2024

Authored by National Tsunami Hazard Mitigation Program Coordinating Committee Members October 2024
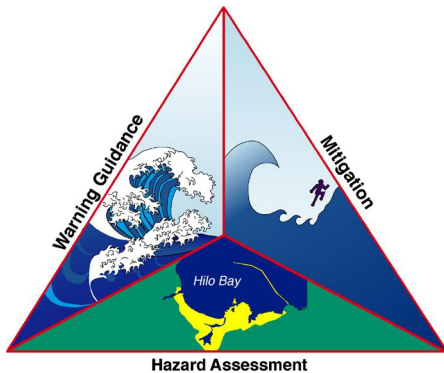

Image: NTHMP fieldtrip to Cannon Beach, Oregon coast. Jay Patton (California Geologic Survey) introduces the Cascadia earthquake and tsunami story (Credit: Alex Lopes, DOGAMI, 2 August 2023)

Accomplishments of the National Tsunami Hazard Mitigation Program: An Annual Report

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The National Tsunami Hazard Mitigation Program (NTHMP) works to protect lives and reduce economic losses from tsunamis at the community level. The NTHMP includes the National Oceanic and Atmospheric Administration (NOAA), the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), and 28 U.S. states and territories. Through collaboration, coordination, and support to partner states and territories, the NTHMP focuses on three key functions: hazard assessment, warning guidance, and mitigation. This report was produced to highlight some of the NTHMP's 2023/24 accomplishments. It is a compilation of submissions from the NTHMP's subcommittees and partner states and territories. Summaries provided by the following state and territorial agencies and institutions:

- Alaska Division of Homeland Security and Emergency Management/University of Alaska Fairbanks Alaska Earthquake Center/Alaska Division of Geological and Geophysical Surveys
- American Samoa Territorial Emergency Management Coordination
- California Governor's Office of Emergency Services/California Geological Survey
- Commonwealth of the Northern Mariana Islands Homeland Security and Emergency Management
- Guam Homeland Security
- Hawai'i Emergency Management Agency/University of Hawai'i
- Oregon Office of Emergency Management/Oregon Department of Geology and Mineral Industries
- Puerto Rico Emergency Management Agency/University of Puerto Rico Puerto Rico Seismic Network
- Texas A&M University at Galveston (Gulf Coast)
- University of Delaware/University of Rhode Island (East Coast)
- U.S. Virgin Islands Territorial Emergency Management Agency
- Washington Emergency Management Division/Washington State Department of Natural Resources

weather.gov/nthmp/

National Tsunami Hazard Mitigation Program (NTHMP) General Updates

Annual Meeting: The National Tsunami Hazard Mitigation Program (NTHMP) routinely meets two times per year, normally at locations in the Continental United States (CONUS). For Fiscal Year [FY] 2024, the two meetings were combined into one annual meeting, held in Pago Pago, American Samoa, from July 23-25, 2024. Additionally, a tour of the Pacific Tsunami Warning Center (PTWC) and the International Tsunami Information Center (ITIC) on Ford Island at the NOAA Daniel K. Inouye Regional Center (IRC), Honolulu, HI, was offered on July 22 and 26. This marks the first time that an NTHMP meeting was held outside of the CONUS and also at a U.S. Territory. Staff from the Pago Pago NWS Weather Service Office (WSO) and the American Samoa Department of Homeland Security (ASDHS) hosted this event. About 40 people representing state and territory NTHMP partners and partnering federal agencies attended the meeting.

One of the primary goals of this meeting was to highlight the importance of vigilance and preparedness against the ever-present threat of tsunamis, particularly for island states and territories across the Pacific and Caribbean. With over half of the NTHMP's partners being island states and territories, the meeting emphasized listening to the challenges and opportunities they face, allowing other partners in the program to hear about ways in which to discuss and work toward more equitable goals and solutions that will strengthen the program as a whole. The three subcommittees held separate meeting sessions so that representatives could provide updates and the groups could discuss new and ongoing initiatives, as FY23 work was winding down, leading into the FY24 funding cycle.

Grants: For the FY23 grant cycle (September 1, 2023 – August 31, 2024), NOAA's National Weather Service (NWS) awarded $6,000,000 to the 12 NTHMP partners and NOAA's National Centers for Environmental Information for digital elevation model development, and within the scope of the NTHMP Strategic Plan. More information on the NTHMP, grant recipients, and resources on grant-funded projects is available at weather.gov/nthmp/Grants.

NTHMP Publications and Resources: *TsuInfo Alert*[1] (*1999 to present*) is a bi-monthly newsletter, issued by the State of Washington's Dept. of Natural Resources (DNR), on behalf of the NTHMP. The newsletter showcases newsworthy updates on current efforts in the work of tsunami research, mitigation efforts, community awareness, education, and outreach by NTHMP partners. Six editions were released in FY24.

Administration: The NTHMP Coordinating Committee (CC) has undergone substantial turnover in representation over the past few years. An updated list of CC members has been compiled and has been posted to the NTHMP website[2]. The NTHMP continues to be led by Chair, Ray Tanabe, NWS Pacific Region Director. The new NTHMP Administrator, as of March 2024, is Sarah Rogowski. Sarah serves as the Tsunami Program Analyst at NWS Headquarters. Sarah replaces Ian Sears, who left the Tsunami Program in June 2023. As of July 2024, Corina Allen is the new NWS Tsunami Program Manager. Corina replaced Michael Angove, who retired in December 2023.

The Coordinating Committee welcomed replacement state and territorial members of the NTHMP Coordinating Committee:

- Stephen Cahill, Emergency Management Guam Homeland Security, Guam
- Skylar Suiso, Hawaii Emergency Management, Hawaii
- Daniel Eungard, Geologist-Tsunami Hazards, State of Washington

New NTHMP Website: In July 2024, the NWS discontinued a legacy server that hosted a number of agency webpages, including the legacy NTHMP webpage. In preparation for that action the Tsunami Program transferred content from the legacy webpage to: weather.gov/nthmp/. The new webpage maintains a similar structure to the menu options and other included links, but the aesthetics are more consistent with base NWS webpages. As of the end of FY24, some of the subpage content and certain legacy resource webpages and documentation could not be immediately ported over to the new site, due to page formatting differences. In FY25, the goal is to update all webpages, content, and documentation to reflect the current status of the program as well as contain and provide archived content.

For more information about the NTHMP and its nationwide efforts to effort to mitigate the impact of tsunamis through public education, community response planning, hazard assessment, and warning coordination, contact nws.tsunamigrants@noaa.gov.

[1]https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis/tsuinfo-alert
[2]https://www.weather.gov/media/nthmp/Shared%202024%20NTHMP%20Membership%20Update%20-%20CC%20for%20Website.pdf

Mapping and Modeling Subcommittee (MMS)

Revised Guidelines and Best Practices for Tsunami Hazard Analysis, Planning, and Preparedness for Maritime Communities: Ports, harbors, and the maritime community at large are some of the most vulnerable populations to tsunamis. The MMS recognized the importance of developing standardized guidance and recommendations with the most current science available and prioritized revamping the NTHMP guidelines and best practices document related to tsunami hazard analysis, modeling, and mapping for maritime communities. This update highlights over 7 maritime tsunami hazard preparedness products that range from identifying areas of past tsunami damage and strong currents to estimating areas of potentially large water-fluctuations and increased currents through modeling, in addition to evacuation options based on safe offshore depths and timeframes exposed to damaging currents. The MMS plans to collaborate with the rest of the NTHMP subcommittees to update these best practices further by developing recommendations for tsunami response, preparedness, education, mitigation, and recovery.

