Manual for Tsunami Vertical Evacuation Structures

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Interviews were essential to producing this manual. Interviewees included elected, tribal, and school district officials, emergency managers, structural and geotechnical engineers, tsunami modelers, an architect, a USGS researcher, and others. Interviewee names can be found in *Appendix A: Interviewing Process*.

The contributions made by all these individuals to support this project are greatly appreciated.

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Front Cover: Tsunami Siren. Photo Credit: EMD / Tsunami evacuation platform on roof of the Ocosta Elementary School. Photo Credit / Ocosta Elementary School and Helicopter. Photo Credit: Pete Eckert of Eckert and Eckert Photography.

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EXECUTIVE SUMMARY

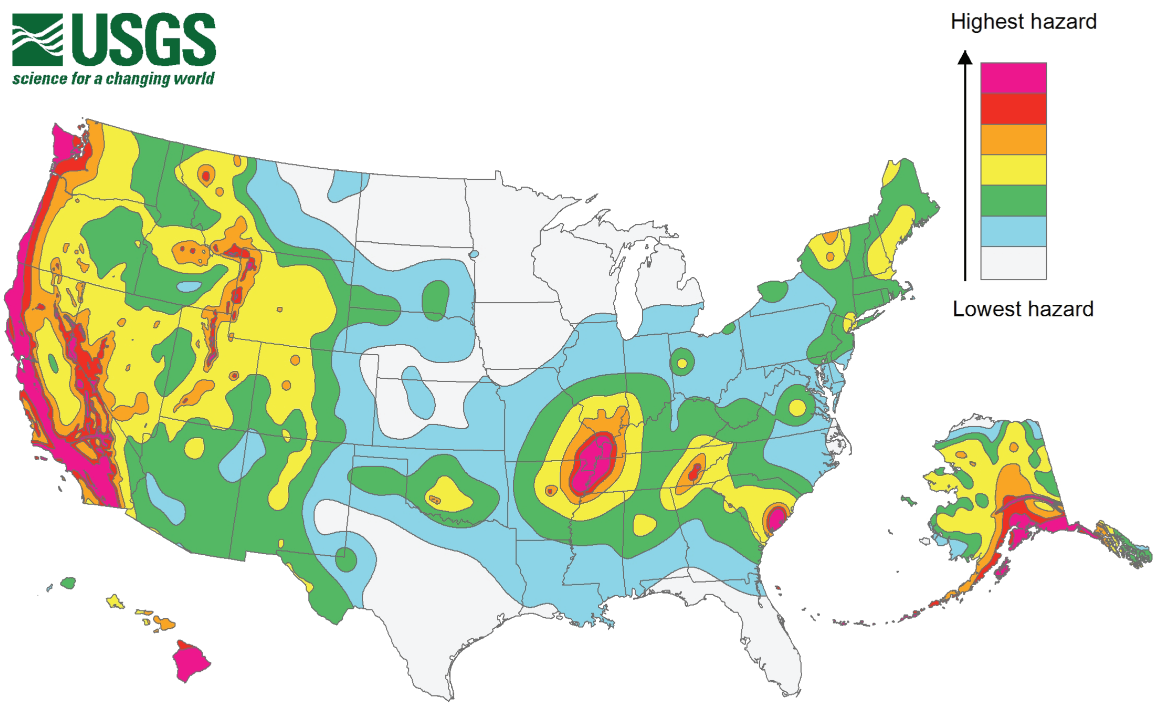
Looking towards the Pacific Ocean from Ocean Shores. Photo Credit: UW Project Team

Why a Manual?: To reduce Washington State's huge tsunami risk.

Washington State has the second-highest earthquake risk in the United States. Western Washington has several active faults that impact communities along its coastlines. The Cascadia Subduction Zone (CSZ), just off the Pacific Ocean coastline, runs from Northern California up to Canada and is capable of generating a magnitude 9 earthquake. Earthquakes are a major source for tsunamis in Washington State. A local CSZ tsunami will leave some coastal communities with as little as 15 to 20 minutes to evacuate and is estimated to cause over 8,000 fatalities. Distant tsunamis, coming from as far away as Alaska and Japan, allow for significantly more warning time.

