during the initial event. Waterborne debris could render ferries and other vessels inoperable.

Debris that may be combustible or contains flammable fluids presents a fire risk on land and a vector for conflagration over water. Waterborne debris could severely affect the ability of local communities to recover from an earthquake-tsunami event.

12.1 Debris Prevention and Containment Planning

Issue: Minimizing debris generation and dispersal at the source

Findings

Preventing debris being created in the first place and containing debris that is generated reduces its impact on the community during response and recovery. Areas with high concentrations of vulnerable structures, on-site storage of floatable materials (e.g. logs, automobiles, RVs, manufactured homes, etc.) will yield higher amounts of debris, and should therefore be given high priority in the planning mitigation measures. However, it may not be feasible to retrofit or replace certain vulnerable structures:

"When waterfront-dependent infrastructure… cannot be newly designed or retrofitted to withstand tsunami forces, (it) should be considered expendable and planning should be undertaken for evacuation, emergency response, recovery, and replacement facilities. It is important to remember that in a tsunami an expendable building may turn into debris that can batter people and non-expendable structures." (NTHMP, 2001)

Existing Mitigation Activities

No debris management tasks are listed in KEMD's current Multi-Hazard Mitigation Plan, but the County is assessing needs and developing a plan to prepare for the removal and disposal of large amounts of debris.

Current education programs to limit structural and non-structural damage would have the corollary effect of reducing the potential for debris generation.

Objective

Reduce the generation of debris from earthquakes and tsunamis and contain what cannot be eliminated.

Mitigation Actions

Short-term:

12.1.1 Assess debris generation potential throughout study area and identify means to minimize and contain sources. (KMED, City and County Public Works and Engineering Depts., Port of Bremerton, USN, waterfront and adjacent businesses)

12.1.2 Continue to educate and train local businesses and residents in low-cost mitigation techniques that can reduce the amount of non-structural debris generated,

e.g. tie-downs for PCs and water tanks, etc. (KMED)

12.2 Debris Collection and Disposal

Issue: Large amounts of debris in the water could result in closed waterways or increased risk to vessels.

Findings

The window of opportunity to remove waterborne debris could be very small: tidal currents in Puget Sound would quickly disperse this material. There are few options for "corralling" waterborne debris, and there are few sites where this type of debris can be removed from the water. This process would be very time-consuming and would require immense financial resources.

It is unclear what resources/personnel would be available to remove waterborne debris. When roadways are damaged or closed, outside resources may only be available via waterways. Mutual aid from Seattle-based contractors could be unavailable in a regional-scale event.

Existing Mitigation Activities

The County is currently assessing needs and developing a plan to prepare for the removal and disposal of large amounts of debris.

There are currently no plans in place to deal with large amounts of waterborne debris.

Recommended Actions

Objective

To remove and dispose of waterborne debris and restore navigability promptly following an earthquake-tsunami event.

Mitigation Actions

Short-term:

12.2.1 Develop plans with local and regional contractors to determine feasibility and methods of debris removal. (Port of Bremerton, USN, US Coast Guard, KMED)

12.2.2 Identify vessels and heavy equipment likely to survive an earthquake-tsunami event that might be pressed into service for debris removal. (USN, Port of Bremerton, private marine salvage and construction contractors) (See also action 2.3.5, above)

12.2.3 Identify areas of Sinclair and Dyes Inlets where debris tends to aggregate naturally as a result of oceanographic factors (bathymetry, shoreline contour, currents, tides, etc). Designate these areas as "debris collection areas." (NOAA-PMEL, USN, US Coast Guard)

12.2.4 Identify shore access and loading areas for debris removal. (Port of Bremerton, USN, KMED)

12.2.5 Assess the current state of readiness for a massive debris removal project (e.g. number of personnel, trucks, transportation links).

12.2.6 Identify critical transportation links and, based on estimated losses, develop contingency plans to circumvent these damaged links (e.g. determine alternate routes

for accessing areas with higher levels of damage, and critical roadways.)

12.2.7 Identify solid waste/debris disposal sites in advance with the least environmental harm to the environment; include plans for post-event debris recycling; include on environmental resources map. (City and County Public Works and Engineering Depts., KDCD)

Long-term:

12.2.8 Partner with local and regional jurisdictions to develop a Puget Sound-wide, large scale hazardous materials recovery plan, which could be modified to address waterborne debris. This plan could potentially include military personnel and resources if the proper partnerships were encouraged. (KEMD, WDOE, USEPA, US Coast Guard, USN)

13. Business Continuity

Community Importance

All too often, communities that have experienced major disasters lose a significant portion of their economic base. Studies have shown that after a disaster, 60% of small and medium size businesses fail within two years. Many never return to business once they are closed for even a few days because of floods, tornadoes, earthquakes and hurricanes. Not only does the community suffer from the effects of the hazard itself, but also in the long run the loss of jobs and tax base further reduces the community's ability to return to normal[41].

