TsuInfo Alert
prepared by the Washington State Department of Natural Resources on behalf of the
National Tsunami Hazard Mitigation Program
a state/federal partnership funded through the National Oceanic and Atmospheric Administration (NOAA)

JUNE 2021 Volume 23, Number 3

Landslide Tsunami Models Developed and Used by the NTHMP East Coast Group for Tsunami Inundation Mapping to Help Elucidate the Messina 1908, Anak 2018, and Palu 2018 Events

By Stephan Grilli, University of Rhode Island, and James Kirby, University of Delaware

IN THIS ISSUE:

WASHINGTON STATE DEPT OF NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

Since the 1998 Papua New Guinea event, in which a moderate M7.2 earthquake triggered a deep underwater slump that caused a major tsunami that devastated the Sissano spit, causing 2200 fatalities, the tsunami community has become increasingly aware of the hazard posed by landslide tsunamis (Tappin, 2021; Tappin et al., 2021). In the United States (US), many coastal areas are facing significant risk from tsunamis triggered by submarine or subaerial mass failure (SMF), as well as volcanic collapse (e.g., Hawaii, Alaska, California, Gulf of Mexico, US East Coast (USEC); e.g., Day et al., 2005; Kirby et al., 2016; Greene et al., 2006; Horrillo et al., 2013). On the upper US East Coast (USEC), the most recent significant historical tsunami, the 1929 Grand Banks (Bent, 1995; Løvholt, et al., 2018), was caused by an underwater landslide triggered by a M7.2 earthquake (the largest on record to have impacted the USEC), resulting in over 20 fatalities. The low seismicity and widespread paleo-slide scars on the continental shelf indicate that this may be the dominant source of tsunami hazard in this area (Ten Brink et al., 2014).


Post-collapse image of Anak Krakatau, January 11, 2019 drone survey (Reynolds, 2019).

To estimate the coastal hazard posed by landslide tsunamis along the USEC, Grilli et al. (2009) proposed a simple probabilistic approach. However, this was an order of magnitude analysis, since most landslide tsunami models at the time were idealized and typically combined the idealized kinematics of rigid slumps or slides with a dispersive wave propagation model such as FUNWAVE (e.g., Watts et al., 2003; Shi et al., 2012; Kirby et al., 2013). Nevertheless, their analysis predicted that, for a 500 year return period, a 5 m coastal inundation could be caused by landside tsunamis, in some areas of the upper USEC. This approach was later improved with the development of NHWAVE, a 3D non-hydrostatic wave model that, initially, could only simulate rigid slides or slumps, whose motion was specified to cause wave generation (Ma et al., 2012). NHWAVE was used, in combination with the tsunami propagation model FUNWAVE, to simulate landslide tsunamis from the largest potential SMFs parameterized along the USEC, as part of the first generation NTHMP tsunami inundation maps for the USEC (e.g., Grilli et al., 2015). This approach of modeling landslide tsunamis with the combination of NHWAVE-FUNWAVE was successfully validated for the Tohoku 2011 tsunami by Tappin et al. (2014), who sited, parameterized, and modeled a large rigid slump as a secondary tsunami source triggered by the earthquake, that could explain the large runups observed along the Sanriku coast.

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Prepared and published bimonthly by the Washington State Department of Natural Resources, Washington Geological Survey, on behalf of the National Tsunami Hazard Mitigation Program (NTHMP), a state/federal partnership led by the National Oceanic and Atmospheric Administration (NOAA).
Assembled and edited by Stephanie Earls (stephanie.earls@dnr.wa.gov).
This publication is free upon request and is available online at:
http://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis/tsuinfo-alert

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http://d92019.eos-intl.net/D92019/OPAC/Index.aspx

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New versions of NHWAVE were later developed that could simulate deforming slides made of granular material or represented by a dense viscous fluid (Ma et al., 2015; Kirby et al., 2016). These were experimentally validated and used to improve the modeling of landslide tsunamis along the USEC (Schnyder et al., 2016; Grilli et al., 2017; Schambach et al., 2019). While different, these results showed that the earlier assumption of using rigid slumps was conservative as far as tsunami hazard. More recently, NHWAVE was again improved to include vertical accelerations also within the sliding mass, which is important on steep slopes, and allow the slides to move over an arbitrary topography/bathymetry (Zhang et al., 2021a,b).

