TsuInfo Alert

prepared on behalf of the

National Tsunami Hazard Mitigation Program

by the Washington Department of Natural Resources

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Contents

Summary Report of the Tsunami Hazard Mitigation Steering Group Meeting

April 27-30 1999, Arcata, California

Attendees

Steering Group

Eddie Bernard - NOAA
Richard Eisner - State of California
Robert Kamphaus - NOAA
Lori Dengler - State of California
Richard Hagemeyer - NOAA
Brian Yanagi - State of Hawaii
Chris Jonientz-Trisler - FEMA
Augustine Furumoto - State of Hawaii
David Oppenheimer - USGS
George Crawford - State of Washington
Roger Hansen - State of Alaska
Timothy Walsh - State of Washington
Gary Brown - State of Alaska

Guests

Dr. Alistair McCrone, President, HSU
Jeanette Mullin - FEMA
Mike Shore - FEMA
John Lovegrove - NWS
Mike Mahoney - FEMA
Costas Synolakis - USC
Robert Olson, President, Robert Olson Associates, Inc.

Field Trip to Study Tsunami Hazard Mitigation Issues in the Humboldt Bay Region

The field trip (May 27, 3:30 to 6:30 p.m.) focused on the Humboldt Bay Region, population about 75,000. This area is featured in the CDMG planning scenario which describes, in a general way, the ground shaking effects, tsunami inundation (from NOAA modeling), and the effect on infrastructure of a Cascadia earthquake. The entire Humboldt Bay region sits about 8 miles above the Cascadia megathrust. Stops on the field trip included: (1) Mad River Slough---the edge of the mapped tsunami inundation zone and also one of Gary Carver's paleoseismology sites. One of the two primary water supply lines to Eureka crosses the slough in this area. The slough is a saltwater marsh which shows repeat submergence events tied to movements on the Little Salmon fault. This is a different source of submergence that may not be familiar. From mid-Oregon north, the elastic relaxation caused by the primary fault slip is expected to cause submergence--similar to what was seen in Alaska and Chile. In northern California, our coast is expected to go up due to the primary rebound because we are so close to the subduction zone margin. However, life at the edge is more complicated. There are numerous secondary folds and faults exposed near the coast which make up the Cascadia fold and thrust belt. The best studied of these is the Little Salmon fault which apparently slips in sympathy with each megathrust event. Little Salmon slip causes a deepening of the syncline which runs under Humboldt Bay, causing repeat submergence events. (2) Manilla Community Center, Samoa Peninsula. This is an example of the high dune region on the northern part of the Samoa Peninsula within the mapped inundation zone. (3) LP pulp mill, Samoa Peninsula. The central, industrialized core of the peninsula where the peninsula is less than 3000 feet in width and elevations average about 10-20 feet. Winter storm waves typically cover this part of the spit a few times a year. (4) Bayshore Mall, Eureka. The major commercial district in Eureka sits adjacent to the tank farms and at the narrowest part of Humboldt Bay. The local Fire

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Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands

Chief, heads of PG&E, and the head of the Humboldt Bay Municipal Water District were invited to address the group.

Overview

Dr. Alistair McCrone, President of Humboldt State University (HSU) presented the introductory remarks and welcome. Dr. Bernard presented him with a National Tsunami Hazard Mitigation Program mug.

Richard Eisner acknowledged Dr. McCrone's leadership and support of the seismic and tsunami programs. HSU has just dedicated its Emergency Operations Center and instituted a new course on the curriculum that will use the new room in course work exercises.

Papua New Guinea (PNG) Aftermath

Lori Dengler and Jane Preuss spent 10 days in PNG surveying the aftermath of the PNG tsunami. There is still much confusion on the exact cause of the PNG tsunami, however, it now appears that a slump may have enhanced the tsunami. The timing of the earthquake and tsunami coincided with the beginning of a 4-day holiday so people were at home in the villages on this Friday evening getting ready for the holiday. The location of the villages on a long, narrow, flat spit between the ocean and the lagoon further exacerbated the impact. Some important points were learned from the survey: (1) Oral tradition is an important mitigation tool, (2) 24-hour emergency relief is essential, and (3) inadequate assessment of damage slows response.

Review of action items from the previous meeting

The cataloging of the library at the International Tsunami Information Center (ITIC) is in progress. *Ongoing Action:* Mike Blackford.

Historical Tsunami Database for the U.S. Pacific Coast (HTDB/US)

Work on the development of the HTDB/US continues. A number of new things have been added which will be demonstrated later. The program will be introduced to the county level emergency managers at a meeting scheduled for Seattle on May 20. OPEN: Richard Hagemeyer

Enhanced web page presentation of the mitigation subcommittee report

Preparation of the Status Report for publication has taken precedence over web page enhancement discussions. As soon as the Status Report is published, work will begin on the web page. Copies of the draft Status Report were distributed at the April meeting for Review. *Open Action:* Chris Jonientz-Trisler.