13.1 Business Failures

Issue: High rates of small to medium size business failures follow natural disasters

Following a disaster, businesses will be challenged to resume normal operations and continue to serve their customers and their community

Findings

In a variety of ways seismic disasters cause disruptions of businesses. Loss of inventory; structural and non-structural damage to physical plant; loss of power and utility connections; loss of or damage to computers, and record storage devices; loss of business demand and capacity to service it due to physical access blocked by debris, and disruption of employees' and customers' lives. All these effects compound to threaten business continuity following an earthquake and/or tsunami.

In the Gorst/Port Orchard area where tsunami inundation and currents would put many businesses at risk, there is not one single business that, if lost, would spell disaster for the area; instead, there is a cumulative risk of losing the numerous small waterfront businesses.

The Institute for Business & Home Safety (IBHS) and the Small Business Administration

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[41] FEMA Disaster Resistant Jobs Train the Trainer Courses (at http://training.fema.gov/EMIWeb/e464.htm)

(SBA) have developed a disaster toolkit for conducting a small business impact analysis and recovery plan and a number of other helpful publications for business planning for disasters, including:

- *Open for Business: A Disaster Planning Toolkit for the Small Business Owner* available from http://www.ibhs.org/docs/openforbusiness.pdf
- *Getting Back to Business – A Guide of the Small Business Owner Following Disaster* available from http://www.ibhs.org/docs/GBB.pdf

CREW's *"What Businesses Learned From The Nisqually Earthquake of 2/28/2001,"* provides place-relevant knowledge gained from this recent Pacific Northwest disaster.

Existing Mitigation Activities

KMED's Hazards Mitigation Plan addresses business continuity up to 3 days after a disaster, but not beyond.

Recommended Actions

Objective

Enhance the preparedness of waterfront businesses to restart their operations soon after a seismic disaster.

Mitigation Actions

Short-term:

13.1.1 Utilize KEMD's community business forums that provide local operators with assistance in developing emergency management plans for their businesses. (KEMD, Chambers of Commerce, other service clubs.)

13.1.2 Ensure that financial and service records are "backed up" and stored off-site. There are currently a number of different options for businesses to maintain their records remotely (off site), including internet services and big business assistance (e.g. IBM). (Individual business enterprises.)

IV MOVING TOWARDS SUSTAINABILITY

Sustainable Communities

An emerging paradigm in hazard mitigation focuses attention on achieving sustainability– "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Proponents of this paradigm challenge communities to plan for disasters over a longer time-span (multiple generations); to become more self-sustaining and resilient (less dependent on other communities and the nation as a whole); to assess risks not only to populations and the built environment, but to natural resources (wetlands, nearshore environments and coastal waters) that sustain damage from the event as well as from the response and recovery operations, and mitigation actions following it; and, to plan to achieve these goals through a consensus-building, community-based approach involving all stakeholders (Mileti, 1999).

The last point is particularly important for the design of the planning mode used in this

demonstration project. Stakeholders enhance traditional technical analyses with otherwise unattainable insight into the social, economic, political, and cultural systems of a community, thus incorporating multiple goals and motives into the process[42].

What does it mean to be an earthquake- and tsunami-resilient port and harbor community?

A disaster-resistant (we prefer the term "resilient–") community, according to a mid-west US earthquake disaster mitigation consortium, is characterized as a one where, following a disaster, there has been:

- Minimal loss of life and limited interruption of public services including emergency medical and health services, electric and water utilities, transportation and communications
- Resumption of private sector business operations in a timely manner.
- Community management of response operations, supplemented by resources from neighboring communities and state government.
- Recovery to at least pre-disaster conditions in an ordered pre-planned manner

Achieving these ends involves “an approach to reducing risk from natural disasters that incorporates all elements in a community. It involves businesses, government, community organizations, local universities, and others working together to identify the natural hazards (i.e. earthquakes, floods, tornadoes, hurricanes, etc.) that can affect a community, and subsequently develop a long-term planning strategy to reduce prioritized risks associated with the hazards.” [43]