This latest version of NHWAVE, in combination with FUNWAVE, was recently applied to modeling three important historical landslide tsunami case studies, for which field data was available. This allowed for validation of the models that were only previously applied to hypothetical events in the context of tsunami hazard assessment work done for the NTHMP along the USEC. These historical events are the Messina 1908, Palu 2018 and Anak 2018 tsunamis (Schambach et al., 2020, 2021; Grilli et al., 2019a), with the first two being dual earthquake-landslide source events and the latter being a volcanic flank collapse of about 0.22 km3, likely triggered by an eruption (Hunt et al., 2021). In each case, both the subaerial or submarine mass failures, and the corresponding tsunami generation were modeled with NHWAVE and tsunami propagation and coastal impact (inundation, runup, tide gauge elevations) with FUNWAVE, and results compared with field data.

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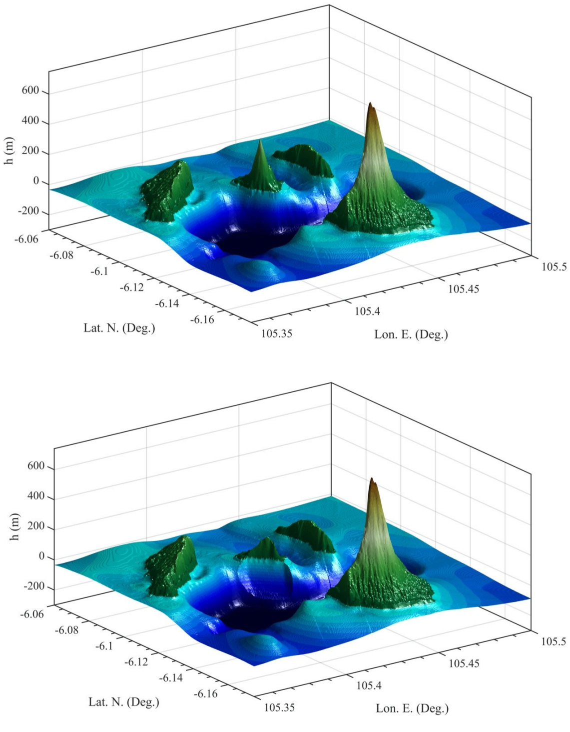
Messina 1908, the worst natural disaster in modern history in the Mediterranean basin, was triggered by a moderate M7.1 earthquake in the Messina Straits that caused a large tsunami, with up to 12 meters runup, and widespread destruction along the coasts of Calabria and Sicily. The combined fatalities from the earthquake and tsunami were over 80,000. This event was immediately surveyed with many investigators suggesting that the earthquake was too weak to have generated such a large tsunami and some other source was required. Concluding work started in 2008, Schambach et al. (2020) performed dual source modeling with NHWAVE and FUNWAVE, which convincingly showed that a 2 km3 fairly rigid slump, triggered with a delay by the earthquake on the submerged slopes of Mount Etna, was the source of the major runups measured in Sicily.

Palu and Anak 2018 are two major tsunami events that struck a few months apart in Indonesia, causing over 450 and 4,300 fatalities, respectively. Both events were modeled with the combination of NHWAVE and FUNWAVE whose results were shown to agree very well with measurements made in numerous field surveys. In Palu, the M7.5 earthquake triggered with a delay more than half a dozen significant subaerial slides along the shores of Palu Bay. Modeling a dual source combining a supershear earthquake and the multiple slides, parameterized based on data from marine geology surveys, Schambach et al. (2021) provided the most comprehensive model of the event to date, that explained most of the observations. There was only one small coastal segment on the SE of the Bay where results underpredicted tsunami impact and, in this area, they modeled a yet to be fully identified additional submarine slide.



3D view of composite pre- (top) and post-collapse (bottom) bathymetry/topography of AK and surrounding islands used in NHWAVE Grid G2, based on available pre-event data outside of Krakatau islands and August 2019 field survey data in the caldera and surrounding islands (Hunt et al., 2021). There is a factor 10 vertical exaggeration.