Local Warning Subcommittee progress report

The contract for the warning system guidance document has been awarded to Robert Olson Associates, Inc., and they have started work (created list of contacts, developed questionnaire) and will be in contact with the subcommittee members for input. Robert Olson attended this meeting and presented a progress Summary. *Open Action:* Mark Darienzo/Local Warning Subcommittee

PAWG Project to prepare video for anniversary of 1964 Alaska earthquake/tsunami and update press kits

Funding was not received in time to produce the video as planned, however, a media advisory was issued nationally about the anniversary of the 1964 Alaska earthquake/tsunami. Local and regional press picked up the story but no national coverage was done. NOAA Tsunami Press kits have been updated at OAR Public Affairs. *Closed*.

Issues raised concerning Jim Lander's Tsunami Forecast for the Next 100 Years article in *Time* magazine.

Eddie Bernard spoke with David Berkely of *Time* magazine who reported that the tsunami story was condensed to one chart and appeared only in the international edition of *Time*. The editor basically turned down the story. He will visit our web page and try to increase the interest of his editor for a future story. *Closed*.

Develop State/NOAA Coordination and Technical Support

Richard Hagemeyer demonstrated the Historical Tsunami Database. This version will be demonstrated at the May 20 Emergency Managers' Meeting in Seattle, Washington. The Windows version of the program should be available soon and will be added to the NWS Pacific Region FTP site as soon as testing is completed. TSUHAZ will be notified when it is available on the FTP site. The list of WCMs and CCEMs has been updated and the use of EMWIN continues to expand.

Deploy Tsunami Detection Buoy

Eddie Bernard reported on the status of the tsunami detection buoy program. The September buoy deployment operated for 86 days with 96.3% data return but was vandalized on Christmas day. Engineering modifications have been made as a result of the test and we plan to deploy a buoy in Monterey Bay, California, for a six-month test in May 1999. Data from the Monterey buoy will be posted on the real-time web site. We plan to deploy 4 systems--2 in Alaska and 2 off the West Coast of the U.S. in September/October 1999.

Produce Inundation Maps

Lieutenant Robert Kamphaus gave a report on inundation mapping for Oregon, Alaska, California, and Washington . Mapping for Newport and Seaside, Oregon, have been completed. Maps in progress for Oregon include Gold Beach, Warrington-Astoria, and Coos Bay. Willapa Bay/Long Beach, Washington, maps are complete. Washington maps in progress include Gray's Harbor and Port Angeles/Port Townsend. California maps in progress include the San

Francisco area, the Santa Barbara area, and the San Diego area. For Alaska, the Kodiak area mapping is in progress. For Hawaii, the Request for Proposals is on the street.

Develop Hazard Mitigation Programs

Chris Jonientz-Trisler presented the mitigation report. Each state gave a brief report on their activities. The 1998 Annual Mitigation Subcommittee Report draft was given to Steering Committee members for review. Chris Jonientz-Trisler asked that respondents e-mail comments to her prior to publication. It is attractive, explains the program, and shows successes. Its target audience would be interested communities and Congressional members/staffers. The matrix will be incorporated into the annual report as well as descriptions of the multi-state projects with color photographs and graphics. The goal is to highlight projects per state and how they are tied to the Mitigation Strategic Plan.

The Mitigation subcommittee determined that there are two gaps in mitigation efforts that need to be addressed: (1) dealing with loss estimations and (2) incorporating tsunami into all-hazard planning. Project Impact (FEMA) can be valuable as an interagency coordination tool for direct pass-through to communities.

In Washington state, NOAA Weather Radio has been expanded through coordination among the National Weather Service, Emergency Management Division, coastal counties, the coastal Native American tribes and U.S. Navy. When the expansion is operational in August 1999, NOAA Weather Radio will be available to the entire Washington coast. Washington will also be printing brochures with evacuation maps and putting evacuation maps and procedures into the local telephone directories and other local media. The National Tsunami Hazard Mitigation Program *TsuInfo Alert* newsletter has been in publication since the first of the year and has proved to be a very useful tool. The possibility of putting the newsletter on the web was discussed. Copies of Brian Atwater's booklet, *Tsunami Survival* will be available from George Crawford when published. The Cascadia Regional Earthquake Working Group (CREW) will be sponsoring forums in Oregon and Washington communities to bring local emergency managers and businesses together to partner against hazards that exist in the community.

Brian Yanagi showed a video prepared by a Hawaiian television station for Tsunami Awareness Month (April). Historic footage was furnished by the Pacific Tsunami Museum and there were many interviews with survivors of the 1946 and 1964 tsunamis in Hawaii.

Richard Eisner reported that the State of California is preparing a Local Planning Guide on Tsunami Response that will become an official California document. The Request for Proposal guidance on land use planning is being reviewed and the selection of a contractor is due in the next two weeks.

In Alaska, a contractor has been identified to make tsunami evacuation signs for Sitka, Alaska. The next three communities to receive signage should be identified soon. The DOGAMI pamphlets have been distributed to many Alaskan communities. Gary Brown has given several tsunami preparedness presentations at the local level. Alaska will continue to develop community database information.

