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Tsunami Mitigation and Preparedness Activities in California

Open-File Report 2013–1170–L
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COVER—Top: Warning signs guide people to safe, high ground as a tsunami approaches King Salmon, Humboldt County, California. Middle: Buildings and infrastructure adjacent to beaches are common on the coast, and an important target of tsunami education and mitigation. Coronado, San Diego County, California. Bottom: Fixed piers, infrastructure, and boating vessels of all varieties provide ample opportunity and challenge for mitigating the effects of tsunamis, here at Ventura Harbor, California. Photos by Rick Wilson.

The SAFRR (Science Application for Risk Reduction) Tsunami Scenario

Stephanie Ross and Lucile Jones, Editors

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Tsunami Mitigation and Preparedness Activities in California

By Rick Wilson[1] and Kevin Miller[2]

Abstract

Scenario planning and final results associated with the U.S. Geological Survey Science Application for Risk Reduction (SAFRR) tsunami project are providing great benefits to the ongoing tsunami risk-reduction efforts of the California Tsunami Preparedness and Hazard Mitigation Program. This program, led by the California Governor's Office of Emergency Services and the California Geological Survey, works with coastal communities to improve tsunami preparedness and mitigation at the local level through various efforts, such as improving tsunami hazard analysis, establishing consistent evacuation communications and planning, and leveraging national risk-reduction efforts associated with the National Tsunami Hazard Mitigation Program.

The recent 2010 Chilean and 2011 Tohoku tsunamis did not cause notable inundation of dry land in California, but dozens of harbors sustained damages totaling nearly $100 million (Wilson and others, 2012a). Estimates associated with the SAFRR distant tsunami scenario suggest socioeconomic and environmental losses could be even larger. Information gathered from these events and the SAFRR scenario is guiding the development and implementation of new strategies for emergency response, maritime planning, and land-use planning, including

- a reassessment of the tsunami threat along the California coast;
- scenario-specific, tsunami evacuation "playbook" maps and guidance;
- in-harbor hazard maps and offshore safety zones for potential boat evacuation during future distant source events;
- "probability-based" products for land-use planning under the California Seismic Hazard Mapping Act; and
- an expansion of real-time and post-tsunami field reconnaissance teams and information sharing through a state-wide clearinghouse.

The state tsunami program has benefitted greatly from participation in the SAFRR tsunami scenario process, and hopes to continue this relationship with the U.S. Geological Survey to help improve tsunami preparedness in California.

Introduction

The 2013 U.S. Geological Survey (USGS) Science Application for Risk Reduction (SAFRR) tsunami scenario project provides a broad analysis of the impacts from a large distant-source tsunami event along the entire California coast. Like with previous SAFRR scenarios (for

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example, the 2008 ShakeOut earthquake and 2011 ARkStorm flood scenarios), the State of California has acquired useful information that will help it prepare for future large-scale disasters. The State and Federal partnership through the SAFRR project has improved the understanding of physical events (for example, tsunami source mechanisms and sediment deposition), potential socioeconomic and environmental losses, and challenges to an effective response and recovery for a significant state-wide tsunami event. The purpose of this chapter is to summarize current tsunami risk-reduction efforts of the California Tsunami Preparedness and Hazard Mitigation Program (referred to as the "state tsunami program" herein) and to discuss how results from the SAFRR tsunami scenario will support these ongoing efforts.

California Tsunami Preparedness and Hazard Mitigation Program

The state tsunami program is a hazard-reduction program managed by the California Governor's Office of Emergency Services (Cal OES), with assistance from the California Geological Survey (CGS), and in cooperation with the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service and other Federal, State, and local agencies. The program promotes tsunami planning, preparedness, and hazard mitigation among California's coastal communities (fig. 1), and participates in the National Tsunami Hazard Mitigation Program (NTHMP), which is responsible for setting U.S. policy and guidance for tsunami warning and long-term planning. Within the state, the program works through the California Tsunami Steering Committee with its 20 coastal and San Francisco Bay Area county emergency management partners and other State and Federal agencies with tsunami hazard responsibilities.

Figure 1. January 2012 tsunami evacuation drill in King Salmon, Humboldt County (photograph by Rick Wilson, California Geological Survey). Tsunami evacuation drills, exercises, and workshops are vital to sustaining community-level tsunami preparedness.