Finally, Anak 2018 is perhaps the first such volcanic collapse event to have been extensively monitored and surveyed in recent history, for both the precursor volcanic eruption (that started in June 2018), the flank collapse, and the tsunami. A combination of satellite, video, and seismic observations were applied in the NHWAVE-FUNWAVE models, which allowed Grilli et al. (2019a) to provide the first comprehensive simulation of the event that reproduced all the early observations and tsunami field surveys (prior to March 2019). Following extensive marine geology surveys in the summer 2019 (Hunt et al., 2021), the flank collapse was more accurately parameterized (in geometry and volume) using data from submarine surveys. Combining this new source with a more accurate bathymetry, higher-resolution modeling was performed that predicted both the distribution of runups (up to 85 m) measured on the nearby Islands of Rakata and Sertung as well as all the far-field runups in Sumatra and Java that reached 12 m (Grilli et al., 2019b, 2021).

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Shelter from the Waves

By Ken Ufkin, Shoalwater Bay Tribe Director of Emergency Management

Located on the outer coast of southwest Washington State, the Shoalwater Bay Indian Tribe had a vision going back nearly 20 years to keep the tribe and surrounding community of Tokeland safe from the threat of a tsunami. Nearby high ground was identified and paths were marked out to offer citizens a place to take refuge. However, the tribe wished to do better.

The 2011 Tohoku earthquake and tsunami served to remind the entire world just how devastating a tsunami event can be. The Shoalwater Bay Tribe began seeking a better form of refuge from this threat. By 2017, the tribe had formulated a clear picture and plan of how to provide this place of safety; a vertical evacuation tower modeled similarly to the Japanese vertical evacuation towers.

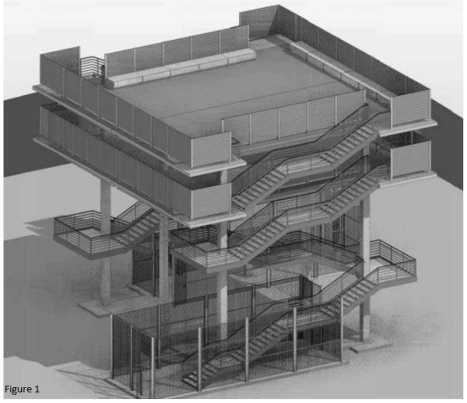

Figure 1. Digital rendering of the future vertical evacuation tower being built by the Shoalwater Bay Indian Tribe.

Over the next three years the tribe worked tirelessly with members of academia, local, state, and Federal government to develop adequate geologic and tsunami inundation modeling to pursue federal grant funding for a first of its kind vertical evacuation tower funded by FEMA. These studies significantly punctuated the need for this tower, as they revealed a wave as high as 10 feet, travelling at high speed, could make landfall in the Shoalwater Bay/Tokeland area within 10 – 22 minutes as a result of an 8 – 9 magnitude earthquake emanating from the nearby Cascadia Subduction Zone.

By 2019 the tribe had secured $2.5 million in FEMA grant funding. The COVID pandemic caused nearly a year's delay in construction. However, with much determination the project pushed forward. FEMA provided additional funding amounting to more than $2.8 million, with the tribe contributing over $1 million in matching funds.

On May 17, 2021, ground breaking officially commenced on the Vertical Evacuation tower. The tower is being built at the end of Blackberry Lane, which is about 1.4 miles south from the Tribal Center located at 2373 Tokeland Rd. This location is on the southern edge of the Shoalwater Bay Indian Tribe Reservation. The tribe decided on this area as it is approximately in the middle of Tokeland. Thus, it can serve as a place of refuge for not only tribal members, but the residents of Tokeland as well. In total it will serve over 300 full time residents of both the reservation and Tokeland.

When completed the tower will stand approximately 50 feet tall and 40 feet wide, with support piers anchoring it nearly 51 feet below grade. There will be two decks, one at 40 feet, and the other at 50 feet in height, for a total of 4,000 square feet. The building specifications call for 1 person per 10 square feet making it possible to hold 400 people. Structurally, the tower engineering could hold people shoulder to shoulder without compromising its structural integrity.