States discussed the future of models and mapping. Suggestions for gathering mapping information included one on working with the Department of Defense and possibly getting a pilotless drone to get real-time coastal photos for mapping and modeling purposes.

The Local Warning Subcommittee has hired a private contractor, Robert Olson Associates, Inc., to gather data and develop a document for everyone's use based on the statement of work. Mr. Olson gave copies of the questionnaire he has prepared for this project as well as a copy of the project planning guide. The Project Objective is to provide guidance to local and state governments in five states that can be used to improve or develop new public tsunami warning systems, procedures, and methods. Mr. Olson also want to develop a performance standard for the project by determining the ideal desired behavior under both local and distant tsunami warnings. Key issues that need to be addressed are (1) who is responsible for establishing and maintaining systems and issuing warnings? and (2) What is the information path from the states to the local communities and the timing of information transmission will be studied?

Improve Seismic Networks

David Oppenheimer reported the USGS. has completed the installation of the CREST communications and computing system at the Pacific Tsunami Warning Center(PTWC). Another CREST communications and computing system has been installed at the Hawaii Volcano Observatory with data transmitted continuously to the PTWC via the Internet. The CREST network is basically completed, however, installation of upgraded stations has been slow due to equipment delivery problems and software interface problems. Another 16 stations should be in place by this fall. Equipment has been purchased for 37 sites. A station will be installed at Newport, Oregon. The National Earthquake Hazard Reduction Program has been reauthorized. A Seismic Detection Working Group was formed to explore the use of strong motion data for quick detection of location and dissemination of small earthquakes. The Working Group consists of D. Oppenheimer, R. Hansen, R. Hagemeyer, and L. Dengler.

Public Affairs Working Group Report

Ann Thomason presented the Public Affairs Working Group (PAWG) Report. All states have been active in outreach activities. The National Weather Service issued a media advisory to national press regarding the 35th anniversary of the 1964 earthquake and tsunami. The media advisory generated local media coverage in Alaska and Washington. A media advisory to national press on this Steering Group meeting was picked up by the Associated Press and resulted in interviews of L. Dengler and E. Bernard by two Eureka television stations: KIEM (NBC) and KVIQ (CBS), and by the local *Times-Standard* newspaper. A discussion ensued on two items the Steering Group would like to see produced by the Public Affairs Working Group. (1) the need for a more organized access to tsunami videos. The PAWG is to work up a budget for this and present it at the next meeting. (2) A generic media kit that local areas can take and localize by adding their materials to the generic kit. A draft generic media kit is to be presented at the next Steering Group meeting in October. *Action*: PAWG

Local Tsunami Warning Systems

Mark Darienzo joined the group by telephone from his office in Oregon. The Local Tsunami Warning Systems Subcommittee has let the contract for the warning system guidance document to Robert Olson Associates, Inc. Mr. Olson presented a brief overview of the status of this project. The project objective is to develop a document primarily for use by local and five state governments to improve or develop new, locally-activated, consistent public tsunami warning systems, procedures, and methods. A Data Collection Guide has been prepared and sent to government officials in the five states. When completed Data Collection Guides are returned and collated, a final report will be prepared for presentation to the Steering Group. *Action***:** Robert Olson and Associates

Discussion of FY 2000 Plans

Because of financial adjustments in years 2 and 3 of the program and the dates funds are received and actually used, it was decided that a self-evaluation of the program should not be done until the end of year 5. It was also suggested that due to the group's extended knowledge, the Implementation Plan should be amended to use a 2-year time horizon vs. a 1-year time horizon. E. Bernard will contact each Steering Group member to better assess where we are as a group financially (spending patterns) and determine our actions over the next 6 months. He will present the status and bring ideas for the future to the October Steering Group meeting. *Action:* Bernard

Future Initiatives beyond FY 2000

Establishment of a broad band seismological network for WC/ATWC and PTWC -- Hagemeyer --Mr. Hagemeyer put forward this initiative to add backup redundancy to the routes for data reception for the two tsunami warning centers. Initially this backup system would work between the two warning centers and be the first step in a Pan-Pacific network. Mr. Hagemeyer requested $70K from the seismic budget for two stations. He said recurring costs would be handled from the NWS budget. After much discussion, it was requested that Mr. Hagemeyer consult with satellite experts on the his PSAT data transmission needs to be sure there is sufficient capacity. He will bring the results of his inquiries to the October meeting for discussion. Funds were approved for later years. *Action***:** Hagemeyer

New Data Initiative-- Kamphaus --Lt Kamphaus presented an initiative to promote the generation of high quality digital bathymetry and topography data for future inundation studies. There is a definitive need for more and better available data (digital) in order to produce models and inundation maps. He requested $50K for the first year (FY 2000) to participate in cooperative efforts with other agencies; $25K to the National Geological Data Center to support prioritized digitization of data for Alaska and $25K for additional projects and to attract matching funds. Some possible additional projects could be to expand the ALACE flight paths, do add-on multibeam surveys, or digitize county topographical maps. There are no funds left for this fiscal year but we might try one project as there is no manpower for more. Lt Kamphaus will contact NGDC to see if digitizing priorities can be rearranged to move Alaska forward. *Action*: Lt Kamphaus

