ANNUAL PROJECT SUMMARY

Title: MAPPING TSUNAMI INUNDATION HAZARDS AT NEWPORT, OREGON

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INVESTIGATION UNDERTAKEN

The Oregon coast is vulnerable to tsunami inundation from both distant and local sources. Locally generated tsunamis and coseismic subsidence from Mw 8-9 earthquakes on the Cascadia subduction zone could cause severe loss of life and property . This risk can be mitigated by education, warning systems, and by providing flooding maps to emergency and land use planners. This project will explore techniques for mapping potential tsunami flooding at Yaquina Bay in Newport, Oregon. The work will complement a pilot tsunami hazard mapping project 29 km to the north at Siletz Bay. Siletz Bay is only slightly altered by works of man, whereas Yaquina Bay has been extensively modified by installation of two major jetties guarding the bay. Mapping of prehistoric tsunami deposits at Siletz Bay serves as an important check on numerical models of inundation, but not so at Yaquina Bay. The Yaquina Bay jetties and jetty-induced aggradational beaches will modify modern Cascadia tsunami inundation very significantly from that experienced in prehistoric times. This study will explore methodologies for mapping potential tsunami inundation in heavily modified bays. The Siletz Bay and Yaquina Bay hazard mapping projects will therefore provide complementary methodologies for tsunami hazard mapping for population centers on the Pacific Northwest coast.

The resulting hazard map will be an important educational tool which will complement recent distribution of tsunami hazard brochures and installation of an educational marker sign in the area. The map will also provide a means of installing tsunami evacuation and warning signs, as well as implementing proposed state legislation requiring tsunami evacuation drills in schools and prohibiting construction of critical facilities in tsunami hazard zones. The proposal addresses principally Element II but also Element V of the NEHRP program.

At the beginning of the project a resolution will be sought of the following uncertainties identified during the Siletz Bay project: (1) size of the scenario Cascadia earthquake(s); (2) bottom deformation from the earthquake (s); and (3) heights of prehistoric tsunamis as a guide to what may be expected in the future.

The approach is to produce numerical models of inundation at Yaquina Bay from possible Cascadia subduction zone tsunamis. Using as inputs digital bathymetry, digital topography, tidal spectra, paleoseismic estimates of coseismic subsidence, and scenario tsunamis, numerical modeling will map areas of high, intermediate, and low risk. The scenario tsunamis will be established by consideration of tides, and paleo-tsunami data from the Cascadia margin, and numerical models of tsunamis generated by theoretical bottom excitations from potential Cascadia earthquakes.

The final products will be an inundation map and report documenting the methodology. The map will be published by the Oregon Department of Geology and Mineral Industries (DOGAMI) on a 1:12,000 orthophoto base. This map will be utilized in a workshop aimed at education and training of coastal planners and emergency responders. Results will also be summarized in an article for *Oregon Geology* and published in a refereed journal such as *Marine Geodesy.*

RESULTS

The project is still in the early stages, but considerable progress has been made. A complete digital terrain model and orthophotographic base map have been produced. A bathymetric survey was also completed to better describe the shallow parts of Yaquina Bay not surveyed by the U.S. Army Corps of Engineers. These data will be used to assemble a detailed finite element grid for numerical simulation of tsunami inundation in the study area. A regional-scale finite element grid has already been assembled for the Pacific Northwest coast and Alaska. This grid is being tested and refined at the present time.

Much of the last few months has been spent developing scenario earthquake sources for the Cascadia subduction zone. Detailed discussion of this work is beyond the scope of the project summary, but some of the preliminary conclusions can be shown. The range of possibilities for various rupture widths and slip distributions are summarized in Table 1. Other major variables are:

1. Rupture length of 1,050 km, (recurrence of 450 years)

2. Rupture length of 450 km (recurrence 225 years) rupturing[1] :
    a. 44.8° N to southern Vancouver Island, or
    b. 44.8° N to Eureka, California
3. Coseismic slip
    a. With the strike-parallel component of oblique convergence, or
    b. Without the strike-parallel component of oblique convergence.
4. Seaward transition zones in the accretionary wedge achieved by[2]
    a. Linear decreases of coseismic slip
    b. Linear decreases of coseismic uplift from a free slip dislocation model (fault slips with 100 percent slip all the way to the surface).

Combining these variables with those of Table 1, gives a total of 72 scenarios. Given the complexity of the regional fault simulation, additional bottom excitation from submarine landslides, turbidity currents, and secondary faulting are beyond the scope of this study.

Table 1. Rupture scenarios based on lateral position of the locked zone (Scenarios 1 and 2) and slip distribution on the seaward transition zone (Scenarios A, B, and C). All assume strain accumulation at 100 percent of the convergence rate over 450 years and a linear decrease in interseismic slip deficit landward of the locked zone.