Coastal communities that lack sufficient natural or artificial high ground are particularly vulnerable. Residents, employees, and visitors will have limited time to evacuate to safety. For at-risk communities, tsunami vertical evacuation structures are a way to save lives. Evacuation structures are designed to withstand an earthquake, aftershocks, liquefaction, and multiple tsunami waves. They can be included as part of a new building or be a standalone tower or berm. Evacuation structures have performed successfully in Japan and have also been built in New Zealand. In 2016, the Ocosta Elementary School was completed with an evacuation area above the gymnasium. This school, located near Westport, Washington, is the first tsunami vertical evacuation structure to be built in North America.

Communities on Washington State's Pacific Ocean coastline have limited resources. Unlike California and Oregon, Washington State's major ports, infrastructure and associated funding resources are concentrated in the Puget Sound and along the Columbia River and not along the Washington coast. Tsunami vertical evacuation structures are complex and relatively new. Building these high-performance structures requires a variety of partners and expertise. Communities also have to administer a robust public engagement process to build support, plan, and determine funding options. Given all these factors, Washington State Emergency Management Division (EMD) felt that it was important to provide coastal communities with a manual that could help them navigate this process and protect their communities.



Earthquake Hazard Map. Image Credit: USGS

Manual Layout

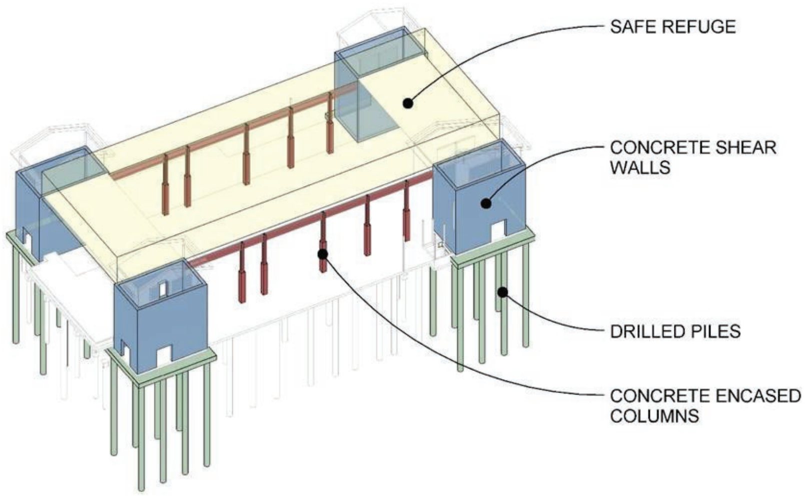
Chapter 1 contains the core of this report and describes the 7 Phase Process. This process lays out the various steps that communities should follow to plan, design and construct tsunami vertical evacuation structures. Some of the phases, like community engagement, continue throughout the entire process. Other phases, such as funding, occur during a specific period in the process. The other chapters and appendices are referenced throughout the 7 Phase Process. They are intended as "deeper dives" to fill in important details and provide background information.

The following are the 7 Phases:

- 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: Construct, Complete, and Operate

Chapters 2 and 3 describe the various roles of those involved in planning, design, and construction of evacuation structures. These projects are complex, clarifying the various roles and responsibilities can help communities to know who is involved and when to involve them in the process. The roles described include community leaders, stakeholder committee members, emergency managers, tsunami modelers, geologists, geotechnical engineers, structural engineers, and architects. Chapter 3 also provides an in-depth explanation of tsunami models and building codes.

Chapter 4 provides various bulleted planning guides. One guide is a distilled version of the 7 Phase Process while other guides describe consideration about structure type and design. Also included, is an explanation of the original *Project Safe Haven* planning process that was used to identify potential evacuation structure sites for several coastal communities. In addition, there is a guide for how to respond to and prepare for a tsunami. Communities can make use of these guides during various parts of the process.