Developed Methodology for Probabilistic Tsunami Hazard Analysis: The MMS has been developing a methodology for probabilistic tsunami hazard analysis (PTHA) through collaboration with the USGS Powell Center. PTHA and the identification of multiple probabilistic hazard curves (e.g. the 475, 975, and 2,475 return periods) for given areas will prove to be beneficial in a variety of risk applications, but especially with respect to future revisions of the American Society of Civil Engineers (ASCE) tsunami 2,475-year tsunami design zone and as they relate to FEMA's National Risk Index. Six workshops have been completed where discussions of the PTHA methodology and logic tree process took place. These
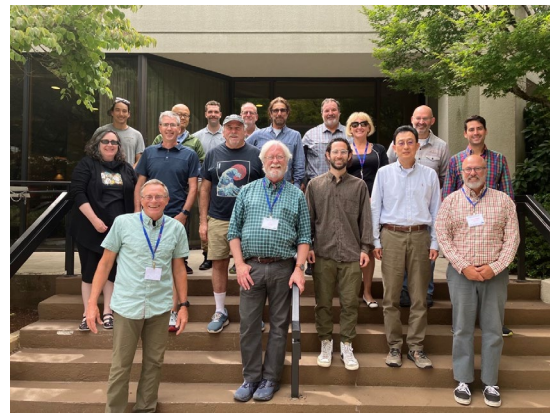
workshops included focused meetings on the following sources: Alaska, Caribbean/Gulf/East coasts, Cascadia, other Pacific sources, and crustal faults. Pending available funds, an additional PTHA meeting via the Powell Center on landslide and volcanic generated tsunamis may take place during the upcoming year. Logic trees developed in the workshops will be used to guide PTHA development in each of these regions.

Organized Debris and Sediment Transport Modeling workshops: Real world tsunami events face the realities of erosion, deposition, and changing coastlines. The MMS realizes the importance of these dynamic processes and aims to incorporate both sediment and debris transport in future modeling studies. In 2023, the MMS organized benchmarking workshops for both sediment and debris transport processes, and modeling results are actively being submitted to evaluate both real world and laboratory-based test cases. Reporting and documentation of these benchmark tests are expected in the next fiscal year.

***Prioritized Digital Elevation Model Development by NOAA's National Centers for Environmental Information:*** Current digital elevation models (DEMs) are imperative for all tsunami modeling activities. In 2024, the MMS completed DEMs with a 1/9th arc-second native resolution for the following locations: Puget Sound (including the gaps between the San Juan Islands, Vancouver Island, and Point Roberts, Washington), the Columbia River (Oregon and Washington), and Gustavus, Alaska. Additionally, the DEMs currently in development include Nome, Alaska to the northwestern Bearing Sea, and the southwest coast of Washington State. MMS will continue to support DEM development in the future, prioritizing areas of Western Alaska and the tsunamigenic volcanic sources within the Aleutian Island chain for the upcoming fiscal year.

Mitigation and Education Subcommittee (MES)

The MES convened quarterly virtual meetings throughout the year in addition to the in-person NTHMP Annual meeting held 23-25 July 2024 in Pago Pago, American Samoa. MES meetings provide an opportunity for NTHMP partners to share tsunami preparedness and mitigation accomplishments as well as other activities initiated by Partner agencies. Featured talks at the virtual meetings included "How the USVI utilizes other Federal Grants to strengthen the Tsunami Program" (Virgin Islands Territorial Emergency Management Agency), and "TsunamiReady and TsunamiReady Supporter in Puerto Rico" (Puerto Rico Emergency Management Bureau). An MES 2024 Summer Meeting Summary is included in the August 2024 *TsuInfo Alert* newsletter.

2023-24 MES Coordination and Accomplishments include:

- Exercise support for NTWC, PTWC, and the Warning Coodination Subcommittee (WCS) in annual tsunami exercises (CaribeWave, Lantex, Pacifex).
- Recommendations for TsunamiReady® program and guidelines as requested by NWS. The MES TsunamiReady® Tiger Team efforts resulted in twenty-five TsunamiReady® Program Recommendations.
- Hazus tsunami module expansion coordination with FEMA to advance the operationalization of the Hazus tsunami module for the U.S. East Coast. This effort aims to establish a standardized framework that ensures uniform and equitable tsunami risk assessments for all regions.
- Methods for identifying Potentially Tsunami Vulnerable Populations. A guide was developed: "Social Vulnerability Analysis Using FEMA's Hazus Software, A Guide For Emergency Managers". This resource provides a step-by-step framework for integrating social vulnerability into tsunami hazard assessments.
- Tsunami Debris Guidebook. This first of its kind guidance emphasizes the importance of advance planning for debris management, including identifying potential collection sites, pre-establishing agreements, and ensuring intergovernmental coordination.
- Manual for Tsunami Vertical Evacuation Structures, Second Edition. A road map developed to assist communities in evaluating and planning for tsunami vertical evacuation structures.
- *TsuInfo Alert* newsletter. Six issues of the bi-monthly NTHMP newsletter *TsuInfo Alert* were published.
- Draft methods and sources for estimating temporary populations in tsunami hazard zones.
- Draft Tsunami Wayfinding Evacuation Guide. Washington State completed a tsunami evacuation route wayfinding project and is nearly finished with a Tsunami Wayfinding Guidance document.
- TsunamiZone.org was utilized to promote and recruit participation for tsunami exercises (CaribeWave, Lantex, Pacifex). NTHMP partner pages were maintained, created, and updated. Tsunami preparedness materials are available in multiple languages.
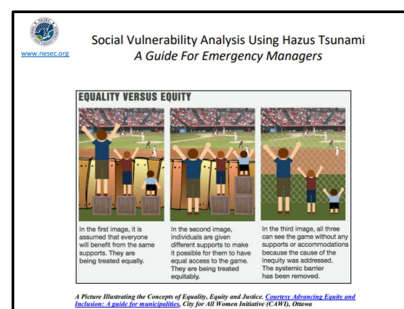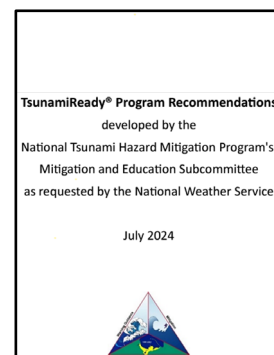
Warning Coordination Subcommittee (WCS)

Over the past year, one of the primary accomplishments for the WCS came through the Hazard Simplification Deep Dive Project, led by the Washington State Emergency Management Division. The first phase of the project was working to document existing tsunami alerting and response procedures, processes and products for each NTHMP state and territory partner. This process was collaborative, as expertise was provided by a wide range of partners, including state and territory tsunami program leads and those with alerting and response expertise, including: National Weather Service Weather Forecast Office personnel, the Tsunami Warning Centers, and Coast Guard and Navy personnel. Information gathered during these discussions was incorporated into a template modeled from Washington's Tsunami Alerting and Response Timeline and adjusted to fit both National and Pacific Tsunami Warning Center customer needs.

Within the past year, five states and territories finalized an initial Tsunami Alerting and Response Timeline for their respective jurisdictions: American Samoa, California, the Commonwealth of the Northern Mariana Islands, Guam and Puerto Rico, with the U.S. Virgin Islands very close to finalizing their own timeline. These timelines represent a first-of-its-kind document for each partner, creating a tsunami alerting and communications foundation that identifies roles and responsibilities in alert dissemination, initial response actions, and the specific methods and software used in disseminating alerts from the moment an earthquake is detected that could

generate a tsunami to the moment the public receives the tsunami alerts. The documents provide essential planning information for tsunami incidents that can be shared with critical partners, reducing confusion and establishing clear roles when it comes to tsunami alerting and communication. They can also be adjusted for planning purposes for alerting of other hazards, such as lahars.