Turning to the specific threat of tsunamis, a recent publication of the National Tsunami Hazard Mitigation Program[44] (NTHMP, 2001), a multi-agency committee comprising NOAA, FEMA, USGS, the Pacific Coast states, plus Alaska and Hawaii, states that a tsunami-resistant community would:

- Know the community's tsunami risk: hazard, vulnerability, and exposure
- Avoid new development in tsunami run-up areas to minimize future tsunami losses
- Locate and configure new development that occurs in tsunami run-up areas to minimize future tsunami losses
- Design and construct new buildings to minimize tsunami damage
- Protect existing development from tsunami losses through redevelopment,

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[42] Wood, et al. 2002

[43] Central United States Earthquake Consortium (CUSEC), Memphis, TN (see: http://www.cusec.org/DRComm/)

[44] National Tsunami Hazard Mitigation Program. Designing for Tsunamis: Seven Principles for Planning and Designing for Tsunami Hazards. March 2001

retrofit, and land reuse plans and projects

- Take special precautions in locating and designing infrastructure and critical facilities to minimize tsunami damage
- Plan for evacuation

The Challenge in Sinclair Inlet

Some of those seven principles for designing tsunami-resistant communities are difficult to follow in developing a tsunami hazards reduction plan for the Sinclair Inlet Port and Harbor Community, however. First, Puget Sound ports occupy a region where the threat of tsunami is evident, but it's dimensions are largely undetermined; robust, peer-reviewed tsunami modeling, for the most part, has not yet been undertaken. Consequently, the tsunami hazard and the community's exposure and vulnerability to it, are only partly understood.

Second, port and harbor communities in general cannot get out of harm's way because their port infrastructure and marine business workplaces are water-dependent enterprises, which, by their very nature, must be located on or over waterways.

Third, a tsunami is a very rare event[45] in Puget Sound; the last one of regional significance occurred more than a thousand years ago. Faced with such a remote threat, communities, enterprises, and households tend to be unwilling to invest in capital-intensive structural mitigation measures, or support avoidance strategies such as land-use regulations which prohibit development – especially single family homes – in shoreline areas. In fact, in Washington State, single family homes are by statute declared a "preferred use" of the shorelines (RCW 90.58.020).

By looking ahead 50 years or more, might it be possible to get beyond the immediate "winners and losers" view of land use decisions that will be necessary to protect life and property from inevitable natural hazards in the Pacific Northwest? Oregon has already moved in this direction by passing Senate Bill 379 which requires that certain facilities (most schools, hospitals, police and fire stations, communication centers, etc.) to be constructed landward of a mapped tsunami inundation line. Ports and water-dependent businesses are specifically exempted. Single- and multi-family residences are not covered by SB 379; such structures are permitted wherever local zoning allows, including mapped tsunami run-up areas.

As tsunami science improves and tsunami hazard mapping within the complex waterways Puget Sound becomes more refined, it may be possible to delineate precisely those zones where development is in harm's way and where it is not. At the moment that is not possible, but preliminary tsunami modeling does raise red flags for the immediate shoreline and low-lying areas of Sinclair and Dyes Inlets. Where mapped geological hazard zones and these low-lying shoreline areas coincide, it makes sense to factor this information into public and private investment decisions and emergency preparedness planning.

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[45] At least two landslide-induced tsunami were recorded in Puget Sound in the 20th. Century, but their effects were localized.

V GLOSSARY

Natural Hazard: An extreme natural event that poses risks to life, property, or resources

Natural Disaster: An event that has a large adverse impact on society or significantly disrupts the workings of society

Risk: Probability of life, property, or resources suffering some adverse consequence as a result of exposure to natural hazards

Vulnerability: Identification and estimations of the potential for damage of significant buildings, utilities, and transportation systems exposed to natural hazards

Disaster Cycle: Hazards specialists have characterized the “disaster cycle” as comprising four parts: **preparedness**, **response**, **recovery** and **mitigation**.

Preparedness: an element of mitigation focusing on actions *taken before the event occurs* to limit the impact of natural phenomena by structuring response and establishing a mechanism for effecting a quick and orderly reaction

Response: begins as soon as a disaster is detected or threatens. It involves mobilizing and positioning emergency equipment; getting people out of danger; providing needed food, water, shelter and medical services; and bringing damaged services and systems back on line.

Recovery: the task of rebuilding after a disaster can take months, even years. Not only services and infrastructure, not only the facilities and operations, but the lives and livelihoods of many thousands of people may be affected.

Mitigation: Sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects

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