Manual for Tsunami Vertical Evacuation Structures

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Front Cover: Shoalwater Bay Indian Tribe's tsunami vertical evacuation structure (Photo: Degenkolb Engineers); Ocosta Elementary School groundbreaking ceremony, Ocosta Elementary School & vertical evacuation building, Washington Pacific coast beach (Photos: Washington State Emergency Management Division).

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Introduction

An earthquake strikes. The ground shakes. Windows and doors rattle. Pictures fall off the wall. Having practiced in drills like the Great ShakeOut, you drop, cover, and hold on. Books fall and bookshelves topple. You hear car alarms go off. Windows break. The shaking seems to go on forever. When it finally stops, you get up, check your surroundings to make sure it's safe, and help your family members. All of you immediately leave your house and follow your tsunami evacuation route, just like you practiced, because you live in a tsunami hazard zone. The streets are cracked and buckled. Trees and powerlines have fallen down, so you walk with caution. Because your community invested in a tsunami vertical evacuation structure, you and your family now have a safe place to go. When you get to the top of the evacuation structure, you breathe a sigh of relief. As you look out towards the water, you see a powerful tsunami wave racing to shore, the first of several life-threatening waves. Thankfully, you, your family, and your neighbors are safe.

Why a Manual? To Reduce Washington State's Huge Tsunami Risk

Earthquakes are a major source of tsunamis in Washington. Our state has the second-highest earthquake risk in the United States. Several active faults in western Washington impact coastal communities. The Cascadia Subduction Zone (CSZ), just off the state's Pacific coastline, runs from Northern California to British Columbia and is capable of generating a magnitude 9 or larger earthquake. A local tsunami caused by the subduction zone will leave some outer-coast communities in Washington with as little as 10 to 20 minutes to evacuate and could result in tens of thousands of fatalities. Distant tsunamis, coming from as far away as Alaska and Japan, can also impact Washington's coastal communities but these are preceded by significantly more warning time.

Coastal communities that lack sufficient natural or artificial high ground are particularly vulnerable to a local tsunami. Residents, employees, and visitors will have limited time to evacuate. For at-risk communities, tsunami vertical evacuation structures are a way to save lives. These structures are designed to withstand an earthquake, aftershocks, liquefaction, and multiple tsunami waves. They can be built as part of a new building or as a standalone tower or berm (artificial hill).

Figure 1. Tsunami evacuation sign.

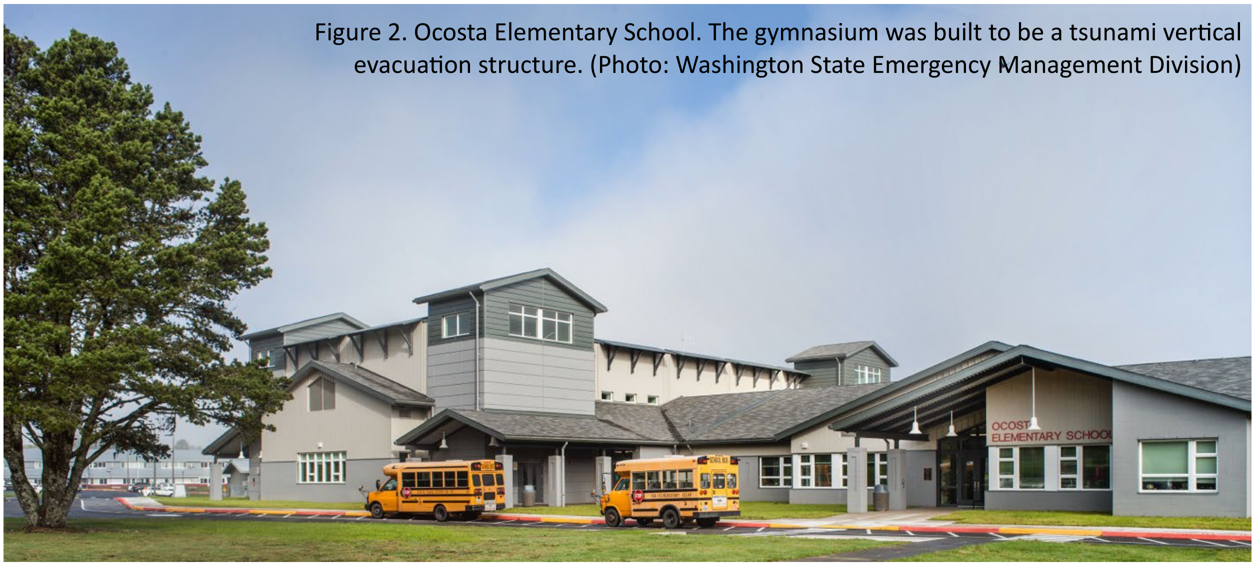

Figure 2. Ocosta Elementary School. The gymnasium was built to be a tsunami vertical evacuation structure. (Photo: Washington State Emergency Management Division)

Tsunami vertical evacuation structures have performed successfully in Japan and have also been built in New Zealand. The first tsunami vertical evacuation structure in North America was built in 2016 as part of the new Ocosta Elementary School in Grays Harbor County, Washington. A few years later, Oregon State University completed a vertical evacuation building at the Hatfield Marine Science Center in Newport, Oregon. In 2022, the Shoalwater Bay Indian Tribe dedicated Washington's first standalone vertical evacuation tower. Planning, funding, and design work for additional structures in Washington is currently underway. These exciting efforts provide inspiration for at-risk coastal communities everywhere.

Tsunami vertical evacuation structures are complex, high-performance structures. Planning, modeling, designing, and constructing them is different from your typical building project. Strong community involvement, support, and leadership are needed to evaluate the need for evacuation structures, plan for potential locations, identify funding, and follow through to the end of construction and beyond. To achieve this, communities must administer a robust public engagement process. Also key to success are partnerships with local, state, and federal agencies, universities, and a variety of experts.

Communities on Washington state's Pacific Ocean coastline have limited resources. Unlike California and Oregon, Washington's major ports, infrastructure, and associated funding resources are concentrated in the Puget Sound and along the Columbia River and not along Washington's outer coast. Given all these factors, Washington State Emergency Management Division (WA EMD) created this manual to provide coastal communities with practical guidance that will help them navigate the process and protect their communities.

Whether you are a community leader, a concerned citizen, a staff member of the planning and construction department of a local government agency, a non-profit manager, a business owner, or other vital member of the community, we hope this manual will assist you in your efforts to make your community safer.

What's Inside

Section 1 describes the *8 Phase Process* that communities can use to guide their efforts to plan, design, build, and maintain tsunami vertical evacuation structures. Some of the phases, such as community engagement, continue throughout the entire process.

- Phase 1: Involve Emergency Management Partners
- Phase 2: Assess Tsunami Risks and Current Evacuation Options
- Phase 3: Engage the Community
- Phase 4: Identify and Evaluate Potential Sites
- Phase 5: Develop a Funding Plan with Alternatives
- Phase 6: Assemble Project Team, Complete Design, and Confirm Budget
- Phase 7: Oversee Construction and Completion
- Phase 8: Operate and Maintain

The subsequent sections and appendices of the manual are referenced throughout the 8 Phase Process and provide a "deeper dive" into details, along with additional guidance and tips.

Section 2 and **Section 3** describe the various roles of those involved in planning, design, and construction of evacuation structures, including community representatives, emergency management staff, tsunami experts, and project team members. In addition to clarifying their various roles and responsibilities, these sections suggest when to involve them in the process.

Sections 4–9 supplement and expand upon the 8 Phase Process outlined in Section 1:

- Section 4 *(More Guidance for Planning Vertical Evacuation Structures)* can assist communities in understanding and making decisions about the siting and design of evacuation structures. It provides an overview of the technical requirements and a brief look at the scenario earthquake and what is involved in tsunami modeling.
- Section 5 *(Educating the Community About Tsunamis)* presents content for public outreach and education aimed at informing the community about the hazard, encouraging tsunami preparedness, and raising awareness of evacuation routes, including the need for vertical evacuation. Topics include tsunami warning signs, alerts, and recommended response actions.
- Section 6 *(Engaging the Community in Vertical Evacuation Planning)* provides tips and models to help project planners shape a communication strategy and engage their communities in the planning process for siting, designing, and building a tsunami vertical evacuation structure.

- Section 7 *(Tools for Funding and Planning Vertical Evacuation Structures)* describes various funding, planning, and regulatory tools that support efforts to build evacuation structures.
- Section 8 *(Maintaining & Operating Vertical Evacuation Structures)* offers guidance on what comes after the vertical evacuation structure is built, including suggestions for supplies and equipment to stock within the refuge. Also presented are security and maintenance decisions and planning, ongoing public education and drills, and use of the refuge in the event of a tsunami.
- Section 9 *(Tsunami Signage and Wayfinding)* provides guidance on tsunami wayfinding and includes examples of tsunami signage for vertical evacuation structures.

Finally, the manual concludes with four appendices. These provide descriptions of different kinds of tsunami maps and how each is used (Appendix A), a list of resources (Appendix B), a glossary (Appendix C), and an acknowledgments section (Appendix D).

Figure 3. Staircase leading to the refuge platforms on the tsunami vertical evacuation tower built in Tokeland, Washington, by the Shoalwater Bay Indian Tribe. (Photo: Washington State Emergency Management Division)

Behind the Scenes: A Continuum of Efforts

Many individuals and organizations have contributed to helping make coastal communities more resilient to tsunamis. These efforts go back decades and include the growing research in mapping earthquake faults and modeling seismic and tsunami hazards.

- Particularly important to the planning and construction of tsunami vertical evacuation structures are county and local emergency managers, local leaders, engineers, designers, planners, and residents, who were involved in each phase of the process and without whose contributions vertical evacuation refuges would not have been built.
- The National Tsunami Hazard Mitigation Program (NTHMP) provided funding for both the original version of the manual and this update, as well as for other efforts to support community preparedness.
- The Federal Emergency Management Agency (FEMA) awards grants for tsunami structures and publishes reports, like *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis* (FEMA P-646, 3rd edition), that provide guidance.
- The National Oceanic Atmospheric Administration (NOAA) and the University of Washington (UW) develop tsunami models, and the United States Geological Survey (USGS) generates research on tsunami evacuation models.
- The Washington State Emergency Management Division (WA EMD) works closely with coastal communities to support preparedness, response, recovery, and mitigation efforts, including the siting and construction of tsunami vertical evacuation structures.
- The Washington State Department of Natural Resources (WA DNR) provides tsunami inundation maps and assists with pedestrian evacuation mapping.
- A collaboration of the University of Washington's Institute of Hazards Mitigation and Planning, WA EMD, and various partners produced Project Safe Haven, the first effort to help communities plan for evacuation structures.
- The Resilient Washington Subcabinet Project Team and WA EMD produced the 2017 Resilient Washington Subcabinet Report: Findings and Recommendations, which states as Recommendation #9: "Improve life safety in communities at risk for local tsunamis."

This manual fits into the continuum of these many and diverse efforts. The manual project teams carried out a series of interviews with community representatives, experts, and professionals involved in the vertical evacuation planning process. This included elected officials, school district leaders, tribal leaders, emergency managers, engineers, architects, geologists, tsunami modelers, coastal residents, and others. The manual was also informed by the output of public meetings held in Ocean Shores and Aberdeen, and by published research and guidance. It builds on the work of agencies, universities, and individuals to support tsunami-resilient communities.

Section 1. The 8 Phase Process

The 8 Phase Process represents the practical experience and lessons learned of people actively involved in planning, building, and maintaining tsunami vertical evacuation structures. It can assist you in building such a structure in your community. The phases vary in length, and some involve several parts. Some phases last the whole process while others may be shorter. Additional sections in the manual are referenced in these phases to provide added detail.

The 8 Phase Process is intended to offer guidance but not be overly prescriptive. You may follow these phases in a different order or emphasize different aspects of a phase. How your community implements it will be unique to your circumstances. Before undertaking your tsunami vertical evacuation structure project, read through Section 1 from start to finish so that you understand the full 8 Phase Process and will be able to adapt the phases to suit your needs. Communities that work together and collaborate with their partners will be most successful.

Phase 1: Involve Emergency Management Partners

A key first step is to contact vertical evacuation subject matter experts. Local emergency managers are the initial point of contact. It is recommended that the local emergency manager work in tandem with the Washington State Emergency Management Division (WA EMD).

Contact your county or tribal emergency manager and the WA EMD Tsunami Program. Washington state is fortunate to have a strong network of local, tribal, and state partners to help your community with tsunami evacuation planning.

Go to Appendix B: Resources for contact information

Ask your county emergency manager and WA EMD staff to connect you with other relevant state and federal partners. For example, partner agencies include the Washington State Department of Natural Resources (WA DNR), the University of Washington's tsunami modeling team, the United States Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), and the National Oceanic and Atmospheric Administration (NOAA).

Go to Section 2: Community and Emergency Management Roles (p. 28), and Appendix B: Resources

Be prepared to work with a diverse range of partners and share information to achieve better outcomes. Building tsunami vertical evacuation structures is a complex and challenging undertaking. Unsurprisingly, close collaboration with partners is required during the entire process. The Ocosta School Board and the five communities in the Ocosta School District in

Grays Harbor County, Washington, worked closely with a variety of partners to build the first official tsunami vertical evacuation structure in North America.

Phase 2: Assess Tsunami Risks and Current Evacuation Options

It is essential for communities to evaluate their tsunami risk and evacuation options. Guidance and resources are available to help you better understand your community's specific risks and opportunities.

Identify the types of tsunami events that may impact your community. If you are in a coastal community in the state of Washington, including within the Puget Sound, you have a tsunami risk. Work with your local emergency manager, WA EMD, and WA DNR to understand your community's tsunami risk. Washington state is at risk from two tsunami sources: local and distant. Local source tsunamis will likely come from the Cascadia Subduction Zone (CSZ) just off the Pacific coast. Within the Puget Sound, a crustal earthquake on the Seattle Fault, Tacoma Fault, or other faults could generate a local source tsunami. Distant source tsunamis can come from as far away as Alaska (such as happened in 1964) and even Japan (such as in 2011). However, usually only local source tsunamis generate the kind of immediate extreme flooding that necessitates vertical evacuation structures.

Go to Section 5 (How to Respond to and Prepare for a Tsunami, p. 46)

Assess flooding impacts and current evacuation routes. In 2021, WA EMD completed the Outer Coast Tsunami Vertical Evacuation Assessment, a comprehensive assessment of tsunami vertical evacuation structure needs for Pacific, Grays Harbor, and Clallam counties. This assessment, conducted by the Institute for Hazards Mitigation Planning and Research at the University of Washington, analyzed potential sites for vertical evacuation structures using walk-time estimates based on a tsunami from a 9.0 magnitude earthquake along the Cascadia Subduction Zone. The research team used their findings to develop four vertical evacuation options for each community studied. These options range from no vertical evacuation structures to the highest number needed to attain total coverage.

The study is accompanied by maps showing proposed tsunami refuge locations, photos of the locations, the number of people within 15-25 minutes' walk to high ground, and graphics displaying the data in an easy-to-read format. Summary tables for each county identify the minimum number of structures needed for the entire county and the percent/number of people in the tsunami zone who would be within 15- or 25-minutes' walking distance of high ground if all those structures were built.

If your community is located within Pacific, Grays Harbor, or Clallam County, check out the Outer Coast Tsunami Vertical Evacuation Assessment first to see if locations for vertical evacuation structures have already been recommended.

If your community was not included in the assessment, the state offers a variety of other helpful resources.

- Washington State Department of Natural Resources (WA DNR) has published inundation maps for the entirety of Washington's coastline that show where and how deep the flooding may be in your community during a Cascadia Subduction Zone tsunami.
- WA DNR also publishes tsunami evacuation walk time maps that show designated tsunami evacuation routes and the estimated time it will take from a given location to walk out of the tsunami inundation zone. Areas where the walk time exceeds the estimated tsunami wave arrival time may need one or more vertical evacuation structures to reduce the amount of time needed to get to high ground.
- Washington State Emergency Management Division (WA EMD) provides tsunami hazard, preparedness, mitigation, evacuation, and other guidance and resources.

Go to Appendix A: Kinds of Tsunami Maps and How They are Used for VES Planning

Go to Appendix B: Resources for links to WA DNR Maps and WA EMD resources

See Section 3 (Geologist, p. 33) for information about WA DNR

Determine if your community needs vertical evacuation. Your evacuation needs will become clearer when you review the data with your partners. If your community already has sufficient natural and artificial high ground that your whole community can reach before tsunami waves arrive, you will not need to build vertical evacuation structures. Alternatively, you may discover that even if you improve evacuation routes to high ground, your community needs one or more vertical evacuation structures where high ground is simply too far away for people to reach it in time. Some communities will need to build many vertical evacuation structures due to lack of natural and artificial high ground and insufficient time to evacuate. Whatever your community's situation, vertical evacuation structures should be seen as part of an overall tsunami evacuation plan that includes improving bridges and identifying potential barriers such as landslides that could block evacuation routes and access to evacuation structures.

Phase 3: Engage the Community

By this stage, it has been determined that your community needs tsunami vertical evacuation structures. The organization that leads a vertical evacuation planning process may be the local government, a school district, a fire district, a private company such as a resort, or a local champion. Strong community engagement throughout the process results in better project outcomes. Critical steps going forward include identifying trusted community leaders and creating a stakeholder committee to strengthen decision-making and project oversight.

Go to Section 2 (Community Leaders and Stakeholder Committee Members, p. 28)

Engage community members and key stakeholders often to support successful outcomes. Your public process will be unique to your community. Public meetings, going door-to-door, and using social media are all valuable ways to inform your community.

- **Learn from past tsunami evacuation planning efforts by your community and other communities.** Previous planning efforts, such as Project Safe Haven, can provide insights and models for engaging community members in tsunami vertical evacuation planning.
- **Hold public meetings to discuss tsunami risk and mitigation options.** Meetings should include subject matter experts such as geologists, engineers, tsunami modelers, planners, and emergency managers. Try to make the public meetings engaging with humor, prizes, and food. Inform your community of the risk while maintaining a sense of hope and opportunity.

Go to Section 6: Engaging the Community in Vertical Evacuation Planning, p. 50

Figure 4. Public meeting in Ocean Shores. (Photo: TVW screenshot)

In 2018, meetings were held in the cities of Ocean Shores and Aberdeen, Washington. At the meeting in Ocean Shores (figure 4), nearly 90% of people who filled out survey cards felt strongly that vertical evacuation structures could save their lives and the lives of people in their community.

Half of participants at these meetings indicated that they looked to their local officials and emergency managers to help lead the tsunami vertical evacuation planning process.

Identify a trusted community leader who will manage the overall process. A community leader understands the threats posed to their community by tsunamis and is willing to take the initiative to get the process moving. They are willing to be persistent, even relentless, in this effort. A community leader is a problem solver who seeks to overcome barriers and identifies resources. A community leader will set a clear direction that the entire community can understand. They will communicate regularly with all partners involved in the project to identify goals and achievable milestones. Enthusiastic, trustworthy community leaders are the most vital part of successful vertical evacuation structure projects.

Figure 5. Lee Shipman (left) at the dedication of the "Auntie Lee" vertical evacuation tower, which was built by the Shoalwater Bay Indian Tribe and named after Shipman, who was the tribe's former emergency manager and the driving force behind the project. (Photo: Washington State Emergency Management Division)

Manage an open process from start to finish. Transparency builds community trust, welcomes assistance, and helps achieve community acceptance. If a process runs into complications, the community is more likely to maintain their support when they feel like they have been consulted and updated.

Establish a stakeholder committee. The role of the committee is to discuss the community's tsunami risk, research and analyze the issue, and explore possible ways forward. The committee can then develop consensus around recommendations and provide project oversight. The committee and the community leader can work together to develop an outreach strategy and build support. Identify people to join the committee that have credibility and influence and know how to get things done. In most communities, things cannot get done without the right people on board. The Ocosta Elementary School project strongly benefited from a stakeholder committee that included PTA members, teachers, senior groups, community service groups, tribes, city government officials, the Chamber of Commerce, and realtors.

Phase 4: Identify and Evaluate Potential Sites

This phase might be challenging for communities, but selecting workable sites is critical to a successful project. Identifying, evaluating, and testing support for potential sites requires community involvement.

Explore potential sites for future vertical evacuation structures. Involve the community in these discussions. Choosing sites on land already owned by the jurisdiction avoids the cost of purchasing new sites. Also, evacuation structures with multiple uses, including community amenities, can generate greater community support.

The following considerations may help you determine your first site and/or overall strategy:

- If planning a tsunami vertical evacuation structure in Clallam County, Grays Harbor County, or Pacific County, refer to the 2021 *Outer Coast Tsunami Vertical Evacuation Assessment*. Guides for each county identify options for tsunami vertical evacuation sites. The guides are available on the Tsunami webpage of the Washington State Emergency Management Division's website.
- Evaluate opportunities for vertical evacuation within other planned projects: Your community may need to build a new school, fire tower, city hall, or parking garage; or perhaps you anticipate the need for new or replacement facilities a few years down the road. This could provide an opportunity to add a tsunami vertical evacuation component to the project—which is what the Ocosta School District did when they needed to replace their existing elementary school. If your community has an upcoming opportunity like this, it might be a good place to start.
- Evaluate sensitivity/density sites: Vertical evacuation planning includes tough choices about how your community wants to prioritize its efforts and resources. For example, your community may be most concerned about the safety of school children, as were the residents in and near the city of Westport who voted to build the Ocosta Elementary School. You might also begin with sites in busy commercial areas and/or community gathering places. These sites may more easily garner the required broad public support.
- Evaluate neighborhood sites: Vertical evacuation structures in neighborhoods could be larger or smaller depending on the number of residents served. These projects could even be funded with a neighborhood tax district. Homebuyers who are aware of coastal hazards may value properties that have access to vertical evacuation.
- Evaluate higher ground/inland sites: The location of these sites can reduce the required height and associated costs of vertical evacuation structures. A tsunami wave is highest just as it comes ashore and then gets smaller as it moves inland.