Utilizing the information compiled during the development of the Tsunami Alerting and Response Timelines, the project has now shifted to gathering tsunami alerting and communication gaps, needs, and challenges for each state and territory tsunami program. Over the course of the next year, this information will be analyzed and compiled into a report that highlights both commonalities between partners and unique alerting and communication gaps. This information will be assessed by the Warning Coordination Subcommittee, and cross-cutting needs will be identified. An implementation strategy will then be drafted to address the tsunami alerting gaps, needs, and challenges over time.

In addition, Warning Coordination Subcommittee members have provided initial feedback for an update of the tsunami.gov website, a NOAA-funded initiative focused on long-term improvements and recommendations through this body. The site design is in the second year of a two-year plan where direct user feedback will be required and valued.

The Warning Coordination Subcommittee is also tracking the ongoing NOAA-funded social science initiative known as "Hazard Simplification," which is intended to support data-driven decisions regarding tsunami alert messaging, including the use of the word "Advisory".

Mitigation and Recovery Planning Work Group (MRPWG)

The Mitigation and Recovery Planning Work Group (MRPWG) was established in 2018 to enhance the effectiveness of tsunami mitigation and recovery planning products, with the goal of strengthening coastal community resilience on a national scale. The work group consists of science and emergency manager representatives from NOAA, FEMA, USGS, Washington, Oregon, California, Hawai'i, U.S. Virgin Islands, and Puerto Rico. The work group collaborates on all things mitigation and recovery but has four primary subgroups:

Funding Strategies for Mitigation and Recovery Products Group: MRPWG continues to document lessons learned from successful and unsuccessful attempts to acquire funding for tsunami mitigation projects and recovery planning, including the construction of vertical evacuation structures and maritime mitigation projects. In the future, MRPWG plans to develop a living guidance document to address issues such as obtaining local match funds, completing benefit-cost analyses (BCAs), and applying best practices. The goal is to develop 1-pager "cookbooks" of key funding strategies and sources of mitigation funding that can be shared with stakeholders. MRPWG is also working with FEMA to identify potential improvements to the FEMA BCA tsunami module to ensure tsunami mitigation projects are competitive with other hazards.
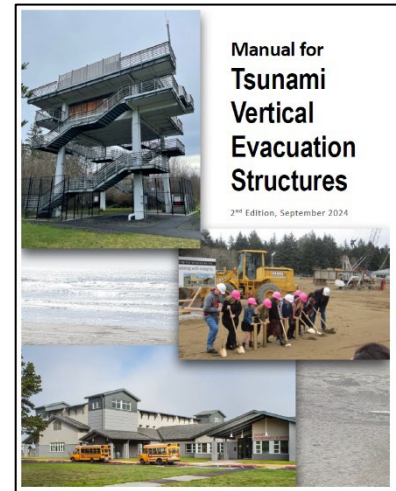
Tsunami Maritime Mitigation and Guidance Group: MRPWG has developed an online resource for [tsunami maritime mitigation planning and preparedness](). The guidance is intended for harbor engineers, owners, and operators, community hazard mitigation specialists, and the US Coast Guard. In the future, MRPWG plans to expand on additional resources, including risk reduction strategies, best practices, mitigation activities, modeling capabilities, and harbor assessments. Additional future work will include revisiting recommended offshore depths for boaters, harbor cost-benefit analysis guidance, and the use of real-time draw-down forecast information for maritime planning and response.

Tsunami Debris Recovery Planning Group: Representatives from NTHMP and the Oregon Department of Emergency Management recently published a new technical guide called Understanding Tsunami Debris and Sediment Planning and Mitigation- A Guide for Local Debris Planners (2024). This guide provides knowledge, tools, and insights needed to plan and mitigate for the dynamics of tsunami debris and debris management. In addition, MRPWG is working to create a tsunami recovery planning guide for California coastal communities that incorporates scenarios and international recovery experiences into its guidance.

Hazard Communication Guidance Group: MRPWG has initiated the development of draft guidance for the use of both deterministic and probabilistic tsunami hazard assessments, as well as strategies for communicating the results to relevant stakeholders. This guidance is intended for emergency managers, building officials, planners, elected officials, emergency responders, and the general public. In the future, MRPWG plans to expand this work to include uncertainty communication and the development of stakeholder-specific guidance.

Tsunami Digital Elevation Model Development (NCEI)

NOAA's National Centers for Environmental Information (NCEI) provides environmental data, products, and services to drive resilience, prosperity, and equity for current and future generations. Yearly NTHMP funding to NCEI goes toward the production of tsunami digital elevation models (DEMs) to further tsunami modeling and mapping in coastal communities. These DEMs incorporate bathymetry and topography seamlessly at the coast, crucial for inundation and sea level research. NCEI provides high resolution DEMs (~3 m) along the U.S. coast, and lower resolution further offshore (Coastal Relief Models) to ~ 1 km global resolution (ETOPO).

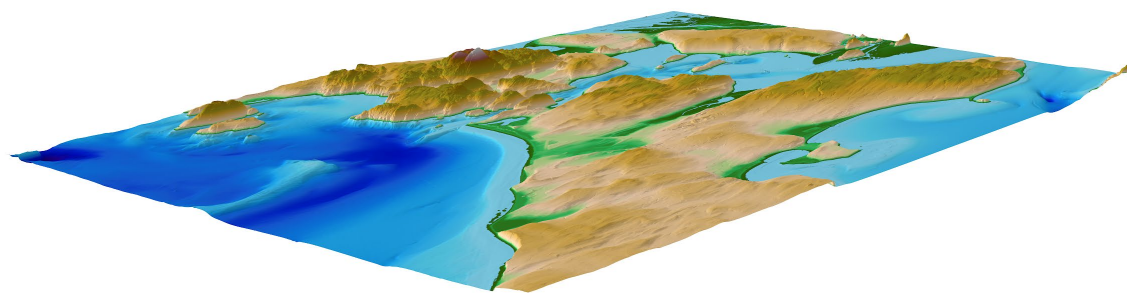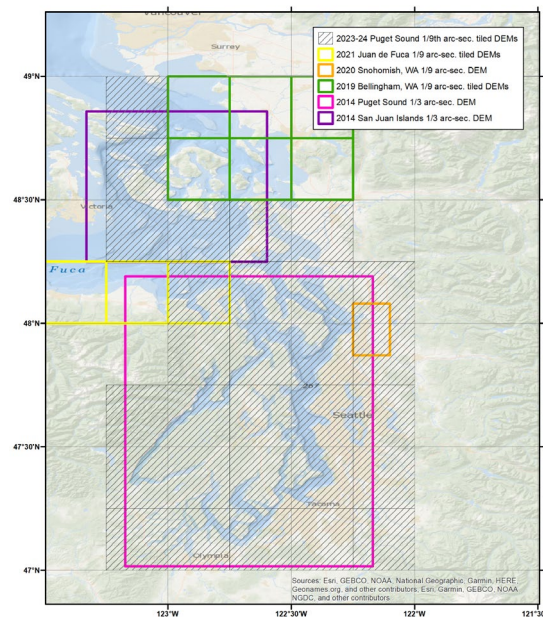| NTHMP Funded	Status
Puget Sound, WA including San Juan Islands gap to Vancouver Island and Point Roberts	Completed March 2024
Gustavus, Alaska	Completed May 2024
Columbia River, OR and WA	Completed August 2024
Nome, Alaska	Completed September 2024
Norton Sound and Northwestern Bering Sea (nested DEMs)	In progress