Ongoing Activities

The State tsunami program has first sought to identify and characterize the tsunami hazard in California, and then integrate this knowledge into the state's emergency management system and hazard mitigation efforts. The program promotes tsunami planning, preparedness, and mitigation in California's coastal communities, and applies the latest scientifically vetted information to improve emergency management through the following activities:

1. Tsunami scenario modeling;
2. Inundation zone maps/Evacuation zone mapping;
3. State/Local emergency response and evacuation planning;
4. Exercises and training;
5. Warning system testing; and,
6. NTHMP coordination and support.

The progress and completion of these activities have been implemented through several specific tasks. The following paragraphs summarize each of these tasks.

Development and completion of tsunami inundation maps for the entire California coast for the purposes of local tsunami evacuation planning.—Definition of the hazard zone is vital to guiding emergency response through the unknowns of any incoming tsunami. The state completed tsunami inundation modeling and 130 maps for all low-lying, populated sections of the California coast (Wilson and others, 2008; Barberopoulou and others, 2009). Maps noting zones of maximum tsunami inundation from a variety of local and distant tsunami sources were developed to assist coastal jurisdictions to: (1) identify areas likely to be inundated in a tsunami; (2) facilitate the development of plans for evacuating vulnerable populations; and (3) place tsunami-evacuation signs.

Collaboration and coordination to assure that all coastal operational areas have tsunami response plans and the capability to implement plans.—The state tsunami program works with communities on their response planning to Tsunami Alert messages (Warnings, Advisories, Watches, and Information Statements) issued by the West Coast/Alaska Tsunami Warning Center (WC/ATWC). This assistance is in accordance with plans and procedures developed in cooperation with the California State Warning Center and Cal OES Executive staff. During events, especially prior to the arrival of a tsunami, the state program transfers information about expected arrival times and wave heights from the WC/ATWC to the communities, and provides feedback to the communities regarding evacuation. On an annual basis, the Cal OES works with the NOAA Weather Forecast Office in Eureka and with the Redwood Coast Tsunami Work Group to conduct a multi-county test of the Emergency Alert System. This test is important to the region as it faces a significant local threat from the Cascadia subduction zone just offshore. Considerable planning goes into this "live-code" warning communications test, including gaining approval from the Federal Communications Commission and coordinating California Civil Air Patrol-supported activities. The program also provides assistance on the use of new rapid notification and situational awareness technologies for earthquake and tsunami emergencies.

Communication with local emergency managers and the public to maintain on-going tsunami preparedness in coastal communities.—Cal OES convenes and chairs the California Tsunami Steering Committee, which includes representatives of all coastal counties,

the National Weather Service, and several State agencies. The state program also supports planning and technical assistance guidance to local government in the form of workshops, exercise facilitation, review of local tsunami response plans, and guidance in the use of tsunami inundation maps. As an example, the state tsunami program held more than 90 meetings, workshops, and community forums with local planning partners and the public from August 2011 to August 2012. Sharing new ideas and obtaining feedback during these meetings are the keys to sustaining state-to-federal and state-to-local communication, and to improving preparedness and outreach. Sustained activities that work toward the overall goal of preparing government officials, first responders, emergency planners, and the public include development and dissemination of outreach materials (for example, brochures, pamphlets, DVDs), educational workshops, support of exercises and evacuation drills, participation in National Tsunami Preparedness Week, and support of regional work groups.

Collaboration between NOAA National Weather Service and the state tsunami program to assist jurisdictions in the planning, preparedness, and mitigation activities that qualify them for TsunamiReady™.—TsunamiReady™ is a NOAA designation recognizing tsunami preparedness activities at a community level. To help these communities achieve TsunamiReady™ status, the state tsunami program assists communities in the development of tsunami evacuation plans, the purchase of tsunami hazard signs, and the development of tsunami sign placement plans. California has 34 communities (counties, cities, and other entities) that have qualified for TsunamiReady™ (National Weather Service, 2013), more than any other state in the nation.

Updates of the tsunami source and deposit databases produced by CGS.—The tsunami source database catalogs the input parameters applied to the tsunami model simulations for tsunami hazard map production. The tsunami deposit database has been completed for the northern region of the state, adjacent to the Cascadia subduction zone, and will be used to validate the probabilistic analysis needed to create land-use planning maps for tsunamis. These databases are being updated with the tsunami source and deposit information collected during the SAFRR project.