Ocosta Elementary School auditorium with roof top tsunami refuge structural design. Rendering Credit: Degenkolb Engineers

Chapter 5 describes a variety of funding, regulatory and planning options. Although grants are one source of funding, the ones available are competitive and do not cover all the project costs. Local funds will be needed and can be raised through a variety of funding mechanisms. In addition, planning can help to prioritize, incentivize and mandate evacuation structures. Other approaches that support coastal community resilience are also described in this chapter.

Chapter 6 outlines five recommendations that can assist coastal communities in building tsunami vertical evacuation structures. The first three recommendations are broader in scope and involve advocacy and overall planning efforts. The last two recommendations are aimed at helping to reduce project costs and provide needed project management support. The recommendations are as follows:

- R1: Develop a Coastal Alliance Network
- R2: Integrate Tsunami and Seismic Risk into all Planning Efforts
- R3: Support Tsunami Risk Reduction and Continuity Planning
- R4: Develop Approaches that Reduce Project Costs
- R5: Provide Vertical Evacuation Structure Project Management Assistance

Lastly, this report provides five appendices with important background information. Appendices A, B, and C document interviews and public meetings that are the research foundation for this manual. Appendix A outlines the interviewing process, who participated in it and a selection of findings from the interviews. Appendix B includes agendas and survey findings from the public meetings conducted in the cities of Ocean

Shores and Aberdeen. Tsunami experts made presentations and the audience asked questions. Audience members also filled out survey cards. Appendix C was prepared by a research team from New Zealand that conducted a series of interviews with Washington State coastal residents. Appendix D provides a host of valuable resources for communities including key contact information, reports and articles. Appendix E is a glossary.

Tsunami Evacuation Route sign. Photo Credit: EMD

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 of earthquake faults and the modeling of seismic and tsunami hazards. The National Tsunami Hazard Mitigation Program (NTHMP) provided funding for this report and other efforts to support community preparedness. The Federal Emergency Management Agency (FEMA) awards grants for tsunami structures and publishes reports, like FEMA 646, that provide guidance on vertical evacuation structures. 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 (EMD) works closely with coastal communities to support preparedness, response, recovery and mitigation efforts, including the construction of tsunami vertical evacuation structures. The Department of Natural Resources (DNR) provides tsunami inundation maps and assists with pedestrian evacuation mapping. *Project Safe Haven*, the first effort to help communities plan for evacuation structures, was an effort of various organizations already listed and the UW Institute of Hazards Mitigation and Planning. County and local emergency managers, local leaders, engineers, designers, planners, residents and others have all made critical contributions.

Washington State places a priority on community resilience. The Resilient Washington Subcabinet Project Team and EMD produced the *2017 Resilient Washington Subcabinet Report: Findings and Recommendations* that 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.

Chapters

1964 Alaska Tsunami. Photo Credit: USGS Historic Coast & Geodetic Survey Collection (left) / 2011 Japan Tsunami. Photo Credit: Reuters (right)

INTRODUCTION

An earthquake strikes. The ground shakes. Windows and doors rattle. Pictures start to fall off the wall. Because you have practiced in drills like the Great ShakeOut, *you immediately 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 but then 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 route, just like you practiced, because you live in a tsunami zone. The streets are cracked and buckled. Trees and power-lines have fallen down, so you walk with caution. Because your community has invested in a tsunami vertical evacuation structure, you and your family have a safe place to go. You get to the top of an evacuation structure. 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.*

The above scenario demonstrates the value of tsunami vertical evacuation structures for the communities that need them. This manual provides practical guidance to assist your community in building these structures. You may be 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 some other member of the community. Whatever your role in the community, we hope this manual will assist you in your efforts to make your community safer.

The Ocosta Elementary School near Westport, Washington, was completed in 2016 and is the first tsunami vertical evacuation structure in North America. In Washington State, planning, funding, and design work for additional structures is currently underway. These exciting efforts provide inspiration for communities along the Washington coastline and for coastal communities elsewhere in the United States and around the world.

Tsunami vertical evacuation structures are unique and complex. Planning, modeling, designing, and constructing these structures is different from your typical building project. Strong community involvement and leadership are needed to evaluate the need for evacuation structures, plan for potential locations, locate funding, and follow through to the end of construction and beyond. Partnerships with local, state, and federal agencies, universities, and various experts are also key to success.

