The First Tsunami Vertical Evacuation Structure in the United States: Ocosta Elementary School, Washington

Abstract

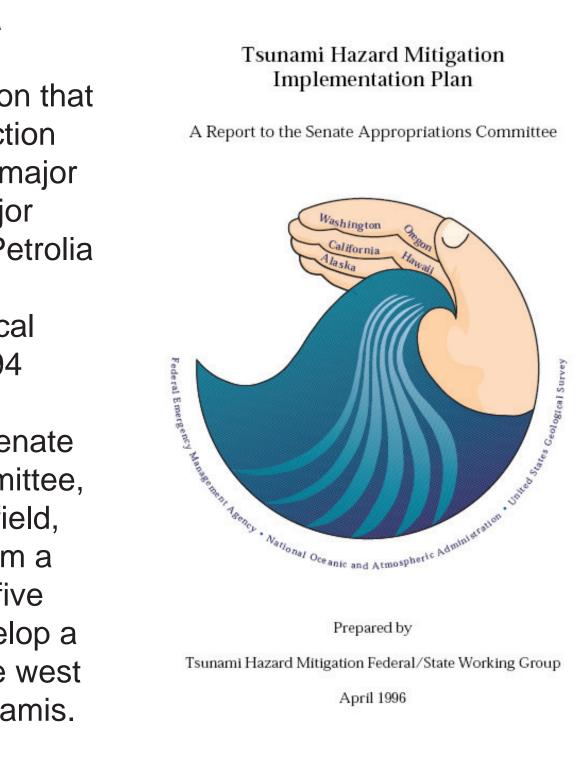
The Washington coast lies adjacent to the Cascadia subduction zone, where a magnitude 9+ earthquake and ensuing tsunami will imperil communities on low-lying spits of the Columbia River littoral cell. Paleoseismic investigations demonstrate that this area has been subject to repeated tsunami attack. Three different numerical models simulating three different earthquake scenarios demonstrate that the communities of Long Beach, Westport and Ocean Shores would

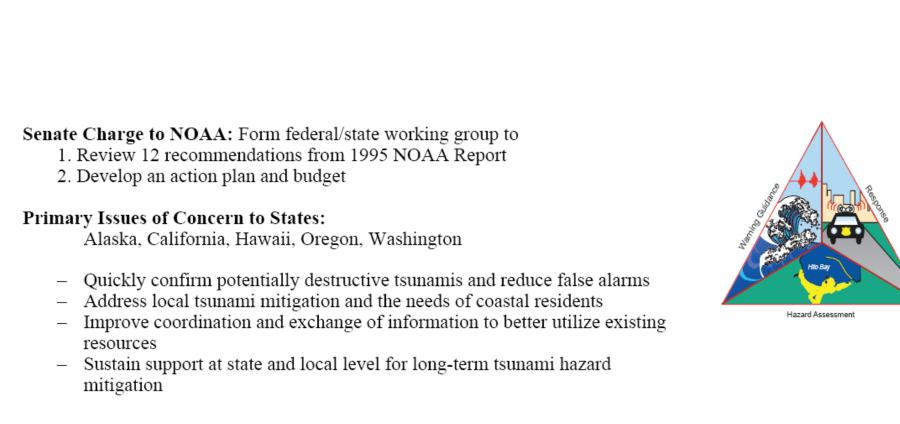
The National Tsunami Hazard Mitigation Program (NTHMP), a federal-state partnership administered by NOAA, sought to address that issue by developing modeling, siting, load calculation, and structural design guidance for structures to both survive a near field earthquake and be tall and robust enough to be used for local evacuation from tsunamis. The result was entitled "Guidelines for Design of Structures for Vertical Evacuation from Tsunamis" (FEMA P646), published jointly by NOAA and FEMA. It was updated in 2012 to incorporate information from the Tohoku tsunami.

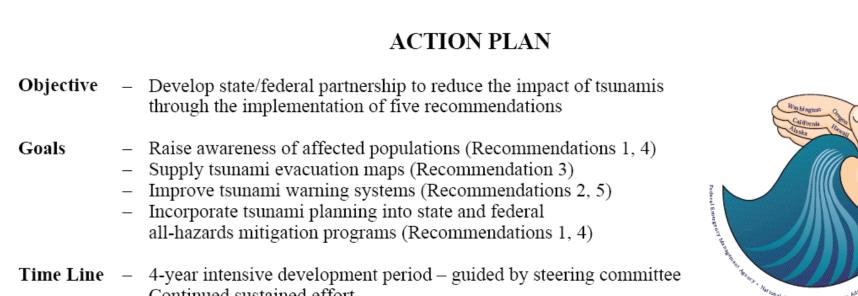
A multi-agency planning team led by University of Washington researchers and graduate students and Washington Emergency Management Division, including Washington Department of Natural Resources, NOAA, FEMA, USGS, county and tribal emergency management officials, created a community-driven process to identify potential sites for vertical evacuation in these at-risk areas.