Other Business

Each member of the Hazard Mitigation Subcommittee was tasked to provide a distribution list of interested state and local government officials for distribution of the *Tsu-Info Alert* Newsletter. *Action*: Hazard Mitigation Subcommittee Members

Copies of any letters of support generated by states for the FY 2000 budget need to be faxed to E. Bernard by next week. *Action*: All

E. Bernard suggested that he would submit the Steering Group for a Western States Seismic Policy Council award. *Action*: Bernard

On behalf of the Steering Group, L. Dengler extended her thanks to Jim Hulsebus, Program Manager for the Humboldt State Emergency Operations Center (EOC), for supporting us by allowing us to meet in the newly dedicated EOC. He was presented with a National Tsunami Hazard Mitigation mug.

Next Meeting Date and Location: October 4-8, in Newport, Oregon.

May 30 Field Trip to Crescent City to examine paleotsunami deposits.

Stops include: (1) Redwood Park Information Center, Orick. The current Information Center sits at the mouth of Redwood Creek. Carver has mapped tsunami deposits at the site of the Yurok village of Orik. There is a wealth of oral history connected to this site. Tserkr told a story to Kroeber in the late 1800s about an earthquake and "flood" which inundated a house site mapped at 70 feet above the current sea level. Two other oral history sources give similar water marks on the opposite side of the valley. This is arguably the best site anywhere in Cascadia which ties native stories to a specific paleotsunami deposits. The area is also the part of a current controversy about camping on the Freshwater spit and the location of the Information Center. (2) Lagoon Creek, near "Trees of Mystery." This is a mile-long fresh water pond extensively studied by two of Gary's graduate students. Twenty-seven vibracores were recovered from the lagoon and detailed sedimentology and diatom studies conducted. It is an amazing story. The lagoon was not flooded by the 1964 tsunami but has been repeatedly breached in the past 2500 years. (3) Crescent Beach Motel marsh. A series of fresh water marshes occupy both the west and east sides of Highway 101. The westernmost ponds were inundated both in 1960 and 1964. Gary poked a number of cores extending inland nearly 1 km. from the coast. The historic tsunami deposits are thin and die out very quickly east of the highway. Two paleotsunami deposits are preserved--the earlier event (1100 ybp?) is so robust that it apparently obliterated the stratigraphy beneath it. (4) Downtown Crescent City. The group walked the inundation zone of 1964 and talked to survivors and emergency management officials. The first evacuation route signs in California went up about a month ago!

Coastal Earthquake Effects: Tsunamis

by
Jane Preuss,
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Overview of Issues

Coastal effects from earthquakes have been defined for this paper as tsunamis and loss of ground support, generally attributable to liquefaction. In addition, earthquakes frequently result in landslides. If the landslide is submarine it can in turn generate a tsunami. Thus, the generating mechanism of the various phenomena are inextricably interrelated and it is often impossible to differentiate them. Structure can first be destabilized through liquefaction, and subsequently be destroyed by the effects of the tsunami (which in many cases can be quite small). An apt example of this interaction occurred after the Loma Prieta earthquake when a highly focused tsunami destroyed the Moss Landing oceanographic research institute building. The remainder of this paper will focus on tsunamis because they are highly interactive, and because mitigation of projected effects from tsunamis must be based on an inclusive frame of reference, i.e. loss of ground support, as well as potential for debris impacts, and fire.

A tsunami is a potentially destructive wave that is generated by a local or distant source earthquake. Tsunamis occur infrequently, but when they do occur the impacts are devastating because the strength of the wave is not in the ocean *but* rather when it hits the beach. It should be noted that water has approximately 1,000 times the density of air (wind).

Since 1983 there have been 10 damaging tsunamis, and in the four years between 1995 and 1998 over 4,000 people have been killed by tsunamis. In addition thousands of homes and businesses have been lost through the direct wave impacts and indirect effects such as fire.

Although recent major tsunamis have all occurred outside of the U.S. the conditions leading to life loss and destruction are comparable to conditions in the U.S. For example it is reported that the immediate cause of the Papua New Guinea event which killed an estimated 2,200 people was an underwater landslide generated by a magnitude 7 earthquake. Such conditions were present in Alaska in 1964 and resulted in destruction of the Seward waterfront. Vulnerability to landslide induced tsunamis from a Cascadia subduction earthquake also constitutes a significant source of risk for Washington, Oregon and the Northern California coastal regions.