Representation of California in the NTHMP regional and national meetings that address budgeting, policy, and procedural issues.—Emergency management and science representatives from Cal OES and CGS, respectively, represent the state on the NTHMP Coordinating Committee and the three subcommittees that address national issues related to mapping and modeling, mitigation and education, and warning coordination. The participation of the state tsunami program in the NTHMP is important for coordinating effective and consistent tsunami preparedness activities with partners in Federal agencies and other States. The NTHMP also provides Federal funding support for state tsunami programs to maintain and improve tsunami planning at a local level.

New Activities and Products

Although significant accomplishments have been achieved by the state tsunami program, the SAFRR scenario and the 2010 Chile and 2011 Tohoku tsunamis have helped identify areas where improvements in tsunami hazard analysis and emergency response planning are needed (Lynett and others, 2012; Miller and others, 2012; Wilson and others, 2012a, 2012b). Post-event survey teams and questionnaires were used to gather information on both the physical effects and emergency response lessons (Wilson and others, 2012a). The 2010 tsunami caused approximately $3million in damage to 12 harbors in California, while the 2011 tsunami caused

more than $100million in damage to 27 harbors (fig. 2). During both events, people on docks and near the ocean were at risk to injury; one fatality occurred during the 2011 tsunami at the mouth of the Klamath River. In addition, the significant sediment deposition and damage within Crescent City and Santa Cruz Harbors during the 2011 event caused long delays in recovery of those harbors because of regulatory and reconstruction issues (Wilson and others, 2012b).

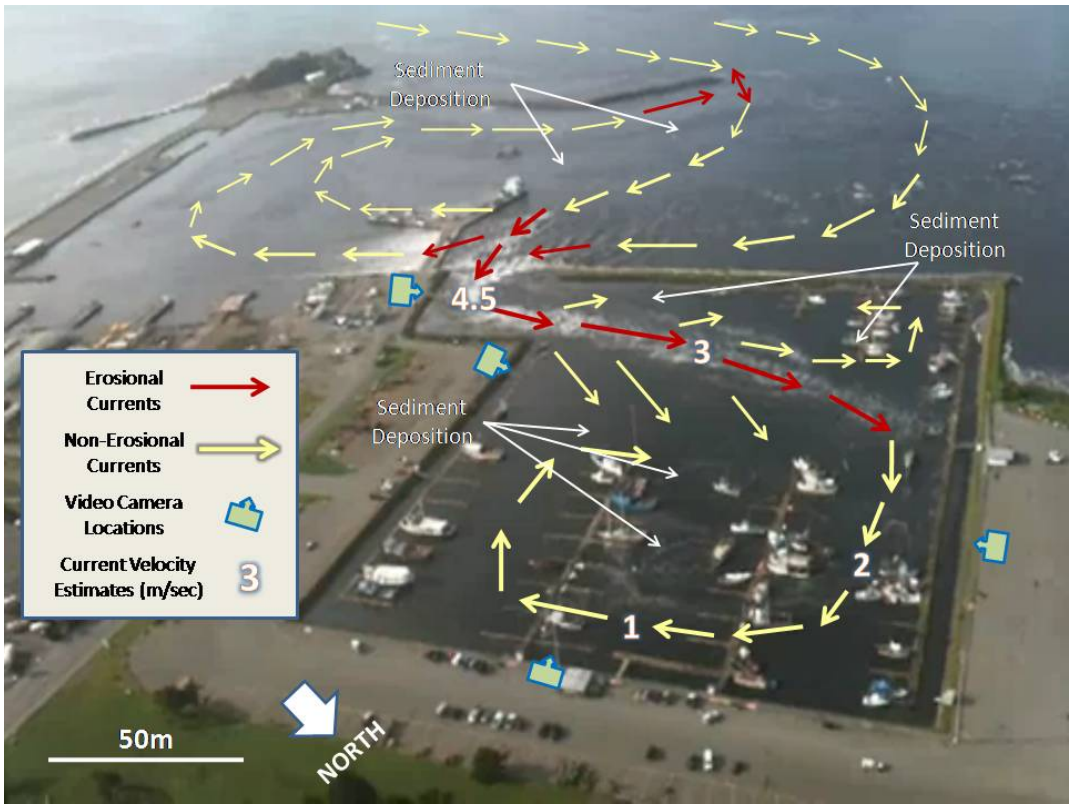

Figure 2. Tsunami flow-regime map for Crescent City harbor (from Wilson and others, 2012a). Current directions and velocities and areas of sediment erosion and deposition are based on observations of the various (30) ground-level and aerial video, pre- and post-tsunami bathymetry, and sediment analyses.