Seaward Transition Zone Slip Distribution	SCENARIO 1 Locked and Landward Transition Zone Constrained by Thermal and Geodetic Data[3]	SCENARIO 2 Locked and Landward Transition Zones Constrained by Paleoseismic Data
SCENARIO A 2-5 km width (Linear change in slip deficit)	Scenario 1A	Scenario 2A
SCENARIO B 15-60 km width (Linear change in slip deficit)	Scenario 1B	Scenario 2B
SCENARIO C 15-60 km width (0 slip deficit over all but the landward 2-5 km)	Scenario 1C	Scenario 2C

The purpose of this study is to put limits on the tsunami hazard by examining reasonable rupture scenarios. This purpose may be served without running all 72 dislocation models.

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[1] Note that these two segments combined emulate a 900 km rupture with a seismic:total slip ratio of approximately 0.5.
[2] The method of decreasing deformation across the accretionary wedge is still being formulated. Either one, both, or neither of these techniques may ultimately be utilized.
[3] All models utilize the 350° C and 450° C isotherms of Fleuck (1996) which are very similar to those of Hyndman and Wang (1995).

Examining the above 6 scenarios for a 1,050 km rupture using both seaward transition cases (decreasing slip and decreasing uplift) will help to establish which are likely to generate largest and smallest tsunamis. Subtracting the strike-parallel component of slip from areas of oblique convergence only lowers the vertical deformation in Oregon and northern California by about 13 percent, so this is not a major effect, although it is worth considering in a least-hazard scenario. Likewise, assuming a 450 km segment reduces the total slip by about half (225 year recurrence) relative to a 1,050 km rupture. Combining these decreases in slip and applying them to the largest and smallest tsunami run-up scenarios for Table 1 would explore most of the variation for least-hazard scenarios. Largest and smallest tsunamis are likely to be generated by Scenarios 1A (slip decrease in seaward transition) and 2C (vertical uplift decrease in seaward transition), respectively. Given north and south segment breaks for Scenarios 1A and 2C, an additional four scenarios illustrates the least-hazard variation (Table 2). Table 3 summarizes the main features of all of the scenarios.

Table 2. Least-hazard scenarios for the maximum (Scenario 1A) and minimum (Scenario 2C) hazard scenarios of Table 1. Scenarios combine the effects of decreased slip from (1) segment ruptures (450 km lengths north and south of 44.8° N lat.) and (2) deletion of the strike-parallel component of convergence. All scenarios assume a build up of interseismic strain for 225 years, giving a total slip of about 8-10 m, reducing to 7-9 m in areas of oblique convergence.

Scenario (from Table 1)	North Segment	South Segment
1A (slip decrease in STZ)	1An	1As
2C (uplift decrease in STZ)	2Cn	2Cs

Table 3. Earthquake magnitude parameters for each scenario. Calculations of moment magnitude assume rigidity = 4×10^{11} dyne/cm^2.

Scenario	Rupture Length (km)	Locked Width (km)	Locked Width in Partially Locked zones (km)	Weighted Mean Locked Width (km)	Slip (m)	(M_w)
1A	1,050	35-105	20-58	78	15-20	9.1
1B	1,050	14-43	33-88	64	15-20	9.0
1C	1,050	14-43	20-58	51	15-20	9.0
2A	1,050	60-105	38-58	107	15-20	9.2
2B	1,050	29-50	48-88	92	15-20	9.2
2C	1,050	29-50	38-58	79	15-20	9.1
1An	450	45-105	53-58	103	7-10	8.7
1As	450	39-45	22-25	60	7	8.5
2Cn	450	29-43	38-58	80	7-10	8.7
2Cs	450	43-50	38	77	7	8.6

These scenarios are currently being explored utilizing new fault dislocation software developed by Fleuck (1996) based on the point source solution of Okada (1985). They may or may not be used for final tsunami inundation mapping, pending a review of a preliminary paper outlining the scientific basis for the earthquake sources. The paper is in the final stages of preparation.

AVAILABILITY OF PROCESSED DATA

The chief processed data currently available is regional bathymetry and topography for the Pacific Northwest coast. This data is in general available from public repositories. Requests for information regarding the data assembled for this project or the numerical grids derived from it should be forwarded to António Baptista (address on the cover page of this report).

REFERENCES CITED

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NON-TECHNICAL SUMMARY

MAPPING TSUNAMI INUNDATION HAZARDS AT NEWPORT, OREGON

Tsunami inundation at Newport, Oregon from great (magnitude 8-9) Cascadia subduction zone earthquakes will be mapped by computer techniques and field observations. Much of the project activity over the last few months was aimed at deciding how big scenario earthquakes might be and what sea floor deformation they might cause. The tsunami hazard map will be published by the Oregon Department of Geology and Mineral Industries. It will then be presented to a workshop aimed at education and training of coastal planners and emergency responders. The project will also be summarized in articles for *Oregon Geology* and a peer-reviewed journal.