Among the factors leading to their destructiveness is the interactive nature of tsunamis. Critical interactive issues include fire, access disruption, and debris (generation of debris and impacts of debris onto houses, tank, electrical facilities, etc.). Debris is defined as floating objects such as vehicles, boulders, trees and dislodged structures. The 1994 tsunami which struck southwest Hokkaido and Okushiri Island, Japan resulted in destruction of approximately 500

[PHOTO]

Debris impacts and fire were major sources of loss in Okushiri, Japan

[PHOTO]

Structures were damaged by waves and also by impacts from dislodged structures

[FIGURE]

Source: URR - *Local Effects of Tsunamis*
Figure 1: Structures on piers have a high potentiality to become debris especially if liquefaction occurs. Cars also have a high likelihood of becoming debris. Power will be disrupted.

homes and businesses, from fire and debris as well as direct impacts of the waves. The impacts of these recent events are comparable to the causes of destruction in Seward, Valdez and Whittier, Alaska as well as Crescent City, California, after the tsunamis generated by the 1964 earthquake.

Vulnerability Assessment

It is well known that the tsunami hazard does not result in a single risk factor to all vulnerable communities. Furthermore, the effects for any tsunami event vary throughout the community. Responsive plans must, therefore, integrate a high level of uncertainty with regard to time and characteristics of the event with a relatively high level of precision with regard to causes of damage. The first step in development of a mitigation strategy is to conduct an assessment to define direct and indirect vulnerabilities. Key vulnerability issues are based on three criteria which present the most significant risks: a) potentiality for significant damage, b) high disruption and/or, c) potentiality for interactive and collateral damage.

Direct Impacts

An initial land use inventory will reveal characteristics of uses/occupancies and buildings in the inundation zone which communities can use to define primary risks. They also identify uses and building conditions which can cause problems (become debris) for nearby structures. All land uses within a projected inundation zone are subject to direct impacts of the earthquake including ground motion, which frequently is amplified in the saturated soils which frequently characterize the coastal area. Such soils are prone to liquefaction, which can lead to structural failure, making such structures even more vulnerable to the tsunami.

The land use inventory will also reveal related safety issues such as difficult or non-existent pedestrian evacuation routes and problematic access for search and rescue or fire response after the event.

Lifeline Issues

Vulnerability of lifelines must also be assessed in light of land use configurations which include pedestrian as well as vehicular access; pedestrian access is particularly important for evacuation from locally generated events. Disrupted roadways will hamper search and rescue as well as fire suppression.

Highway 101, the north south coastal highway provides the only continuous access along the coast. Maintenance and upgrade priorities are determined by the states, all of which have conducted seismic analysis for the bridges, however retrofit priorities tend to be correlated with population which means that coastal routes are comparatively low. In many areas routes will be disrupted simply by debris on the roadway and/or landslides - and not necessarily by structural failures. Finally it is essential to plan for the probable disruption of water (transmission and storage disruption) as well as interruption of power.

Fire and Debris Issues

Tanks and various types of fuel storage are frequent uses in coastal communities. They are exposed to high velocity and pressure effects from tsunamis and generally are in close proximity to wood structures, as such they are prime fire hazards.

[PHOTO] [PHOTO]

Structures on the right will in all likelihood become debris impacting structures on the left. The roadway will become impassable.

Fueling depots served by underground tank (on shore) with connecting piping are common along the entire coast.

[FIGURE]

Source: URR - *Local Effects of Tsunamis*

Figure 2: A large natural gas storage tank located on a manmade spit. Inland portions of the spit are used for log storage. There is one access route into the site. The tank consists of two structures; an outside shell separated by a 6' space with another tank inside. Code standards regulate the thickness of the exterior and interior tanks. In addition the retainage (spill) is 1.5% of capacity.

Interviews with local officials indicates that any vulnerability assessment should analyze tanks from two aspects. One category pertains to standards: design standards under which a tank was constructed, *and* standards to which it is maintained. The other pertains to preparedness. The most critical preparedness issue is vapor release and the resulting need for evacuation; thus vapor is of higher concern than immediate conflagration. Other preparedness concerns pertain to planning which maximizes distance between possible ignition sources and vapor generators. Note: on Okushiri the gas tanks of boats thrown inland leaked; then the vapor "found" an ignition source.

Theory of Wave Dynamics

In order to understand the destructive dynamics of the wave impacts it is necessary to understand two basic concepts: moment and force.

A moment is measured by units of length times units of force. To understand moments visualize children playing on a seesaw; in order for one child to go up, the other has to apply a moment downwardly. The longer the distance from where the child is sitting to the pivot point, the more leverage the child will get. This principle is why wrenches are long and we open doors by pushing as far away from the hinges as possible, which is where the knob is, as opposed to pushing right next to the hinge.

Force is defined as an action capable of accelerating an object. Its unit of measurement is a Newton. One Newton is the force required to impart acceleration of 1 meter/second^2 on a mass of 1 kilogram (2.2 pounds). A moment is measured by multiplying Newtons times meters (meters being the length and Newtons being the force).

When the impact takes place it is important to understand how big the moment is during the initial impact, how big the force is and subsequently how the moment behaves when the wave turns around to hit the back face of the structure.

Simulation of Mitigation Alternatives to Reduce Tsunami Impacts

The methodology used by the project upon which this paper is based focused on case studies which illustrate representative land use and building conditions located on a sloping beach. A 3 dimensional numerical simulation initially identified the moment and forces; subsequently to validate the simulation, laboratory experiments were conducted using the same assumptions. The laboratory experiments yielded results almost identical to the numerical simulation.