Explore potential structure-type options for the site. Site opportunities will likely favor particular structure types such as buildings, towers, berms, and hybrid options. Sometimes, a structure type will influence the selection of a site.

Go to Section 4 (Structure Types and Considerations, p. 38)

Hire a geotechnical engineer and tsunami modeler to assess the sites chosen by the community. A tsunami vertical evacuation structure must resist an earthquake, aftershocks, liquefaction, and multiple tsunami waves. Geotechnical site investigations are essential for understanding site conditions and foundation requirements. Tsunami models are needed to determine the forces that a structure must resist and how high the structure needs to be. An architect and structural engineer may also be hired to do an initial conceptual design for grant applications. Be ready to share with the design team any prior studies done on the site, such as an environmental impact assessment.

Go to Section 3: Tsunami Experts and Project Team Roles, p. 33

Hire a project management consultant to help with facility planning, cost estimation, bond planning, architect selection, and construction services. This step can occur at this point in the process or later, depending on circumstances. The Ocosta School District benefited from project management assistance from the Washington State Educational Service District (ESD) for facility, bond planning, and construction services. The Shoalwater Bay Tribe searched for a project management consultant after they had been awarded a major FEMA grant.

Phase 5: Develop a Funding Plan with Alternatives

While grants are a desirable funding option for vertical evacuation structures, they are competitive and will generally not cover all costs, so it is important to explore local funding options and other possible sources as well.

Assess funding sources. By this point, your community has selected a potential site and structure type and completed initial geotechnical and tsunami studies. You may also have completed initial design. As a result, you are able to draft a budget working with your project management consultant, architect, and structural engineer. A fleshed-out proposal and budget is helpful when reviewing funding options. Federal grants are available, but local funds are also needed. Local funding mechanisms include bonds, property taxes, and special districts, among others.

Go to Section 7: Tools for Funding and Planning Vertical Evacuation Structures, p. 57

In 2018, the Shoalwater Bay Indian Tribe was awarded a federal Pre-Disaster Mitigation Grant (PDM) to build a tsunami evacuation tower in Tokeland, Washington. The completed tower was dedicated on August 5, 2022.

Apply for grants. It is best for projects to have funding secured before major design starts. The grant process takes time, so get started early by identifying what parts of your project need grant funding, which grants may be used for that purpose, and for which grants you intend to apply. Both federal and state grants may be options, depending on your project. State agencies such as WA EMD can assist you with the application process, but grants are not guaranteed.

Some grants cover the cost of the initial site studies, tsunami modeling, and benefit-cost analyses needed to prepare larger construction grant applications. Others cover a project's design and construction costs. For example, the City of Westport first applied for a grant to help cover the costs of initial scoping for their tsunami vertical evacuation project. They then used this funding to apply for a larger grant to cover the costs of designing and building the structure.

Standalone vertical evacuation towers are currently preferred—most grants can fund only the tsunami evacuation component of a multi-use project (such as a parking garage or school) and cannot be used for non-tsunami construction costs. Also, if construction on the project has begun before you apply for grants, the project won't be eligible for funding. The Washington state Hazard Mitigation team can explain and help you to navigate the grant process.

Go to Section 2 (State Hazard Mitigation Officer, p. 32) and Section 7 (Grants, p. 60)

Prepare a backup plan if some funding sources do not come through. For example, the Ocosta School District leadership and stakeholder committee made the decision, early on, to move forward even if grant funding did not come through. They were turned down for grant funding but went on to build a successful and internationally lauded project using local bonds.

Build public support for local funding initiatives through outreach by your community leaders and stakeholder committee. This is part of your ongoing public engagement efforts. Don't speak in terms of millions of dollars of total project cost; instead, speak to the amount each household might need to pay each day. If community members see a benefit to them and those they care about, they will be more likely to support the project. Although your first project will likely cover only a portion of your community, it is a vital step toward eventually providing everyone with safe evacuation options. Your community must start somewhere.

Maintain open and frequent communications with your community. Plan to go back to them with another funding option or site alternative if the first one does not succeed. Let them know you will keep coming back until the evacuation structure gets built. Remember, this is a long-term project to save lives and will require multiple efforts. Even if a grant application does not succeed, it will serve as a strong foundation on which to build for your next attempt.

Figure 6. Public meeting in Aberdeen.

Photo: UW Project Team

Before you pursue a funding plan, consider presenting recommendations to the community and inviting feedback. For example, at two public meetings in 2018 in the cities of Ocean Shores and Aberdeen (figure 6) participants were asked to fill out survey cards to indicate their preferences for various funding options.

Phase 6. Assemble Project Team, Complete Design, and Confirm Budget

It is essential to select a capable project team that maintains good communication. The project will also benefit from having a community leader in charge of overseeing the project from start to finish. Other recommended actions include continually tracking the budget and scope, being transparent about the project and sharing progress updates with the community, and reassessing as the project proceeds.

Create a selection process to hire project team members. Select professionals for the project team who have expertise in earthquake and tsunami projects and some local knowledge. Professionals from Washington state, or nearby coastal states, will often have a better grasp of local conditions. In making your selection, seek guidance from your partners, project management consultant, and stakeholder committee. With the Ocosta Elementary School project, prospective firms had to make presentations to the stakeholder committee, and committee members visited firm offices before making a final decision.

Go to Section 3: Tsunami Experts and Project Team Roles, p. 33

Finalize the project team once funding is secured. Your project team will include an architect, structural engineer, geotechnical engineer, tsunami modelers, and other professionals. A civil engineer and landscape architect are often needed, particularly for berm design. Strong coordination between all project team members is essential given that vertical evacuation structures are relatively new and complex. Time should be budgeted for this coordination.

Confirm your internal project manager. This person is often the community leader who has been leading the process since the beginning. The internal project manager represents your organization in the contractual relationship with the consultant project team and the construction contractor. This person works in tandem with the project management consultant and is the bridge between the stakeholder committee and the consultant project team. Given the complexity of these projects, this is a job that should not be delegated down.

Go to Section 2 (Internal Project Manager, p. 29)

Conduct further tsunami modeling. As the architect and structural engineer design the structure, site-specific tsunami modeling will be required. Any changes to the structure's shape or location must be brought to the attention of the tsunami modeler. Such changes can alter the modeling results and require changes to the design. It is essential to have strong lines of communication between the consultant project team—specifically, the structural engineer and architect—and the tsunami modeler.

Go to Section 3: Tsunami Experts and Project Team Roles, p. 33

Exercise strong oversight of the project budget. The internal project manager and all project team members must keep tabs on the project budget and scopes of work. Most communities have limited funds and need to keep within a project budget, or the project won't get built. Re-assess costs at appropriate milestones to limit significant budget increases. The Ocosta Elementary School project team did exhaustive cost studies and made adjustments as needed.

Confirm the design, capacity, and accessibility considerations for the evacuation structure. Features to consider may include, for example, ramps alongside stair access, emergency lighting, and storage space for emergency supplies, water, and sanitation facilities. All of these elements will impact costs. It is more than likely that trade-offs will need to be made in order to keep on budget. If you are designing a multi-use structure, you will need to consider the impacts for the building as a whole.

Go to Section 4 (General Criteria for Assessing Vertical Evacuation Designs, p. 41)

Identify approaches that combine life safety and good design. You will want a tsunami vertical evacuation structure that is attractive. The structure needs to fit into its surroundings but also be identifiable as a tsunami refuge. Working with your project team and community input, you can identify a strategy to incorporate all of these key factors. An attractive and functional structure will help build support for future projects.

Go to Section 4 (General Criteria for Assessing Vertical Evacuation Designs, p. 41)

Conduct a peer review during the design phase of the project. The building code requires peer review for all tsunami vertical evacuation structures to ensure that the design meets building code requirements. Peer review may also be required for federal grants. The review team will include a structural engineer, geotechnical engineer, and tsunami modeler. Choose qualified experts who are not affiliated with the firms hired to do the design. Hiring the peer reviewers usually starts with a request for qualifications (RFQ), issued by the project's planners or their project management firm.

Figure 7. An early design concept for a 400-person tsunami evacuation tower being planned for a Washington coastal community. (Image: Rice Fergus Miller and Degenkolb Engineers)

Phase 7. Oversee Construction and Completion

The construction phase presents new challenges that can be successfully managed through good communication and oversight.

Hire a construction contractor. Send out a *Request for Proposals* (RFP) when the design and cost estimate for the project are finalized. Make sure that the RFP describes the unique nature of constructing tsunami vertical evacuation structures, such as extensive foundation work. In addition, as mentioned in Phase 4, this may also be a time to select a project management consultant if one has not already been hired. The construction process itself will involve unanticipated challenges. In the case of the Ocosta Elementary School, budget constraints required that some project elements be eliminated—for example, the original design included an elevator to the roof, but the superintendent and stakeholder committee decided to eliminate it, because it would not be operable after an earthquake anyway.

Schedule regular project meetings and reviews during construction. Your community leaders/internal project manager, project management consultant, project team, and contractor will meet regularly to discuss progress and resolve issues that may arise. Brief the stakeholder committee and update the public on progress.

Celebrate your newly constructed tsunami vertical evacuation structure by having an open house/ribbon cutting. Your community can and should take pride in this achievement. The completed project is a valuable legacy and an inspiration to other communities around the world.

Figure 8. Ribbon-cutting ceremony at the opening of the newly completed Ocosta Elementary School and vertical evacuation structure. (Photo: Washington Emergency Management Division)

Phase 8. Operate and Maintain

The job is not done when the structure has been built. It is important to think through and plan not only for maintenance and use of the structure, but also for ongoing public education so that the community and visitors know what to do and where to go in the event of a tsunami.

Set up a maintenance plan and a security plan for your evacuation structure. What these plans include will depend on whether your evacuation structure is a building, tower, or berm and where it is located. Maintenance and security plans ensure that your evacuation structure will be durable and used appropriately.

Go to Section 8: Maintaining & Operating Vertical Evacuation Structures, p. 69

Conduct community outreach and training. Ongoing community engagement and education continue to be crucial once a tsunami vertical evacuation structure is built, ensuring that residents understand how and when to use the structure. This includes:

- Conducting regular evacuation drills that involve the structure's occupants (if the structure is part of a multi-use building) and nearby residents.
- Regularly reviewing and updating evacuation plans.
- Responding to feedback from the community to improve the structure's accessibility and effectiveness.

Go to Section 5: Educating the Community About Tsunamis, p. 46

A tsunami can occur at any time. If it happens at night, a vertical evacuation structure may be used by a different group of people than would have been present during the day, so outreach and education must target these different populations. A New Zealand research team interviewed Westport residents living near the Ocosta Elementary School and learned that they were unaware that the tsunami evacuation area on the roof of the school was available to them as well as the school children. Ongoing outreach by the local government and other stakeholders is necessary to get this information out to the public.

Consider ongoing improvements to the evacuation structure that may not have fit into the original project budget. For example, add emergency supplies, sanitation facilities, and other enhancements. It is a good idea to think about these possible later additions and modifications while the structure is still in the design phase so that the completed structure includes the spaces you will need and will be easier to adapt down the road.

Next Steps

Tsunami vertical evacuation structures are part of a larger evacuation planning strategy and overall community resilience. Completing your first structure is a great springboard for continued momentum.

Engage in other efforts that support your evacuation structure within the larger network of tsunami evacuation planning. You may need to improve existing evacuation routes or add new ones leading to the vertical evacuation structure. This might include strengthening bridges and adding evacuation signage.

Start planning your next tsunami vertical evacuation structure if your community needs more structures. Having completed a project, you better understand the process, including the barriers and issues you had to overcome. Each completed project will increase the knowledge, confidence, and safety of the people in your community.

Figure 9. Standard tsunami vertical evacuation sign. (Image: Oregon State University)

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8 Phase Process Quick-Reference Sheet

This condensed version of the 8 Phase Process provides a brief description of the elements under each phase.

Phase 1. Involve Emergency Management Partners

- ☐ Contact your county or tribal emergency manager and the WA EMD Tsunami Program.
- ☐ Ask your emergency management contacts to connect you with other relevant partners.
- ☐ Be prepared to work with a diverse range of partners and share information.

Phase 2. Assess Tsunami Risks and Current Evacuation Options

- ☐ Identify the types of tsunami events that may impact your community.
- ☐ Assess flooding impacts and current evacuation routes.
- ☐ Determine if your community has a need for vertical evacuation structures.

Phase 3. Engage the Community

- ☐ Engage community members and key stakeholders often to support successful outcomes.
- ☐ Review past efforts by your community and other communities.
- ☐ Hold public meetings in your community to discuss tsunami risk and mitigation options.
- ☐ Identify a trusted community leader who will manage the overall process.
- ☐ Manage an open process from start to finish.
- ☐ Establish a stakeholder committee.

Phase 4. Identify and Evaluate Potential Sites

- ☐ Explore potential sites for future vertical evacuation structures. Consider sites already owned by the community and multi-use structures.
- ☐ Explore potential structure-type options for the site.
- ☐ Hire a geotechnical engineer and tsunami modeler.
- ☐ Hire a project management consultant.

Phase 5. Develop a Funding Plan with Alternatives

- ☐ Assess potential funding sources.
- ☐ Apply for grants.
- ☐ Prepare a backup plan if some funding sources do not come through.
- ☐ Build public support for local funding initiatives.
- ☐ Maintain open and frequent communications with your community.

Phase 6. Assemble Project Team, Complete Design, and Confirm Budget

- ☐ Create a selection process to hire project team members.
- ☐ Finalize the project team once funding is secured.

- ☐ Confirm your internal project manager.
- ☐ Conduct site-specific tsunami modeling.
- ☐ Exercise strong oversight over the project budget.
- ☐ Confirm the design and capacity considerations for the evacuation structure.
- ☐ Identify approaches that combine life safety and good design.
- ☐ Conduct a peer review during the design phase of the project.

Phase 7. Oversee Construction and Completion

- ☐ Hire a construction contractor.
- ☐ Schedule regular project meetings and reviews during construction.
- ☐ Celebrate your newly constructed structure by having an open house/ribbon cutting.

Phase 8. Operate and Maintain

- ☐ Set up a security plan for your evacuation structure.
- ☐ Prepare a plan for ongoing maintenance of the structure, facilities, and supplies.
- ☐ Consider ongoing improvements to the evacuation structure.
- ☐ Create an operations plan and update it regularly.
- ☐ Conduct community outreach and training.

Next Steps

- ☐ Improve routes, bridges, and signage that assist with access to the evacuation structure.
- ☐ Start planning for your next tsunami vertical evacuation structure.

Section 2. Community and Emergency Management Roles

A variety of roles within your community are important to a successful tsunami vertical evacuation structure project. Emergency managers will be key partners for your community throughout the process. In the previous section, these roles were introduced within the context of the 8 Phase Process. This section provides further detail about each role.

Community Leaders and Stakeholder Committee Members

Community leaders and stakeholder committee members play the leading role in assessing the need for tsunami vertical evacuation structures and getting necessary structures built. Open and effective community engagement is a recurring theme throughout the entire process.

Community Leaders

Your community leader may be a superintendent, tribal leader, emergency manager, fire chief, city administrator, local elected official, or some other person in a leadership role. They will need to have dedication, perseverance, and accountability to get the job done. Tsunami vertical evacuation structures are complex projects that cannot be completed without dedicated leadership. Leaders help facilitate an open public process; they work with partners and tsunami experts; they help create and work closely with the steering committee; and they attend the meetings with the consultant project team and the construction contractor. The leader will also likely be the internal project manager, described later in this chapter.

Stakeholder Committee Members

The committee consists of stakeholders in the community with diverse perspectives; it could include representatives from nearby neighborhoods, community organizations, non-profits, business leaders, parents, teachers, homeowners, and major employers. Committee members should stay with the process from start to finish. They assist in decision-making and provide a sounding board. Committee members will become project experts who can credibly inform the wider community. Engaging the right stakeholders is crucial for the project’s success, as it secures diverse perspectives that will inform overall planning assumptions and decisions.

How These Roles Fit into the Overall Process

Successfully building vertical evacuation structures in communities hinges on the engagement, passion, and expertise of onsite community leaders and stakeholders. Proactive community leaders and stakeholders will bring the right people to the table from the beginning. Community leaders must be willing to prioritize vertical evacuation planning and invest the necessary time and resources. This is the only way that the process will get started and keep moving. Without leadership, the process can easily stall. Various individuals may lead particular parts of the process, such as efforts to go door-to-door to pass a ballot initiative; however, there should be one point-person for the overall process who is recognized as such by the consultant project team, partners, and the community.

The stakeholder committee should be assembled in the early stages of the project. The committee and leadership work together to research and analyze the issue and then make recommendations. They help determine if the community truly needs evacuation structures and what sites might be best. Next, they explore funding options and help generate public support. During design and construction, committee members help to choose the project team and make decisions that keep the project within budget and on schedule.

Internal Project Manager

The internal project manager should be a visible community leader that attends stakeholder committee meetings, project team meetings, and construction meetings. The internal project manager provides the community with progress updates and notifies them about any changes.

The internal project manager may need to work with a project management consultant that will help with facility planning, cost estimation, bond planning, architect selection, and construction services.

For the Ocosta Elementary School tsunami vertical evacuation project, Paula Akerlund (figure 10), who was then superintendent of the school district, was both community leader and internal project manager.

The Washington State Educational Service District (ESD) provided the superintendent with project management assistance, from facility planning through construction.

Figure 10. Paula Akerland (Photo: Washington State National Guard)

Role

The internal project manager will likely be the same person who is leading the overall effort. This is important for a variety of reasons. The internal project manager needs to be the point of contact between the stakeholder committee and the consultant project team. This person must have the requisite investment in the project and be seen as visible and responsible to the community.

The internal project manager represents the client's interests with the consultant project team. The client could be a school district or a tribal council that needs to be a good steward of public funds. By being present in project meetings throughout the process, the internal project manager helps to keep the consultant project team accountable.

How This Role Fits into the Overall Process

The internal project manager will likely be involved with the project from the very start. They will be involved in bringing stakeholders together to look into options and come up with a plan. They will help direct the initial site investigations and review of funding options. They will be involved in project team selection and oversight of the design process. They will work closely with the stakeholder committee and partners.

The internal project manager will likely hire a person with construction experience to help manage the construction phase of the project. They will look to that person for guidance while remaining fully involved in decision-making.

Figure 11. Lee Shipman (left). (Photo: Washington Emergency Management Division)

Lee Shipman (figure 11) was the Shoalwater Bay Tribe's emergency manager when their tsunami vertical evacuation project began: she served as the community leader and the internal project manager, and she was both active and visible as she worked with her community and the neighboring community.

The Shoalwater Bay Indian Tribe, working with the Washington State Emergency Management Division, secured a Pre-Disaster Mitigation (PDM) grant in 2018. After this, they hired a project management consultant to help with construction services.

State, County, and Tribal Emergency Managers

Emergency managers are integral conduits between people, local communities, business and industry, and government. Coordinating multiple partners and stakeholders, they assist in development of emergency plans as well as mitigation, response, and recovery efforts. They assist in reducing the impact any emergency or disaster event may have upon affected communities, their people, and critical infrastructure.

Washington State Tsunami Program

The Tsunami Program staff of the Washington State Emergency Management Division (WA EMD) are experts in tsunami and earthquake risk and the steps communities can take to improve their resiliency. WA EMD is the lead state agency available to assist communities to plan for tsunami evacuation. They work with a network of federal, state, and local government partners, private organizations, and individuals.

The program manager and staff support community efforts to build tsunami vertical evacuation structures. They help connect communities with partner agencies, tsunami experts, and information about potential grant funding. They are available to help raise public awareness about tsunami hazards and preparedness, including vertical evacuation, through workshops and community presentations. They also coordinate the Great Washington ShakeOut, which involves both earthquake and tsunami preparedness, and support local evacuation drills. They are the lead agency for publishing guidance materials such as this manual.

Go to Appendix B: Resources

County or Tribal Emergency Manager

The county or tribal emergency manager's role is to assist local communities, government, businesses, and industry within their jurisdiction. Many local governments do not have a dedicated emergency management position, and responsibilities may be shared between elected officials and fire and police departments. The county or tribal emergency manager assists local governments in their disaster preparedness, mitigation and response, and recovery efforts following disasters.

The county or tribal emergency manager works closely with WA EMD Tsunami Program staff to address tsunami evacuation options and to support efforts to enhance evacuation routes and build tsunami vertical evacuation structures.

How These Roles Fit into the Overall Process

Your county and state emergency management partners are among the first people to contact when researching your community's tsunami evacuation needs. They can connect you with experts in the field of geology at the Washington State Department of Natural Resources (WA DNR) and tsunami modelers at the University of Washington and NOAA. They can assist your community in setting up public workshops and expert panel discussion forums.

Your emergency management partners can also help to connect you with other communities that have built, or are in the process of planning, evacuation structures. When you apply for federal grants, WA EMD can help your community find appropriate grants and assist you with the application. From start to finish, your emergency management partners at the county, tribal, and state level are there to support your efforts, provide feedback, and assist in connecting you with resources. Their mission is to protect life, property, and critical infrastructure and to help foster resilient communities.

State Hazard Mitigation Officer

The Hazard Mitigation Officer at the Washington State Emergency Management Division (WA EMD) works closely with state Tsunami Program staff to assist communities to identify federal grant funding opportunities that can help them complete tsunami vertical evacuation projects.

Role

Planning, design, and construction of a tsunami vertical evacuation structure are all eligible activities for state and federal grants. The state Hazard Mitigation Officer and Hazard Mitigation Team help communities to identify and apply for federal grant funding. The Hazard Mitigation Team administers grants once they have been awarded. This involves monitoring and providing technical assistance. Tribes can apply directly for federal grants; however, the state Hazard Mitigation Officer can provide assistance as needed.