The manual project team 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. In addition, two public meetings were held for Washington State coastal communities: one was held in the city of Ocean Shores and the other was held in the city of Aberdeen and included the adjacent cities of Hoquiam and Cosmopolis. The insights and recommendations from these interviews and public meetings are the foundation for this manual.

Chapter 1 provides a 7 Phase Process that communities can use to guide their efforts in assessing, planning, and building tsunami vertical evacuation structures. This process is the heart of the manual. The other chapters and appendices are referenced by and support the 7 Phase Process. Chapters 2 and 3 describe the roles of community representatives, emergency management staff, tsunami experts, and project team members. Chapter 4 provides guides and planning references that support the process. Chapter 5 describes various funding, planning, and regulatory tools that support efforts to build evacuation structures. Chapter 6 concludes with a set of five recommendations that can further the effort to building evacuation structures and improve coastal community resiliency. The five Appendices are as follows: A: Interviewing Process; B: Public Meetings; C: New Zealand Report; D: Resources; and E: Glossary. The first three appendices provide important findings from interviews and public meetings that have been incorporated throughout the manual.

This manual builds on a strong continuum of work by agencies, universities, and individuals to support tsunami-resilient communities. Partners in this work include: Federal Emergency Management Agency, National Oceanic and Atmospheric Administration, National Tsunami Hazard Mitigation Program, United States Geological Survey, Washington State Department of Natural Resources, Washington State Emergency Management Division, University of Washington, and county and local emergency managers, planners, elected officials, and residents.

7 PHASE PROCESS

Groundbreaking ceremony for Ocosta Elementary School. Photo Credit: Degenkolb Engineers

The following 7 Phase Process can assist you in building a tsunami vertical evacuation structure in your community. This process is intended to provide guidance, but not be overly prescriptive. How your community and other communities follow this process will be unique to the circumstances.

The process in broken down into phases that often involve several parts and vary in length. Some phases last the whole process and others can be shorter in duration. You may follow these phases in a different order or emphasize different aspects of a phase. Other sections in the manual are referenced in these phases to provide added detail.

This 7 Phase Process is the result of the interviews with community representatives, elected officials, school district leaders, tribal leaders, emergency managers, engineers, architects, geologists, tsunami modelers, coastal residents, and others. Interviewees also reviewed drafts and made comments that have been integrated into this final version. This process represents the practical experience and lessons learned of people actively involved in planning and building tsunami vertical evacuation structures. Communities that work together and collaborate with their partners will be most successful.

Phase I: Involve Emergency Management Partners

Community representatives said that contacting vertical evacuation subject matter experts was a key first step. Local emergency managers were identified as the initial point of contact. It is recommended that the local emergency manager work in tandem with the Washington State Emergency Management Division (EMD). Those interviewed suggest that you:

- **C**ontact your county or tribal emergency manager and the EMD Earthquake, Tsunami, and Volcano Program Manager. 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 D: Resources for emergency manager contact information.*

- **A**sk your county emergency manager and EMD program manager to connect you with other relevant state and federal partners. For example, partner agencies include the Washington State Department of Natural Resources (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 Administration Agency (NOAA). *Go to Chapter 2.3: State, County and Tribal Emergency Managers and Appendix D: Resources.*