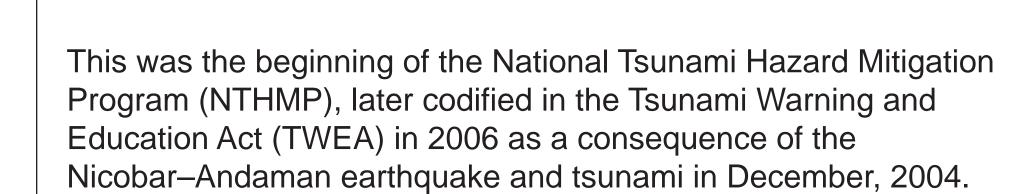
On the Westport peninsula, the principal site identified was the location of Ocosta Elementary School, which is approxi-

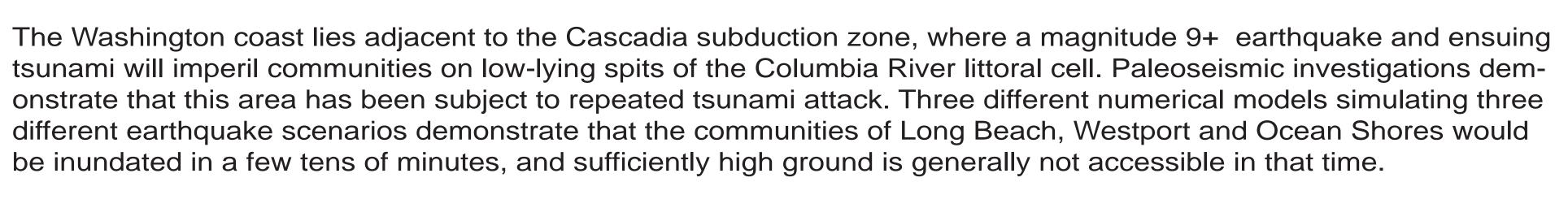
In the early 1990's, a confluence of three events—the realization that the Cascadia subduction zone produced both major earthquakes and major tsunamis; the 1991 Petrolia earthquake, which generated a small local tsunami; and the 1994 Kuril Islands tsunami warning; —led the Senate **Appropriations Committee** chaired by Mark Hatfield, to direct NOAA to form a partnership with the five Pacific states to develop a plan to safeguard the west coast from local tsunamis.