Figure 1: Top) Map of DEM extents for Puget Sound region. Bottom) Perspective image of Whidbey Island and Fidalgo Island in Northern Puget Sound (2x vertical exaggeration).
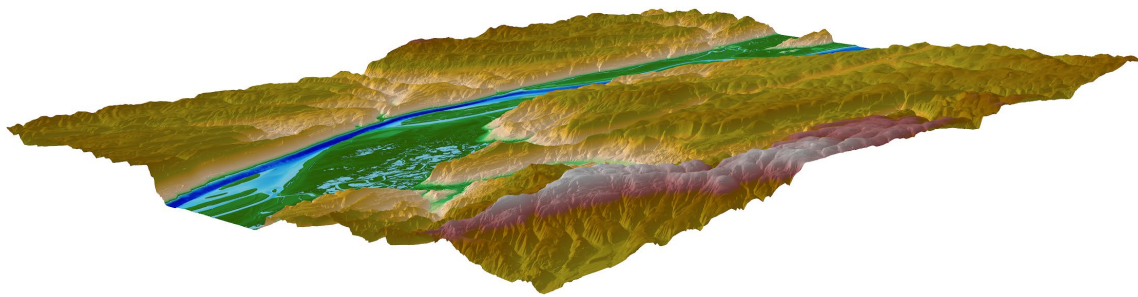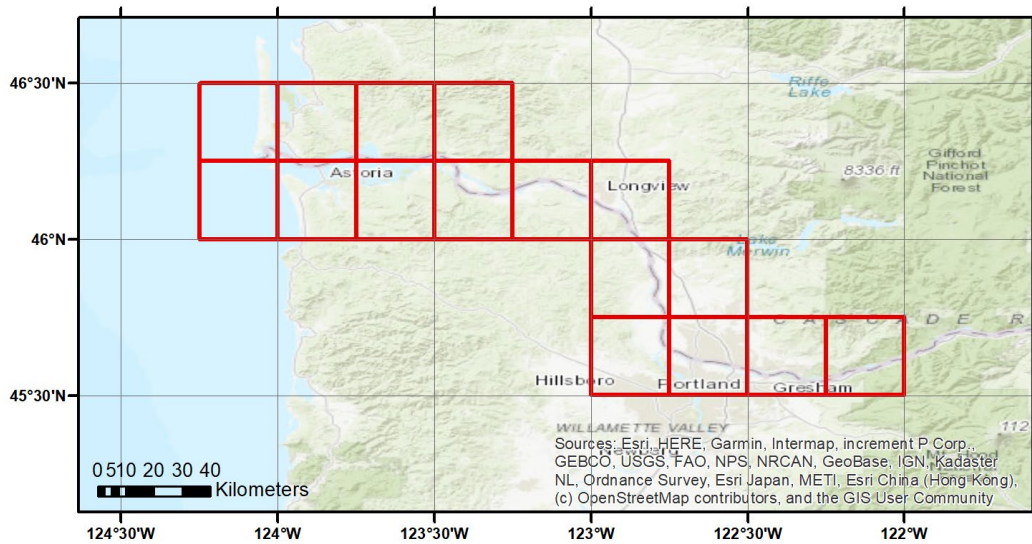
Figure 2: Top) Columbia River DEM tiles. Bottom) Perspective image of the Lower Columbia River just west of Longview, WA (2x vertical exaggeration).
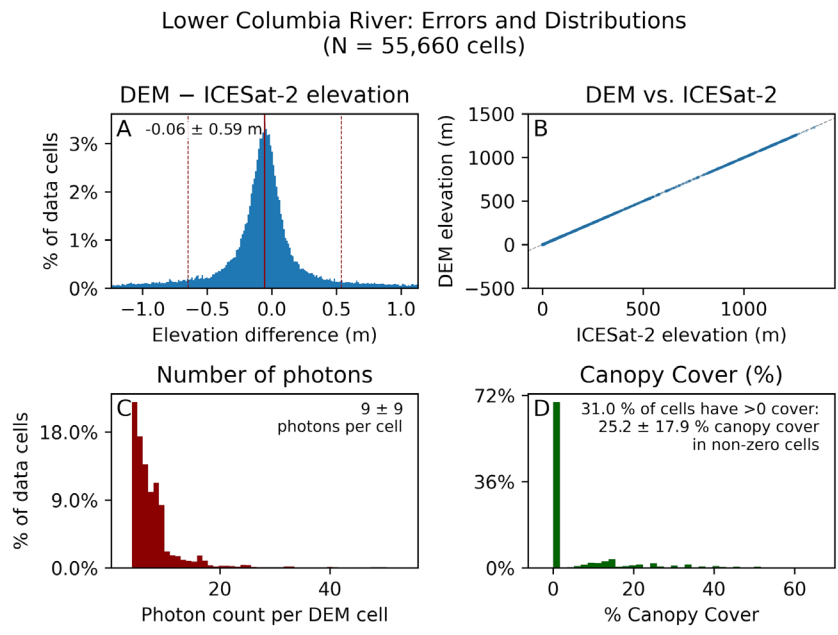

Figure 3. ICESat-2 validation plots for the Lower Columbia River (16 tiles).

Alaska

Tsunami Ready: With the support of the National Tsunami Hazard Mitigation Program (NTHMP) and in partnership with the Alaska Division of Homeland Security and Emergency Management, the State of Alaska successfully certified two communities as TsunamiReady: the City of Seldovia and Seldovia Village. Notably, Seldovia Village is the first Alaska Tribal community to achieve TsunamiReady certification.

Installation of Tsunami Sirens: The communities of Haines, Hydaburg, and Whittier have been outfitted with tsunami sirens in the past year. All three locations experience significant population increases during the summer months due to peak tourist season, making these safety installations particularly crucial for public safety.


Tsunami Hazard Assessment: Modeling of potential tsunami scenarios and publication of the tsunami inundation maps and reports are done for Anchorage, Girdwood, Hope, Ninilchik, Tyonek, Anchor Point and Kenai. A tsunami hazard assessment report for False Pass is expected to be published by the end of 2024. Community brochures with tsunami evacuation zones are completed for Seldovia, Anchorage, Hope and Matanuska-Susitna Borough.

Outreach: The Alaska tsunami program successfully conducted education and outreach campaigns targeting both public and school audiences. They delivered presentations on tsunami science and emergency preparedness to community members and schools in Dutch Harbor, False Pass, Anchorage, Matanuska-Susitna Borough, Kenai Peninsula Borough, Kodiak, Seldovia, Hope and Valdez.

Seward Tsunami Operations Workshop: The State of Alaska hosted its annual Tsunami Operations Workshop in Seward, Alaska. The timing was particularly meaningful as it marked the 60th anniversary of the Good Friday Earthquake. Holding the workshop in Seward was symbolic, demonstrating how far a community can progress in the 60 years following such a life-altering event and highlighting their remarkable resilience. The workshop brought together 25 tribal and local emergency managers with state and federal subject matter experts. Participants received comprehensive training on tsunami science, emergency preparedness, and the historical context of seismic and tsunami activity in their regions.
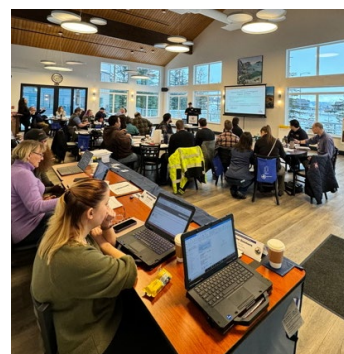
Tsunami Evacuation Drills: The program successfully completed two tsunami evacuation drills with the City of Dutch Harbor, involving the local high school and elementary school. The drills received support from local, state, and federal agencies and were deemed a success.

American Samoa

Siren Rehabilitation and/or Repairs Project: From January to February, Mr. Robert Basil, a siren technician from American Signal Corporation (ASCJ, traveled to American Samoa to provide training on the Compulert Siren System. This training was provided for the EOC Watch Officers and other ASDHS staff, focusing on how to effectively operate the Compulert in the EOC Communications Room.