Three mitigation alternatives were then simulated as a basis for development of strategies to reduce the effects of tsunamis.

Size and Location of Impacts On the Structure

When a wave comes in the water splits and flows around the structure causing pressures and forces on both the front and the back. Mitigation should be based on a clear understanding of the size and location of forces on each face of the structure.

[FIGURE]

Figure 3: Comparison of Mitigation Alternatives:
Alternative #1: low dike catapults forces to higher elevation on the structure
Alternative #2: a porous medium such as created by widely spaced pilings or trees had minimal effect
Alternative #3: long ditch or groove reduces the impacts

[FIGURE]

Figure 4: No Mitigation

The forward wave creates forces primarily on the front face while the return wave creates forces on the back face. The moment arm of each is about the same. Net forces on the front face are somewhat higher during the forward wave.

[FIGURE]

Figure 5: Alternative #1, Low Dike

The first alternative placed a low obstacle (dike or small building) in front of a structure. Results of the simulation found that the dike creates a ski jump effect; the water basically went up and hit the obstacle at a highter elevation than it would have without the dike. The water builds up upstream, topples over the dike, and splashes violently over and behind it. In addition the new moment arm is significant (25% higher moment than no dike) indicating a concentration of the force. A second moment is also created which is of the same magnitude. Total forces during the forward wave are slightly less than without the dike but they are higher on the structure.

[FIGURE]

Figure 6: Alternative #2, Porous Medium

The second simulation created a porous medium which allowed the water to flow through and round five pilings or trees in front of a structure.

In the porous case, water flows both around and through the medium (pylons or trees), and the large wave that fell over the impermeable dike never develops. Because of the finite permeability of the porous medium, the velocity of the fluid going through is smaller than that of the flow around it. Furthermore, because of the pressure field, a lateral flow develops from the clear fluid region toward the porous "dike." Since water was forced to come back off the front face of the pylons there was somewhat less water impacting the "obstacle" which reduced the impacts by a small amount

[FIGURE]

Figure 7: Alternative #7, Groove
The third simulation was a long ditch or groove. This alternative was found to significantly reduce the moment and therefore is the most effective tool to reduce forces on coastal structures. In the simulation the water goes down into the depression which disrupts the activity and reduces acceleration. On the one hand this alternative reduces both the moment and the forces more effectively than the other alternatives. On the other hand it could be considered more environmentally invasive than the other alternatives and thus unfortunately its applicability from an environmental standpoint could be limited to tank drainage and other such uses.

Policy Implications of Mitigation

Structures, lifelines and land uses must comply with a complex set of federal, state and local regulations. In some cases, the regulations are quite complex; in other cases important issues can “fall between the cracks.”

All of the states vulnerable to tsunami impacts have differing administrative structures and planning vehicles in place which can guide land use and building practices in the hazard zone. These differences impact both the manner in which tsunami hazard issues are addressed and the manner in which mitigation can be implemented. They have however each developed tsunami hazard reduction and planning processes in very different ways. For example, Oregon’s legislature adopted SB bill 379 requiring coastal communities to address tsunami vulnerability in their land use planning and permitting processes. It charged DOGAMI with implementing authority for the SB379 and preparation of inundation maps for the entire Oregon coast. Subsequently, three communities have been given top priority for preparation of detailed plans based on numerical simulation with funding through NOAA’s National Tsunami Hazard Mitigation Plan. The State of Washington Growth Management Act (GMA) administered by the Department of Trade and Economic Development requires communities to identify sensitive and hazardous lands and to adopt the areas as part of their comprehensive plans. Coastal hazard areas are considered to be sensitive areas. In California the Planning Scenario in Humboldt and del Norte Counties for a great earthquake on the Cascadia Subduction zone considers the implications of tsunami inundation - in addition to ground motion, ground failure, liquefaction, etc. The planning implications of the tsunami (as well as liquefaction, compaction, etc.) are explicitly addresses by each section of the scenario.

Mitigation is the translation of identified direct and interactive vulnerabilities into public policies to reduce the risks. Public policies which address mitigation issues are multifaceted including but not limited to some of the ones listed below:

Building Damage Reduction Issues

Buildings and structures rarely occur in an isolated setting; i.e. they are located in communities consisting of many structures where some face the waterfront, and others are located adjacent to, but behind the first tier of buildings. In many communities newer buildings have been constructed to recent codes with relatively high levels of resistance to lateral forces, while adjacent sites are occupied by single family and older structures.