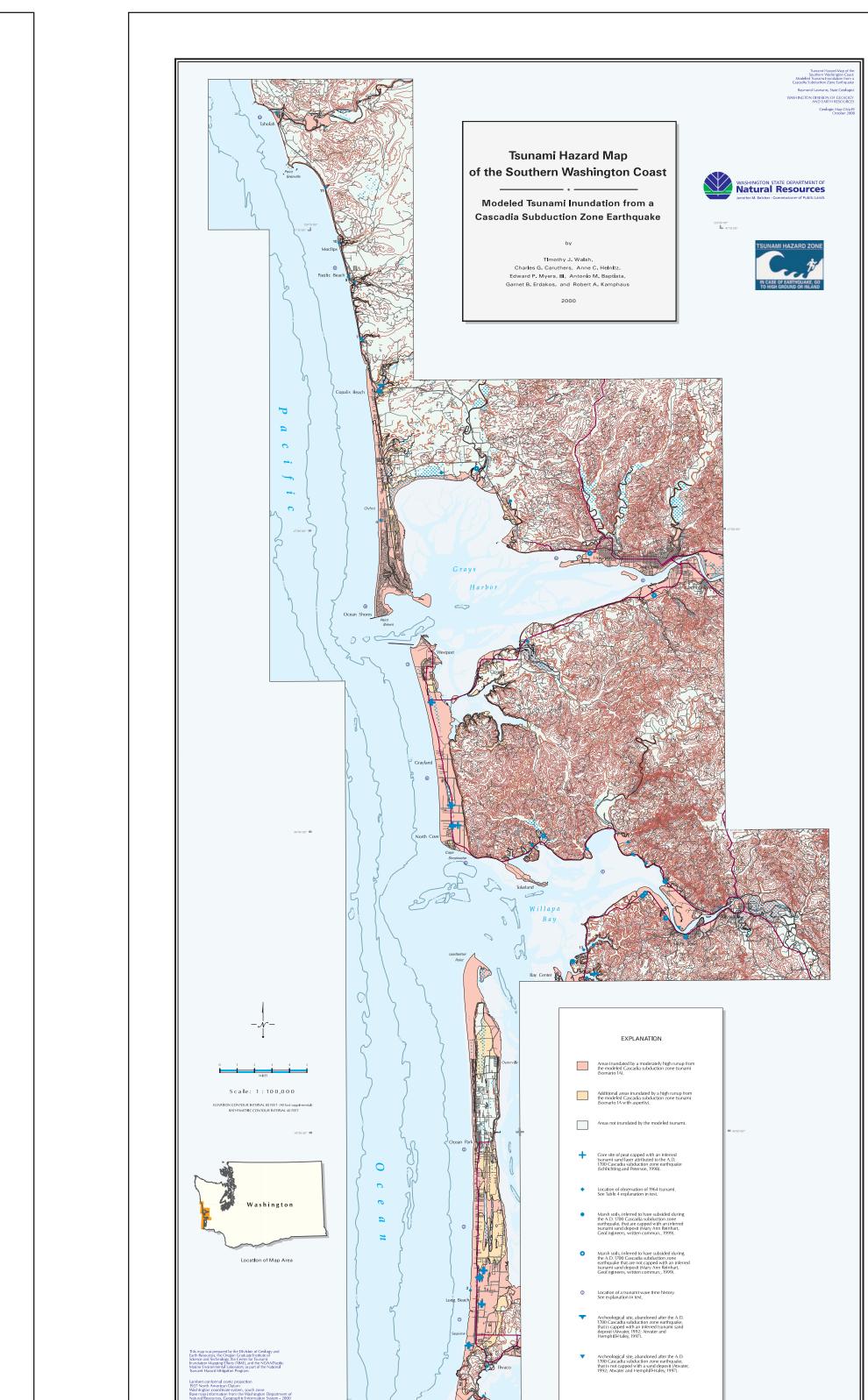


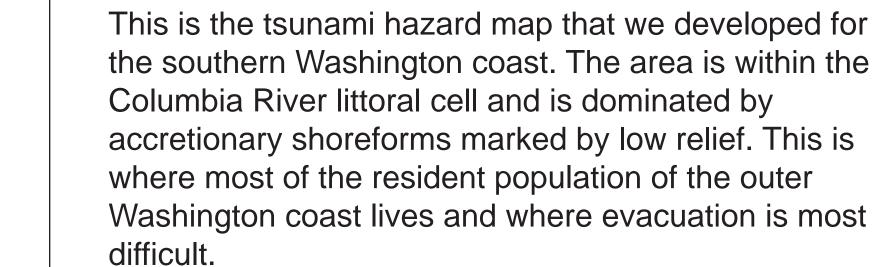


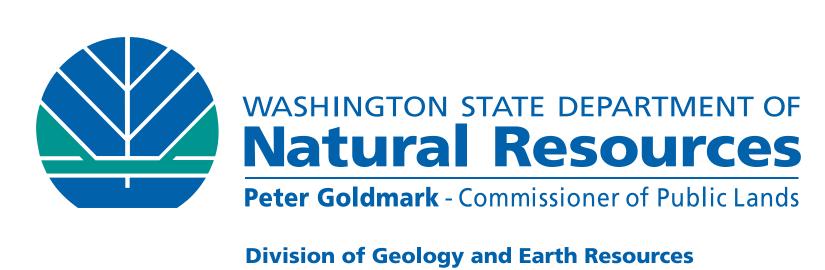


mately at the limit of modeled inundation but also at risk from earthquake-induced ground failure of the adjacent protective ridge. Two previous attempts to pass bond issues to replace the school failed. The current plan to replace the school called for making part of the new school a tsunami vertical evacuation structure that could host as many as a thousand people. This time the bond issue passed...by a 70/30 majority.

The gym is designed to be 30 feet above grade and 55 feet above sea level following earthquake-induced subsidence. Its roof will be accessed from the outside of the four corners and will be capable of holding more than 1,000 people. Ground breaking for the new school is scheduled for fall 2014.