The level of cooperation between academia and the local, state, and federal emergency management community is truly commendable. It took considerable dedication from the Washington State Emergency Management Hazard Mitigation team, advisors from the University of Washington, FEMA, and many others to bring this project to fruition. For that, the Shoalwater Bay Indian Tribe and citizens of Tokeland are deeply grateful.

TsunamiReady Supporter Renewal of La Jamaca Hotel

By Wildaomaris Gonzalez Ruiz, Puerto Rico Emergency Management Bureau

A TsunamiReady Supporter is an organization, business, facility or local government entity that is actively engaged in tsunami planning and preparedness but does not have the ability to meet all of the formal recognition guidelines.

TsunamiReady Supporter eligibility and designation is determined by local National Weather Service (NWS) Weather Forecast Offices based on criteria like having ways to receive and disseminate tsunami messages, having a tsunami response plan with evacuation instructions, having a tsunami hazard or evacuation zone map available, and conducting tsunami awareness and preparedness activities. In Puerto Rico, the local evaluation committee also requires that the staff of the agency applying to be recognized as a TsunamiReady Supporter take training on the subject. At the moment, a variety of organizations have been recognized including a supermarket, a hospital, some Head Start programs, and some government agencies.

La Jamaca TsunamiReady Recognition

Commonly the agencies that decide to apply to be recognized as a TsunamiReady Supporter are located within the tsunami evacuation zone. However, the Hotel La Jamaca located in La Parguera, Lajas Puerto Rico, is outside the tsunami evacuation zone. With the awareness that guests that visit the hotel visit La Parguera coastal area to enjoy the beautiful beach, which is vulnerable to tsunamis, the hotel decided four years ago to apply to become a TsunamiReady Supporter. Four years later, the Hotel La Jamaca has renewed its TsunamiReady Supporter recognition demonstrating the commitment they have to their staff and guests.

Caribe Wave 2021

In March 2021, Hotel La Jamaca employees participated in the Caribe Wave tsunami drill, putting their evacuation plan into practice. During this drill, they educated their guests about what to do if a strong earthquake occurred or if they've received an official tsunami warning alert for Puerto Rico. Guidance was given to return to the hotel premises since it is outside the tsunami evacuation zone. The preparation of this hotel is such that during the strong seismicity that occurred in Puerto Rico in January 2020, people from the coastal area came to take refuge in its facilities.

The TsunamiReady evaluation committee in Puerto Rico is very proud of the excellent work and preparation of these facilities and all the many TsunamiReady Supporter agencies that during a tsunami emergency, would facilitate the work of emergency management response because they will self-manage the emergency in their facilities saving lives. We encourage states and countries of the world to promote preparedness programs of this type that would facilitate the management of a tsunami emergency.

Using TsunamiZone.org to Encourage Public Interest and Action in Your Region

By Jason Ballmann and Mark Benthien, Southern California Earthquake Center,
and Yvette LaDuke, California Governor's Office of Emergency Services (Cal OES)

Are you in the zone? Since 2014, TsunamiZone.org has supported and coordinated with NTHMP partners and others to inspire tsunami preparedness activities in their communities. This has involved thousands of people registering their participation in tsunami walks, mapping tsunami zones and evacuation routes, attending tsunami webinars and lectures, and conducting essential disaster preparedness activities such as building a kit or updating insurance policies. There are many different types of eligible tsunami preparedness activities that could be just a few minutes of one's time or much more.

While California's Tsunami Preparedness Week and the Caribbean's Caribe Wave exercise have been the most visibly supported campaigns of TsunamiZone.org, with more than 536,600 participants combined in 2021 so far, other regions such as Alaska, Guam, Hawaii, Oregon, USVI, and Washington also have official pages, activities, and multimedia materials supported through TsunamiZone.org. All regions can have pages, but they can also have much more through TsunamiZone.org support: customized graphics, email campaigns, social media messaging, news media resources, statistics, registration forms, and recruitment techniques through phone and email.

Official TsunamiZone Regions' Pages:

Alaska: TsunamiZone.org/alaska **
California: TsunamiZone.org/california
Caribbean: TsunamiZone.org/caribewave
Guam: TsunamiZone.org/guam *
Hawaii: TsunamiZone.org/hawaii **
Oregon: TsunamiZone.org/oregon **
USVI: TsunamiZone.org/usvi *
Washington: TsunamiZone.org/washington **

*New for this year **Major revisions/updates this year

WELCOME TO THE TSUNAMIZONE IN USVI!