Examples of grants received by Washington state coastal communities are indicated under the specific grant types in Section 7 of the manual. Projects to improve evacuation routes and move a school out of the tsunami inundation zone have also received grant funding. Newport, Oregon, used grant funds to create evacuation routes to a nearby hill in 2012. Waldport, Oregon, used grant funds to help relocate an existing school out of a tsunami inundation zone in 2013. Your project may be eligible for other grant funding opportunities besides those offered by FEMA, but FEMA is a well-recognized source for these types of grants.

Go to Section 7 (Grants, p. 60)

How This Role Fits into the Overall Process

Once a community has selected potential sites for a project, it is time to look into state and federal grant funding. Grants can cover the initial site investigations, basic design, and even the cost of putting together a larger grant application. Grants can also help to cover the costs of overall design and construction.

The state Hazard Mitigation Officer and Team can help a community determine whether their project is eligible for grant funding, provide guidance to help them prepare the application, and review the application for completeness. Even if a community's grant request is turned down the first time, the community may be able to reapply. Unfunded grant applications may be given a higher priority in future funding rounds. Because grants are competitive and funding is limited, a community should have an alternate funding plan in case they do not get a grant.

The City of Westport and the Shoalwater Bay Indian Tribe received federal grants for evacuation structures. After grants are awarded, the state Hazard Mitigation Team monitors work progress, releases funds, answers questions, and serves as an intermediary with FEMA.

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Section 3. Tsunami Experts and Project Team Roles

Tsunami experts and project team consultants play a variety of roles in the planning, designing, and construction phases of a tsunami vertical evacuation project. These roles were introduced in Section 1 in the context of the 8 Phase Process and are described in greater detail here.

Geologist

State and federal geologists play an important role in helping communities to assess the impacts of earthquakes and tsunamis. They provide information on the likelihood of various earthquake and tsunami events and map tsunami inundation zones. They also create pedestrian evacuation models and help map likely evacuation routes with input from the community.

Role

The Washington State Department of Natural Resources (WA DNR) works closely with the state Emergency Management Division (WA EMD) and other partners to help communities with their decision-making and mitigation efforts. WA DNR produces tsunami inundation maps for Washington state. These maps show the amount of flooding or inundation depths for specific tsunami scenarios. These inundation depths include both flooding due to wave dynamics and earthquake-induced subsidence. This subsidence may cause the ground to drop between 3 to 6 feet during the earthquake. Earthquakes from other faults in the Puget Sound may also produce localized subsidence and/or uplift. WA DNR has published tsunami inundation and current velocity maps for the entirety of Washington's coastline for a magnitude 9.0 Cascadia Subduction Zone earthquake and tsunami.

Utilizing tools created by the U.S. Geological Survey (USGS) with input from local emergency managers, WA DNR creates tsunami pedestrian evacuation models that inform the development of evacuation maps. These maps display the amount of time it takes pedestrians to walk to high ground within specific areas of the inundation zone. Evacuation walk time maps guide communities to recognize areas where evacuation structures may be needed.

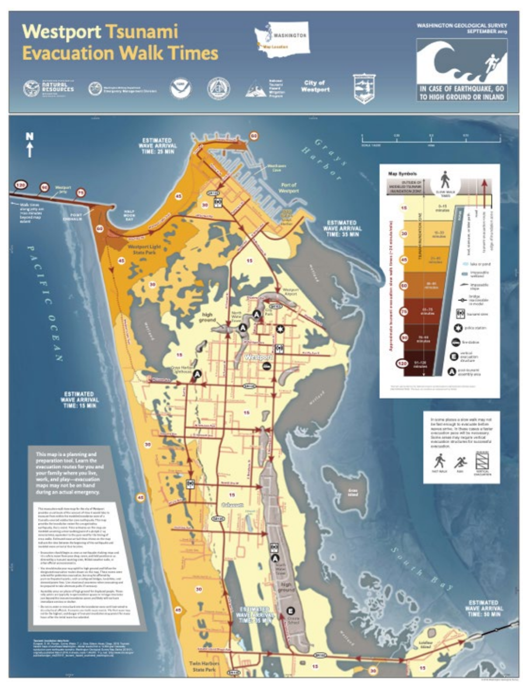

Figure 12. Example of a tsunami evacuation walk time map. Maps are available on the *Tsunamis* webpage at dnr.wa.gov

How This Role Fits into the Overall Process

The WA DNR geologist is an important partner for communities, particularly in the initial assessment and planning stages of the project. The geologist can both help communities identify potential structure locations, and answer questions from the public about tsunami hazards, modeling, and local risk.

Tsunami Modeler

Tsunami modelers are essential for determining the inundation depths, flow characteristics, and forces for a specific structure and site. These models help to set the height of the structure and inform the structural engineer's design. It is important that models be revisited throughout the process, especially if there are changes to the shape and location of the evacuation structure.

Role

The tsunami modeler creates computer models that attempt to predict the behavior of tsunami waves. Models are based on a variety of possible earthquakes that might trigger tsunamis. Modelers can simulate the impact of tsunami waves on a specific site and the forces that evacuation structures must withstand, such as liquefaction and scour. The geotechnical engineer, structural engineer, and architect depend on these models to design evacuation structures.

Modeling work for Washington state has typically been carried out by researchers at the University of Washington's Departments of Earth and Space Sciences, Applied Mathematics, and Civil and Environmental Engineering and at the National Center for Tsunami Research (NCTR), part of NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle. Both organizations have modelers, mathematicians, and tsunami experts who work closely with the Washington Emergency Management Division (WA EMD) and Department of Natural Resources (WA DNR). They model a variety of faults, including the Cascadia Subduction Zone, in western Washington. These models are crucial for hazard mitigation planning and emergency management.

How This Role Fits into the Overall Process

The tsunami modeler should be brought in once potential sites have been identified. Throughout the design process, it is essential for the project team to set up regular check-ins with the modeler. If there are any changes in the shape or location of the structure, the modeler should be contacted as soon as possible.

Go to Section 4 (Building to Withstand a Tsunami: Technical Requirements, p. 42)

Geotechnical Engineer

The geotechnical engineer is critical for investigating site conditions, verifying the suitability of a site, and working with the structural engineer to determine foundation design.

Role

The geotechnical engineer investigates and assesses site geology and seismic hazards. Tsunami evacuation structures require significantly more work up front than most structures. Initial work includes subsurface explorations (i.e. borings) to characterize subsurface soil and groundwater conditions at the site. The geotechnical engineer then provides information about the strength of the soils and their susceptibility to liquefaction, scour, and settlement.

The geotechnical engineer works closely with the structural engineer and tsunami modeler to make decisions about the specific type of foundation system and develop the scour parameters needed for the design of evacuation structures. Tsunami evacuation structures are typically designed with deep foundations that can withstand earthquake shaking, liquefaction, and tsunami wave and debris impact forces. Specialized ground improvement measures may also be required to mitigate liquefaction and improve stability of structures during earthquake shaking. Foundation costs are high in these projects because of typical coastal sandy soils, lack of bedrock, and combined earthquake and tsunami forces.

Figure 13. Tsunami vertical evacuation tower built by the Shoalwater Bay Indian Tribe. The structure is 50 feet tall and 40 feet wide. The support piers anchoring it descend 55 feet below grade. (Photo: Degenkolb Engineers)

How This Role Fits into the Overall Process

A geotechnical engineer should be hired to investigate conditions for potential sites. Geotechnical engineers can also assist with the initial siting alternatives analysis. Once there is a preliminary design for the evacuation structure, the geotechnical engineer will work with the structural engineer to determine the appropriate foundation system and confirm the design.

Structural Engineer

The structural engineer works with the other project team consultants and tsunami experts to ensure that the structure can withstand earthquake and tsunami forces. They follow the most recently adopted International Building Code (IBC) in their design work.

Role

The structural engineer is responsible for designing an evacuation structure that will resist earthquake and tsunami forces. The engineer works closely with the architect and others to design a vertical evacuation structure or to integrate the vertical evacuation component into a building design. The structural engineer coordinates with the tsunami modeler to get information on tsunami wave depth and forces. Working with the geotechnical engineer, the structural engineer determines what type of foundation system is needed.

How This Role Fits into the Overall Process

Initial tsunami modeling and geotechnical investigations should be completed early in the design phase. In addition, a structural engineer should be hired to do conceptual design work to help validate the project budget for bond measures and large grant applications. Generally, this represents approximately 15 percent of design completion, and the community may pay for this work with local funding or with grants.

The next step is to secure project funding for completing the design and possibly construction. The community may choose to continue working with the same structural engineering firm or award the contract to another firm. The structural engineer is a key member of the assembled project team to complete the evacuation structure.

The biggest factors in structure costs are the foundation system and the height of the structure. Foundation systems will tend to be deep and extensive. The Ocosta Elementary School required 160 concrete piles that extend 50 feet deep. The supports of the Shoalwater Bay Indian Tribe's vertical evacuation tower extend 55 feet below ground. Even evacuation berms may require significant ground improvement to minimize the impacts of liquefaction and protect against tsunami scouring.

Go to Section 4 (Building to Withstand a Tsunami: Technical Requirements, p. 42)

Architect

The architect designs the structure and usually coordinates the consultant project team. The architect works to design an attractive structure that meets local planning and building codes and design guidelines. The architect seeks to create a design that fits into the community's landscape and built environment while serving vertical evacuation and other program functions.

Role

The architect is responsible for designing a building that is functional, attractive, and meets the clients' needs and budget as well as various code requirements. The architect is often the project team lead and coordinates with all the other disciplines and the community. The architect works directly with the structural engineer throughout the whole process. The architect also works closely with the building contractor during construction. The architect plays an important role for both buildings and towers. For berm design, a landscape architect may be the project lead if there is not a building component.

How This Role Fits into the Overall Process

A good time to bring in the architect is when a site has been identified and initial tsunami modeling and geotechnical work has been carried out. An architect working with a structural engineer can develop alternative studies for the proposed structure. This work may be paid for with available local funds or by grants. When a preferred design is selected by the community, the concept can then be developed enough to determine project costs. These costs can be the basis for a public bond or other local funding mechanism and for a future grant request.

The community can select an architect to do the initial design and either continue with that architect or select another architect to design the full project. Selecting an architect could include presentations by various architectural firms to the stakeholder committee and the community. Community leaders and stakeholder committee members should also visit the offices of architectural firms. Your project management consultant and local and state partners are also valuable resources in the selection process.

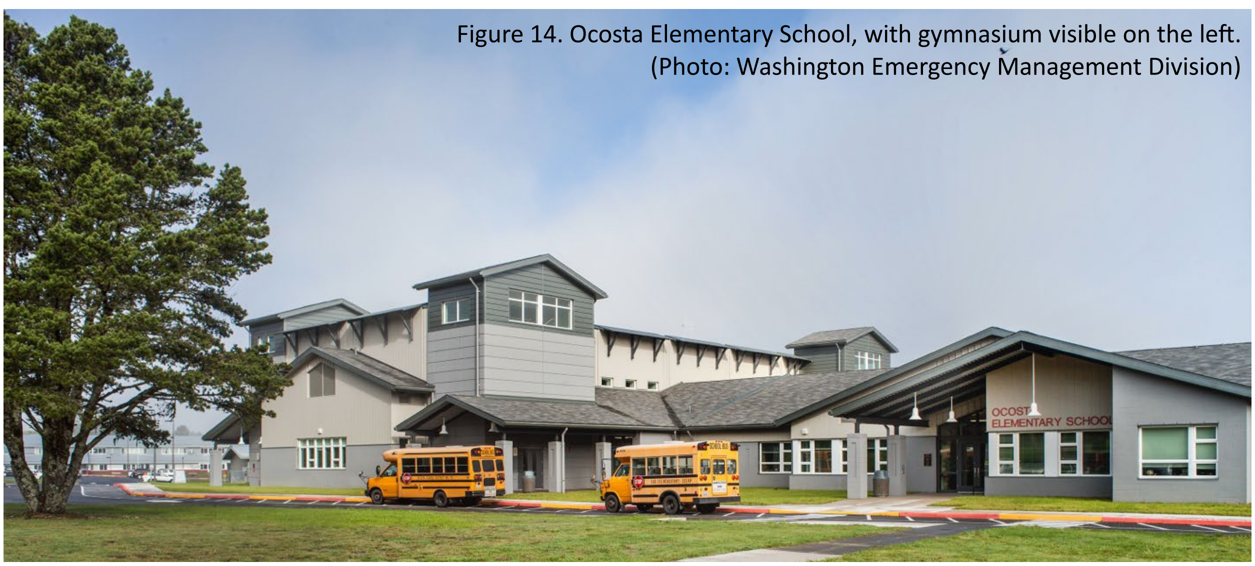
Figure 14. Ocosta Elementary School, with gymnasium visible on the left. (Photo: Washington Emergency Management Division)

For the Ocosta Elementary School (figure 14), the architects had to design a building that served all the required school functions. The gymnasium roof is tall and large enough to serve as a vertical evacuation platform. The architects designed large stair towers to the roof that could be accessed at ground level, outside the building. Following community feedback, they refined the design so that the vertical evacuation function was evident but not overpowering. The completed building is attractive, fits nicely within its site, and serves a variety of functions. This is a building the community is proud of and an inspiration to other coastal communities in Washington state and beyond.

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Section 4. More Guidance for Planning Vertical Evacuation Structures

Structure Types and Considerations

The type of tsunami vertical evacuation structure you choose will be tied to the site. If your community is constructing a new building, then including a vertical evacuation element may make sense. A community with a large public open space near an area of population density might consider a berm for that location. Other sites may be best suited for a tower. This section describes various structure types and considerations for choosing one over another.

A factor to bear in mind with any option is how the upkeep of the structure will be financed over time. One approach is to plan a structure that includes an every-day, non-emergency function or use that can generate revenue. For example, the City of Westport plans to build a vertical evacuation structure in the marina area. They have discussed a number of multi-use possibilities for the structure, including incorporating retail space or an outdoor performance area and market spaces. A further advantage of such an approach is to make the vertical evacuation structure a familiar and accepted part of the community landscape, which can in turn help raise public awareness of it as a safe place to go in the event of a near-source tsunami.

If planning a tsunami vertical evacuation structure that will serve more than one purpose or will be a multi-use building, investigate how each possibility increases the cost of construction. If the project is relying on grant funding, ask which parts of the project the grant funds can and cannot be used for. Consider also:

- How the proposed uses may affect the kinds and costs of maintenance the facility will require.
- What type of security is necessary and which options will allow access to the structure at all times for evacuation purposes.
- What insurance coverage, if any, may be needed.

The four general vertical evacuation structure types are:

Buildings

New buildings and significant additions and retrofits to existing buildings may offer a good opportunity for vertical evacuation. Examples include schools, city halls, community centers, conference centers, parking garages, apartment buildings, and resorts and hotels. Buildings may also make consistent maintenance and security easier to implement. The Ocosta Elementary School in Westport, Washington, and Oregon State University's Gladys Valley Marine Studies

Building in Newport, Oregon, are examples of buildings that were constructed to be tsunami vertical evacuation structures.

Existing buildings may be an option, but they would typically have to be of steel and concrete construction to resist tsunami wave forces. Potentially eligible buildings also require an engineering review to determine if they meet tsunami and earthquake structural requirements. Additionally, these buildings would have to meet height requirements based on tsunami modeling for the site. Washington coastal communities generally do not have concrete and steel-frame buildings of sufficient height that could be retrofitted for vertical evacuation.

Considerations for buildings:

- How many people will be inside the building and within evacuation radius of the building?
- For people near the building:
  - Is the site accessible to them?
  - Are there significant barriers to accessing the refuge that would be hard to modify?

Towers

Towers are generally stand-alone structures with a platform at the top on which people can gather. Towers can be single purpose but can also support multiple uses, such as viewing and bird-watching platforms. Towers generally require less land than other options. Tsunami towers have been built in Japan and saved lives during the 2011 Tohoku earthquake and tsunami. In Washington, the Shoalwater Bay Indian Tribe built a tower (fig. 15) that serves both the Tribe and the nearby town of Tokeland.

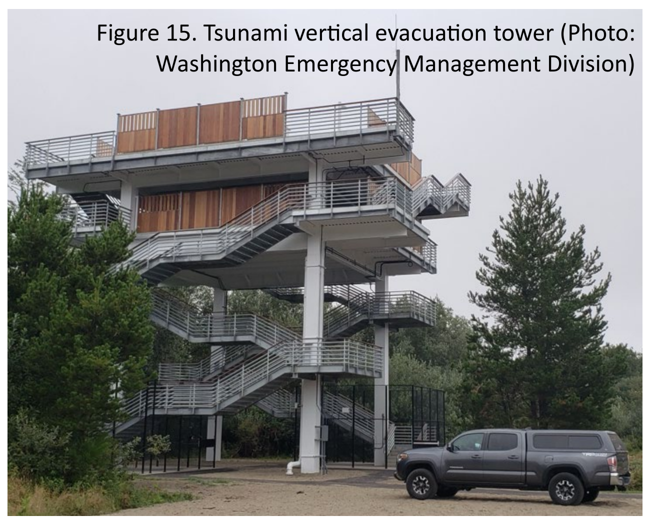

Figure 15. Tsunami vertical evacuation tower (Photo: Washington Emergency Management Division)

Considerations for towers:

- How many people are within evacuation radius of the tower?
- What other purposes could the tower be used for?
- How does the tower fit into the landscape and impact nearby buildings?

Berms ("artificial hills")

Berms are artificial, engineered hills that provide high ground. They usually have a large footprint. They can be landscaped and located in such a way as to provide seating for sports fields and picnic and viewing areas. Berms can have a large capacity to hold people. They may need concrete elements and some foundation work, especially as they get taller. As berms get taller, they may become cost prohibitive, and this should be considered as part of site selection. Tsunami berms have been built in Japan and New Zealand but not yet in the United States.

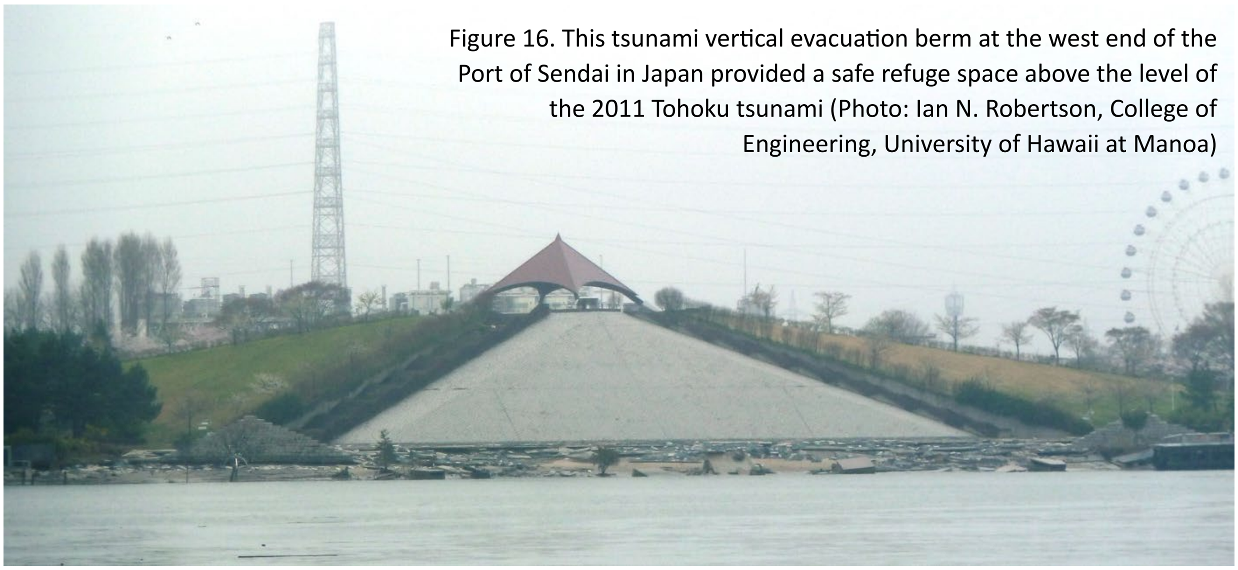

Figure 16. This tsunami vertical evacuation berm at the west end of the Port of Sendai in Japan provided a safe refuge space above the level of the 2011 Tohoku tsunami (Photo: Ian N. Robertson, College of Engineering, University of Hawaii at Manoa)

CONSIDERATIONS FOR BERMS:

- Is there a large enough open area to locate a berm?
- How many people are within evacuation radius of the berm?
- How does the berm fit into the landscape and impact nearby buildings?
- What other uses could this berm support (i.e., seating, picnic areas, etc.)?
- Could a tower be considered as an alternative option for the site?

Hybrid

A hybrid option would be some combination of the three options above. A one-, two-, or three-story building could include a tower component. A berm could also include a tower element. There may be ways to combine vertical evacuation with infrastructure projects such as roads and bridges.

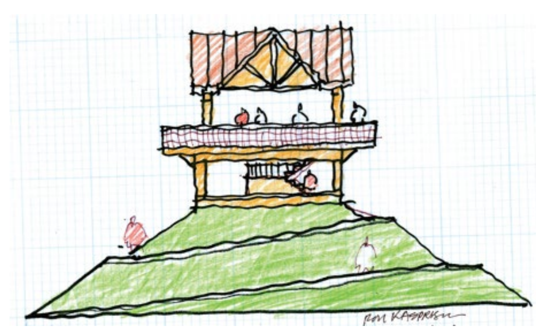

Figure 17. Illustration of a hybrid berm-tower. (Sketch: Ron Kasprisin, UW Project Team)

General Criteria for Assessing Vertical Evacuation Designs

The following criteria are a valuable back-check at different points in the design process. By this stage, you will have already hired an architect and structural engineer.