David K. Norman - State Geologist

PROCEEDINGS

of a

WORKSHOP ON CONSTRUCTION GUIDANCE
FOR AREAS OF HIGH SEISMIC AND TSUNAMI LOADING

convened by
TIMOTHY J. WALSH¹, GEORGE CRAWFORD², RICHARD EISNER³,
AND JANE V. PREUSS⁴

GEOENGINEERS

On November 21, 2002, George Crawford, Rich

workshop to investigate whether it was feasible

attractive for an evacuation refuge, and also be

high and resilient enough to serve as a shelter

to design facilities to withstand a nearfield M9

earthquake, suffer so little damage as to be

Guidelines for Design

FEMA P646 / June 2008

of Structures for Vertical

Evacuation from Tsunamis

We then formed a partnership with FEMA and

facilities to withstand a magnitude 9 earthquake

demonstrated by the Tohoku tsunami, planning

the Applied Technology Council to provide

building code style guidance for building

and be suitable for vertical evacuation. As

for the right size earthquake is critical.

for people in the near-field.

Eisner, Jane Preuss, and Tim Walsh held a

Timothy J. Walsh, Washington Department of Natural Resources John D. Schelling, Washington Emergency Management Division Cale R. Ash, Degenkolb Engineers

Randall J. LeVeque, University of Washington, Applied Mathematics Loyce M. Adams, University of Washington, Applied Mathematics Frank I. Gonzales, University of Washington, Department of Earth and Space Sciences



WASHINGTON STATE DEPARTMENT OF Natural Resources

Doug Sutherland - Commissioner of Public Lands

We contracted with Harry Yeh and Ian

the basis of guidelines for structures in

vertical evacuation facilities.

tsunami inundation zones to be used as

Vertical Evacuation from

Tsunamis: A Guide for

Community Officials

his was accompnied by a guide for

community officials to initiate a planning

process for vertical evacuation structures

FEMA P646A / June 2009

Robertson to investigate tsunami damage in

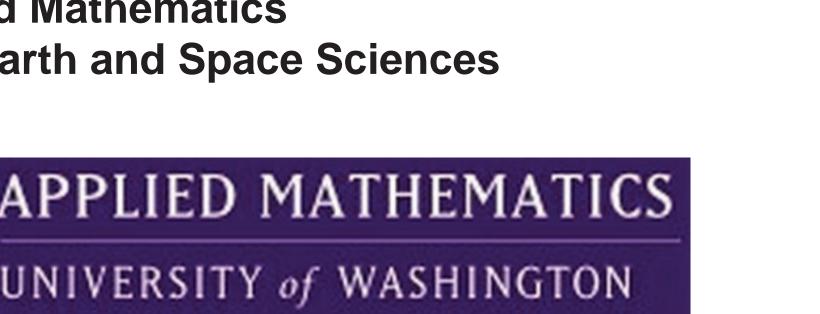
which some buildings survived where nearly

everything was destroyed. They estimated the

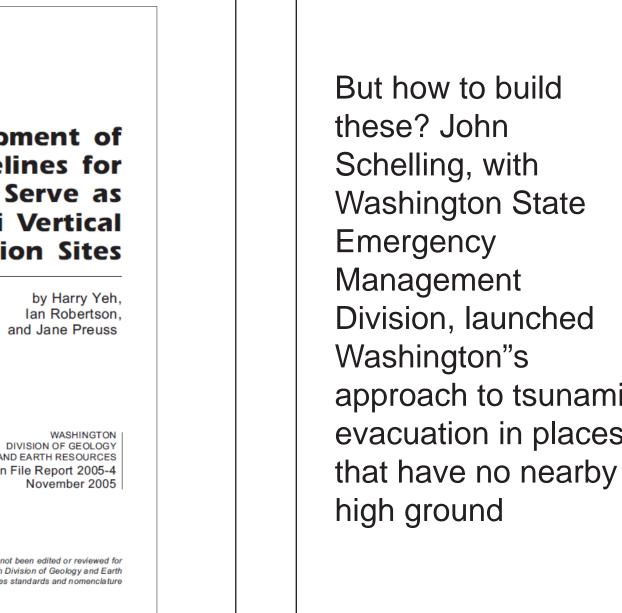
forces on the buildings and the features of the