The SAFRR project also provides a framework for evaluating the statewide impacts from a much larger, distant-source tsunami. The potential loss of life and projected billions of dollars in damage and recovery costs in the SAFRR scenario demonstrates the importance of sustained and improved tsunami preparedness and mitigation for the State of California (Porter and others, 2013; Wein, 2013).

Based on the analysis of these recent events in Chile, Japan, and California, and the information provided by the SAFRR scenario, the state tsunami program is enhancing existing products and developing new products that will improve tsunami preparedness and mitigation statewide. These products will help: (1) the maritime community better understand tsunami hazards within their ports and harbors, as well as if and where boats should go offshore to be safe; (2) emergency managers to develop evacuation plans for smaller ‘‘Warning’’ level events where extensive evacuation is not required; and (3) coastal land-use planners, engineers, and policymakers better understand the tsunami hazard from a probabilistic (risk-based) approach.

The ultimate goal of these improvements is to save lives and reduce immediate and long-term impact to coastal communities.

Maritime communities in California were impacted the most during the 2010 and 2011 tsunamis, and could be impacted again, as demonstrated by the SAFRR tsunami scenario. Although millions of dollars were lost during the 2010 and 2011 events, the eyewitness accounts and video information collected after each event provided a resource for improving tsunami hazard analysis in harbors and bays. Through a Co-operative Technical Partnership developed between the State and Federal Emergency Management Agency (FEMA), observed strong tsunami currents and damage are being used to validate/calibrate numerical tsunami model currents. Using validated modeling, the state tsunami program has initiated a plan to develop three sets of products for these maritime communities: (1) detailed maps identifying in-harbor tsunami hazards, such as strong currents and eddies, peak amplitude surges, and large tidal fluctuations (fig. 3); (2) offshore safety zones where ships can evacuate to and safely gather during a tsunami (fig. 4); and (3) preparedness, mitigation, and recovery/continuity plans to help maritime communities be more resilient to tsunami hazards. Harbor-specific guidance will be created to help maritime communities better prepare for, respond to, and recover from future tsunamis. Most of this mapping and guidance work with the maritime communities will be completed by the year 2015.

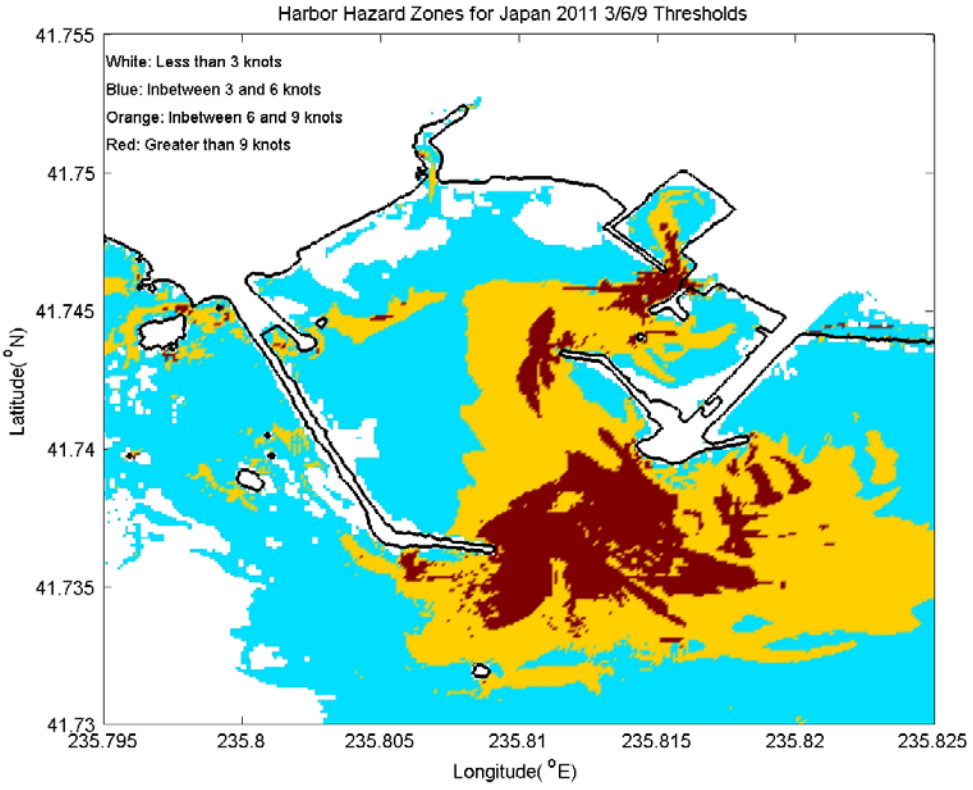

Figure 3. Map showing draft tsunami current velocity hazard zones using 2011 Tohoku event modeling in Crescent City (from Lynett and others, in press).The colors are water velocity groupings related to anticipated damage levels to harbor facilities and boats: 3–6 knots (blue) for minor damage; 6–9 knots (yellow) for moderate damage; and greater than 9 knots (red) for severe damage.