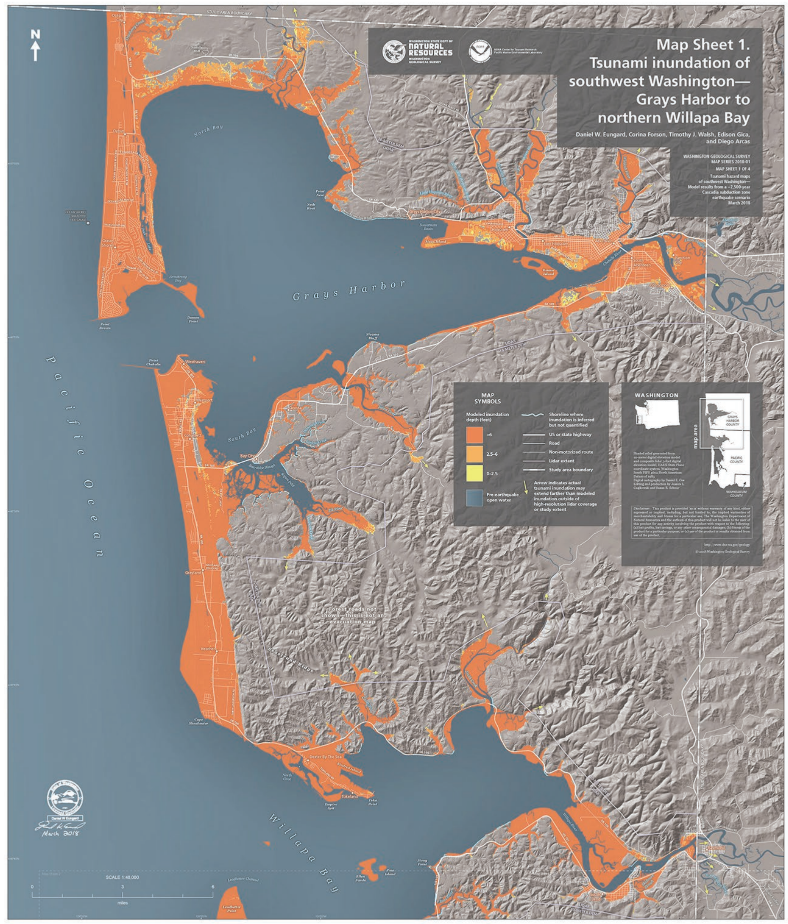
Emergency Management Officials meeting with local officials in Aberdeen, WA. Photo Credit: UW Project Team

- **B**e prepared to work with a diverse range of partners and share information to achieve better outcomes. Unsurprisingly, close collaboration with partners is required during the entire process. Building tsunami vertical evacuation structures is a new, complex, and challenging process. The International Building Code (IBC) just adopted a tsunami section in 2018, the first of its kind. On June 11, 2016, Ocosta Elementary School in Grays Harbor County, Washington, was dedicated and officially opened. This is the first official tsunami vertical evacuation structure in North America. The Ocosta School Board and the five communities in the Ocosta School District worked closely with a wide range of partners to ensure positive outcomes.

Phase 2: Assess Tsunami Risks and Current Evacuation Options

Emergency managers and tsunami experts agreed that it is essential for communities to evaluate tsunami risk and evacuation options. Community representatives appreciated the guidance and resources available to better understand their specific risks and opportunities. As a next phase, those interviewed suggest that you:

- **I**dentify the types of tsunami events that may impact your community. Work with your local emergency manager, EMD, and DNR to understand your community's tsunami risk. If you are a coastal or Puget Sound community in the state of Washington, you have 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 or within the Puget Sound from a crustal earthquake on the Seattle Fault, Tacoma Fault, or other fault and/or from landslides. Distant source tsunamis can come from as far away as Alaska (1964) and even Japan (2011). *Go to Chapter 4.1: How to Respond to and Prepare for a Tsunami for what to do when you feel an earthquake or have been given a tsunami warning.*



Tsunami inundation map for southwest Washington. Image Credit: DNR

- **A**ssess flooding impacts and current evacuation routes. Your partners offer a variety of helpful resources. DNR creates tsunami inundation maps that show where and how deep the flooding may be in your community. The USGS and DNR publish evacuation studies for several tsunami-risk communities. These studies estimate how long it takes to reach high ground, possible evacuation routes, and areas with a lack of nearby natural high ground. Both EMD and FEMA provide tsunami fact sheets, vertical evacuation guidance, and other resources. *Go to Appendix D: Resources for links to DNR maps and USGS evacuation studies and Chapter 3.1: Geologist for more information about DNR.*