survivors that led to their survival. This formed







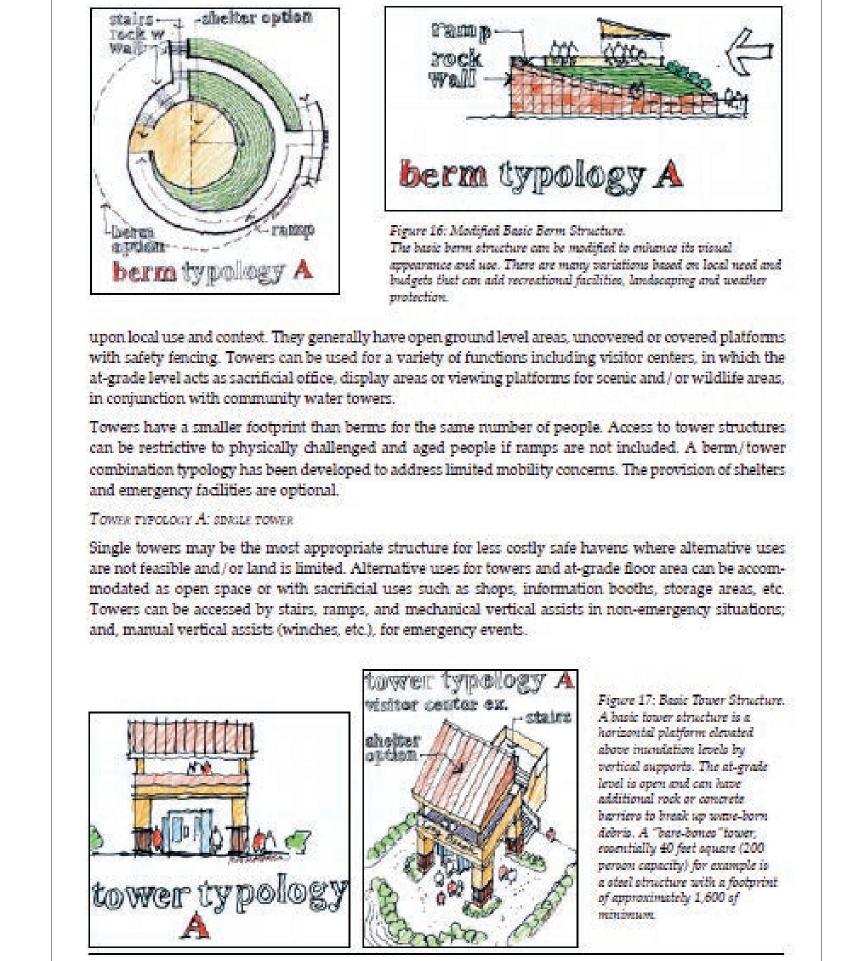




Project Safe Haven: Vertical Evacuation on the Washington Coast Grays Harbor County, Washington







After selecting areas for vertical evacuation, Ron Kasprisin (UW) and students led citizens through conceptual designs of vertical evacuation structures that fit into the communities.

Safe Haven Options (from FEMA 646):

Limited Space Blocks Views

May be Placed to Limit View





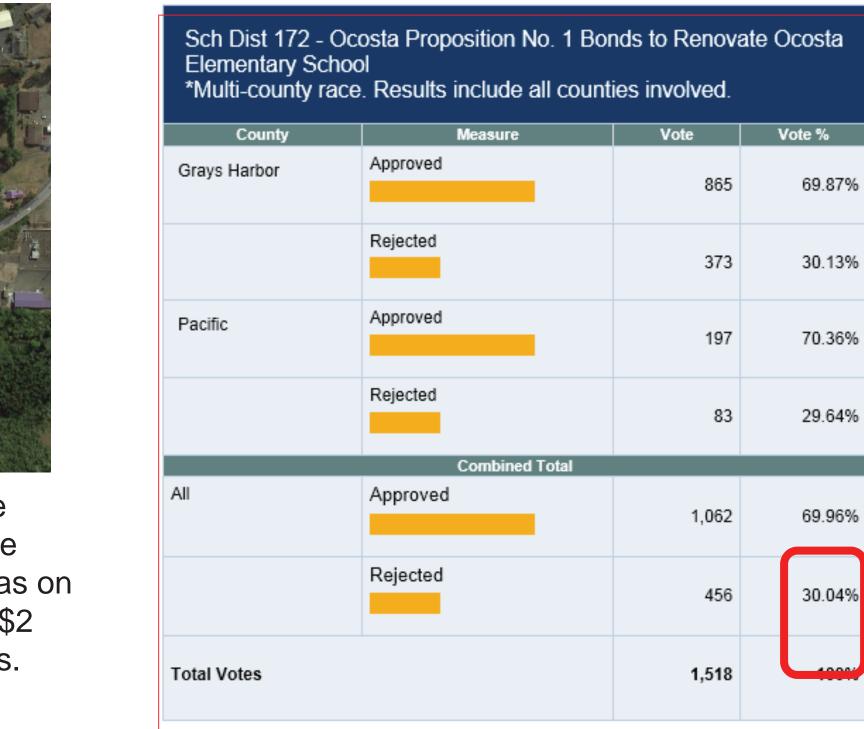
We started by developing walking circles that illustrated how far pedestrians could travel in 20 minutes. This established logical places for vertical evacuation structures to maximize the number of people who could evacuate from an impending tsunami