Outreach Activities: Villages consist of village councils, mayors, and young men who play vital roles in ensuring the protection and safety of residents. In line with our overarching goal of tsunami ready, we are dedicated to supporting and educating all village mayors on effective tsunami preparedness strategies. In May, we organized an outreach event for all village mayors, which included the participation of the Secretary of Samoan Affairs and District Governors. Outreach efforts included a range of visits to schools and faith-based organizations. This involved reviewing their emergency drills and evacuation procedures. Furthermore, ASDHS team has been leading the Tsunami Awareness Week events in September and the Great ShakeOut Earthquake Drill in October.

NTHMP Annual Summer Meeting: In July and in collaboration with the local National Weather Service Office, American Samoa held the NTHMP Annual Meeting. The local government and various partners also provided their support. The agenda was packed, featuring a traditional Samoan culture ava ceremony hosted by the village of Leone. Welcoming remarks were delivered by the Honorable Governor Lemanu P.S. Mauga. Additionally, Dr. Fai Cheung presented a briefing on the latest Maritime Hazard Maps for the small harbors of Aunu'u and Auasi.

Other Activities: The NTHMP Team actively engaged in the HERicane CAMP initiatives organized by the Pacific Center for Human Security and also contributed to the 3rd Annual Disaster Resilience Summit in September. Furthermore, our team has been proactive participants in the American Samoa Coastweeks event, hosted by the local Department of Commerce.

California

The California Tsunami Program (CTP) is a collaboration between the California Governor's Office of Emergency Services (Cal OES) and the California Geological Survey and partners with the National Weather Service and other agencies to enhance preparedness and mitigation across California's twenty coastal counties and 70+ ports and harbors by identifying risks and planning and preparing for potential tsunamis.

Comprehensive Tsunami Preparedness Led by the CTP: The CTP generated tsunami hazard maps and facilitated tsunami sign plan development and guidance to support the creation of publicly accessible tsunami evacuation maps. These maps are the foundation for local tsunami response plans which are rigorously tested through exercises and drills. The CTP planned, led, and engaged in multiple tsunami exercises and drills during the last year including a U.S. Coast Guard Pacific Area tsunami workshop, Santa Cruz Harbor tabletop exercise, and the Unified Port of San Diego tsunami exercise.

Groundbreaking Tsunami Risk Assessments and Impact Reports for Coastal California: The CTP used the Hazus Tsunami module and other risk assessment tools to collect and analyze data to produce customized reports for potential tsunami damages and economic impacts along coastal California. The results for [Damages and Exposure from Tsunami in California](#) are a first-of-its-kind for California and provide consistent population exposure and loss estimates using the best-available methods and data. These results are provided at the local, county and state-levels as a resource for tsunami mitigation and response planning. An interactive dashboard and county-level summary sheets for the tsunami damage and exposure results are available for the twenty California counties.

Enhanced Tsunami Response Tools and Collaborative Workshops for California: The CTP updated California's tsunami response decision-support tools (Tsunami Playbooks) for all twenty California coastal counties to support tsunami response operations. The CTP led workshops with federal, state, and local partners to provide subject matter expertise on the use of the Tsunami Playbooks and how they support the decision-making process during tsunami response.

TsunamiZone.Org with Global Exercise and Tsunami Education Support: Cal OES contracts with the University of Southern California Statewide California Earthquake Center to develop and maintain [TsunamiZone.org](#) and to provide tsunami education, Tsunami Preparedness Week, and exercise support, including Caribe Wave, for all NTHMP members.

Collaborative Development of Tsunami Debris and Sediment Mitigation Resources: The CTP participated in the development of the NTHMP Tsunami Debris and Sediment Planning and Mitigation Guide. Work is in progress with the University of Southern California Tsunami Center to develop a suite of draft tsunami debris visual and statistical products for this Guidance that can be used by harbor and other coastal officials for response, mitigation, and recovery planning.
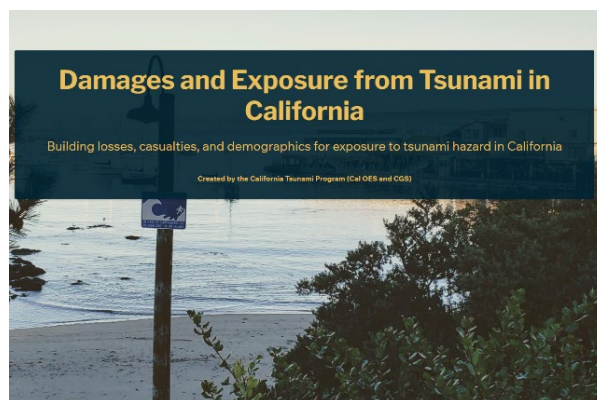
Commonwealth of the Northern Mariana Islands

The Commonwealth of the Northern Mariana Islands (CNMI) Homeland Security and Emergency Management (HSEM) has made significant strides in enhancing CNMI's preparedness and resilience against natural disasters, particularly tsunamis, achieved through education, collaboration, and integration of modern technologies.

Acquisition of Mobile Alert Siren Trailer Units: CNMI HSEM successfully acquired two Mobile Alert Siren Trailer units, greatly enhancing the Commonwealth's Early Alert and Warning capabilities. These mobile units improve the region's ability to issue real-time alerts during emergencies, ensuring the public receives timely warnings. This marks a significant achievement, as CNMI HSEM previously did not have any early warning sirens in place.

Public Education & Outreach: In an effort to raise awareness and preparedness, HSEM conducted numerous public education and outreach activities. These initiatives targeted government elected officials, public school faculties and staff, and community members living in tsunami inundation zones. By focusing on education and preparedness, HSEM empowered individuals to take proactive measures in ensuring their safety.

Tsunami Response for Businesses' Workshop: With invaluable support from the International Tsunami Information Centre (ITIC), CNMI HSEM conducted a unique workshop entitled "Tsunami Response for Businesses," targeting private sector businesses operating in tsunami inundation zones. This workshop provided crucial training to business owners and staff, helping them develop tsunami response strategies and standard operating procedures to enhance the safety of both employees and customers.

Development of Inundation Modeling Strategies and Evacuation Maps: With assistance of the CNMI NTHMP science representative and a contractor, CNMI HSEM completed its tsunami evacuation maps. The science representative also developed a comprehensive modeling strategy and provided several science reports.

Collaborative School Tsunami Drills: CNMI HSEM worked closely with key stakeholders, including the CNMI Public School System, Department of Public Safety, Department of Fire & Emergency Services, and Northern Marianas College, to conduct multiple school tsunami drills for schools located in inundation zones.

Updated Outreach Materials: To support public education efforts, CNMI HSEM produced and distributed updated outreach materials, including Children's Activity Books, Tsunami Awareness Brochures, updated Tsunami Inundation Zone Maps, Tsunami Pinwheels, and family-friendly playing cards featuring emergency tips. These materials provide critical information in a variety of engaging and accessible formats.

Revitalization of Tsunami Signage: CNMI HSEM revitalized and updated critical Hazard Zone, Evacuation Route, and Assembly Area signage across Saipan, improving public awareness and evacuation readiness. The signage provides clear, visible guidance in case of an emergency, ensuring safer evacuations for the community.
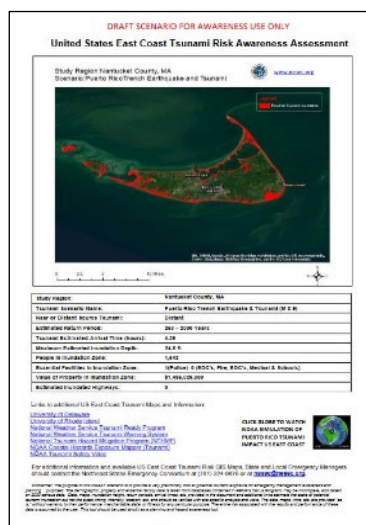
East Coast

A preliminary probabilistic tsunami hazard analysis was performed for the U.S. East Coast (USEC), based on 14 extreme sources for each case (coseismic, volcanic, and landslide) causing Probable Maximum Tsunamis (PMTs) in some area of the USEC, by estimated return periods for each source. 500- and 2500-year hazards were simulated for these sources, for 5 different tsunami metrics. Results indicate that the risk of a potentially damaging tsunami along the USEC is remarkably comparable to that of the US West Coast. A paper detailing the methodology and results is currently under review[3].