- ☐ **Confirm the required height of the evacuation structure.** The height is based on the findings of the tsunami modeler and geotechnical engineer in combination with the building code requirements.
- ☐ **Confirm the occupant capacity of the evacuation structure.** Consider nonresidents such as visitors, tourists, and employees who may need to use the structure. Compare this to the number of people within walking distance during the evacuation timeframe. (FEMA P-646 offers recommendations for sizing and siting tsunami vertical evacuation refuges.)
- ☐ **Confirm the estimated cost of the structure within the budget constraints of your community.** Expect to update this regularly during the design and construction phases.

Questions to Consider

- ☐ Does your evacuation structure fit with the surrounding landscape and neighboring buildings while also being recognizable as a tsunami vertical evacuation structure?
- ☐ Is the design of your evacuation structure attractive and well proportioned? Will this be a building that the community can take pride in?
- ☐ Have you considered multiple uses for your evacuation structure? How might a structure support other needed community functions? Could any of the other uses generate revenue to support maintenance of the structure?
- ☐ How does the shape of the design respond to incoming and retreating tsunami waves, including debris? For example, a solid flat wall perpendicular to the incoming tsunami wave will take the full impact whereas a wedge-shaped wall will allow the water to flow more easily around.
- ☐ What other elements have you considered for your evacuation structure? What might you want to add after the structure is built, if you don't have the budget for it now?
    - Is there storage space for emergency supplies and water? Can the stored items be secured so that they can't move around during ground shaking?
    - Do you have emergency sanitation facilities?
    - Does the design include features such as ramps that provide easier access for people with ambulatory challenges?
    - Do you have a backup power source for any lighting or other equipment intended for use during a tsunami evacuation?
    - Will you include some type of cover to protect evacuees from the weather?

- ☐ How is the evacuation structure accessed? For a building with a vertical evacuation element, how will people get access if the building is closed during a tsunami evacuation? Think about access to an evacuation structure if an earthquake strikes in the middle of the night or on the weekend.
- ☐ Is your evacuation structure visible to the public, with clear and obvious points of entry?
- ☐ Does the evacuation structure allow for routine maintenance and repair? Is the design durable and appropriate for the climate zone?
- ☐ Will the necessary signage, evacuation routes, training, and outreach be in place so that the community will know about and be able to access the evacuation structure during a tsunami evacuation?

Building to Withstand a Tsunami: Technical Requirements

Tsunami vertical evacuation structures must be able to withstand a major earthquake, aftershocks, and 12–24+ hours of tsunami waves. They also have to survive ground liquefaction, scouring from tsunami waves, and the impact of floating debris. Consequently, they must be designed to be very resilient structures.

The ways in which a tsunami can damage a structure are called *tsunami load effects*; these include:

- The direct force of fast-flowing water moving against and around the structure and pushing upwards on the structure from below.
- Uplift of the structure due to buoyancy.
- Impacts from very large water-borne debris, which can include buildings, cars, boats, and shipping containers as well as trees and logs; and the increased pressure created by damming if debris gets caught up on some part of the structure.
- Fires spread by floating, burning debris, such as buildings and cars.
- Scouring effects that undermine the stability of the structure, such as when the fast-moving water of a tsunami wave removes the soil that the structure is built on.

A more in-depth overview and general descriptions of various tsunami load effects can be found in FEMA P-646: *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*, 3rd edition (chapters 8.6–8.8). However, for specific design requirements, the engineers and architect on your project team will refer to the latest edition of the *American Society of Civil Engineers/Structural Engineering Institute Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7). ASCE/SEI 7 is published and regularly updated by the American Society of Civil Engineers (ASCE). Chapter 6 “Tsunami Loads and Effects” is the current standard for designers of tsunami vertical evacuation structures, which are designated as Tsunami Risk Category IV. The latest edition of ASCE/SEI 7 is adopted by reference as part of the International Building Code (IBC), which guides design of structures in Washington state.

In addition, structural, geotechnical, and civil engineers and architects working in coastal areas of Washington must use Washington Tsunami Design Zone Maps (WA-TDZ) where available. ASCE Tsunami Design Zones are to be used where WA-TDZ maps are not available.[1] The code further requires the use of Washington State Department of Natural Resources' (WA DNR) tsunami inundation modeling for design purposes. Refer to the Tsunami Design Zone Maps for Washington State Building Code on the WA DNR website. These maps are based on a large tsunami generated on the Cascadia Subduction Zone and are consistent with the earthquake hazard level used for seismic design of buildings. This hazard level is defined as having a 2-percent probability of occurrence in a 50-year time frame. Tsunami vertical evacuation refuges also have an additional safety factor applied to their minimum height to further ensure they serve their intended purpose.

Cascadia Earthquake Tsunami Scenario

The seismic record of the Cascadia Subduction Zone (CSZ) suggests there may have been as many as 19 earthquake events that ruptured the entire length of the CSZ within a period of 10,000 years.[2] The magnitudes of these events are estimated to have been between 8.5 and 9.1. The time between them has been as short as 110 years and as long as 1,150 years, with an average of about 500-550 years. Evidence of the last CSZ earthquake and subsequent tsunami are preserved in the geologic record of the Washington coast. The tsunami was also noted in Japanese historical records, which fix the date as January 26, 1700.

The simulated scenario earthquake known as L1 is one of 15 full-margin rupture models derived from the seismic record along the CSZ. Researchers have suggested that this scenario should be considered for future revisions to building codes, for land use planning, and for engineering design of critical structures along the coast.[3] Washington state has adopted this consideration locally and recommends that the L1 scenario be used in setting design standards when building tsunami vertical evacuation structures. The L1 scenario is a magnitude 9.0 earthquake, which generates a tsunami that encompasses ~95% of the hazard over the 10,000-year-old sequence of available seismic evidence. Within this period, it is inferred that there have been four earth-quake events that were of L (large) size or greater. This suggests an approximate recurrence interval of 2,500 years for these types of events. This probability of occurrence is also on the

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[1] ASCE Tsunami Hazard Tool at asce7tsunami.online (American Society of Civil Engineers).

[2] Goldfinger, Chris; Nelson, C. H.; Morey, A. E.; Johnson, J. E.; Patton, J. R.; Karabanov, Eugene; Gutierrez-Pastor, Julia; Eriksson, A. T.; Gracia, Eulalia; Dunhill, Gita; Enkin, R. J.; Dallimore, Audrey; Vallier, Tracy, 2012, Turbidite event history—Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone: U.S. Geological Survey Professional Paper 1661-F. [pubs.usgs.gov/pp/pp1661f/]

[3] Witter, R. C.; Zhang, Y. J.; Wang, Kelin; Priest, G. R.; Goldfinger, Chris; Stimely, L. L.; English, J. T.; Ferro, P. A., 2011, Simulating tsunami inundation at Bandon, Coos County, Oregon, using hypothetical Cascadia and Alaska earth-quake scenarios: Oregon Department of Geology and Mineral Industries Special Paper 43. [oregongeology.org/pubs/sp/p-SP-43.htm]

same order as the International Building Code seismic standard of 2-percent probability of exceedance in 50 years.

Ultimately, for the design of tsunami vertical evacuation structures, structural engineers must adhere to the requirements of *American Society of Civil Engineers (ASCE) 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, which defines a probabilistic tsunami model.

Western Washington also has a number of local crustal faults known or suspected of producing tsunamis. Tsunami scenarios for these local fault sources, such as the Seattle fault zone, are limited and a topic of ongoing research.

Tsunami Modeling

ASCE 7 guidance requires a factor of safety for vertical evacuation structure height: this includes adding 30 percent to the initially determined height, plus 10 feet (see figure 18). The initial tsunami wave height at the building location is derived from tsunami inundation modeling. Modeling is essential before and during the design of an evacuation structure, and your project team should include a tsunami modeler.

Go to Section 3 (Tsunami Modeler, p. 34)

All modeling relies on Digital Elevation Models (DEMs), which provide a geo-referenced grid of elevation points for the topography and bathymetry of the area. Topography refers to the contours of the land above water. Bathymetry refers to the contours of the land below water. The behavior and impact of tsunami waves are shaped by both topography and bathymetry.

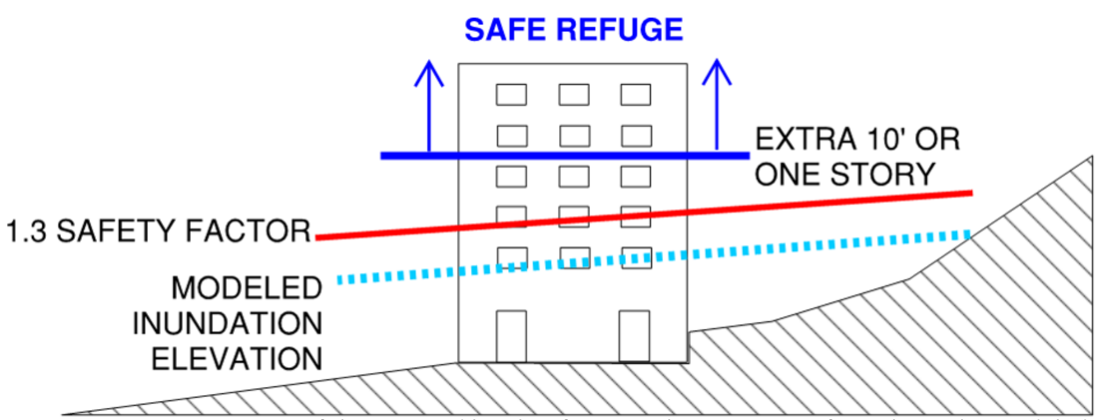

Figure 18. Diagram of the required height of a vertical evacuation refuge above the modeled inundation level. (Graphic: Washington Emergency Management Division)

Washington State Department of Natural Resources' tsunami inundation maps are produced with two-dimensional (2D) fluid dynamic models. 2D models are based on a "bare earth" DEM for land above and below water. The bare earth DEM is a model of the earth's surface without any natural or man-made features such as vegetation, buildings, and roads (exception: in some cases, jetties, breakwaters, levies, and dikes are included). When a site is chosen, the tsunami modeler can provide a finely detailed 2D model of the tsunami waves and current velocities in and immediately surrounding the site. These 2D results are essential to the three-dimensional (3D) model. While 3D models are more complex and costly to create, they more accurately predict tsunami forces on the structure because the underlying physics is more complete, and they are capable of modeling complex structures in greater detail.

Currently, 2D and 3D models do not routinely include surrounding buildings or vegetation but can sometimes be modified to do so if essential data to model these features are available. However, surrounding buildings may be destroyed and become part of the debris flow, and this process is currently very difficult to model.

Most tsunami models assume Mean High Water (MHW) for the entire 12- to 24-hour (or more) tsunami event. Tides will drop below this level during the tidal cycle, so this is an upper-limit, conservative standard. Models do not take into account the interaction of the tsunami with changes in tidal height and the associated tidal currents. Modeling also does not typically include the scouring, erosion, and deposition of soil or the impact of large debris caused by the tsunami waves on evacuation structures. The structural and geotechnical engineers will assess these impacts with the help of the model. Tsunami modeling continues to develop and improve, and it is based on a strong foundation of research.

Tsunami Maps

The Washington State Department of Natural Resources (WA DNR) publishes a suite of tsunami maps based on modeling for a particular tsunami scenario. These maps are peer reviewed by tsunami experts. The maps and source data are available on WA DNR's Tsunamis *webpage. The maps show*:

- *How far inland tsunami waves are expected to travel and the depth of the water on land.*
- *The speed of tsunami currents.*
- *Tsunami evacuation routes and the estimated time it will take from a given location to walk out of the tsunami inundation zone.*

Go to Appendix A: Kinds of Tsunami Maps and How They are Used for VES Planning

The tsunami inundation maps are available to the public and will play a role at different points in your vertical evacuation structure planning efforts as you determine where to put your structure and how many people it will serve. However, these maps do not contain the detailed, site-specific modeling required for the design of evacuation structures. For that, your project team will need to include a tsunami modeler, who will determine the inundation depths, flow characteristics, and forces for a specific structure and site.

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Section 5. Educating the Community About Tsunamis

How to Respond to and Prepare for a Tsunami

Education and training are essential to enable community members to understand and make the most of their evacuation options and to assess the need for further efforts. Preparedness can improve post-tsunami outcomes for your community.

Washington state coastal communities are at-risk from two tsunami sources:

1. **Local source tsunamis** occur within or very close to Washington state, and their waves arrive on Washington's shores in less than three hours—typically in just tens of minutes. Local tsunamis will likely come from the Cascadia Subduction Zone (CSZ) just off the Pacific coast. Within the Puget Sound, local source tsunamis may come from a crustal earthquake on the Seattle fault, Tacoma fault, or other fault. Local tsunamis can also be generated by landslides into or under the water.

2. **Distant source tsunamis** originate elsewhere in the Pacific Ocean and must travel across the Pacific basin to reach Washington, so their waves typically arrive in over 3 hours. Distant tsunamis can come from as far away as Alaska (as happened in 1964) and even Japan (as occurred after the Tohoku earthquake in 2011). Distant tsunamis can be generated by earthquakes, volcanic eruptions, and other events.

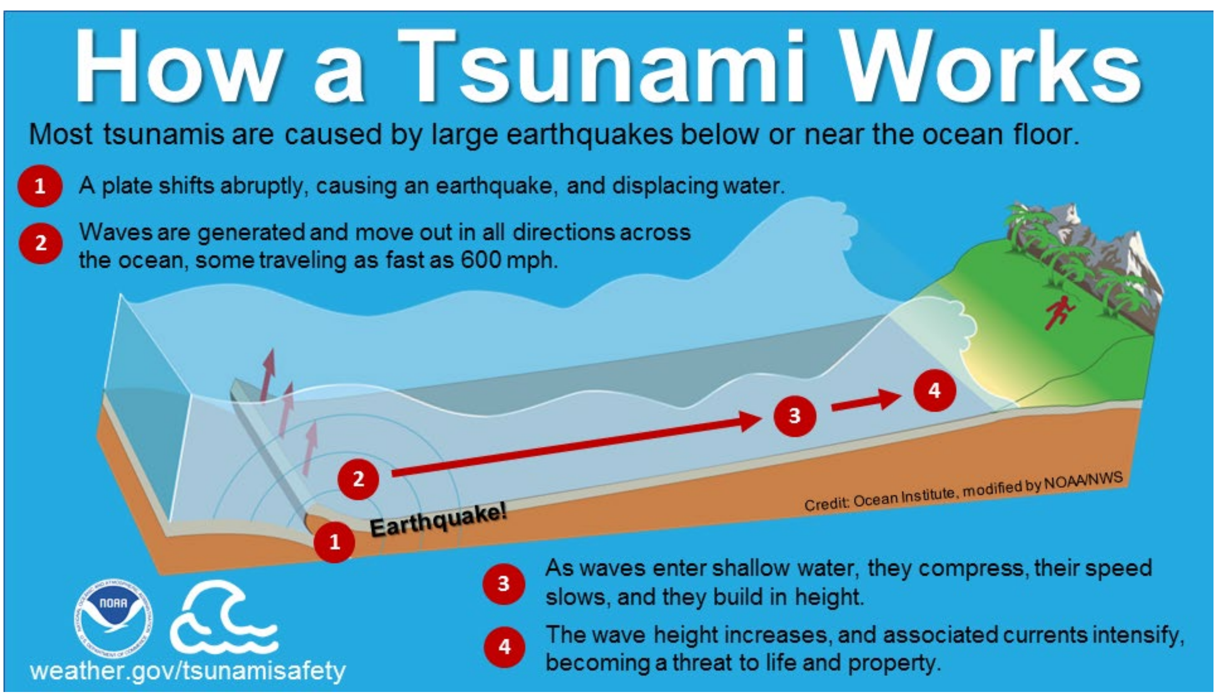

Figure 19. Poster illustrating how an earthquake causes a tsunami. (Graphic: Ocean Institute and NOAA/NWS)

How to Respond to a Local Source Tsunami

For local source tsunamis, the waves will often arrive after the ground shaking from a large local earthquake. Evacuation times can vary from minutes to several hours. If you feel ground shaking while on the coast:

1. Drop, cover, and hold on. This helps to protect you from injury, particularly your head and neck.
2. When the shaking stops and/or you feel it is safe to move, assess your surroundings and move immediately inland to high ground. The earthquake is your first, best, and potentially only warning that a tsunami may be on the way. Do not wait for announcements telling you to evacuate—just go. Do not waste precious time. Also, don't forget to grab your go-bag (described under "Preparedness Efforts" near the end of this section).
3. You will most likely need to evacuate on foot, taking care to avoid hazards along the way. The earthquake may have buckled roads, knocked down powerlines, and caused landslides, making driving nearly impossible.
4. Children, the elderly, people with access and functional needs, and those with health issues may move more slowly and will likely need assistance.
5. Tsunamis consist of multiple waves that could impact coastal areas for 12 to 24 hours or longer. The first wave is often not the highest. Once you reach high ground, do not come down until local authorities notify you to do so.

How to Respond to a Distant Source Tsunami

You are unlikely to feel ground shaking from a distant source tsunami, which is why tsunami alerts are especially important. Because of distance and the network of early warning systems, people will likely have several hours to evacuate before the first waves from a distant source tsunami arrive.

1. Your state and local emergency management officials will tell you what areas are unsafe and need to be evacuated. Follow their instructions.
2. Do not go out to the shoreline to observe the tsunami waves; you could be swept away.

Tsunami Alerts

Tsunami alerts help warn the public when a distant source tsunami is approaching. Alerts about tsunamis are delivered in a variety of ways, and you should choose multiple methods to receive tsunami alerts in case one method fails during a tsunami event.

- Local emergency alerts through your city, county, and/or tribe: to find your local region and "opt in," go to mil.wa.gov/alerts#local
- NVS Tsunami Evacuation App: nanoos.org/mobile/tsunami_evac_app.php

- NOAA Weather Radios: weather.gov/nwr/
- All Hazard Alert Broadcast (AHAB) Tsunami Sirens: mil.wa.gov/tsunami#sirens
- Wireless Emergency Alerts (WEA) via cell phone: mil.wa.gov/alerts#WEA
- Emergency Alert System (EAS) alerts via TV and radio: Emergency Alert System webpage at fema.gov
- Email service via UNESCO/IOC email service: tsunami-information-ioc@lists.unesco.org

Go to the Washington State Emergency Management Division's ***Alert & Warning Notifications*** webpage to learn more and sign up for tsunami alerts.

Preparedness Efforts

All coastal communities need to become better informed about their tsunami risk so that people can make the best decisions for their own safety and contribute thoughtfully to community planning and preparedness efforts. The following steps can help you build tsunami awareness and become better prepared on both an individual and community level:

1. Ongoing community education. This outreach builds awareness and support and can take many forms. For example, one option is to invite a panel of tsunami experts to a public meeting to present information about the hazard and answer questions. Another is to provide tsunami awareness and preparedness materials at a preparedness fair or other community event, or to stock them in public spaces like convention centers, tourism offices, and informational kiosks.

> *An outreach program used in the past to support tsunami awareness in many coastal communities was the annual Washington State Emergency Management Division (WA EMD) Tsunami Roadshow. Upon request, WA EMD Tsunami Program staff can come to your community to give in-person presentations or host virtual webinars.*

2. Perform evacuation drills in your community so everyone knows where to go before the tsunami hits. Drills also help to raise awareness and increase support for building vertical evacuation structures. The Washington State Great ShakeOut drill is held every third Thursday in October. Many communities and tribal nations hold evacuation walks, such as the Yellow Brick Road health fair and tsunami evacuation walk hosted by the Shoalwater Bay Indian Tribe each summer. In Washington state, schools in tsunami inundation zones must conduct annual tsunami evacuation drills. Once built, a tsunami vertical evacuation structure should be included in the local drill or evacuation walk and any related activities.

Go to Section 8 (Ongoing Public Education and Drills, p. 72)

3. Work on a community-wide tsunami evacuation plan. This plan should include information on existing evacuation routes, high ground, signage, and AHAB tsunami siren locations, if applicable. The plan should also identify what parts of the community may have challenges reaching safety. The plan should have a list of priority projects, such as vertical evacuation structures and evacuation route sign installations that can help your community reach the goal of providing everyone with access to safety.
4. Encourage community members to create family emergency plans. Everyone should build their own go-bags and work on storing at least two weeks of emergency supplies at home. A go-bag/kit is a bag that you can carry with you during an emergency that contains essential supplies. You may need to go to a shelter, to reunite with your children and other family members, to work, to the hospital, to high ground or elsewhere.
    - Download a “2 Weeks Ready” brochure and view a video on how to prepare a kit at *mil.wa.gov/preparedness*
    - Learn more about tsunamis and preparedness at *mil.wa.gov/tsunami*

Figure 20. Display of earthquake and tsunami preparedness education materials.
(Photo: Washington Emergency Management Division)

While grabbing a go-bag should become second nature for everyone regardless of the hazard, it is especially important to promote this practice in your community if you do not plan to provide water, food, or other emergency supplies at your tsunami vertical evacuation structure. If evacuees must provide these essentials for themselves, it is imperative that you educate community members beforehand so that they know the evacuation structure lacks supplies and are prepared to bring their go-bags.

Items to have in a go-bag include a NOAA weather radio, first-aid kit, flashlight, clothing to keep you dry/warm, water filtration devices, medication, water bottle, food, fire starter, multi-tool with can opener, sturdy shoes, comfort items, and cash.

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Section 6. Engaging the Community in Vertical Evacuation Planning

Given the scale of this type of building project and the long lifespan of vertical evacuation structures, community engagement is critical. It encourages participation in and support for the project, builds trust, and generates goodwill, and it enables you to gather feedback on decisions and address concerns and questions early on.