Many people have contributed to all of the efforts documented here. The NTHMP would never have been Wallace of Grays Harbor County has been a continuing source of encouragement, and Paula Akerlund. established without the tireless efforts of Eddie Bernard, recently retired from NOAA. Tsunami inundation superintendent of the Ocosta Shool District, persevered after 2 levy failures to promote this effort and to modeling was also performed in this area by Ed Myers and Antonio Batista at the Oregon Health Sciences convince the voters or her school district to support it. And of course, thanks to the voters of the Ocosta University and by Vasily Titov and colleagues at NOAA's Pacific Marine Environmental Laboratory. Charles School district for their courageous and farsighted vote.

A consistent theme in the Safe Haven process was protecting children by placing vertical evacuation refuges at or near schools. Near Westport, a logical place to build safe haven is at the site of Ocosta Elementary School.



Ocosta Elementary School is an old school that the district has tried twice to replace, but the bond issue failed twice. In April of 2013, another bond issue was on the ballot to replace the school, this time including \$2 million for a wing to be built to FEMA 646 standards

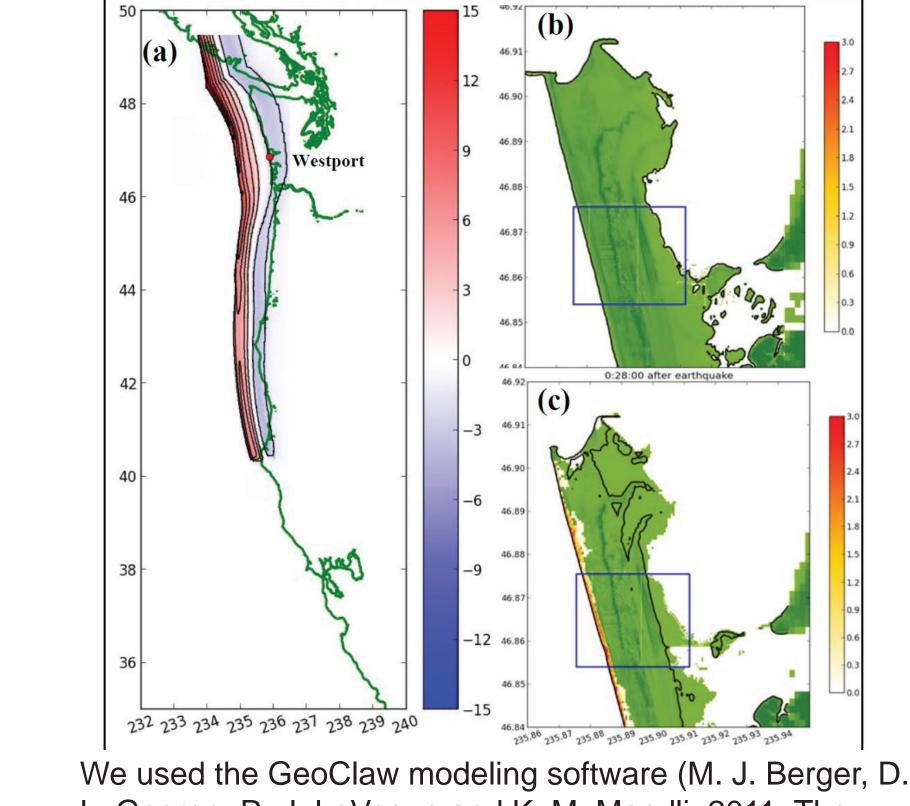


Tsunami Hazard Assessment of the Ocosta School Site in Westport, WA Final Report: September 11, 2013 Supersedes February 24, 2013 Report Frank González, Randy LeVeque and Loyce Adams