A new methodology developed to perform PTHA for landslide tsunamis was applied to the USEC (middle and southern areas). Results will be used in future, more comprehensive PTHA work, for the USEC. Figures below show examples of the application of the landslide PTHA to the middle USEC region, with results used to illustrate a paper in preparation detailing the landslide PTHA methodology.
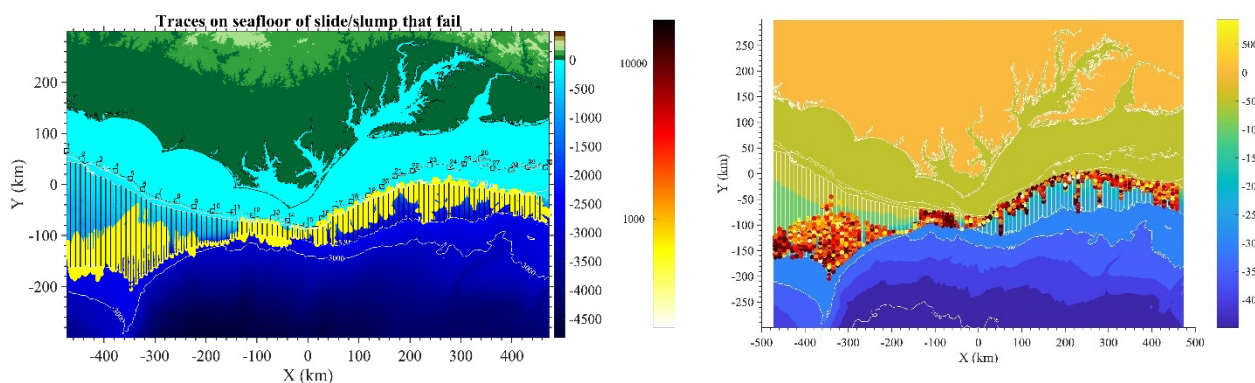
Two high resolution tsunami inundation maps for USEC were developed for Dukes and Nantucket Counties in Massachusetts. Tsunami Risk Awareness Assessments were developed from the high-resolution inundation maps for Dukes and Nantucket Counties and are available at https://nesec.org/mapyourrisk.

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[3] Grilli, S.T., L. Schambach, M. Mohammadpour, A.R. Grilli, J.T. Kirby, E. Fratto and F. Shi. Tsunami hazard assessment along the US East Coast from extreme sources in the North Atlantic Ocean: a preliminary probabilistic analysis. Natural Hazards (submitted)

Guam

Over the past year, Guam has made significant strides in enhancing its tsunami preparedness and response capabilities. These advancements reflect Guam's commitment to the safety and well-being of its residents, particularly in light of challenges posed by Typhoon Mawar in June 2023.

Key Achievements:

- Updated NEOWAVE Inundation Modeling
  - Guam received updated inundation modeling for southern villages.
  - This technology provides accurate predictions of tsunami reach, aiding evacuation plans and response strategies.
- All Hazard Alert Warning System (AHAWS) Improvements
  - Following Typhoon Mawar, only two functional sirens were operational.
  - AHAWS repair initiative aims for 100% functionality by September 2024.
  - Enhanced siren system ensures timely warnings for residents during disasters.
- Social Media Engagement for Tsunami Preparedness
  - Creation of updated social media, radio, and tv products focusing on:
    - Local tsunami warning signs.
    - Inundation zone wayfinding.
    - Appropriate responses/actions to siren alerts
    - Educational material explaining tsunami alerts
    - Educational material explaining tsunami information for boaters
  - Engaging the community through accessible platforms to promote safety awareness.
- Ongoing outreach and partnerships
  - Strengthen ties with hotels through outreach and future tsunami evacuation planning
  - Continuous outreach events at schools and public events

Gulf of Mexico

During the 2024 calendar year, the Gulf Coast (GC) tsunami program completed three important tasks. First, in FY23, the Gulf Coast program developed two new high-resolution tsunami inundation maps covering urban areas along the Mississippi coastline. This coastline strip includes Long Beach, Gulfport, Mississippi City, Biloxi, and Pascagoula, MS. These maps in addition to inundation depth, feature maritime products, such as current and vorticity data, which are useful for identifying areas of tsunami strong currents and assessing associated damage potential. These two map developments bring the total number of tsunami inundation maps in the Gulf Coast region to 20, providing significant coverage of the most populated coastal areas along the Gulf Coast. The Gulf Coast program hopes these results will assist maritime communities, port managers, and other NTHMP stakeholders.
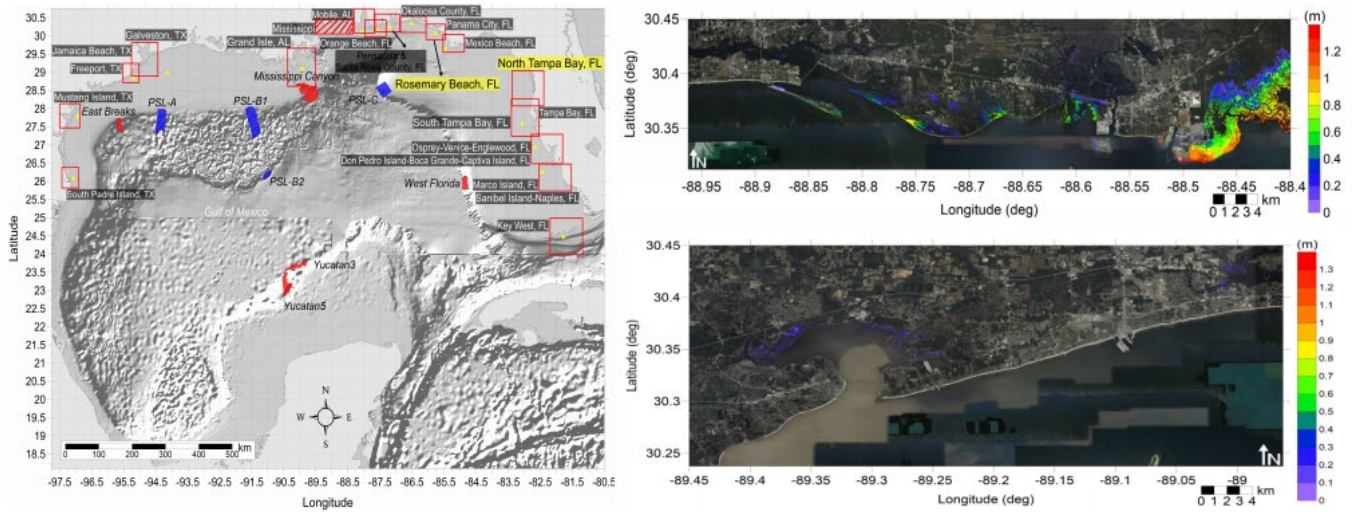

Figure 1. a) Left panel shows the area mapped for tsunami products (red hatch). b) Right panel shows tsunami inundation depths for the Mississippi coastline covering Long Beach, Gulfport, Mississippi City, Biloxi, and Pascagoula, MS[4].