Tips for Public Outreach and Engagement

Identify Your Audiences and Partners

- ☐ Do research at the beginning of the process to identify who you will need to engage and communicate with:
  - Who will the tsunami vertical evacuation structure serve?
  - Who will it affect?
  - Who in the local community will be asked to contribute to the cost of building or maintaining it?
- ☐ Consider which decision makers, influencers, organizations, community groups, and residents ought to be consulted or invited to participate in the tsunami vertical evacuation planning process.
  - Seek out stakeholders from a broad cross-section of the community to ensure that everyone feels heard and involved.
  - Find out who the trusted leaders and voices are. Ask them how best to communicate and engage with people in their communities.

First Steps. *To communicate effectively about a tsunami vertical evacuation project and engage the groups you want to reach, it helps to understand who they are:*

- *What is their history?*
- *How do they see themselves?*
- *What are their concerns, values, and priorities?*

Make sure you are aware of any existing tensions or trust issues in the community around past vertical evacuation efforts or comparable projects.

Take Time to Build Trust

- ☐ Partner with trusted community leaders and neighbors. Foster a relationship with them and invite them to participate in the tsunami vertical evacuation planning process. They, in turn, can become ambassadors to their communities and locally trusted sources of information about the project.
- ☐ Provide information about the proposed project from the beginning so that people understand it and know how to participate. This should include:
  - The reasons a tsunami vertical evacuation structure is needed.
  - The science of tsunamis and vertical evacuation structures.
  - The steps involved in the project.
- ☐ Be transparent. Make sure information about the process and proposed project are communicated openly to all concerned.
- ☐ Provide accurate information.
- ☐ Listen to your stakeholders. Genuinely consider the input that you receive. Make sure the input is representative; if it isn't, expand your outreach. Register the criticisms, too, and look for and try to address the concerns and priorities underlying them.

Shape the Message and Information to Fit the Audience

Core messages and factual content should be consistent, but your strategy, the narrative and words you choose, the tone, the methods used to communicate, and your means of gathering feedback should be tailored to suit the various groups within your audience. Be sure to:

- ☐ Use clear, plain language and avoid acronyms, abbreviations, and highly specialized vocabulary.
- ☐ Explain unfamiliar concepts and emphasize the points that are most important for the audience to take away.
- ☐ Consider ways to incorporate storytelling into your communications. For example, recount the story of how the community pulled together and overcame obstacles to accomplish a comparable public project, address a hazard, or meet a similar challenge in the past; or share the story of how and why a neighboring community successfully prioritized and built their tsunami vertical evacuation structure. Stories can help people imagine and personally relate both to the project and the reasons for undertaking it.
- ☐ Compare tsunami vertical evacuation to other hazard mitigation efforts that people are already familiar with, such as fire escape routes in buildings. Setting your project within the context of emergency preparedness can help people see it as part of the community's overall effort to keep people safe.

- ☐ Avoid “doom and gloom.” It is important to be clear and realistic about the tsunami hazard and its impacts, but you should avoid invoking fear and instead focus your message on positive actions and the safety and peace of mind that will result.
- ☐ Prepare the strategy and message ahead of time and make sure everyone on your team knows how to tailor their particular content or role to fit the audience.

When planning a multi-use tsunami vertical evacuation structure, be sure to communicate all of the ways that the structure will serve the community and add value.

Use a Variety of Methods to Communicate and Engage

Various groups and demographics within your community may be easier to reach or more responsive if you use the form of communication that they prefer. To reach everyone, you'll likely need to use several methods to communicate information, gather input, and involve community members in the planning process.

Methods to consider include:

- public meetings
- social media posts and blogs
- print and digital surveys
- an online message board
- press releases
- door-to-door visits
- printed posters and flyers
- outreach at community gatherings and events

Using a variety of channels and venues to reach different groups can help:

- Draw in people who are often underrepresented.
- Collect input from people who are not comfortable speaking in public but are willing to share their feedback in other ways, such as through an anonymous survey.
- Engage people who are unable to attend a public meeting.
- Prevent the few loudest or most insistent voices from dominating the process.

When holding a public meeting or taking advantage of a public event to communicate about the project:

- Consider providing incentives, such as a raffle prize, to draw attention and improve participation.
- Be aware of how the timing and location of the event may limit which groups can attend.

Carefully Plan Public Meetings

- ☐ Involve subject-matter experts in public meetings. State geologists, emergency managers, tsunami experts, and engineers who design vertical evacuation structures can present factual information about the tsunami hazard and vertical evacuation options and answer attendees' questions. They can also provide other emergency and tsunami preparedness information that is relevant to your community.
- ☐ Plan the agenda for the meeting and publish it in advance.
- ☐ Publicize the meeting using the methods and channels preferred by the groups you want to attract.
- ☐ At the start of the meeting, consider setting out ground rules for participation. This may include talking-time limits when attendees are invited to speak or ask questions. Although this can have the disadvantage of cutting short a meaningful contribution, it helps prevent one or two attendees from dominating the conversation. Your rules might also define and limit the topics to be discussed so the conversation does not get derailed by other community concerns.

Prepare to Answer Common Questions

Based on the experience of those involved in developing and maintaining tsunami vertical evacuation structures in Washington, certain questions come up frequently when community members ask about the structure. For example:

- How and when will the vertical evacuation structure be used?
- How will individuals with mobility challenges get up to the safe levels?
- How many people can the structure hold? (capacity)
- Will pets be allowed in the tower during a tsunami evacuation?
- How safe will evacuees be in the structure during a tsunami?

Outreach to the community, conversations with community members, and even surveys can help you identify common concerns, anticipate questions, and prepare appropriate answers. Having talking points prepared in advance of community meetings helps ensure that your project team is perceived as prepared, knowledgeable, and trustworthy.

For additional guidance as well as tips for handling misinformation about tsunami vertical evacuation, contact the Washington Emergency Management Division Tsunami Program at Public.Education@mil.wa.gov

Project Safe Haven: Example of a Community Planning Process

Washington state's Project Safe Haven was a community planning process in 2010–2011 that involved communities, several state and federal agencies, and the University of Washington.

Through public meetings and workshops, communities created a tsunami vertical evacuation plan, including potential structure design concepts and the selection of potential sites.

A subsequent study commissioned by the Washington Emergency Management Division—the 2021 *Outer Coast Tsunami Vertical Evacuation Assessment*—now provides Pacific, Grays Harbor, and Clallam counties with more in-depth guidance on vertical evacuation site options, but the original Project Safe Haven process still offers a template for community engagement and stakeholder involvement in vertical evacuation planning.[4]

The Project Safe Haven planning process took place in eight coastal communities, including the Long Beach peninsula, Grays Harbor County, Clallam County, the Shoalwater Bay Indian Tribe, and the Makah Tribe, among others. Local elected and tribal officials invited Project Safe Haven into their communities and supported the process. *Support by local officials is an important component of an effective planning process.* A series of at least four meetings were held in each community, by county.

The Project Safe Haven Model

Assemble a steering committee. To guide the project, the Washington Emergency Management Division and the University of Washington assembled a steering committee. It included representatives from local and state agencies, emergency managers, and tsunami experts. Many of the steering committee members led or participated in each community meeting and workshop.

Organize site visits. Site visits helped the steering committee to explore preliminary locations for evacuation structures, the community's general landscape and built environment, and tsunami risk considerations. Some steering committee members were local or otherwise already familiar with the community being visited; but for many steering committee members, this was their first visit to each community.

Meet with local decision-makers. At the first local official meeting, the design team and tsunami experts were introduced to key local decision-makers (i.e., mayor, planning director, emergency manager). The design team included a combination of planners, urban designers, and engineers. They presented to the local officials how vertical evacuation structures save lives during a tsunami.

Hold a series of meetings to confer with community members.

- ***Meeting 1: Consider, discuss, gather input.*** At the first community meeting, community members were asked to provide their ideas and comments. At these meetings, participants gathered at tables to discuss vertical evacuation structure options together.

[4] Both the 2021 *Outer Coast Tsunami Vertical Evacuation Assessment* and the Project Safe Haven reports are available on the Tsunami webpage at mil.wa.gov/tsunami (Washington Emergency Management Division).

They talked about the advantages and disadvantages of three structure options: buildings, towers, and berms. Participants used risk maps of their community to identify preliminary structure locations and appropriate structure types for those locations. Considerations included population densities and various walking abilities.

- ***Meeting 2: Narrow down the options.*** At the second community meeting, the narrowed down alternatives from the first meeting were presented. Participants discussed the advantages and disadvantages of each alternative. The result of this second meeting was a draft tsunami vertical evacuation plan for the community.
- ***Meetings 3 and 4: Present a plan and gather feedback.*** Two final community meetings were then held to present the draft plan, get feedback, and confirm the final strategy. These meetings provided the community with one more opportunity to assess the plan before publication.
- ***Meeting 5: Illustrate and visualize proposed structures.*** Lastly, a design team was introduced to help conduct a public design charrette where designers made sketches of the vertical evacuation proposals. These hand-drawn and colored drawings were included in the final reports. This helped the community visualize how the proposed vertical evacuation structures could fit into their community and also provide other benefits.

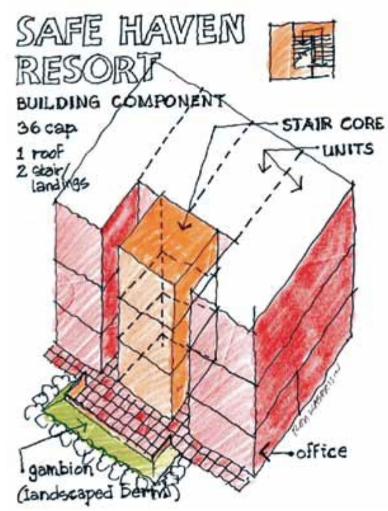

Figure 21. A sketch from *Project Safe Haven* design charrette. (Graphic: Ron Kasprisin, UW Project Team)

Model for a Public Engagement Meeting

In 2018, a public meeting was held in Ocean Shores and another in Aberdeen (the Aberdeen meeting also served the adjacent cities of Hoquiam and Cosmopolis). The meetings featured presentations by tsunami experts, time for questions, and survey cards to collect the audience's input. The format of these meetings serves as one model for educating the community about the tsunami risk and initiating discussion about tsunami vertical evacuation planning.

The survey cards were a means of discovering attendees' feelings, support for, and concerns about vertical evacuation. They included a short list of multiple-choice questions and space for comments on the back of the card.

Examples of Audience Survey Questions

- How certain are you that tsunami refuges could save your life and/or the lives of people in your community?
- What are your top 2 preferences to help fund tsunami vertical evacuation refuges in this community, given limited state and federal funds?

- Who do you trust in your community to lead a tsunami vertical evacuation refuge process?
- What do you see as the biggest opportunities & barriers to building tsunami refuges in this community?

Maps of Potential Sites for Vertical Evacuation

Another means of collecting community input at the meetings involved the use of maps, on which the locations for potential vertical evacuation structures had been marked. These maps were put up on the walls outside the meeting rooms before the meeting and were taken down after the meeting ended and all the attendees had left. Each attendee was given two stars to put on a map: attendees were asked to put one silver star on the site they thought should be completed first for the whole community and a colored star on the site nearest to their home.

The resulting input was limited by the fact that only a handful of attendees chose to put stars on these maps, but the concept provides another potential tool for gauging the preferences of community members and involving them in the planning process.

Figure 22. Public meeting in Ocean Shores about tsunami vertical evacuation. (Photo: Washington Emergency Management Division)

The agendas, survey card results, and other supporting materials for the public meetings in 2018 in Ocean Shores and Aberdeen can be found in Appendix B of the [2018 edition of the *Manual for Tsunami Vertical Evacuation Structures*].

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Section 7. Tools for Funding and Planning Vertical Evacuation Structures

Building tsunami vertical evacuation structures and implementing a tsunami evacuation plan requires creativity, financial resources, determination, and community buy-in. The following tools and approaches represent a comprehensive, yet not exhaustive, list of options for financing tsunami vertical evacuation.[5] You will likely utilize several funding options throughout the course of your project.

Revenue Generating

To finance construction and maintenance of tsunami vertical evacuation structures, local funding will be necessary. This is true even if your community applies for and receives a federal grant, because such grants require a local match.

Go to Grants, p. 60

The following revenue-generating tools are commonly used by local governments to fund community infrastructure and other necessary amenities.[6]

Municipal Bonds

Municipal bonds are debt securities issued by states, cities, counties, and other governmental entities to fund day-to-day obligations and to finance capital projects such as schools, highways, or sewer systems. Generally, the interest on municipal bonds is exempt from federal income tax. Municipal bonds are not secured by any assets. Rather, they are backed by the "full faith and credit" of the issuer, which has the power to tax residents to pay bondholders.[7] The Ocosta Elementary School, including the vertical evacuation component, was financed through a municipal bond.

Regular Property Tax

Property taxes are imposed at regular intervals on land and improvements to the land. A property tax is a tax levied on the value of property; the owner of the property is required to

[5] A number of the definitions provided in this section are derived from the FEMA Higher Education Program Course "Principles and Practice of Hazard Mitigation" (David J. Brower and Charles C. Bohl), Mitigation: Integrating Best Practices into Planning (James C. Schwab, Editor), and the Environmental Protection Agency's (EPA) "Nonpoint Source Outreach Toolbox."

[6] For more information, refer to MRSC's ***Revenue Guide for Washington Cities and Towns*** and ***Revenue Guide for Washington Counties***, available on the Publications webpage at mrsc.org (Municipal Research and Services Center).

[7] Municipal Bonds webpage at Investor.gov (U.S. Securities and Exchange Commission).

pay the tax to a government in whose jurisdiction the property is situated. In Washington, regular property tax is "unrestricted" revenue that can be used for any lawful governmental purpose.

Regular Local Sales Tax

Sales tax is an indirect tax collected by an intermediary (retail store) from the person who bears the ultimate economic burden of the tax (consumer). The intermediary later files a tax return and forwards the tax proceeds to the government.[8]

Special Assessment and Local Improvement Districts

Local improvement districts can be created by a city, county, or other local government to finance capital improvements that chiefly benefit property owners in a particular area.[9] The improvements are paid for by means of a special assessment on the properties of those who benefit. There are numerous possibilities, from temporary creations designed simply to raise revenue for a specific improvement, to independent, special-purpose governmental entities. This technique shifts the financial burden from the general public to those directly benefiting.

In order to issue special assessment district bonds, a majority of owners must agree to a self-assessment. Special assessment districts have been used to finance major infrastructure upgrades such as public transit systems, roads, and water and sewer systems. Appealing aspects of this type of tool are that it expands the available capital budget and aligns incentives of payees and beneficiaries. However, tsunami vertical evacuation structures that serve the general public would not qualify for this financing. Special or multi-use structures that serve a specific population, such as a school campus or private community, may qualify, depending on the situation.

Excise Taxes

Excise taxes are paid when a specific good is purchased. Excise taxes are often included in the price of the product. There are also excise taxes on activities, such as on wagering or on highway usage by trucks. Excise taxes are typically intended to promote an objective as well as raise income—for example, taxes on tobacco may be used to promote health programs.[10]

In Washington, the real estate excise tax (REET 1 and REET 2) is levied by the state. Cities and towns can impose local real estate taxes on top of the state's rate. Counties can also, but only within the unincorporated area. REET 1 revenues must be used on capital projects listed in the city's or county's capital facilities plan or capital improvements plan, so a tsunami vertical evacuation structure would need to be in the plan to qualify.[11]

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[8] Sales and Use webpage at MRSC.org (Municipal Research and Services Center).
[9] Local Improvement Districts (LIDs) webpage at MRSC.org (Municipal Research and Services Center).
[10] Excise tax webpage at irs.gov (U.S. Internal Revenue Service).
[11] Real Estate Excise Taxes (REET) sections of MRSC's *Revenue Guide for Washington Counties* and *Revenue Guide for Washington Cities and Towns* at mrsc.org/publications (Municipal Research and Services Center).

Many coastal communities experience high tourism levels, so a dedicated lodging or "tourist" tax could potentially help fund tsunami vertical evacuation projects—but only in very specific circumstances. To be eligible, a tsunami vertical evacuation structure would need to be part of a multi-use, tourism-related facility that attracts people from over 50 miles away to stay overnight in the jurisdiction. Standalone towers and other single-use towers that are not otherwise open to the public or used for other tourist purposes would not qualify for the lodging tax.[12]

Development Impact Fees

Development impact fees are one-time fees governments impose on proposed developments to offset some of the construction cost or public infrastructure improvements needed to service them. The Growth Management Act (GMA) allows cities to collect impact fees for public streets and roads, parks, schools, and fire protection facilities. Impact fees are tightly regulated. They must be used within 10 years of collection and can only fund projects on a city's capital facilities plan. Cities must develop policies for how these funds are collected and used, establishing ties between growth and projects. Funds cannot go to the relief of existing growth pressures. Washington State RCW 82.02.050-.110 and WAC 365-196-850 authorize counties, cities, and towns planning under the GMA to impose impact fees for public streets and roads; parks, open space, and recreation facilities; school facilities; and fire protection facilities. A standalone vertical evacuation structure thus would not qualify, but a multi-use tower being built as part of a school, park, fire protection facility, or transportation project may qualify.

Partnerships and Other Strategies

Sometimes communities need to identify new or creative strategies to fund innovative projects. Partnerships or other strategic alliances and relationships may serve coastal communities well. Work with state agencies, local partners, and even businesses to help your community identify possible sources for the total amount of money needed to fund vertical evacuation. The following creative tools may work for your community.

Public Private Partnerships (P3)

A public-private partnership (P3) is a contractual arrangement between a public agency (federal, tribal, state, or local) and a private sector entity, such as a business or non-profit organization. Through the agreement, the skills and assets of each sector (public and private) are shared in delivering a service or facility for the use of the general public.[13] P3s offer several possibilities. For instance, private landowners can gift land to the government for public purposes. The gifted land might help improve public transit that would both benefit city residents and bring customers to the contributing landowner's business; or a nonprofit organization could gift land

[12] Lodging Tax (Hotel-Motel Tax) webpage at mrsc.org (Municipal Research and Services Center).
[13] Public-Private Partnership (P3) Basics webpage at AGC.org (Associated General Contractors of America).

to the city to build a vertical evacuation structure. P3s need to be structured with care so that the local government receives fair and proportional benefits.

Value-Capture Strategies

Increasing your community's resilience and safety may have financial benefits. For example, the city of Mandeville, Louisiana, has one of the highest rates of home elevation in the country in response to their high risk of flooding. The elevated homes have higher real estate values than the homes that are built at-grade.

Homes with access to tsunami vertical evacuation structures may see similar benefits or may better hold their present value with the increasing public awareness of coastal risk.

Infrastructure Project Integration

At-risk communities could consider combining vertical evacuation projects with upcoming local infrastructure projects. A funding line-item for such projects could be targeted at resiliency enhancements.

Grants

Grants can be a valuable component of vertical evacuation projects. At the same time, grants are often hard to get due to their competitiveness and factors such as the timing of grant cycles. To be awarded federal grants, it is essential to have an eligible project, to prepare a strong and complete application, to be eligible to receive the grant(s), and to work closely with your local, county, tribal, and state partners. Contact the Washington State Emergency Management Division (WA EMD) early if your community is interested in applying for a grant.

Go to Section 2 (State Hazard Mitigation Officer, p. 32)

FEMA Mitigation Grant Programs

The Federal Emergency Management Agency (FEMA) provides Hazard Mitigation Assistance Grants to eligible communities through a number of grant programs.[14] All grants require a local match. Upon receiving a grant, the community has three years to complete the work. All grants are awarded on a competitive basis. Jurisdictions must have a FEMA-approved Hazard Mitigation Plan (HMP) to be eligible. Projects funded by federal grants will require an environmental and historic preservation review.[15] FEMA grants currently represent one of the best ways to obtain funding for local evacuation structure projects.

[14] Hazard Mitigation Assistance Grants webpage at FEMA.gov (Federal Emergency Management Agency, U.S. Department of Homeland Security).
[15] Environmental Planning and Historic Preservation webpage at fema.gov (FEMA)

1. **Hazard Mitigation Grant Program (HMGP)**. Only after a statewide federal disaster declaration do federal funds flow into this program. The larger the disaster declaration, the larger the size of funds channeled into the HMGP. These grants are only available to communities within the state with the federal disaster declaration. Once this funding is available, communities can apply for hazard mitigation projects. FEMA provides 75 percent of the funds, while the state provides a 12.5 percent match, and the local match is likewise 12.5 percent. For applicants that qualify as *Economically Disadvantaged Rural Communities* or *Community Disaster Resilience Zones* and that comply with certain rules, however, a waiver can be sent with the application that could adjust this to a 90/5/5 split. WA EMD recommends to FEMA which applications should be given priority, but FEMA makes the final determination of who gets awarded. The City of Westport was awarded an Advance Assistance grant from the Hazard Mitigation Grant Program in 2016, which helped with initial steps towards building a tsunami vertical evacuation structure, including developing a benefit-cost analysis, determining what was needed, shaping the preliminary concept, and identifying the type of permitting required. For more information on HMGP grants, go to WA EMD's Hazard Mitigation Assistance Grants webpage.

2. **Building Resilient Infrastructure and Communities (BRIC) Program**. This is a nationally competitive grant opportunity. The program is available annually to eligible entities such as states, state agencies, federally recognized tribes, and local jurisdictions for the purpose of mitigation planning initiatives and hazard mitigation projects. WA EMD administers and oversees this program for the state of Washington, including the application process for all eligible entities. (Federally recognized Tribes, however, may apply directly to FEMA.) The city of Westport was awarded a $15.2 million BRIC grant in 2023 to help design and build a new tsunami vertical evacuation structure. For more information on the BRIC program, go to WA EMD's Building Resilient Infrastructure and Communities (BRIC) webpage.