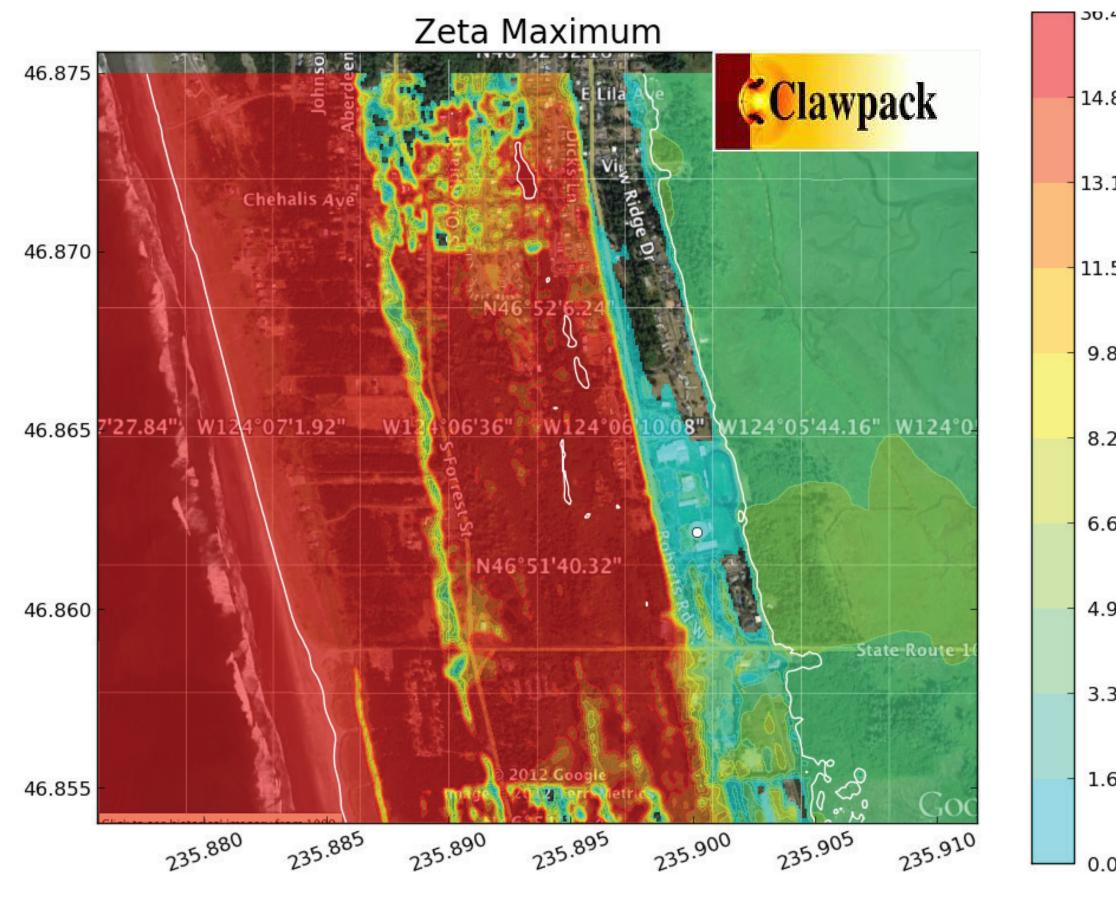
University of Washington



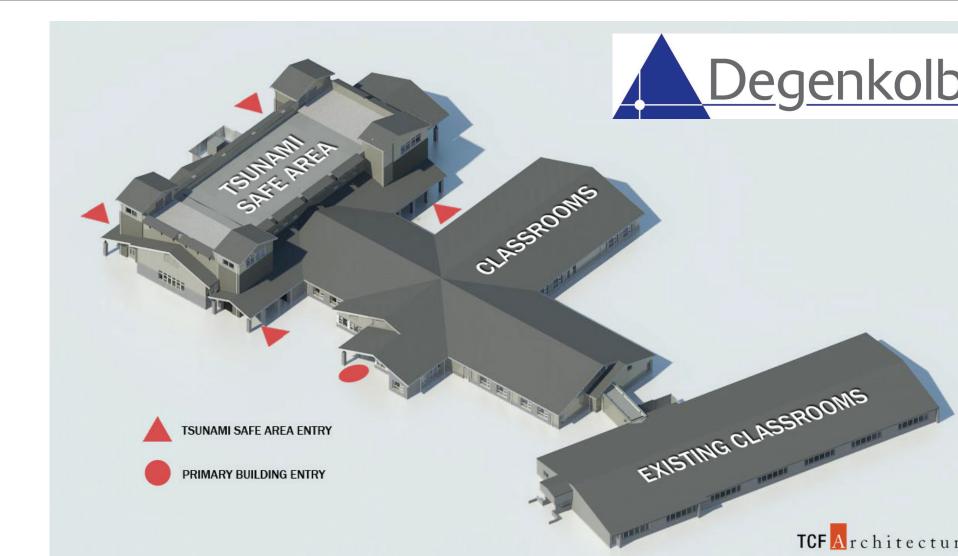
Westport, WA, Google Earth image. Blue rectangle is area of fine resolution GeoClaw tsunami model grid; white circle encompasses Ocosta School campus. Study funded by Washington State Emergency Management Division The next step was to do high-resolution tsunami inundation modeling to define the required height of the structure and to estimate the loads the structure would be designed to resist.