Siting issues will pertain to the location of structures and alignments of lifelines. Large structures facing the water are subject to the most extreme forces. They will also be the focus for the impacts of “debris” such as boats in the marina. Roadway access will be severed by debris. Since

[FIGURE]

Source: URR - *Local Effects of Tsunamis*

Figure 8: Direct impact forces as well as the pressures on adjoining structures define patterns of vulnerability with resulting implications for evacuation and public education.

the forces and the moments are much higher on large long buildings than on smaller ones the long structures will need to withstand much greater impacts than the small ones. Analysis of the site plan and building arrangements in Figure 8 give insights into vulnerability. The section drawing indicates a small house immediately behind the large structure, which will be the focus on the near face of the larger building on the high levels of forces from the return wave. Design and construction quality must take into consideration the behavior of the wave, applying lessons learned from previous issue discussions and Figures 3-7.

Implementation Vehicles:

* Siting: Comprehensive Plan Zoning Code
* Design and Configuration: Zoning Code
* Construction Type: Building Code

Fire and Debris Hazards

The vulnerability assessment must analyze the relative locations of:

* Ignition sources (tanks, flammable debris such as boats and cars/fuel tanks; exposed electrical vaults; etc.
* Fuel (surrounding lumber, wood frame buildings etc.)
* Response issues (access disruption, mutual assistance hindrances, training of fire fighters)

It is critical that the assessment take into consideration the interactivity of debris generating uses and fire. In recent tsunami events it has been this debris impact which resulted in fire e.g. in 1964 a truck was thrown against an electrical vault which sparked the fire which destroyed downtown Crescent City, California.

Once the location of ignition sources tanks is identified a myriad of factors must be documented including:
1) Tank characteristics (single wall, double wall, partitioned, etc.
2) Release detection equipment (Automatic tank gauge; Vapor monitoring equipment; Initial monitoring within secondary barrier; Initial monitoring within double wall; Automatic line leak detector, etc.)

The EPA has published numerous documents defining standards and pointing out their complexity. For example, according to the Code of Federal Regulations, an underground storage tank (UST) is defined as any one or a combination of tanks that have 10 percent or more of their volume below the surface of the ground in which they are installed. This definition includes the tank, connected underground piping, underground ancillary equipment, and containment system. Further, this definition specifically pertains to UST systems that contain regulated substances such as solvents, methanol, and ethylene glycol (anti-freeze).

Not all UST systems are Federally regulated: they may be regulated by the state or local agency that implements an UST program. Interviews with emergency services providers and public works departments in many small coastal communities found that these tanks are not inspected or regulated because the community simply did not have the manpower.

Under the Code of Federal Regulations, 40 CFR part 280.11, the following groups of tanks are **not** included in the definition of an UST:

* farm or residential tanks of 1,100 gallons or less capacity used for storing motor fuel for noncommercial purposes;
* tanks used for storing heating oil for consumptive use on the premises where stored;
* septic tanks;
* tank systems in pipeline facilities (including gathering lines) regulated under the Natural Gas Pipeline Safety Act of 1968 (49 U.S.C. App. 1671 et seq.), the Hazardous Liquid Pipeline Safety Act of 1979 (49 U.S.C. App. 2001, et seq.), or in an intrastate pipeline facility regulated under State laws comparable to the provisions of law referred to in the two previous clauses; surface impoundments, pits, ponds, or lagoons;
* storm water or wastewater collection systems;
* flow-through process tanks;
* liquid trap or associated gathering lines directly related to oil or gas production and gathering operations;
* tanks in underground areas such as basements, cellars, and mineworking drifts, shafts or tunnels, if they are located on or above the surface of the floor.

[PHOTO]

Long massive buildings will be subject to greater forces than narrow ones

Conclusions

Mitigation efforts for flood hazard reduction have to an ever increasing degree focused on removing buildings "out of harm's way." Mitigation for other hazards (e.g. earthquakes and hurricanes) for which it is impossible to project the locational incidence has focused on design standards. Unfortunately tsunamis fall into both and neither of these classifications. When tsunamis do occur damage is confined to a definite area. Because there is rarely data with respect to repeat events the precise location of events cannot be forecast.

To reduce exposure to the tsunami threat communities must first approximate which portions of the community is potentially vulnerable. In 1997 Congress established the National Tsunami Hazard Mitigation Program in which is administered through NOAA with precisely this mandate. The program fosters preparation of tsunami inundation maps through application of numerical modeling. Since it is neither practical nor desirable to abandon the potential inundation areas it is incumbent on planners to ensure that land use practices and building design are as safe as possible.

Once the dynamics and relative magnitudes of such forces are understood it becomes feasible to define polices which decision makers should consider to minimize property damage and life loss. Thus, since protection from property damage and life loss is to a significant degree, dependent upon land use planning and structure design which takes into consideration local tsunami effects application of knowledge pertaining to forces of the waves can serve as an important basis for responsive designs which reduce damage from future events.

Acknowledgments

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Editor's note: This paper is also available electronically. E-mail your request to connie.manson@wadnr.gov

New Tsunami Mitigation Materials
Added to the DGER Library, May, 1999

compiled by
Connie J. Manson

Note: **Free reprints of these materials are available**. (See page 2 for ordering information)

Videos

Ambrose Video, 1990, Fire on the rim; Episode three--The prediction problem: Ambrose Video, 1 videocassette, 57 min.
Earthquakes and tsunamis around the Pacific Rim.