3. **Pre-Disaster Mitigation (PDM) Grants**. These grants are available to any state and are nationally competitive. Available funds will vary by year and are determined by Congress. WA EMD recommends to FEMA which applications should be given priority, but FEMA makes the final determination. FEMA provides 75 percent of the funds and requires a 25 percent local match. The Shoalwater Bay Indian Tribe received a PDM grant to build a tsunami vertical evacuation tower. If a community is eligible (meets the conditions of an impoverished community), the local match can be as low as 10 percent and FEMA will provide the other 90 percent. For more information on PDM grants, go to FEMA's Pre-Disaster Mitigation (PDM) Grant Program webpage.

Community Development Block Grant Program (CDBG)

The CDBG Program is focused on economic development, housing rehabilitation, and neighborhood rehabilitation.[16] In general, CDBG funds must primarily benefit low- and moderate-income persons. During disaster response, CDBG funds are not allowed to substitute for FEMA or Small Business Association (SBA) funding when they are available. Rather, CDBG can supplement other federal funding and can fund hazard mitigation activities. CDBG funds can also serve as part of the local matching funds for federal grants to design and build evacuation structures. CDBG funds have been used to match FEMA sponsored grants. Communities can connect with the CDBG program administrator to determine whether or not these funds may be used for building vertical evacuation.

State Agency Funding

State agencies may provide funding for elements of projects that include a vertical evacuation component. For example, the Washington State Department of Commerce has a Community Capital Facilities Program that covers 25 percent of eligible projects for organizations like non-profits that provide social services or youth recreational facilities.

Certain grants can also be a means of funding additions to a tsunami vertical evacuation structure after the structure has been built. For example, the Ocosta School District received a Solar plus Storage for Resilient Communities grant and a Building Electrification grant from the Washington State Department of Commerce in order to construct rooftop-mounted solar canopies on top of the elementary school's existing tsunami vertical evacuation building. The canopies are designed to provide both power and shelter.

State Funding for Vertical Evacuation Structures at Schools

The Washington Office of Superintendent of Public Instruction (OSPI) administers two funding sources that can be used by state school districts and state-tribal education compact schools for tsunami vertical evacuation projects:

- **School Seismic Safety Grant Program.** These grants can be used to fund individual stages of a vertical evacuation project—the geotechnical survey, conceptual design, design to be permit-ready, and construction—or the entire project from start to finish. A district may use the grant to fund a stand-alone vertical evacuation tower. (See Substitute Senate Bill 5933 for criteria and other details.)
- **School Construction Assistance Program (SCAP).** This program provides state funds for a portion of school construction costs. It can also be used for eligible associated costs, such as architectural and engineering fees. To be eligible for SCAP funds, the vertical evacuation structure must be integrated into a K–12 instructional building—that is, it

[16] Community Development Block Grant webpage at hudexchange.info (U.S. Department of Housing and Urban Development).

cannot be a stand-alone tower. The amount the state contributes varies by district and is determined by a funding formula.

Both of these OSPI grants can be used to fund a vertical evacuation structure of the size required to provide a refuge to the students and school staff only. However, by combining the OSPI grant with funds from another source, such as a FEMA grant, a district may be able to expand the size of the structure to accommodate people in the surrounding community as well.

To learn more about these two OSPI options, school districts can contact OSPI School Facilities staff.

> *A number of Washington school districts have received funding through the Washington Office of the Superintendent (OSPI) for various stages of tsunami vertical evacuation planning and construction.*

Foundations

Communities could look to private or community foundations like the Gates Foundation or the Bullitt Foundation for funding to support tsunami vertical evacuation projects and tsunami planning generally. A joint project proposal between a city and a local non-profit may strengthen the application.

Congressionally Directed Spending & Community Project Funding (Earmarks)

Congressionally Directed Spending (Senate) and Community Project Funding (House), also known as earmarks, are funds provided by the U.S. Congress for specific projects or programs. Members of Congress request these funds for local and community projects within their respective districts. Such appropriations have been used to fund a wide variety of projects, ranging from planning and project development to the construction of levees.[17]

Combine with Other Grants

Communities can look for opportunities to combine vertical evacuation projects with other projects receiving grant funds. Grant-funded coastal restoration or economic development projects might provide opportunities to include a vertical evacuation and tsunami evacuation planning component. In the majority of cases, however, you cannot use funds from one federal grant to serve as the local match in your application for another federal grant. Contact Washington's Hazard Mitigation Officer and Hazard Mitigation Assistance Team if you have questions or would like more information: HMA@mil.wa.gov

[17] Tracking the Funds—Community Project Funding and Congressionally Directed Spending webpage at gao.gov (U.S. Government Accountability Office).

Planning

Planning is the first step to creating a community vision for resilience and tsunami vertical evacuation. It all begins with an idea. There are many planning resources and tools available to support your tsunami evacuation planning. Additionally, there are plans already in place that your community can look to for inspiration, guidance, and technical assistance—such as the 2021 *Outer Coast Tsunami Vertical Evacuation Assessment*, which provides analysis of possible sites for tsunami vertical evacuation structures in Clallam, Grays Harbor, and Pacific counties. Findings from this study can be used by local jurisdictions when planning vertical evacuation structures and applying for grant funding to support their projects.

The following planning tools identify a range of resources and planning documents to support vertical evacuation in your community.

General Comprehensive Plan

Comprehensive plans and land-use plans identify how a community should develop and where development should not occur. They govern the rate, intensity, form, and quality of physical development. A thorough comprehensive plan will also address economic development, environmental, social, and hazard mitigation concerns. Uses of the land can be tailored to match the land's hazards, typically through dedicating hazard areas for parks, golf courses, backyards, wildlife refuges, natural areas, or similar compatible uses.

Comprehensive plans are useful for creating a body of information about local hazard risks. These plans help identify hazard areas such as tsunami inundation zones. They also cite related plans, such as an adopted hazard mitigation plan, and could even show potential sites for vertical evacuation structures. Comprehensive plans identify areas that are less vulnerable, where development should be directed. Their main advantage as a planning tool is that they guide other local measures, such as capital improvement programs, zoning ordinances, and subdivision ordinances. A comprehensive plan can help direct community resources towards identified projects.

Capital Plan / Capital Improvement Plan (CIP)

Capital facilities range from streets and roads to public recreational facilities and schools. A capital improvement plan defines how capital facilities will be financed over a period of at least six years and specifies the sources of public funding to be used for this purpose.[18] Capital planning decisions need to take a number of concerns and priorities into consideration.[19] One priority could be funding and resource allocation in support of vertical evacuation. For example, the construction and maintenance of a vertical evacuation structure could be a line item within a capital budget.

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[18] Capital Facilities Planning webpage at mrsc.org (Municipal Research and Services Center).

[19] Multi-Year Capital Planning webpage at gfoa.org (Government Finance Officers Association).

Hazard Mitigation Plan (HMP)

The Disaster Mitigation Act (DMA) of 2000 amended provisions of the United States Code related to disaster relief and provided the legal basis for FEMA mitigation planning requirements for state, local, and tribal governments as a condition of mitigation grant assistance.[20] The plan and the process undertaken supports long-term risk reduction strategies and breaking the cycle of disaster damage, reconstruction, and repeated damage. The plan creates a framework for risk-based decision making to reduce damages to lives, property, and the economy from future disasters. Only communities with a FEMA-approved hazard mitigation plan are eligible for FEMA grants. The recommendations of the hazard mitigation plan should be integrated into the comprehensive plan and the capital improvement plan.

Tsunamis are infrequent, but for at-risk communities, the impact is intolerably high. Access to natural and artificial high ground is easier to achieve if this priority is addressed in a community's planning documents, codes, procedures, and policies, including community comprehensive plans, capital improvement plans, building and development codes and ordinances, environmental and coastal regulations, and other planning and policy tools.

Focused Public Investment Plan (FPIP)

A focused public investment plan (FPIP) is a capital improvements plan for a specific public investment area (PIA). The plan coordinates and concentrates investments in such things as water, sewer, streets, schools, and parks within the designated public investment area. Public investment areas permit a government to choose which parts of its jurisdiction are suitable for growth. FPIPs correspondingly help to limit growth that is dispersed or inadequately served by public services. Such a plan could provide a vehicle whereby communities limit growth within a tsunami inundation area until risk reduction measures are present.[21]

Purchase of Development Rights and Easements

The owner of an easement has one or more rights in land, leaving the rest in the hands of the landowner. Easements either grant an affirmative right to use property—most commonly right-of-way access—or restrict the landowner's right to use the property in a particular way. By owning development rights, a government has a high level of control while allowing the land to remain in private hands. This tool has been used to limit development within a risk area and promote construction in safer locations.[22] King County, Washington, for example, purchased

[20] Hazard Mitigation Planning: Regulations and Guidance webpage at FEMA.gov (FEMA).
[21] Hazard Mitigation Planning: Tools & Techniques PDF , pp. 13–14, at oas.org (Organization of American States).
[22] Easements webpage at mrsc.org (Municipal Research and Services Center); Transfer of Development Rights webpage at commerce.wa.gov (Washington State Department of Commerce).

hundreds of acres of development right in the Cedar River watershed to better control water discharge and limit flooding. In tsunami inundation zones, the tool could be used to confirm rights of access to a vertical evacuation space in a privately owned building in the event of a tsunami; or it could be used to limit development until a vertical evacuation structure is built.

More risk reduction measures. *In addition to building tsunami vertical evacuation structures and improving evacuation routes, risk reduction can involve reducing the amount of community assets exposed to the tsunami hazard. Some tribal communities with access to high ground are in the process of relocating structures out of the tsunami inundation zone. Homeowners can reduce their risk of loss by purchasing insurance through the National Flood Insurance Program. All at-risk communities and businesses should follow sound government and business continuity of operations practices, including storing data off-site and developing response capabilities and communication systems outside of the tsunami inundation zone.*

Regulation

Regulations guide development and help to protect public safety and welfare. Regulations such as codes and ordinances have the greatest impact when there is change or growth. New construction and modifications to existing structures trigger a series of local government approvals and reviews to confirm adherence to regulations. Regulation can support the inclusion of vertical evacuation into new structures. The following tools identify a range of examples of relevant regulations.

Building Codes

Building codes are laws, ordinances, or governmental regulations that set forth standards and requirements for the construction, maintenance, operation, occupancy, use, or appearance of buildings, premises, and dwelling units. Building codes are typically developed at the national and state levels. In the state of Washington, all building codes except for the Washington State Energy Code refer to national standards. Building codes should be designed to ensure that development is built to withstand the combined impacts of multiple natural hazards, like earthquakes and tsunamis, and may necessitate a new approach in regions with extreme risk. Chapter 6, “Tsunami Loads and Effects,” of the most recent edition of *American Society of Civil Engineers/Structural Engineering Institute Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7) provides the current building code guidance for tsunami vertical evacuation structures. This guidance is included by reference as part of the International Building Code (IBC).

Go to Section 4 (Building to Withstand a Tsunami: Technical Requirements, p. 42)

Bonus and Incentive Zoning

Some governments allow developers to exceed limitations imposed by regulations, such as building height or dwelling unit density, in exchange for concessions like providing new community open space or affordable housing.[23] Bonus and incentive zoning is most commonly used in metropolitan areas.[24] As such, it can be counterproductive in some locations, such as coastal areas, if it encourages higher densities at the fringe of a hazard zone or contradicts existing shoreline regulations that limit building heights in coastal communities. In unique situations, a developer could be allowed to build an additional floor that would not otherwise be allowed by code and simultaneously include a vertical evacuation component.

Overlay Zoning

These zones coexist with other zones, operating like a transparency overlaying existing land use controls. Examples include floodplain and historic districts; within these areas, development is regulated by the standard zoning ordinance and the unique requirements of the overlay zone. Overlay zones allow communities to isolate and protect areas not covered by the rest of the ordinance. However, like any zoning, the protections of overlay zones can be changed or removed.

Transfer of Development Rights (TDR)

Transfer of Development Rights programs use the market to implement and pay for development density and location decisions.[25]

TDR programs allow landowners to sever development rights from properties in government-designated "sending areas" (areas of vulnerability) and sell them to purchasers who want to increase the density of development in areas that local governments have selected as "receiving areas." TDR programs appear to offer many advantages to local governments that want to control land use but also compensate landowners for restrictions on the development potential of their properties.

Tampa Bay, Florida, created the safer Priority Redevelopment Areas (PRAs) program to locate redevelopment and development outside of high-risk areas (2010). They are considering assigning development rights to coastal at-risk development and allowing those development rights to be transferred to PRAs further inland.

Density/Cluster Zoning

This type of regulation allows flexible design of large- or small-scale developments that are constructed as a unit. The actual design is a matter of negotiation, but the basic premise is that some areas are developed more intensively than would normally be allowed, while others are

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[23] Affordable Housing Techniques and Incentives webpage at mrsc.org (Municipal Research and Services Center).
[24] As an example, see the Incentive Zoning webpage at seattle.gov (City of Seattle).
[25] Transfer of Development Rights webpage at commerce.wa.gov (Washington State Department of Commerce).

de-prioritized for a number of reasons. This type of development usually has to conform to zoning, but there is a trend toward allowing mixed-use (e.g., a downtown mixed-use development with a tsunami vertical evacuation component). The common goal for this designation is to create open space, protect sensitive features, or protect tenured land uses. Increased profits brought by additional density or cluster zoning may subsidize the addition of a tsunami vertical evacuation element.

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Section 8. Maintaining & Operating Vertical Evacuation Structures

Deciding What Supplies and Equipment to Provide

Typically, tsunami vertical evacuation structures are built to be short-term refuges rather than longer-term shelters, so the emergency supplies and equipment stored on the structures may be minimal. To decide how much of a given item will be needed, consider the number of people the structure was built to hold and the duration of time evacuees are likely to remain on the tower. A tsunami event may last 12–24 hours or more. Many additional hours may pass before it is possible or advisable for people to leave the evacuation structure.

Even if supplies, equipment, and facilities will be addressed after the structure is built, be sure to consider the space and storage that will likely be needed for them so that these can be incorporated into the design of the structure. This can save money in the long run as it ensures that you won't have to make costly modifications to the completed structure.

Supplies to Consider

- ☐ Potable water, sufficient for expected number of people (and for pets, if allowed)
- ☐ Non-perishable food rations
- ☐ Emergency blankets and tarps
- ☐ First-aid kits and automated external defibrillator (AED)
- ☐ Sanitizing supplies
- ☐ Toilet paper
- ☐ Cat litter

Equipment to Consider

- ☐ Flashlights with continuously charging batteries, or flashlights with hand-crank charging (FEMA P-646, chapter 6, recommends 1 flashlight per 10 people)
- ☐ Fire extinguishers, suitable for use in a closed environment with human occupancy
- ☐ NOAA weather radio(s)
- ☐ Communications equipment with continuously charging batteries, such as:
    - Base station radios
    - HAM radios
    - Public Service radios
- ☐ Battery charging equipment
- ☐ Extra batteries
- ☐ Backup power source

Facilities to Consider

- ☐ Camp toilets (or equivalent)
- ☐ Privacy screens, hanging tarps, or canopy pop-up tents that can be used to:
  - Screen off a triage space.
  - Provide privacy for the camp toilets.
  - Create emergency shelter from wind, sun, and rain if the refuge space is not enclosed or covered.

See also suggested supplies and equipment in FEMA-P-646, 3rd Edition, pages 6-6 to 6-8. Another helpful resource is the Oregon Community Disaster Cache Planning Guide.

> ***Options for Storing Water***. *At Ocosta Elementary School's tsunami vertical evacuation building, water was initially stored in plastic containers, but staff discovered that solar radiation rapidly broke down the plastic. At the Shoalwater Bay Indian Tribe's tower, water is stored in mylar pouches inside storage chests, which protect it from sunlight.*

If you don't intend to provide any emergency supplies in your tsunami vertical evacuation structure, be sure to communicate this to community members so that those who plan to seek refuge in the structure during a tsunami event will be prepared to bring their own.

Go to Section 5: Educating the Community About Tsunamis, p. 46

> ***Access for those with mobility impairments.*** *If budget limitations prevent you from incorporating a ramp or other permanent accessibility feature into the original design of the structure, consider whether you might want to add such a feature sometime after the structure is built. Discuss the possibility early on with your project team: they may be able to design the structure so that a future modification will be easier and less costly to implement. Even if the vertical evacuation structure lacks a built-in solution, you may be able to provide a non-structural aid to access. For example, at Ocosta Elementary School's vertical evacuation structure, emergency carry chairs (fig. 23) are available at the base of the stairs leading up to the refuge space on the roof.*

Figure 23. Cover of a carry chair. (Photo: Washington Emergency Management Division)

Maintenance and Security Considerations

Creating maintenance and security plans for a tsunami vertical evacuation structure is an important step in Phase 8 of the process, but it is worthwhile to begin thinking about maintenance and security early in the development stages of the project. Decisions made during the planning and construction phases can affect:

- What kind of security will be needed and can be implemented.
- What sort of maintenance will be required, how often, and at what cost.

When planning security measures, consider:

- ☐ Will the structure be open to the public or kept locked until needed for a tsunami evacuation or practice drill?
- ☐ If the structure is locked all or part of the time, how will evacuees gain access in an emergency?
- ☐ If the structure is part of a building, how will people access the structure when the building is closed (such as on weekends and at night)?
- ☐ If emergency supplies, equipment, or facilities will be onsite, how will they be protected from potential tampering or theft? Conversely, how will evacuees access them when needed if they are kept under lock and key?

Door Locks & Access. *The two staircases leading up to the Shoalwater Bay Indian Tribe's vertical evacuation tower are inside a fenced enclosure and behind locked gates. The outside of each gate is equipped with a "break glass for entry" door release device. This will cause the gate to pop open, an alarm to sound, and overhead lights to turn on to illuminate the stairs.*

Ocosta Elementary School's vertical evacuation building is likewise kept locked and similarly makes use of an exterior-mounted unlocking system (figure 24) to permit emergency access to the stairs leading up to the refuge space on the roof. In addition to door locks, Ocosta's security system includes security cameras.

Photo: Washington Emergency Management Division

Figure 24. Emergency door release device.

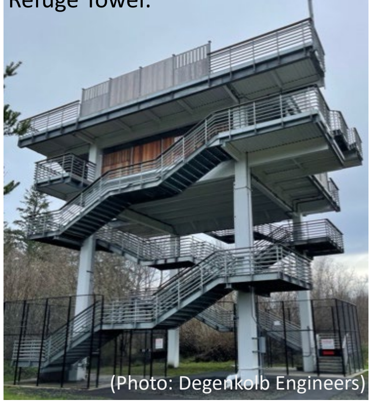
When planning for maintenance, think about:

- ☐ Who will be responsible for creating a maintenance plan and maintaining the structure, including covering the cost?

- ☐ Which features of the structure (such as exposed metal) will require regular inspection to detect corrosion and other deterioration or damage?
- ☐ Which parts or surfaces will require regular maintenance (for example, sanding, priming, and painting or application of a galvanizing compound)? What is the schedule and expected cost for such maintenance, and how will it be funded over the life of the structure?
- ☐ How often will emergency supplies and equipment need to be replaced or upgraded?
- ☐ Who will be responsible for inspecting and maintaining supplies and equipment, and what funding source will pay for them?

Marine Grade Hardware. *The vertical evacuation structure at Ocosta Elementary School near Westport was completed in 2016. Observing how the metal parts of the structure have weathered, the staff who maintain it recommend that anyone building a vertical evacuation structure choose marine grade hardware and fixtures for any parts, such as doors and door handles, that will be exposed to the outside air. Salty, humid coastal air shortens the life of standard metal parts, and they will need to be replaced sooner than marine grade options.*

Figure 25. Shoalwater Bay Tsunami Refuge Tower.



(Photo: Degenkolb Engineers)

Example of a maintenance plan*. The* Shoalwater Bay Tsunami Refuge Tower - Operations and Maintenance (O&M) Plan *(2023) was prepared by Ken Ufkin, the Director of Emergency Management for the Shoalwater Bay Indian Tribe. This plan is reviewed periodically and revised as needed based on observations of how the tower and fence—completed in 2022—withstand weathering over time, and also to address any changes made to the emergency supplies and equipment stored on the tower. To see a copy of this plan, go to Washington Emergency Management Division's (WA EMD's) tsunami page at mil.wa.gov/tsunami#vertical.*

Ongoing Public Education and Drills

Even before the vertical evacuation structure is built, it is a good idea to identify who will have responsibility for ongoing education efforts aimed at teaching people when to evacuate to the tower and what route to take. These outreach efforts should be aimed at the population the structure was built to serve, which may include building occupants, if the structure is part of a multi-use building, or surrounding community members and visitors, or all three. The outreach and education must be ongoing both because the population will change over time and because regular communications and practice increase everyone's familiarity with the vertical evacuation structure and the evacuation routes, ensuring that people will feel comfortable going there and will make the correct decision quickly in an emergency.

Who takes charge of ongoing education & drills? The Ocosta vertical evacuation refuge was built large enough to hold students, school staff, and nearby community members. It was clear from the beginning that school staff would take responsibility for conducting drills for students and school personnel; less clear was who in the community should take charge of educating community members.

Figure 26. Students during a drill on the Ocosta Elementary School vertical evacuation refuge (Photo: Washington Emergency Management)

Once a vertical evacuation structure is built, ongoing outreach should aim to familiarize the community with their walking routes to the tower and up to the refuge. Clear and appropriate signage is an important component of this. Also helpful are community preparedness events and drills. Moreover, such events provide an opportunity to address anxieties and clear up misconceptions. For example, a common anxiety of pet owners is whether they will be allowed to bring their pets into the vertical evacuation refuge. A common misconception is that people will be able to evacuate to the structure by car after a large near-shore earthquake.