L. George, R. J. LeVeque and K. M. Mandli, 2011, The GeoClaw software for depth-averaged flows with adaptive refinement, Advances in Water Resources 34, pp. 1195-1206) which has been validated for use by the NTHMP. We modeled an M9 Cascadia earthquake estimated to have approximately a 2,500 year recurrence interval, designated L1 by R. C. Witter, Yinglong Zhang, Kelin Wang, G. R. Priest, Chris Goldfinger, L. L. Stimely, J T. English, and P. A. Ferro, 2011, Simulating tsunami hypothetical Cascadia and Alaska earthquake scenarios, Oregon DOGAMI Special Paper 43, 53 p.

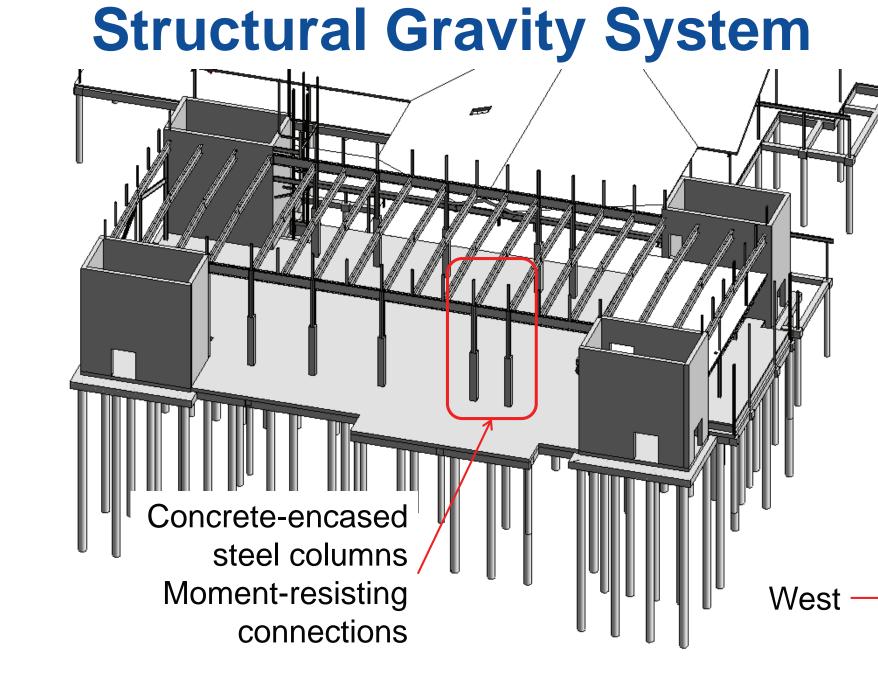


The modeling incorporated anticipated coseismic subsidence as part of the initiial condition. We also artificially reduced the height of topography to approximate coseismic landsliding, based on the findings of S. L. Slaughter, T. J. Walsh, Anton Ypma, and Recep Cakir, 2014, Landslide and liquefaction maps for the Ocean Shores and Westport peninsulas, Grays Harbor County, Washington: effects on tsunami inundation zones of a Cascadia subduction zone earthquake: Washington Division of Geology and Earth Resources Report of Investigations 38,



Degenkolb Engineers was retained to design the structural system for the elementary school. The inundation modeling combined with design guidelines resulted in a refuge which is 55 feet above sea level and 28 feet above grade. The roof of the school gymnasium will be the designated safe refuge and it has a capacity for over 1,000 people. Access to the roof is by stair towers at the corners of the gym, which are reached from the outside only, so that people do not have to enter the building and 24/7 access is maintained.

Structural Lateral System 14" concrete shear / walls w/ relief opening



The details of the structural system are shown above. The gym will be pile-supported, with concrete shear walls and and columns with moment resisting connections. This design resists the maximum considered hydrostatic, hydrodynamic, and impact loads and to guard against progressive collapse.