Thirteen/WNET; Granada Television, 1998, Savage earth--Waves of destruction: Thirteen/WNET, 1 videocassette, 60 min.
A current video about tsunamis around the Pacific Rim..

Thirteen/WNET; Granada Television, 1998, Savage earth--The restless planet: Thirteen/WNET, 1 videocassette, 60 min.
A current video about earthquakes, with examples from Japan, Mexico, and the 1989 Loma Prieta earthquake in California.

Reports on Earthquakes and Tsunamis

Clague, J. J.; Bobrowsky, P. T., 1999, The geological signature of great earthquakes off Canada's west coast: Geoscience Canada, v. 26, no. 1, p. 1-15.
An excellent, current review of the scientific evidence of earthquakes on the Cascadia subduction zone, as gathered by American and Canadian researchers in the last 15 years.
Highly recommended for local emergency managers and government officials.

Gonzalez, F. I.; Satake, Kenji; Boss, E. F.; Mofjeld, H. O., 1999, Edge wave and non-trapped modes of the 25 April 1992 Cape Mendocino tsunami: U.S. National Oceanic and Atmospheric Administration [downloaded May 10, 1999 from http:..www.pmel.noaa.gov/tsunami/gonzalez1995.html].
Technical examination of the small tsunami generated by the 1992 event.
Recommended for tsunami modelers.

Brief research updates

Clague, J. J.; Bobrowsky, P. T., 1999, The AD 1700 giant earthquake at the Cascadia subduction zone [abstract]: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. A-45.

Hutchinson, Ian; Bobrowsky, P. T.; Clague, J. J., 1999, 3000 years of tectonics and tsunamis revealed in the sediments of lakes on the west coast of Vancouver Island, British Columbia [abstract]: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. A-64.

Kelsey, H. M.; Nelson, A. R.; Hemphill-Haley, Eileen; Witter, R. C., 1999, A 7,000 year record of tsunamis generated by the Cascadia subduction zone, evidence from a coastal lake in Oregon [abstract]: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. A-68.

Langridge, R. M.; Weldon, R. J., II; Pezzopane, S. K., 1999, Paleoseismology of the Ana River fault, central Oregon--Implications for recurrence behavior [abstract]: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. A-72.

Witter, R. C.; Kelsey, H. M.; Hemphill-Haley, Eileen, 1999, Contrasting relative sea-level curves in southwestern Oregon--Evidence for late Holocene upper-plate contraction on anticlines overlying the Cascadia megathrust [abstract]: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. A-109.

General Works

Clark, J. R., 1996, Coastal zone management handbook: Lewis Publishers, 694 p.
Intended as a guidebook for those who practice the arts of coastal resources planning and management, from an environmental viewpoint.
Recommended for coastal managers.

U.S. Federal Emergency Management Agency, 1996, Guide for all-hazard emergency operations planning: U.S. Federal Emergency Management Agency State and Local Guide 101, 1 v.
FEMA's guide to developing Emergency Operations Plans (EOP).
Highly recommended for local emergency managers and government officials.

U.S. National Weather Service, 1999, Tsunami--The great wave: U.S. National Weather Service, downloaded May 10, 1999 from http://www.nws.noaa.gov/om/tsunami.htm.
A brief report, downloaded from the Internet.

Infrequently Asked Questions

compiled by
Lee Walkling

What are Warning Coordination Meteorologists and how do they help Emergency Managers?

There are nine Warning Coordination Meteorologists (WCMs) from the coastal Weather Service Forecast Offices in California, Oregon, Washington and Alaska. In 1997 they spent two days in intensive training on tsunamis. The purpose of the training was to ensure that the WCMs have an in-depth understanding of the tsunami warning system and process, and to provide them with familiarization with the warning center's operation during a watch/warning event.

The WCMs were trained to assist coastal emergency managers with community tsunami preparedness activities. Covered in the training were basic seismology, tsunami watch and warning messages, the warning process and communications, and the operations and technology utilized by the West Coast/Alaska Tsunami Warning Center. The role of the WCM was divided into two parts: (1) before a tsunami watch/warning occurs, and (2) during a watch/ warning event. Before the event, the WCM participates in community preparedness and interacts with coastal communities and local, county and state officials. During a watch/warning event the WCMs may answer routine questions and read West Coast/Alaska Tsunami Warning Center messages; but the source of watch/warning messages is the West Coast/Alaska Tsunami Warning Center and the Center is where interpretation or modification of the messages is made.

The West Coast WCMs have now included tsunamis as part of their coastal hazard community preparedness activities.

(Information from http://www.pmel.noaa.gov/tsunami-hazard/wcm.html)

Where can I find a complete list of Warning Coordination Meteorologists and Coastal County Emergency Managers?

For a complete list of Coastal National Weather Service Warning Coordination Meteorologists (WCM) and Coastal County Emergency Managers (CCEM) for Alaska, Washington, Oregon, California, and Hawaii go to http://www.pmel.noaa.gov/tsunami-hazard/wcms.html

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