Go to Section 9: Tsunami Signage and Wayfinding, p. 76

Go to Section 5: Educating the Community About Tsunamis, p. 46

Tsunami Route Quest. *A creative approach to familiarizing people with a vertical evacuation structure and evacuation routes is Oregon State University's "Quest" guidebook featuring the vertical evacuation building at the Hatfield Marine Science Center. This self-guided tour makes exploring the structure and routes an educational adventure. (See HMSC Tsunami BUILDING Quest for Lincoln County, Central at seagrant.oregonstate.edu/education/quests/)*

Preparing for Use of the Structure in a Tsunami Event

While construction of a vertical evacuation tower or building is itself a remarkable achievement, your new structure will need an operations plan to ensure that it best serves its purpose during a tsunami event. People who evacuate to a vertical evacuation structure in response to a major local earthquake will likely be scared, anxious, potentially injured, and looking for someone or something to provide answers and next steps. Even if the structure was intended to serve a particular population, such as a school, one cannot know for certain who will arrive there when a tsunami occurs. If the tsunami happens in the middle of the night or on the weekend, for example, building staff and others trained in response may not be on site to help evacuees.

It is therefore advisable to have an operations plan that outlines how the structure will be accessed and any procedures for its use during an evacuation, including:

- How guidance and instructions will be made available to anyone who ends up at the structure.
- How emergency supplies in the structure will be accessed.
- Any communication protocols to be followed.
- What evacuees should do in the next 12–24 hours.

In addition, it is important to think realistically about what people on the structure may face after the immediate threat passes. Tsunami waves pose a direct risk for anywhere from 12–24 hours or more after the earthquake. Once the final waves have subsided, evacuees may have a difficult choice to make: remain on the structure, or leave it to seek more permanent shelter?

This decision will depend on many things:

- Are their surroundings safe and navigable? Are areas around the structure still underwater? Is debris on fire or blocking the exits? If so, evacuees may need to stay longer than expected.
- Does the vertical evacuation structure provide shelter from the elements? If not, evacuees will need to leave sooner rather than later.
- Does the vertical evacuation structure provide any emergency supplies and/or communications equipment? If not, evacuees will need to leave sooner rather than later.
- Do evacuees know where the nearest tsunami assembly area or other established shelter is located? If so, can they find their way there across what may have become an unfamiliar and challenging landscape?

When preparing an operations plan, think about:

- ☐ Who will assume responsibility for:
    - Creating the operations plan?
    - Periodically reviewing and revising the operations plan?
    - Developing and installing necessary signage and instructions?
    - Conducting ongoing public education?
    - Organizing tsunami evacuation drills in the community or communities served by the tsunami vertical evacuation structure?

- ☐ What kinds of signage will be needed to direct evacuees into the structure and up to a safe level?

Go to Section 9: Tsunami Signage and Wayfinding, p. 76

- ☐ What will evacuees need to know or do once they are assembled inside the structure? For example:
  - What supplies are located in the refuge space, where to find them, and how to access them.
  - How to use whatever communications equipment is present.
  - How long to stay in the refuge and how to know when it is safe to leave.
- ☐ How will evacuees learn what to do once they are assembled inside the structure? For example:
  - Will you plan for trained personnel or volunteers to be present? If so, how will you ensure this in every possible scenario?
  - Will you install signs that explain emergency procedures and that label supplies and equipment and provide instructions?
  - How will you include this information in your education and outreach about the structure?

Instructions for Evacuees. *The Gladys Valley Marine Studies Building at Oregon State University's Hatfield Marine Science Center was built as a tsunami vertical evacuation structure to serve both the population on campus and nearby residents and visitors. The building is marked with a flag displaying universally recognized symbols that signify that the building is a vertical evacuation refuge.*

People who follow wayfinding signs to the building when a tsunami occurs will then find signs to lead them up to the roof. Once there, orientation signs direct them to emergency supplies, including a box marked "Open Me First," inside which is a binder, labeled "Open Me First," that provides essential information and directions.

For more guidance on how to write an operations plan, check out section 6-1 of FEMA P-646, 3rd edition.

See an example of a user guide—the *Auntie Lee Tsunami Tower User Guide* prepared by the Director of Emergency Management for the Shoalwater Bay Indian Tribe—on Washington Emergency Management Division's (WA EMD's) tsunami page at mil.wa.gov/tsunami#vertical

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Section 9. Tsunami Signage and Wayfinding

Tsunami wayfinding plays a vital role in raising awareness and ensuring that people know when they are in a tsunami hazard zone and can clearly identify evacuation routes that lead to high ground—including vertical evacuation structures. When planning a vertical evacuation structure, remember that existing tsunami evacuation routes may need to be modified to lead to the new structure, or new routes may need to be mapped once a structure exists. Either way, tsunami evacuation route signs will be necessary along the routes leading to the structure so evacuees can easily find their way.

Figure 27. Tsunami sign designs used in Washington state, as of 2024. (Graphic: Kolob Industries, 2024)

Six types of official tsunami sign are currently in use across Washington state:

1. **Tsunami Evacuation Route**. A round white and blue sign with a series of waves in the background and the words "Tsunami Evacuation Route" printed across the bottom half of the sign. This sign indicates an official tsunami evacuation route that leads either to high ground or inland out of the inundation zone. These signs have a 24-inch diameter with 3-inch text.
2. **Rectangular Arrow** (not shown above; see figure 28). A small, rectangular blue sign with a white arrow that pairs with the Tsunami Evacuation Route sign to provide directionality

out of the inundation zone. These signs should be either facing right, left, or straight up depending on the position and location of the sign.

3. **Tsunami Hazard Zone Sign**. A large, rectangular blue sign with the text "Tsunami Hazard Zone" printed across the top, a series of waves with a person running to high ground, and text along the bottom that reads "In case of earthquake, go to high ground or inland". This sign is used in public areas to provide awareness that people are within the tsunami inundation zone. The sign is 30 inches wide and 24 inches tall, with the text either 2 or 1.75 inches.
4. **Assembly Area Sign**. A small, white rectangular sign with a group of people on top of a hill above a series of waves. The bottom of the sign has blue text that reads "Assembly Area". These signs are used to identify official tsunami assembly areas within communities. Assembly area signs are 12 inches wide and 18 inches tall, with 1.625-inch text.
5. **Entering Tsunami Hazard Zone**. A large, hexagonal sign with an orange background and black trim. Printed across the top half of the sign in blue and black text is "Entering Tsunami Hazard Zone". Below the text is a series of blue waves and a small black hill. This sign is intended to notify the public that they are entering the tsunami inundation zone. The dimensions are 30 inches wide and 30 inches tall with text sizes of 2.5 and 3 inches.
6. **Leaving Tsunami Hazard Zone**. A large, hexagonal sign with a white background and black trim. Printed across the top half of the sign in blue and black text is "Leaving Tsunami Hazard Zone". Below the text is a series of blue waves and a small black hill. This sign is intended to notify the public that they are leaving the tsunami inundation zone. The dimensions are 30 inches wide and 30 inches tall with text sizes of 2.5 and 3 inches.

These signs are provided by the Washington State Emergency Management Division (WA EMD) Tsunami Program at no cost to local jurisdictions in Washington, when funding allows. The signs can also be purchased directly by local jurisdictions.

Figure 28. Tsunami evacuation sign.

It is the responsibility of the local jurisdiction to ensure that installation of signs along state highways complies with any applicable state rules, as outlined in the Washington State Department of Transportation's (WSDOT) Sign Fabrication Manual, as well as any other local regulations that may apply.

In addition to tsunami signs along the evacuation route to the structure, signage will also be necessary at the bottom and top of the structure. Signage at the bottom of the structure should be aimed at potential visitors to the location and include educational, directional, and regulatory information, as applicable.

Educational signage provides information about the local earthquake and tsunami hazard, the purpose and history of the structure, how to get tsunami alerts, and other relevant information.

Directional signage includes any signage assisting in navigation to and up the tower, including any signage related to emergency access, stairways, and ramps.

Regulatory signage identifies potential dangers and forbidden activities, such as "no smoking" signs or signs indicating the presence of electrical boxes, water pumps, and other equipment.

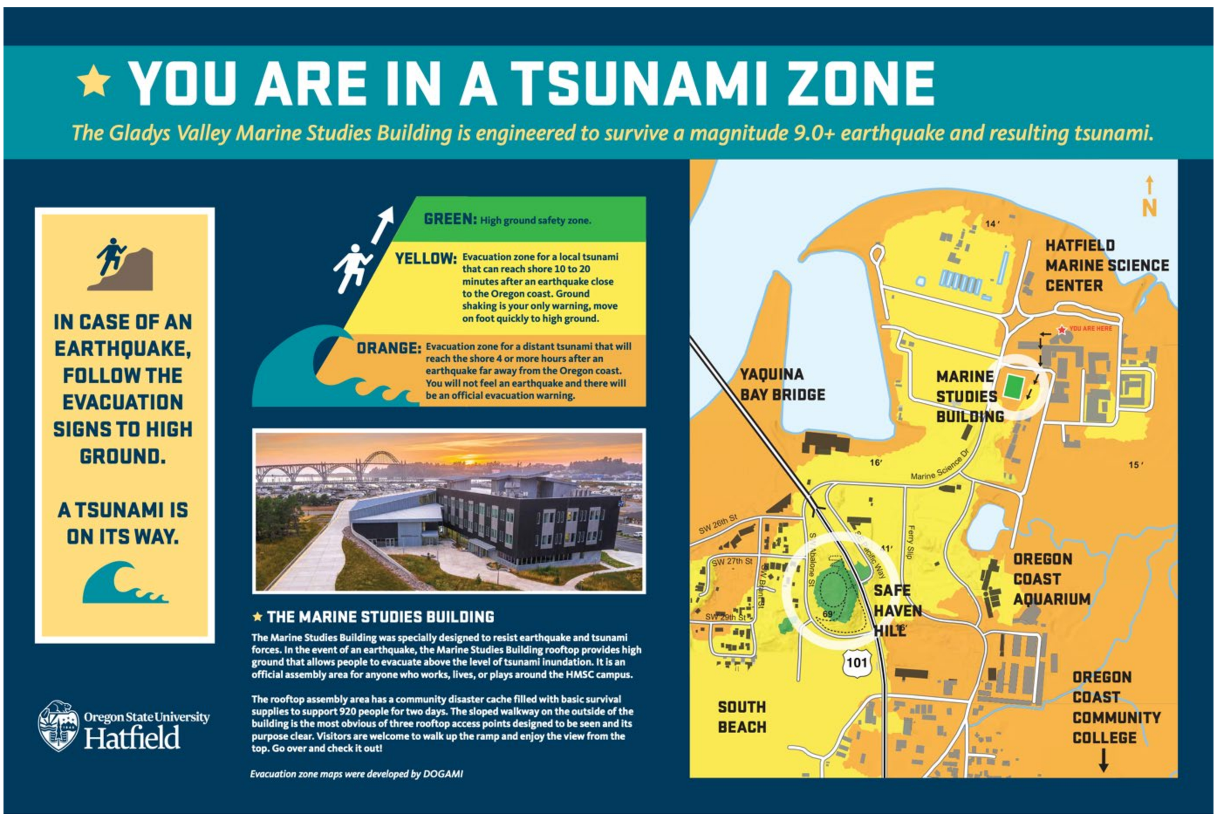

Figure 29. An example of the educational tsunami signs installed around Oregon State University's Hatfield Marine Science Center campus in Newport, Oregon. The sign educates viewers about the local earthquake and tsunami hazard, the purpose of the vertical evacuation building, and where to go in the event of a tsunami. (Graphic: Oregon State University)

To sum up, signage at the bottom of the structure should provide someone unfamiliar with tsunamis a basic understanding of the hazard, the purpose of vertical evacuation, and what to do if they arrive at the structure during an evacuation or feel ground shaking while at the location.

The signage at the top of the structure serves a similar purpose and also includes educational, directional, and regulatory elements; however, the focus is not on educating visitors but on providing vital information to evacuees who take refuge on the vertical evacuation structure during a near-source tsunami event. For example:

Educational signage explains what the next hours and days will be like for evacuees, so they know what to expect and what actions to take. This helps people remain calm and ensures that they can take care of each other until they are able to descend the structure and get to an established emergency shelter.

Directional signage indicates the locations and contents of any emergency supplies, communication equipment, and other tools, including when and how to use everything provided.

Regulatory signage identifies potential dangers and forbidden activities.

Signage for multi-use vertical evacuation structures. If your vertical evacuation structure is part of a larger building, such as a school or other facility that is in use throughout the day, additional consideration will be needed to differentiate between evacuation for a tsunami versus other onsite hazards. Occupants of the building will likely be more familiar with evacuating out of buildings for fires or earthquakes, so evacuating up to the top of the building after an earthquake or after receiving a tsunami alert may feel counterintuitive. Both outer and inner signage around the building will thus need to explain concisely how occupants should evacuate the building for different hazards and in what circumstances the vertical evacuation structure is used. Drills should be held frequently to ensure building occupants are familiar with each kind of evacuation and respond appropriately based on the kind of alert or natural warning sign received.

Choosing the right signs is just the first step. In addition to giving careful thought to where signs are needed and how to locate them so they will be visible and provide clear direction, consider how you will educate the community and visitors so that you foster familiarity with the symbols and ensure that everyone understands what the signs mean.

Figure 30. A sign inside the vertical evacuation building at Oregon State University's Hatfield Marine Science Center in Newport, Oregon, tells viewers what actions to take in the event of different hazards. (Photo: Oregon State University)

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Appendix A: Kinds of Tsunami Maps and Their Uses

Washington tsunami hazard/inundation maps: Tsunami hazard/inundation maps show the highest expected depth of the water above the land or the highest current speeds from an earthquake-generated tsunami. These maps are produced by the Washington State Department of Natural Resources (WA DNR) for Washington's likeliest tsunami scenarios, including a magnitude 9.0 Cascadia Subduction Zone earthquake and tsunami. Tsunami hazard/inundation maps are easy resources for understanding whether a given community or other location is within the tsunami inundation zone. Go to Tsunami Inundation on the Geologic Hazard Maps webpage at dnr.wa.gov

Washington tsunami evacuation walk time maps: Evacuation walk time maps show designated tsunami evacuation routes in a community and the estimated time it will take from a given location to walk out of the tsunami inundation zone. Areas where the walk time exceeds the estimated tsunami wave arrival time are good candidates for vertical evacuation structures, as artificial high ground in these locations can greatly reduce the amount of time needed to get to high ground. These maps are produced by WA DNR for a 9.0 Cascadia Subduction Zone earthquake and tsunami scenario. Go to the Tsunami evacuation maps webpage at dnr.wa.gov

Washington Geologic Information Portal: The Washington Department of Natural Resources maintains the Washington Geologic Information Portal, an online interactive resource which allows the public to easily find any hazard maps associated with a particular location in the state. By navigating to the portal, you can look at a variety of natural hazards and other geologic features, or you can visit the single-topic Tsunami Evacuation Map to view only the tsunami hazard data included in the portal. Go to the Geology Portal at dnr.wa.gov

Washington Tsunami Design Zone maps (WA-TDZ maps): Designers, engineers, and architects in Washington state are required to use Tsunami Design Zone (WA-TDZ) maps, where available, when determining whether a structure is in the tsunami inundation zone and must be designed for tsunamis. In support of these code requirements, the Washington Department of Natural Resources maintains a series of WA-TDZ maps on the Tsunami Design Zone Maps for Washington State Building Code webpage at dnr.wa.gov.

Pedestrian Evacuation Analyst Tool: WA DNR publishes new tsunami evacuation walk time maps each year, and many outer coast communities are covered by existing maps. However, if your community is not included on a current walk time map, another resource available to you is the Pedestrian Evacuation Analyst Tool. This USGS-produced ArcGIS extension estimates how long it would take for someone to travel on foot out of a hazardous area that is threatened by a tsunami, flash flood, or volcanic lahar. Go to the Pedestrian Evacuation Analyst Tool webpage at usgs.gov

Appendix B: Resources

This appendix provides contact information for state, county, and tribal emergency management offices, descriptions of partner-organizations and related websites, and a selection of reports, articles, and videos.

Washington State Contacts

Washington State Emergency Management Division (WA EMD)

Hazards and Outreach Program (Earthquake, Tsunami, Volcano, Preparedness)
mil.wa.gov/tsunami
Public.Education@mil.wa.gov

Hazard Mitigation Program
mil.wa.gov/hazard-mitigation-grants
HMA@mil.wa.gov

Washington State Department of Natural Resources (WA DNR)

Washington Geological Survey
dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis/
Daniel Eungard, Geologist | daniel.eungard@dnr.wa.gov

Washington State Coastal County Emergency Management Departments

Clallam County | Department of Emergency Management
clallamcountywa.gov/226/Emergency-Management

Grays Harbor County | Department of Emergency Management
co.grays-harbor.wa.us/departments/emergency_management/index.php

Island County | Department of Emergency Management
islandcountywa.gov/170/Department-of-Emergency-Management

Jefferson County | Department of Emergency Management
co.jefferson.wa.us/950/Dept-of-Emergency-Management

King County | Office of Emergency Management
kingcounty.gov/depts/emergency-management.aspx

Kitsap County | Department of Emergency Management
kitsapdem.com/

Pacific County | Pacific County Emergency Management Agency
pcema.info/

Pierce County | Pierce County Emergency Management
co.pierce.wa.us/104/Emergency-Management

San Juan County | San Juan County Emergency Management
islandsready.org/

Skagit County | Department of Emergency Management
skagitcounty.net/Departments/EmergencyManagement/main.html

Snohomish County | Department of Emergency Management
snohomishcountywa.gov/180/Emergency-Management

Whatcom County | Division of Emergency Management
whatcomcounty.us/201/Emergency-Management

Washington State Coastal Tribal Emergency Management Contacts

Hoh Tribe
hohtribe-nsn.org/

Jamestown S'Klallam Tribe
jamestowntribe.org/

Lummi Nation
lummi-nsn.gov/Website.php?PageID=215

Makah Tribe
makah.com/

Port Gamble S'Klallam Tribe
pgst.nsn.us/

Puyallup Tribe of Indians
puyalluptribe-nsn.gov/

Quileute Tribe
quileutenation.org/

Quinault Indian Nation
quinaultindiannation.com/

Samish Indian Nation
samishtribe.nsn.us/

Shoalwater Bay Indian Tribe
shoalwaterbay-nsn.gov/

Skokomish Indian Tribe
skokomish.org/

Squaxin Island Tribe
squaxinisland.org/

Suquamish Tribe
suquamish.nsn.us/

Swinomish Indian Tribal Community
swinomish.org/

Tulalip Tribes
tulaliptribes-nsn.gov/

Organizations

State

Washington State Emergency Management Division (WA EMD)

WA EMD leads and coordinates mitigation, preparedness, response, and recovery in Washington state to minimize the impact of disasters and emergencies on the people, property, environment, and economy. WA EMD is the lead agency in helping coastal communities understand and prepare for tsunamis in Washington state. WA EMD assists with public outreach and information, funding, and coordination with a variety of federal, state, and local partners.

- Preparedness: mil.wa.gov/preparedness
- Tsunami: mil.wa.gov/tsunami
- Mitigation Grants: mil.wa.gov/hazard-mitigation-grants
- Emergency Alerts: mil.wa.gov/alerts
- Earthquakes: mil.wa.gov/earthquake

Washington State Department of Natural Resources (WA DNR)

In partnership with residents and governments, WA DNR provides innovative leadership and expertise to ensure environmental protection, public safety, perpetual funding for schools and communities, and a rich quality of life. WA DNR develops and publishes tsunami inundation maps and tsunami pedestrian evacuation maps, as well as tsunami wave simulations and other resources. WA DNR works closely with WA EMD to inform coastal communities of tsunami risk and options.

- Washington Geologic Information Portal: geologyportal.dnr.wa.gov/
- Geologic Hazard Maps, Tsunami Inundation: dnr.wa.gov/programs-and-services/geology/geologic-hazards/geologic-hazard-maps#tsunami-inundation
- Tsunamis: dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis
- Tsunami Design Zone Maps for Washington State Building Code: dnr.wa.gov/wa-tdz

Federal

Federal Emergency Management Agency (FEMA)

FEMA is the national emergency management agency that has a primary purpose of coordinating disaster response for major events that overwhelm local and state authorities. FEMA provides ample information about tsunami readiness, and its report about tsunami vertical evacuation structures, referenced below in the Reports section, was the first of its kind.

- Ready.gov: ready.gov/tsunamis
- Tsunami Information Sheet: community.fema.gov/ProtectiveActions/s/article/Tsunami
- FEMA Hazard Mitigation Assistance: fema.gov/hazard-mitigation-assistance

- FEMA Hazard Mitigation Assistance guidance: fema.gov/grants/mitigation/learn/hazard-mitigation-assistance-guidance | Questions? email HMA@mil.wa.gov
- 3D web map of flood/tsunami hazard in Aberdeen, Hoquiam, and Cosmopolis: fema.maps.arcgis.com/apps/Styler/index.html?appid=6bccc9c8386748b08d20f08626856fed

National Oceanic and Atmospheric Administration (NOAA)

NOAA is an American scientific agency within the United States Department of Commerce that focuses on the conditions of the oceans, major waterways, and the atmosphere. NOAA has the primary responsibility for providing tsunami warnings to the nation and a leadership role in tsunami observations and research.

- U.S. Tsunami Warning System: tsunami.gov
- NOAA Center for Tsunami Research and Forecasting: nctr.pmel.noaa.gov

National Tsunami Hazard Mitigation Program (NTHMP)

NTHMP is a federal and state program designed to protect people and reduce property losses in the event of a tsunami. Led by NOAA, the NTHMP includes other primary partners, like FEMA. As directed by Congress, NOAA provides financial assistance to NTHMP partner states and territories. These grants are the primary funding source for projects that further the efforts of the NTHMP and NOAA's TsunamiReady program. In addition, NTHMP funding supported both the creation of the original 2018 version of this manual and the 2024 update.