Do you think that a tsunami can only happen somewhere else? The recent increase of earthquakes in the The U.S. Virgin Islands have reminded us the threat can occur at any moment.

Join us and practice how to survive a tsunami in The U.S. Virgin Islands! The USVI, along with the rest of the Caribbean, are located in a region with high levels of vulnerability and threat for tsunamis.

Tsunami Tips

- Understand the difference between the terms that identify a tsunami hazard: Advisory, Watch and Warning. Detailed explanation of these terms here
- Plan to act quickly (Emergency Backpack)
- If you are in coastal waters and notice a dramatic recession of water from the shoreline, you should heed nature's warning that a tsunami is approaching.
- Move inland immediately and do not return to the flooded and damaged areas until officials say it is safe to do so.

The 2021 Tsunami Awareness Week is Nov 1 - 5.

Register your participation here on TsunamiZone.org.

RESOURCES

Tsunami Maps, USVI

- St. Croix
- St. John
- St. Thomas

Tsunami Messages

Different types of tsunami alerts, explained.

Tsunami Safety for Tourists

Tsunami information for those visiting.

Emergency Backpack Contents

What you need if you must evacuate quickly.

Children's Book: "Oh No! A Tsunami!"

Ask info@tsunamizone.org for how to get a copy.

New page for the territory of the United States Virgin Islands (USVI) on TsunamiZone.org

Want a TsunamiZone.org page for your region?

Email Jason Ballmann (ballmann@usc.edu) with the following responses:

1. Simple 2-3 paragraph introduction to tsunamis in your region, for the top of the page
2. List of tsunami resources to be linked to (guides, videos, PDFs, and more), in a side box on the page
3. The date/time range you have a special tsunami focus (perhaps a day, week, or month?) and its campaign name, highlighted prominently on the page
4. Two or three images to help make the page look more like your state / territory / region! Could be landscapes, ports, tsunami maps, etc…., placed throughout the page

Contact us and we'll get started on a TsunamiZone.org page for your area!

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Using TsunamiZone.org to Encourage Public Interest and Action in Your Region

By Jason Ballmann and Mark Benthien, Southern California Earthquake Center,
and Yvette LaDuke, California Governor's Office of Emergency Services (Cal OES)

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Over the years, the Southern California Earthquake Center (SCEC) based at the University of Southern California (USC) has coordinated with the California Governor's Office of Emergency Services (Cal OES) to provide such direct support to all regions. SCEC can help create a variety of strategies, resources, and tracking systems for public participation. Here is a breakdown of total, global participation of the years:

TsunamiZone Participation Statistics:

2014: 1,175
2015: 126,438
2016: 405,086
2017: 821,614
2018: 574,343
2019: 845,664
2020: 210,295
2021: 536,600

*See a further breakdown by year, region, and categories
*And, see a wonderful overview of the Caribe Wave 2021 exercise in the NTHMP April 2021 Newsletter

The success in the Caribbean has been extraordinary; more than 500,000 participants have routinely participated over the years. But TsunamiZone.org's work could not have been successful without the collaborative energy of those leading the Caribbean who constantly translate and disseminate emails, media materials, web pages, and more. As an example, search on the hashtag #CaribeWave in Twitter to see how much interest and action was held this year for Caribe Wave!

Some of the languages the tsunami triad has been translated into, all available at TsunamiZone.org/graphics, and downloadable in PDF or PNG format.