The second task focused on the continued implementation of low-order tsunami inundation maps for areas where maps have not yet been developed or where no bathymetric and elevation data exist. In this work, tsunami data were compared with hurricane categories for all mapped communities, allowing the program to draw meaningful conclusions that can be applied to regions lacking sufficient information for developing detailed tsunami inundation maps.

The third effort focused on the continuation and evaluation of the methodology for landslide probabilistic tsunami hazard assessment in the U.S., in partnership with the East Coast and California. Specifically, the GC team developed a high-performance computing (see Figure 2) batch and Fortran programs to simulate more than 100,000 probabilistic submarine landslide events along the EC using the Mild Slope Equation (MSE) calculation for wave propagation. The efficient program implementation is an ongoing activity and can only be achieved using HPC[5]. For the EC case,

Figure 2. UMass Research Computing

took no more than four weeks to complete. This effort was supported by the NTHMP MMS for FY22 and FY23.

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[4] *Gulf Coast Tsunami web-page:* *http://68.183.164.45/tsunamimaps.html*

[5] *UMass Amherst Research Computing & Data* *https://www.umass.edu/research-computing/unity-research-computing-platform*

Hawai'i

Tsunami Ambassador Program: Hawai'i Emergency Management Agency (HI-EMA) launched its first phase of the Tsunami Ambassador Program starting with Saint Louis Schools, with a mission to build a wave of preparedness by empowering students to become informed leaders and advocates for tsunami safety in their communities. The Tsunami Ambassadors met with tsunami experts at the Pacific Tsunami Museum to learn about tsunami history, preparedness, mitigation, mapping, modeling, and warning coordination.

Tsunami Modeling: Hawai'i state commercial harbors are lifelines for the major Hawai'ian Islands. University of Hawai'i's Dr. Kwok Fai Cheung and Dr. Yoshiki Yamazaki, in partnership with University of California Santa Cruz and the U.S. Geological Survey have initiated an effort to model destructive tsunamis with 100- and 500-year return periods in support of emergency management and hazard mitigation. Source models have been developed based on paleotsunami deposits obtained by the USGS and hazard maps have been completed for Honolulu and Kalaeloa Harbors on O'ahu, Hilo and Kawaihae Harbors on Hawai'i Island, Kahului and Kaunakakai Harbors for Maui County, and Nāwiliwili Harbor and Port Allen on Kaua'i. In 2025, Dr. Cheung will cover Kaumalapau Harbor on Lana'i and Hana Harbor on Maui to conclude the effort.

Tsunami Summer Jam: HI-EMA hosted a Tsunami Summer Jam in collaboration with the Pacific Tsunami Museum to launch "Kaiona the Kia'i," a children's storybook that educates readers about tsunami warning signs and appropriate actions to take in the event of a tsunami. The event took place over one day at the Pacific Tsunami Museum, where over 100 parents and children had the opportunity to explore various exhibits, listen to readings of the storybook in English, Hawai'ian, or Tagalog, engage with representatives from NOAA, USGS, and Hawai'i County Ocean Safety, and participate in activities.

TsunamiReady & Hawai'i Hazards Awareness & Resilience Program (HHARP): The aim of HHARP is to help communities prepare to be self-reliant during and after natural hazard events, improve their ability to take care of their own needs, and reduce the negative impacts of disasters. HHARP can enhance community resilience through education and outreach sessions that build awareness and understanding of hazard mitigation, preparedness, response, and recovery. There are seven active communities and more to come from outreach through preparedness fairs and direct communications to communities.

Tsunami Awareness Month – April 2024: Tsunami Awareness Month 2024 kicked off with a press conference and proclamation signing by the governor. HI-EMA produced and distributed a tsunami awareness PSA via traditional broadcast means as well as online. HI-EMA also produced tsunami awareness messages in various languages, through the assistance of its employees (Portuguese and Tagalog) and a local school, Sacred Hearts Academy (Korean, and Mandarin), which were posted online. HI-EMA also created a Tsunami Ambassadors program, partnering with Saint Louis School.

Oregon

With ~61,000 residents living in a tsunami zone and potentially as many as 120,000 visitors overnighting on the Oregon coast, the risk for large loss of life due to a locally generated earthquake and tsunami is high. The Oregon Department of Geology and Mineral Industries (DOGAMI) and Oregon Emergency Management (OEM) work in partnership to provide needed leadership and strategic support for building a resilient Oregon coast.

Tsunami Education and Outreach: Outreach to coastal residents and visitors, community emergency response teams, safety fairs, students, and community leaders continued to be strongly supported in 2023/24. To improve access to tsunami outreach material, a "tsunami outreach business card" was designed by DOGAMI staff, printed, and is being actively disseminated to the public. To assist community needs, ~$45K of thermoplastic and aluminum tsunami wayfinding signage were purchased and distributed to several communities.

Risk Assessments for coastal communities: Using the latest 2020 census data, new USGS Cascadia ensemble earthquake data for an M9 earthquake, soils and landslide data compiled by DOGAMI, and latest tsunami model data, DOGAMI completed updated Hazus risk and exposure analyses for the entire Oregon coast. Analyses indicate 4,500 to ~14,100 potential resident fatalities (depending on scenarios), increasing to 15,600 to ~45,700 when including visitors who recreate on the coast; these latter data assume 100% occupancy. Furthermore, ~$35 billion to $45 billion in earthquake-tsunami related losses in coastal Oregon are estimated. These data are being used by communities and agencies to develop pre- and post-disaster plans, improve evacuation wayfinding, prepare tsunami caches, and to plan for needed vertical evacuation structures.
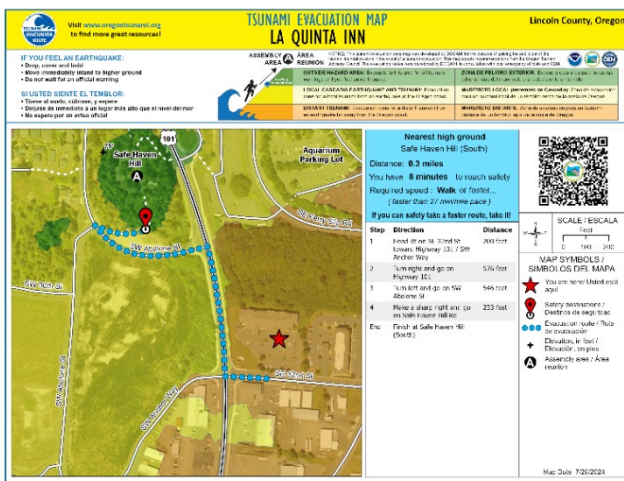
On-the-fly evacuation routing and custom brochures: In 2016, DOGAMI established a goal of completing tsunami evacuation modeling within 10 years for every coastal community. This goal was finally met in 2024 with the completion of "Beat the Wave" evacuation maps for Brookings-Harbor on the southern Oregon Coast and for the Columbia River estuary. These data have been fully integrated into an on-the-fly tsunami evacuation routing portal developed in partnership with the Northwest Association of Networked Ocean Observing Systems (NANOOS). Having built an evacuation routing capability for the entire coast, DOGAMI staff developed an ArcGIS Pro tool and layout that now produces on-demand custom tsunami evacuation brochures for any location on the Oregon coast. This tool is being used to produce detailed evacuation maps unique to local hotels and businesses in the tsunami zone.

Tsunami Debris Planning Guidance: This first of its kind guidance emphasizes the importance of advance planning for post-disaster debris management, including identifying potential collection sites, pre-establishing agreements with contractors, and ensuring coordination with state and federal agencies. The document includes lessons learned from the 2011 Tōhoku Japan tsunami, how modeling the dispersal of debris may help with planning, and provides a roadmap for local planners for developing local plans.