- NTHMP webpage: weather.gov/nthmp/
- 2024–2029 Strategic Plan: vlab.noaa.gov/web/national-tsunami-hazard-mitigation-program/nthmp-strategic-plan-2024-2029

National Tsunami Warning Center (NTWC)

The NTWC is one of two tsunami warning centers that are operated by NOAA in the United States. Headquartered in Palmer, Alaska, the NTWC is part of an international tsunami warning system (TWS) program and serves as the operational center for all coastal regions of Canada and the United States, except Hawaii, the Caribbean, and the Gulf of Mexico. The other tsunami warning center is the Pacific Tsunami Warning Center (PTWC) in Ford Island, Hawaii, serving participating members and other nations in the Pacific Ocean area.

US Tsunami Warning System: tsunami.gov

- X/Twitter: x.com/NWS_NTWC
- Facebook: facebook.com/NWSNTWC

Pacific Tsunami Warning System: tsunami.gov/?page=productRetrieval

- X/Twitter: x.com/NWS_PTWC
- Facebook: facebook.com/UsNwsPacificTsunamiWarningCenter

United States Geological Survey (USGS)

The USGS is the nation's largest water, earth, and biological science and civilian mapping agency. It collects, monitors, analyzes, and provides scientific understanding of natural resource conditions and issues. USGS conducts research on earthquakes and tsunamis; go to the Articles section below to read USGS research articles on pedestrian evacuation modeling.

- The Orphan Tsunami of 1700, Japanese Clues to a Parent Earthquake in North America (report): pubs.er.usgs.gov/publication/pp1707
- Pacific Coastal and Marine Science Center: usgs.gov/centers/pcmsc
- Coastal and Marine Hazards and Resources Program: usgs.gov/natural-hazards/coastal-marine-hazards-and-resources
- USGS earthquake info & resources: usgs.gov/programs/earthquake-hazards/earthquakes

Pedestrian Evacuation Analyst

The Pedestrian Evacuation Analyst is a USGS-produced ArcGIS extension that estimates how long it would take for someone to travel on foot out of a hazardous area that is threatened by a tsunami, flash flood, or volcanic lahar. The modeling tool website address is as follows:

- geography.wr.usgs.gov/science/vulnerability/tools.html

Regional

Cascadia Region Earthquake Workgroup (CREW)

CREW is a coalition of private, public, and academic representatives working together to improve the ability of Cascadia region communities, businesses, and homeowners to reduce the effects of earthquakes and related hazards, such as tsunamis.

- Cascadia Subduction Zone Earthquakes (report): crewdotorg.files.wordpress.com/2016/04/cascadia_subduction_scenario_2013.pdf

Washington Coastal Hazards Resilience Network (CHRN)

CHRN strengthens the resilience of Washington's coastal communities to natural hazards by improving the coordination and collaboration among coastal hazards practitioners.

- wacoastalnetwork.com

Reports

Outer Coast Tsunami Vertical Evacuation Assessment (2021)

The Washington State Emergency Management Division completed an assessment of tsunami vertical evacuation structure needs for Pacific, Grays Harbor, and Clallam counties in 2021. This assessment analyzed potential sites for vertical evacuation structures using walk-time estimates based on a tsunami from a 9.0 magnitude earthquake along the Cascadia Subduction Zone. The study is accompanied by maps showing proposed tsunami refuge locations, photos of the locations, the number of people within a 15- to 25-minute walk to high ground, and graphics displaying the data in an easy-to-read format. Summary tables for each county identify the minimum number of structures needed for the entire county and the percent/number of people in the tsunami zone who would be within a 15- or 25-minute walking distance of high ground if all those structures were built.

Local jurisdictions can use these findings when they apply through WA EMD for grant funding from FEMA's Building Resilient Infrastructure and Communities (BRIC) hazard mitigation grant program. Compressed PDFs for each study county are available for download:

- A Guide to Tsunami Vertical Evacuation Options on the Washington Coast Volume 1: Pacific County (20 MB)
- A Guide to Tsunami Vertical Evacuation Options on the Washington Coast Volume 2: Grays Harbor County (22 MB)
- A Guide to Tsunami Vertical Evacuation Options on the Washington Coast Volume 3: Clallam County (3 MB)

Project Safe Haven Reports (2010–2011)

Project Safe Haven was a community driven public process used to identify potential sites for tsunami vertical evacuation structures. Project Safe Haven worked with many coastal communities and resulted in reports that document identified sites.

- Clallam County Final Report PDF: mil.wa.gov/asset/5ba41ff91ea0a
- Makah and Quileute Tribes Final Report PDF: mil.wa.gov/asset/5ba41ffa22b73
- Grays Harbor County Final Report PDF: mil.wa.gov/asset/5ba41ffb35f02
- Pacific County Final Report PDF: mil.wa.gov/asset/5ba41ffbdc444

To see public engagement models drawn from this process, go to *Section 6: Engaging the Community in Vertical Evacuation Planning* in this manual.

FEMA P-646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis, 3rd edition (2019)

Produced by FEMA and NOAA, this report provides information on tsunami hazards, modeling, evacuation structure planning, and structural considerations. In addition to providing updated information about the hazard, options for vertical evacuation, and design criteria, the third edition includes guidance on the use and operation of existing vertical evacuation structures.

- FEMA P-636, 3rd edition: fema.gov/sites/default/files/2020-08/fema_earthquakes_guidelines-for-design-of-structures-for-vertical-evacuation-from-tsunamis-fema-p-646.pdf

Resilient Washington Subcommittee Report (2017)

The Resilient Washington Subcabinet convened in January of 2017 to help Washington state better prepare for natural disasters, including earthquakes, tsunamis, wildfires, drought, storms, and flooding. The report had broad stakeholder participation. It includes nine recommendations and three directives.

- mil.wa.gov/resilient-washington-subcabinet

Washington State Coast Resilience Assessment Final Report (2017)

The William D. Ruckelshaus Center produced this report based on 104 interviews with coastal tribes, coastal residents, elected officials, federal, tribal, state, county, and city government agency staff, researchers, scientists, engineers, NGOs, and other interested parties. A variety of coastal challenges are assessed including tsunamis. The report includes ten recommendations that support coastal resilience.

- Report: s3.wp.wsu.edu/uploads/sites/2180/2013/06/Executive-Summary_Washington-Coast-Resilience-Assessment-Report_Final_5.1.17.pdf

Articles

The following articles by USGS and other partners provide information on tsunami evacuation modeling with a focus on Washington state coastal communities. This research supports local tsunami planning and decision-making.

Pedestrian Flow-Path Modeling to Support Tsunami Evacuation and Disaster Relief Planning in the U.S. Pacific Northwest (2016): Nathan J. Wood, Jeanne Jones, Mathew Schmidtlein, John Schelling, and Tim Frazier. sciencedirect.com/science/article/pii/S2212420916300140

Community Clusters of Tsunami Vulnerability in the US Pacific Northwest (2015): Nathan J. Wood, Jeanne Jones, Seth Spielman, and Mathew C. Schmidtlein. pnas.org/content/112/17/5354

Tsunami Vertical-Evacuation Planning in the U.S. Pacific Northwest as a Geospatial, Multi-Criteria Decision Problem (2014): Nathan Wood, Jeanne Jones, John Schelling, and Mathew Schmidtlein. sciencedirect.com/science/article/pii/S2212420914000387

Videos

Department of Natural Resources (WA DNR) Tsunami Simulations

In order to show how tsunamis might affect a certain area over time, WA DNR uses computer models to simulate how tsunami waves might behave for a given earthquake scenario. Videos of tsunami simulations show tsunami wave behavior in a way that is difficult to convey through static images and maps. Note that these videos are for informational purposes only and should not be used for site-specific decision-making.

- YouTube playlist: youtube.com/playlist?list=PLKpn_ilWjh51SEKRBO9mFJx688fjzYkJm
- Download the video: dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis/#tsunami-simulation-videos

Washington Emergency Management Tsunami Webinar (2020)

This webinar from 2020 covers tsunami hazards, preparedness, alerts, and response in Washington state. This presentation took the place of the 2020 Tsunami Roadshow.

- youtu.be/RJNAkrL0eN8?si=dZgHIf5TMIwJwebl

Stronger than the Waves (2019)

This video from the United Nations Office for Disaster Risk Reduction is about the first tsunami vertical evacuation structure in North America: Ocosta Elementary School. The video was part of International Tsunami Awareness Day.

- youtube.com/watch?v=jwKed3RMb_g&list=LL&index=52&t=1s

Ocean Shores Technical Tsunami Panel Video (June 2018)

The manual project team and partners put together a panel of tsunami experts to speak at a public meeting at the request of local leaders from the city of Ocean Shores.

- View the TVW recording: tvw.org/watch/?eventID=2018061070
- See findings from the meeting in Appendix B of the 2018 edition of the Manual for Tsunami Vertical Evacuation Structures: mil.wa.gov/asset/5cffea88adefb

Washington Tsunami Roadshow (April 2018)

WA EMD staff visited coastal communities and did presentations on tsunami hazards, resident preparedness, and alert messaging as part of the annual Tsunami Roadshow. This event was recorded and televised by TVW.

- tvw.org/video/tsunami-preparedness-public-forum-2018041007/

PBS National Newshour: How the Pacific Northwest Is Preparing for a Catastrophic Tsunami (2016)

This segment focuses on efforts by Washington state coastal communities to prepare for tsunamis and includes interviews with local leaders.

- pbs.org/newshour/show/how-the-pacific-northwest-is-preparing-for-a- catastrophic-tsunami

Project Safe Haven (2015)

This video, produced by the Washington State Department of Transportation, provides an overview of Project Safe Haven. The focus is on the Ocosta Elementary School (which includes a vertical evacuation component) and the people who helped to make the project a success. Narrated by Grant Goodeve.

- youtube.com/watch?v=otI7bUrUOmI

National Geographic Tsunamis 101 (2015)

This video provides an overview of tsunamis.

- youtube.com/watch?v=_oPb_9gOdn4

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Appendix C: Glossary

American Society of Civil Engineers (ASCE)

Founded in 1852, the ASCE is a professional organization that represents members of the civil engineering profession and assists with code development, among other activities. ASCE publishes ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Chapter 6, Tsunami Loads and Effects, is the current standard for designers of tsunami vertical evacuation structures. The latest edition of ASCE 7 has been adopted by reference as part of the 2018 International Building Code (IBC), which guides design of tsunami vertical evacuation structures in Washington state.

ASCE/SEI 7

ASCE/SEI 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* is a publication of the American Society of Civil Engineers (ASCE) and is updated every six years. Chapter 6, Tsunami Loads and Effects, is the current standard for designers of tsunami vertical evacuation structures. ASCE 7 requires use of digital data that is available via open access from the ASCE 7 Hazard Tool.

bathymetry

Bathymetry is the study of the underwater topography. Bathymetric maps show the contours of land below water. Bathymetric features impact tsunami wave behavior.

berm

Berms are artificial, engineered hills that provide high ground. They usually have a large footprint, and they may need concrete elements and some foundation work, especially as they get taller. Tsunami vertical evacuation berms have been built in Japan and New Zealand.

Cascadia Subduction Zone (CSZ)

The Cascadia Subduction Zone (CSZ) lies beneath the Pacific Ocean just off North America's west coast. It stretches from Vancouver Island, Canada, to Northern California and measures over 600 miles in length. Along this zone, the Juan de Fuca and Gorda oceanic plates are forced to subduct beneath the North America tectonic plate. In the last 10,000 years, at least 19 earthquake events ruptured the entire length of the Cascadia Subduction Zone (CSZ). These earthquakes had magnitudes estimated between 8.5 and 9.1. The time between events has been as short as 110 years and as long at 1,150 years, with an average of about 500–550 years. The last large CSZ earthquake took place in the year 1700. Evidence of this event was preserved in the geologic record of the Washington coast. The tsunami produced was noted in the historical record of Japan, fixing the date as January 26, 1700. See also *subduction zone*.

community design charrette

A community design charrette is a collaborative planning process that brings together community members and design professionals to generate alternative design options. These charrettes include presentations, table discussions, mapping, and sketching. Project Safe Haven used the charrette approach to identify sites and develop preliminary structure designs. The Project Safe Haven reports show the results of these charrettes. Links to these reports can be found in Appendix D: Resources.

earthquake

Earthquakes are a shaking of the earth that can result from a sudden slip on a fault, volcanic activity, or other sudden changes in the earth. Washington state is vulnerable to three types of earthquakes: subduction, intra-plate (deep), and crustal (shallow). Earthquakes can generate tsunamis by the sudden displacement of water through either fault motion or triggered landslides.

earthquake scenarios

Earthquakes along a specific fault can vary in strength and frequency. The most relevant scenarios are chosen for planning and preparedness purposes. The Cascadia Subduction Zone L1 scenario earthquake is a powerful earthquake of approximately magnitude 9.0. This earthquake scenario has a recurrence interval of ~2,500 years or a 2% chance of occurrence within the next 50 years. Other smaller subduction zone earthquakes are also possible. These earthquakes have a 10–30% chance to occur in 50 years, much higher than the L1 but generally causing smaller tsunamis than the L1. The simulated ~2,500-year L1 event scenario is used in setting design standards when building tsunami vertical evacuation structures.

FEMA P-646

The Federal Emergency Management Agency (FEMA) published the third edition of P-646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*, in 2019. While P-646 is not used for engineering design of vertical evacuation structures, it does provide an overview of tsunamis and vertical evacuation structures for the United States, drawing on examples from around the world. It also includes community guidance on site selection for evacuation structures. The first edition of P-646 was published in 2008, followed by an update in 2012. Impetus for this work came from the 2004 Indian Ocean Tsunami and the 2011 Japan Tsunami.

geotechnical study

A geotechnical study assesses site geology and seismic hazards. The study documents subsurface explorations (i.e. borings) to characterize subsurface soil and groundwater conditions at the site and provides information about the strength of the soils and their susceptibility to liquefaction, scour, and settlement.

hazard mitigation

Hazard mitigation is any step or action taken to reduce or eliminate the long-term impacts of hazards such as fires, floods, earthquakes, and tsunamis. Hazard mitigation done before the recurrence of a known hazard can greatly reduce casualties and the costs of responding to and recovering from the hazard once it occurs; such mitigation is therefore a cost-effective approach to protecting people and property. Examples of hazard mitigation strategies include earthquake retrofitting of older buildings, passing laws limiting what can be built within a flood zone, and construction of tsunami vertical evacuation structures.

International Building Code (IBC)

The IBC is adopted by most jurisdictions in the United States as a base building code standard. The first IBC was published in 1997; it is revised every three years. The code provisions are intended to protect public health and safety. *ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, Chapter 6, Tsunami Loads and Effects, has been adopted by reference as part of the 2018 IBC.

liquefaction

Liquefaction occurs when the strength and stiffness of a soil is reduced due to earthquake shaking or other types of rapid loading. During earthquake shaking, the ground can become jelly-like and cause buildings, infrastructure and vehicles to sink into the ground. After the shaking stops, the ground re-solidifies. Liquefaction is responsible for significant amounts of damage in earthquakes. Tsunami vertical evacuation structures are designed to withstand liquefaction.

mitigation

See *hazard mitigation*.

pedestrian evacuation model

Utilizing tools created by the United States Geological Survey with input from local emergency managers, the Washington State Department of Natural Resources (WA DNR) creates pedestrian evacuation models that inform the development of evacuation maps. These maps model the amount of time it takes pedestrians to walk to high ground within all areas of the inundation zone. These models guide communities to recognize areas where evacuation structures may be needed.

refuge

A refuge is an evacuation facility that is intended to serve as a safe haven until an imminent danger has passed (e.g., a few hours). See FEMA P-646, page 1.3.

shelter

A shelter is an evacuation facility that is intended to provide safe, accessible, and secure short-term housing for disaster survivors, typically including a place to sleep along with extended food and water supplies. See FEMA P-646, page 1.3.

subduction zone

A boundary zone along which two or more slowly moving tectonic plates collide and the heavier plate is forced to sink ("subduct") beneath the lighter plate. When the plates stick against each other and their movement is constrained, energy builds up over time until it is sufficient to force the plates to move suddenly, causing an earthquake and, in the case of an undersea subduction zone such as Cascadia, triggering a tsunami. Subduction zone earthquakes typically generate the largest and most destructive types of tsunamis. See also *Cascadia Subduction Zone*.

subsidence

Subsidence is a sudden sinking or a gradual settling of the ground's surface and can result from a variety of natural and human causes. Earthquakes can cause large portions of land to subside along fault lines, as well as settlement and compaction of unconsolidated sediment.

topography

Topography refers to the contours of the land above water. Topography impacts the behavior of tsunami waves moving inland.

tsunami

Tsunamis are generated by a sudden displacement of water caused by earthquakes, eruptions, and landslides. Tsunamis have very long wavelengths and can move at the speed of a jetliner in the open ocean. They can travel far inland and cause massive destruction. A tsunami is a series of waves and can last anywhere from 12 to 24 hours or more. Washington state is at-risk from both local source tsunamis and distant source tsunamis.

A **local source tsunami** is from a nearby source and can arrive in less than three hours or as little as a few minutes. Local source tsunamis will likely come from the Cascadia Subduction

Zone (CSZ) just off the Pacific coast, or within the Puget Sound from a crustal earthquake on the Seattle Fault, Tacoma Fault, or other fault and/or from landslides.

A **distant source tsunami** comes from faraway and has a travel time to Washington of over three hours. Distant source tsunamis can come from as far away as Alaska (as happened in 1964) and even Japan (as occurred in 2011).

tsunami evacuation planning

Tsunami evacuation planning seeks to move people out of the tsunami inundation zone or onto suitable high ground within the inundation zone before the first tsunami wave comes ashore. Planning efforts include building tsunami vertical evacuation structures, improving horizontal evacuation routes, installing alert systems and signage, and informing the public about the risk and evacuation options. Horizontal and vertical evacuation definitions are as follows:

Horizontal evacuation describes the horizontal routes, over land, taken by people to evacuate a tsunami inundation zone. Routes include roads, bridges, and pathways. Evacuations are often by foot as roads are typically too damaged for vehicle travel.

Vertical evacuation occurs when people do not have time to leave the tsunami inundation zone and need to move up onto artificial high ground within the inundation zone. Vertical evacuation structures are towers, berms, buildings, and hybrid structures. (Refer to *Structure Types and Considerations* in Section 4 of this manual.)

tsunami inundation map

The Washington State Department of Natural Resources (WA DNR) produces tsunami inundation maps for Washington state. These maps show the amount of flooding or inundation depth for specific tsunami scenarios. The inundation depths include both flooding due to wave dynamics and earthquake-induced subsidence. This subsidence may cause the ground to drop between 3 to 6 feet during the earthquake. Earthquakes from other faults in the Puget Sound may also produce localized subsidence and/or uplift. WA DNR has published tsunami inundation maps for the entire Washington coastline for an L1 Cascadia Subduction Zone scenario, as well as more localized maps for a Seattle Fault Zone and distant Alaskan-Aleutian Subduction Zone scenario. Tsunami inundation maps are essential for mitigation and evacuation planning. (See Appendix A for an overview of the various types of tsunami maps and their uses in vertical evacuation planning. See Cascadia Earthquake Tsunami Scenario in Section 4 for more information about the L1 Cascadia Subduction Zone scenario.)

tsunami computer model

The tsunami modeler creates tsunami computer models that attempt to predict the behavior of tsunami waves. Models are based on a variety of possible earthquakes that might trigger tsunamis. Modelers can simulate the impact of tsunami waves on a specific site and the forces that evacuation structures will need to be able to withstand. The geotechnical engineer, structural engineer, and architect depend on these models to design evacuation structures. Refer to Tsunami Modeler in Section 3 of this manual.

tsunami vertical evacuation structure

These structures provide artificial high ground above the height of inrushing tsunami waves. Evacuation structures provide a place for evacuation when there is a lack of suitable natural high ground that can be reached before the tsunami strikes. These structures are designed to withstand earthquakes, aftershocks, liquefaction, and multiple tsunami waves. Evacuation structures can be towers, engineered berms (artificial hills), or integrated into buildings.

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Appendix D: Acknowledgements

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Interviews, 2018

Details of the interviews conducted in 2018, including the list of interviewees, questions asked, and some selected findings, can be found in Appendix A of the 2018 edition of the *Manual for Tsunami Vertical Evacuation Structures*.

Public Meetings, 2018

Two public meetings were held in two Washington coastal communities as part of the process to develop the 2018 edition of this manual. The first meeting took place in the city of Ocean Shores at the request of Mayor Crystal Dingler. The second meeting was held in the city of Aberdeen at the request of Aberdeen School Superintendent Dr. Alicia Hendersen—it also included the adjacent cities of Hoquiam and Cosmopolis.

Each meeting featured a series of presentations by tsunami experts. Time was allotted for questions and survey cards were handed out to gather community members' input. The meeting agenda, survey card results, and other supporting materials can be found in Appendix B of the 2018 edition of the *Manual for Tsunami Vertical Evacuation Structures*.

Coastal Communities Survey, 2018

In June of 2018, a research team from New Zealand conducted interviews with several Washington state coastal community residents in order to explore community understanding of and participation in tsunami vertical evacuation planning on the Washington coast. The results of this work—*Understanding community participation of tsunami vertical-evacuation planning in the coastal Washington communities: key findings from 2018 focus groups and interviews*, by David Johnston, Caroline Orchiston, Lucy Carter, Kate Boersen, and Carla Jellum—informed the content of the 2018 edition of Washington's *Manual for Tsunami Vertical Evacuation Structures*.

An overview of the survey and the survey results are presented in Appendix C of the 2018 edition of Washington's Manual for Tsunami Vertical Evacuation Structures.

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