Sample of New and Existing TsunamiZone Resources:

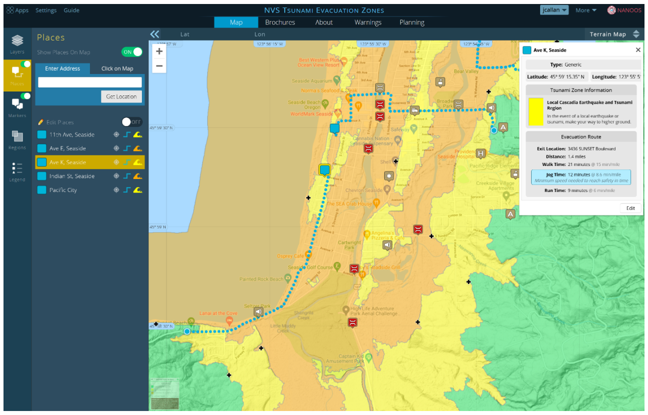
- How to Participate flyers for schools, colleges, businesses, and hotels: TsunamiZone.org/howtoparticipate
- Tsunamis: Fast, Furious, and Fascinating (Webinar, March 23, 2021)
- See email updates sent to TsunamiZone participants at TsunamiZone.org/updates
- The "tsunami triad" - created by the Redwood Coast Tsunami Work Group (RCTWG), available for download in numerous languages at TsunamiZone.org/graphics

As TsunamiZone.org continues to grow, many more regions have come on board in their own way. How will you help others better prepare to survive and recover from tsunamis? We continued to apply the factors that the late Dennis Mileti and other social science colleagues, Michele Wood and Linda Borque, had determined best motivate preparedness behaviors, i.e., when people 1) see and hear clear and consistent messages from many sources; 2) observe others like themselves getting prepared; 3) talk about preparedness with others they know; and 4) learn potential consequences, and how to prepare and mitigate. What do others need to know about the tsunami hazard in their area, and how can you help them?

Using Routable Road Network Analyses in Support of Tsunami Pre-Disaster Evacuation Planning

By Jonathan Allan, Laura Gabel, and Fletcher O'Brien, Oregon Department of Geology and Mineral Industries;
Joanna Merson, James Meacham, Justin White and Ken Kato, University of Oregon; and Troy Tanner, University of Washington.

In the June 2020 edition of *Tsuinfo Alert*, Allan described a multi-year collaborative effort between the Oregon Department of Geology and Mineral Industries (DOGAMI) and the Northwest Association of Networked Ocean Observing System (NANOOS) to build a web-based platform (http://nvs.nanoos.org/TsunamiEvac) and smartphone application (http://www.nanoos.org/mobile/tsunami_evac_app.php) to enable access to tsunami evacuation information and alerting for the Pacific Northwest region. The success of this effort has been impressive, with the portal now receiving ~30 thousand 'pageviews' per year. At the core of the application is the reliance on a variety of visual cues used to characterize vulnerable areas, including state defined tsunami inundation zone(s), areas of high ground (safety), and ancillary information such as assembly areas, building landmarks and to a lesser degree "exit" points on roads that define areas where the inundation zone terminates and safety (high ground) begins. Throughout this process a key requirement has been to emulate these same characteristics defined on conventional (static) evacuation brochures developed for local communities, to ensure consistency between brochures and the portal. Thus, the end user seamlessly transitions from static brochures to a web-based platform, visualizing the same information in a consistent framework. With advances in GIS modeling capabilities, web-based applications are increasingly able to offer so much more information that may be used to further assist individuals and communities prepare for a major earthquake and accompanying tsunami.



Ave K, Seaside

Type: Generic

Latitude: 45° 59' 15.35" N | Longitude: 123° 55' 5

Tsunami Zone Information

Local Cascadia Earthquake and Tsunami Region
In the event of a local earthquake or tsunami, make your way to higher ground.

Evacuation Route

Exit Location: 3436 SUNSET Boulevard
Distance: 1.4 miles
Walk Time: 21 minutes @ 15 min/mile
Jog Time: 12 minutes @ 8.6 min/mile
Minimum speed needed to reach safety in time
Run Time: 9 minutes @ 6 min/mile