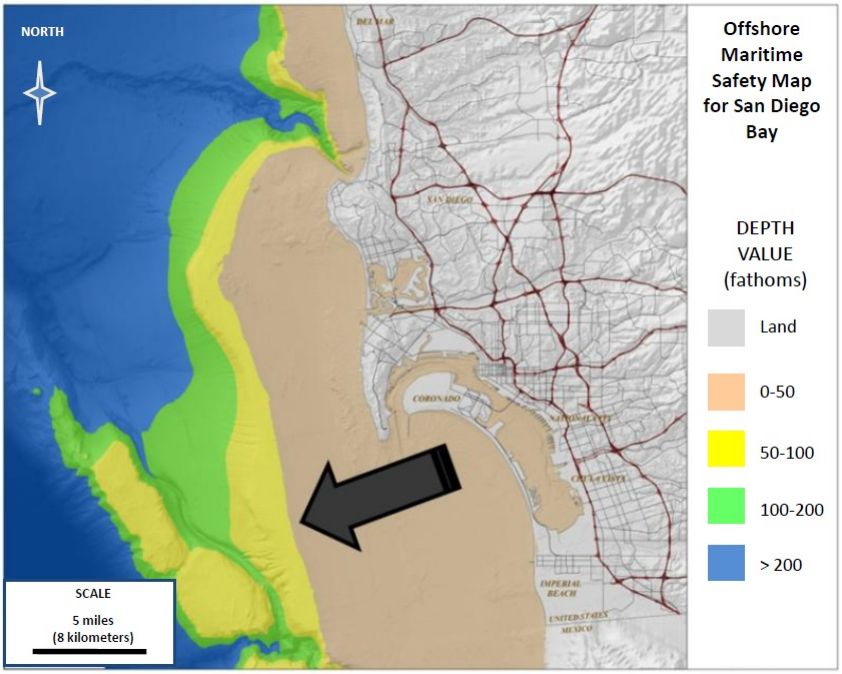

Figure 4. Draft map showing offshore bathymetric depths off the coast of San Diego Bay. Maps similar to this are used to help maritime communities plan for offshore evacuation of ships prior to a tsunami's arrival. Additional modeling is being used to determine if ships can evacuate closer to shore than the NOAA-recommended 100-fathom (600-foot) depth.

The state program also has been involved in improving statewide and local emergency response planning activities. New information available from the 2011 Japan event, a recently created tsunami deposit database, and new paleotsunami and paleoseismic work being done in Oregon, is being evaluated to determine if the existing tsunami hazard analysis for the Cascadia subduction zone is adequate. California also has been in discussions with the State of Nevada to develop tsunami inundation maps for the Lake Tahoe region so that evacuation planning and tsunami sign placement can be done in an accurate and consistent manner. Real-time and post-tsunami field teams also have been expanded to capture additional detailed information that can be shared in a timely manner during and after an event through a state-wide clearinghouse. These new products and related efforts will result in more accurate and efficient emergency response by coastal communities, potentially reducing the loss of lives and property during future tsunamis.

Recent moderate to minor tsunami events have challenged existing evacuation protocols. During the 2011 tsunami in California, the arrival of significant tsunami activity, which was only forecasted to be between 1 and 2.5m for areas within a "Warning" along the coast, coincided with low tide conditions and, therefore, was not expected to inundate dry land. Considerable inconsistencies between communities conducting evacuation and response were noted. Only a few communities in the state called full evacuations and, in most cases, no evacuations were initiated. Many emergency managers indicated that secondary evacuation lines for smaller Warning-level events would have been useful, reducing the potential for under- or over-evacuation, and alleviating the need for an "all or nothing" decision. As a result, scenario-specific, tsunami evacuation "playbook" maps and guidance recommendations are being produced detailing inundation from tsunamis of various sizes and source locations (fig. 5).