Puerto Rico

The main goal of the Puerto Rico tsunami program is to maintain and reinforce the tsunami preparedness level in Puerto Rico, supporting the communities to renew their TsunamiReady® recognition and the TsunamiReady supporter program, and emphasizing the tsunami hazard assessment as well as the response and alerting system. In this period, the accomplishments can be summarized as follow.

TsunamiReady component:

- All 46 tsunami threatened coastal communities maintained TsunamiReady status. Eight (8) communities renewed their recognition, including updates to their vulnerability profiles, evacuation maps, response plans and tsunami signage.

- Four (4) TsunamiReady Supporters renewed their recognition. As of this report, twenty (20) supporters are recognized by the National Weather Service (NWS).

- The Tsunami Guidelines for the Maritime Communities was updated. The new version included new figures, maps and updated

Figure 1. SSA participants visiting one of the PR-TsunamiReady communities

information. The "Marina Puerto Real", located in Puerto Real Bay, Cabo Rojo, became the first Marina TsunamiReady Supporter in Puerto Rico and the Caribbean.

- The school Jose de Diego at Aguadilla became the first school TsunamiReady Supporter in the island.

- The annual Puerto Rico "Tsunami Community Workshop" for emergency personnel first responders, Tsunami Focal Point operators, and community leaders was organized in May 2024 to train them about the NWS tsunami products, the Puerto Rico tsunami protocol, response plans and alerting criteria. One hundred and fifteen (115) officers participated.

- More than 475,929 participants were registered to participate in the regional Caribe Wave exercise through the TsunamiZone website; more than 135,000 were from Puerto Rico.

- One hundred thousand people were impacted directly via conferences, fairs, exhibitions, etc. and close to one million were indirectly impacted via social media, interviews, media clips. Most of the media clips include sign language to be sure that messaging is inclusive.

- A resilience study revealed the importance for communities of having the program's technical support to improve tsunami resilience.

Mapping, Modeling, Warning and Alerting:

- Pedestrian evacuation modelling as well as all mapping layers are available and updated via the Puerto Rico Tsunami Mapping tool.

- Puerto Rico continues working towards the implementation of new tsunami inundation and evacuation maps that use new data, models and results particularly from the Powell Center - PTHA.

- To improve the local tsunami warning focal points participation in the monthly test, a new strategy was implemented that include a new platform with EMO profiles and direct communication chat.

- To support, maintain, and improve the current communication infrastructure to receive and disseminate TWC messages, five (5) DartCom EMWIN turnkey systems are currently installed, and fifty-two EMWIN legacy internet systems are routinely updated. NOAA radios are provided as well as support to the local systems like Community-based FRS Radio network.

U.S. Virgin Islands

Social Science Integration & Community Assessment
- Conducted comprehensive social science survey across diverse U.S. Virgin Islands (USVI) communities targeting selected age groups (18-30, 31-50, 51-70, >70), socioeconomic levels (Low, middle, and high-income households) and geographic distribution (coastal vs. inland residents).
- Survey findings are being used to customize evacuation messaging by age group, target outreach strategies based on socioeconomic factors, and improve accessibility to preparedness materials.

Strengthened Tsunami Ready Program
- Implemented data-driven improvements based on social science findings, including developing age-appropriate educational materials, creating multi-language resources for diverse communities, and establishing community-specific evacuation protocols.
- Enhanced program effectiveness through demographic-specific approaches.
- Improved community engagement through culturally sensitive outreach.

Enhanced Stakeholder Engagement
- Successfully conducted comprehensive stakeholder meetings for Caribe Wave 2024.
- Established new partnerships with the Hotel Association and private sector businesses.
- Introduced the Tsunami Ready Supporter Program to local businesses.
- Achieved unprecedented participation from USVI Senate members in tsunami evacuation exercises.

Public Education and Outreach
- Deployed innovative educational materials including interactive puzzles, magnets, and whistles. Materials have proven highly effective in reaching diverse Caribbean demographics.
- Initiated development of specialized tsunami awareness commercial featuring Alfred Cartoon.
- Created comprehensive Tsunami Exercise Tool Kit (50% completed).

Capacity Building
- Advancing Emergency Managers Weather Information Network (EMWIN) training coordination between USVI subject matter experts and the Puerto Rico Seismic Network (PRSN).
- Weekly Tsunami Preparedness Group Meetings to track all Tsunami Specific Topics.
- Developing Tsunami Guidelines Tool Kit to guide anyone in the USVI with the proper information to facilitate Tsunami outreach from a small to large scale event.
- Building community preparedness through targeted educational initiatives.

Program Evaluation and Development
- Implementing systematic evaluation of tsunami outreach effectiveness through social science surveys.
- Monthly tsunami siren testing and daily polling of functionality of each tsunami siren throughout the Territory.
- Establishing metrics for measuring community engagement and preparedness.
- Developing justification and procurement procedures for program enhancement.

Notable Success Story
- *Political Leadership Engagement:* Unprecedented participation of USVI Senate members in evacuation exercises.
- *Community-Driven Approach:* Social science survey results directly informed program improvements.
- *Inclusive Preparedness:* Development of targeted strategies for all demographic groups.

Washington

With more than 3,000 miles of shoreline, 58+ high-risk coastal communities, significant coastal infrastructure, and a population of over 175,000 living in tsunami inundation zones, Washington continues to make tsunami risk mitigation a high priority. The Washington State Tsunami Program, represented by the State Emergency Management Division and the Washington Geological Survey, has been a member of the NTHMP since its inception in 1995.

Tsunami Education and Outreach: In FY23 Washington's Tsunami Program educated over 542,000 people about Washington's tsunami hazards and risks through outreach events, presentations, webinars, and workgroup meetings, with over 1.4 million people participating in the 2023 Great Washington ShakeOut. The City of Bainbridge Island earned its TsunamiReady status and 17 other jurisdictions maintained their status. The program also continued to provide tsunami subject matter expertise to state, tribal, federal, and international partners. Examples include participation in the NOAA Tsunami Science and Technology Advisory Panel and the American Society of Civil Engineers Tsunami Subcommittee.

Tsunami Hazard, Risk, and Evacuation: Washington published 5 pedestrian evacuation maps for the high-risk communities of Kalaloch, Tsoo-Yess River and Neah Bay (Makah Tribe), Lower Elwha (Lower Elwha Klallam Tribe), and Dungeness. It also published tsunami maritime response and mitigation strategies for the Port of Anacortes and Port of Neah Bay (Makah Indian Tribe) with high resolution hazard modeling for local tsunamis (Cascadia Subduction Zone) and distant source tsunamis (Alaska Aleutian Subduction Zone). A 2-year wayfinding assessment of over 1,550+ miles of mapped tsunami evacuation routes was completed this year, including routes under the jurisdiction of the Makah Indian Tribe, Hoh Indian Tribe, Quinault Indian Nation, and Quileute Tribe. Over 1,300 tsunami signs and 400+ NOAA weather radios were provided to local jurisdictions for free. Lastly, a new edition of Washington's Manual for Tsunami Vertical Evacuation Structures was published, with vital updates and lessons learned since the first edition came out in 2018.

Tsunami Alerting and Response: Washington maintained operational readiness of the state's network of 122 coastal tsunami sirens, 24 of which are located on tribal lands. The program hosted the annual Washington

State Tsunami Seminar and Workshop; helped facilitate the first ever tribal tsunami exercise with the Makah Tribe; and participated in the National Tsunami Warning Center's annual Pacifex tsunami exercise. Washington also led a national-level effort to document tsunami alerting and response procedures and identify related gaps and challenges for all participating NTHMP partner states and territories. Finally, the state created an all-hazards clearinghouse to collect perishable geologic information following a tsunami event and coordinate with researchers, and tested this plan through an earthquake and tsunami reconnaissance workshop and field exercise.