The ability to automatically generate tsunami evacuation routes from any location within an inundation zone remains the panacea for tsunami evacuation preparation, especially when coupled with a web portal or smartphone application. Over the past 7 years, staff at DOGAMI have accelerated efforts to model tsunami evacuation challenges in virtually every community on the Oregon coast. Such modeling uses least-cost distance analysis to account for differences in terrain (e.g. road vs sand vs wetland) and the slope of the terrain to evaluate how long it will take individuals to evacuate out of the tsunami zone. Importantly, the pedestrian evacuation modeling considers variable wave arrival times across the landscape, potential obstacles such as the failure of bridges or liquefaction, ultimately producing maps depicting the minimum speeds required to evacuate and 'beat the wave'. Such information is critically important and has helped us identify areas on the Oregon coast where evacuation speeds faster than a walk (e.g. jog or run) are required to reach safety in time. Leveraging these datasets and recent advances in ArcGIS, DOGAMI staff have worked with researchers at the University of Oregon (UO) Infographics Lab and the UO Safety and Risk Services Location Innovation Lab to develop the necessary tools needed to generate on-demand evacuation routes for any location in the tsunami evacuation zone, which can be queried by a user using the NANOOS tsunami evacuation portal. To implement this capability, a routable road network was first developed, guided by model results defined from our community evacuation modeling, as a pilot study in four communities: Seaside, Rockaway, Pacific City and Charleston/Coos Bay. With knowledge of the inundation zone, wave arrival times across the landscape, exit points and a road and trail routing

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network, the routing tool outputs address points and the predefined routes for any given location within a community. The address points define the discrete locations with minimum assigned evacuation speeds, while the route segments contain a variety of information including the route length, three different travel speeds (walk, jog, run) with times to safety, and the nearest exit point location and name. These data were then validated against our own evacuation modeling, which confirmed the road routing tool was indeed retrieving the correct speed and route information.

With the successful completion of the routing geodatabase, these data are provided as a GeoJSON web service to NANOOS for incorporation into the web portal and smartphone application. NANOOS uses the address points and routing information to then display the route. We chose to use a the google maps walking symbology (cyan colored dots) to define the evacuation route (see accompanying figure), with a pop-up that displays a variety of information, including the starting location, nearest exit location, total route distance, and the three travel speeds and times to safety. Of importance, we highlight the minimum required evacuation travel speed needed to reach safety in time to 'beat-the-wave'. Currently, we are working with our University of Oregon colleagues to output turn-by-turn instructions (similar to google maps), which may be able to be printed in our custom tsunami brochure tool. In time, we anticipate migrating this capability to our smartphone application, while also expanding this capability to every coastal community on the Oregon coast.

A Process to Develop Community Disaster Caches to Prepare Communities to Survive in the Days following a Great Cascadia Earthquake and Tsunami

By Sue Graves, Consultant for Oregon Department of Geology and Mineral Industries

In May 2021 the Oregon Department of Geology and Mineral Industries and Oregon Office of Emergency Management released a comprehensive planning guide that explains how to develop community disaster caches. A community disaster cache is a stock of supplies designed to support a local population in its response to a disaster such as an earthquake or tsunami.

Why do communities need disaster caches? A large Cascadia earthquake and tsunami will leave communities all along the coasts of Oregon and Washington isolated, without electricity or functioning water and sewer systems, and without access to food, shelter, and communications. Communities are likely to be completely cut off from state and federal aid for several weeks and will be on their own for their basic survival needs. Although there are considerable resources for disaster planning for *individuals*, there are notably fewer resources available to assist *communities* trying to plan at a larger scale.

The Earthquake and Tsunami Community Disaster Cache Planning Guide provides a practical four-step planning process to empower planning teams to design disaster caches that will meet their community's unique needs, goals, and limitations (Figure 1). The Guide highlights different disaster cache models and includes information about where to locate caches, what supplies and equipment to include, how to fund a cache, sample budgets, and what is involved in

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A Process to Develop Community Disaster Caches to Prepare Communities to Survive in the Days following a Great Cascadia Earthquake and Tsunami

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(Continued from page 11)

maintaining a cache. Pictures, drawings, and planning templates are included to further aid the user (Figure 2).