Figure 5. Draft playbook tsunami evacuation for the Imperial Beach area. The lines represent secondary evacuation zones based on various land elevations that can be used by communities for less-than-maximum tsunami events.

In addition, a formula that incorporates forecasted tsunami amplitudes (wave heights), tidal conditions, storm activity, and site-specific tsunami run-up potential into a "maximum predicted tsunami run-up height" is being developed to determine which evacuation scenario is most appropriate and conservative to use. These products, expected to be available by the end of 2013, will help coastal emergency managers prepare local response plans when minor distant-source tsunamis, or larger tsunamis from local and regional sources are generated.

Along with improvements to evacuation planning and maritime planning, the state tsunami program has made progress towards the development of products for the coastal land-use planning, engineering, and policymaking communities. Because the existing state-wide tsunami inundation maps are based on maximum inundating maps, and not a time- or risk-based approach, they should not be used for making land-use planning decisions. As with other flood and seismic hazards, a probabilistic tsunami hazard analysis (PTHA) should be completed and utilized. Maps and associated products based on PTHA methods will be similar to other probabilistic flood- and seismic-hazard maps by representing standard risk levels (average return periods) for tsunami hazards that can be used in not only land-use planning, but possibly also in implementing building design criteria, producing more consistent inundation maps for evacuation planning, and setting flood insurance rates. The initial phase of PTHA and land-use planning product development, which has been funded by the NTHMP, includes: (1) development of a technical work group to evaluate existing PTHA methods; (2) determination of the adequacy of the PTHA methods for land-use planning and other uses; (3) acceptance and

improvements made to the PTHA methods; (4) determination of the appropriate risk levels for PTHA-based map production; and (5) initiation of development of PTHA-based maps for the California coast. The process and products of this PTHA in California also will form the basis for the NTHMP to implement nationwide. With this initial work being completed by autumn 2013, the state tsunami program is collaborating with other entities interested in developing PTHA maps for the entire State.

In addition to working on the SAFRR project, the state tsunami program also has partnered with the USGS to improve tsunami planning and preparedness in California in other ways. The USGS completed a vulnerability analysis based on the existing state tsunami inundation maps. The study, titled "Community Exposure to Tsunami Hazards in California," (Wood and others, 2013), provides first responders, emergency planners, and other stakeholders, with valuable new information about the people who live in, work in, and visit each of the 20 counties and the more than 150 incorporated and unincorporated communities located along the state's coast. The state program will work with the report authors to provide individual information sheets to each community for incorporation into their local hazard mitigation plans.

In order to help guide, develop, and improve future tsunami preparedness and mitigation activities, the state tsunami program formed the California Tsunami Policy Work Group (CTPWG) in 2011 (Johnson and Real, 2013). Comprised of members from Federal, State, and local agencies, as well as private organizations, the CTPWG works closely with the state tsunami program to understand the state of tsunami preparedness in California. The CTPWG was formed to help identify gaps and issues in current tsunami hazard mitigation, to make recommendations that will work to eliminate these impediments, and to advise on the development and implementation of effective tsunami hazard products to improve community resiliency. This report should be available by autumn 2013.

Conclusions

The California Tsunami Preparedness and Hazard Mitigation Program will continue to provide support to communities at risk of tsunami hazards. Evaluations of recent tsunamis have resulted in the development of new products to help evacuation planning, maritime planning, and land-use planning. "Playbooks" for less-than-maximum tsunami events will allow communities to more accurately identify and plan for the areas to evacuate in minor to moderate tsunamis. Tsunami-current hazard maps within harbors and offshore safety zones will provide maritime communities a foundation for developing and improving emergency response plans. New tsunami maps developed using probabilistic-based methods will assist in community land-use planning and site evaluations.

The state program also has benefitted from detailed knowledge developed through the range of multi-disciplinary expertise brought to bear by the U.S. Geological Survey to analyze the Science Application for Risk Reduction (SAFRR) tsunami scenario. The SAFRR project provides the framework for evaluating the statewide impacts from a single, large, distant-source tsunami. The potential loss of life, and projected billions of dollars in damage and recovery costs that this scenario estimates, underscores the importance of sustained investment in tsunami preparedness and mitigation for the State of California. Recommendations within this SAFRR report will be carried forward through sustained activities mentioned above to continue to prepare state emergency managers, scientists, the maritime and coastal land-use policy communities, and the public for the next tsunami.

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