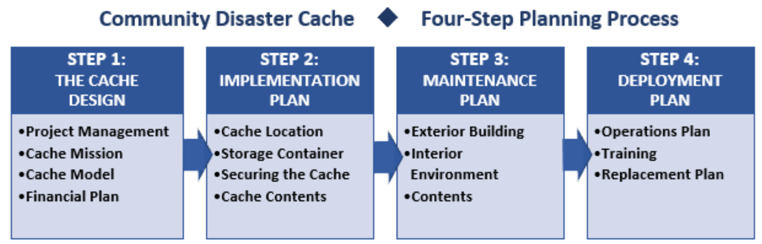

Figure 1: Overview of the Four-Step Community Disaster Cache Development Planning Process

Research for the Guide included a survey conducted in July and August 2020 that over 200 stakeholders participated in. The goal was to see what could be learned from those who had experience developing caches and from those who wanted to develop a cache or who had experienced challenges in developing their cache. Following the surveys, targeted interviews were conducted with key survey respondents that we wanted to learn more from. Finally, eleven successful community disaster cache projects from Oregon, Washington, and California were selected for case studies that are featured in the Guide, highlighting what has worked for these groups. By compiling the experiences, insights, lessons learned, and recommendations gleaned from these groups into a single comprehensive manual, our hope is to reduce the burden that communities face when considering developing disaster caches.

The Earthquake and Tsunami Community Disaster Cache Planning Guide can benefit a wide variety of groups: communities, organizations, agencies, schools, businesses, hospitals, and any group that wants to prepare in advance of a disaster by developing a cache of supplies to assist with the immediate survival needs of their specific population after a disaster. As planning teams invest the time to work through the Guide's four-step planning process they will:

Figure 2: Example of a Community Disaster Cache, Photo courtesy of Susan Graves

1. Complete the foundational design work necessary to determine their mission, select a cache model that is feasible for their community, and develop a realistic financial plan for implementation of a disaster cache;
2. Make informed decisions about where to locate the cache, how to store and secure it, and what to put in the disaster cache;
3. Establish procedures and agreements to maintain the cache so it will be in working order and ready to deploy when there is an earthquake, tsunami, or other disaster; and,
4. Develop helpful instructions and protocols so survivors can safely and effectively deploy the cache during a disaster and in a high-stress environment when resources are scarce.

Communities that prepare customized disaster caches to meet their unique needs are better equipped to respond to the anticipated immense needs created by a great Cascadia subduction zone earthquake, tsunami, or other disaster.

TSUNAMI RESEARCH & EVENTS

RESEARCH

Elbanna, Ahmed; Abdelmeguid, Mohamed; Ma, Xiao; Amlani, Faisal; Bhat, H. S.; Synolakis, Costas; Rosakis, A. J., 2021, Anatomy of strike-slip fault tsunami genesis: PNAS, v. 118, no. 19, e2025632118, https://doi.org/10.1073/pnas.2025632118.

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Lee, J.-W.; Irish, J. L.; Weiss, Robert, 2021, Probabilistic Near-Field Tsunami Source and Tsunami Run-up Distribution Inferred From Tsunami Run-up Records in Northern Chile: Journal of Geophysical Research Oceans, v. 126, no. 6, e2021JC017289, https://doi.org/10.1029/2021JC017289.

Lindsey, E. O.; Mallick, Rishav; Hubbard, J. A.; Bradley, K. E.; Almeida, R. V.; Moore, J. D. P.; Bürgmann, Roland; Hill, E. M., 2021, Slip rate deficit and earthquake potential on shallow megathrusts: Nature Geoscience, v. 14, no. 5, p. 321–326, https://doi.org/10.1038/s41561-021-00736-x.

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Riquelme, Sebastián; Fuentes, Mauricio, 2021, Tsunami Efficiency Due to Very Slow Earthquakes: Seismological Research Letters, https://doi.org/10.1785/0220200198.

UPCOMING NTHMP MEETINGS & TSUNAMI CONFERENCES

- July 19, 2021—NTHMP Partner 101 (NESEC) https://nws.weather.gov/nthmp/index.html
- July 29, 2021—NTHMP CC Summer Meeting (Virtual) https://nws.weather.gov/nthmp/index.html
- August 5, 2021—NTHMP Partner 101 (USGS) https://nws.weather.gov/nthmp/index.html
- September 20-26, 2021—AEG Annual Meeting (San Antonio, TX) https://www.aegannualmeeting.org/
- September 23, 2021—NTHMP CC Fall Meeting (Virtual) https://nws.weather.gov/nthmp/index.html
- October 10-13, 2021— Geological Society of America (Portland, OR) https://community.geosociety.org/gsa2021/home
- December 13-17, 2021—AGU Fall Meeting (New Orleans, LA) https://www.agu.org/fall-meeting