- **D**etermine if your community has a need for vertical evacuation. Your evacuation needs will become clearer based on the review of the data with your partners. You may have sufficient natural and artificial high ground that your whole community can reach. You may be able to evacuate more people by improving evacuation routes but still need structures. 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, it is important to see vertical evacuation structures as part of an overall tsunami evacuation plan. This plan 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 phase, in the overall planning process, it has been determined that your community needs tsunami vertical evacuation structures. Community representatives felt strongly about the need for community involvement throughout the whole process. Those interviewed also said it was critical to identify trusted community leaders. They felt that the creation of some type of Stakeholder Committee was needed to strengthen decision-making and project oversight. Emergency managers and planners were also in agreement that strong community engagement led to better project outcomes. For these reasons, those interviewed suggest that you:

- **E**ngage 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. The organization leading 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. At a 2018 public meeting in Ocean Shores, Washington, 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. *Go to Chapter 2.1: Community Leaders and Stakeholder Committee Members and Appendix B: Public Meetings.*

- **R**eview past efforts by your community and other communities around tsunami evacuation planning. In 2011, *Project Safe Haven* carried out a series of public meetings in several coastal communities. These workshops were part of a process to see how many structures were needed, identify potential sites, and sketch out design alternatives. The tsunami risk was explained and then residents worked in groups to select potential sites. This process engaged residents in coming up with solutions that fit their community. *Go to Chapter 4.5: Project Safe Haven Community Planning Process.*

- **H**old public meetings in your community 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. Public meetings were a critical part of the *Project Safe Haven* planning process. In 2018, meetings were held in both the cities of Ocean Shores and Aberdeen (including the nearby cities of Hoquiam and Cosmopolis). *Go to Appendix D: Public Meetings for the agendas and findings from these two meetings.*

- **I**dentify 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. Survey card results from two public meetings showed that half of participants looked to their local officials and emergency managers to help lead this process. *Go to Appendix D: Public Meetings for the findings from these two meetings*.

Project Safe Haven community meeting. Photo Credit: UW Project Team

- **M**anage an open process from start to finish. Transparency builds community trust, welcomes assistance, and helps achieve community acceptance. For example, the Grays Harbor County *Project Safe Haven* planning process included community members in a variety of meetings alongside local leaders and officials. If or when a process runs into complications, the community is more likely to maintain their support when they feel like they have been consulted and updated. In 2018, a New Zealand research team interviewed residents of Washington State coastal communities and verified the importance of keeping community members well informed. *Go to Appendix C to read their findings*.

- **E**stablish a Stakeholder Committee. The role of the Committee is to discuss 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 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

Planners, emergency managers, and tsunami experts said that identifying sites was the next key phase. Identifying, evaluating, and testing support for potential sites are some of the primary tasks of community involvement as discussed in Phase 3. Those interviewed recognized that this phase might be challenging for communities, but that selecting workable sites is key to a successful project. Community representatives said they appreciated assistance in evaluating site options. Those interviewed suggest that you:

- **E**xplore potential sites for future vertical evacuation structures. Incorporate the community into 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. *Go to Chapter 4.3: Structure Types and Considerations for criteria.* The following considerations may help you determine your first site and/or overall strategy:

    - **Review the Project Safe Haven site selection process:** In 2011, *Project Safe Haven* worked with coastal communities to identify sites for potential vertical evacuation structures. Many residents took part in this planning process. A goal of this work was to plan for enough structures to serve everyone in the community. This work is documented in reports with maps, renderings, and conceptual designs. *Go to Appendix D: Resources for links to these reports.*

    - **Evaluate Opportunistic Sites:** Your community may need to build a new school, fire tower, city hall, or parking garage. This might be a strategic opportunity to add a tsunami vertical evacuation component to the project. Perhaps, also, five or 10 years from now, your community anticipates the need for new or replacement facilities. For example, a few years ago, the Ocosta School District needed to replace their existing elementary school with a new one. If your community has an upcoming opportunity like this, it might be a good place to start.

Map from a Project Safe Haven charrette to locate potential sites and consider structure types. Photo Credit: UW Project Team

    - **Evaluate Sensitivity/Density Sites:** Vertical evacuation planning includes tough choices about where 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. This approach was considered during *Project Safe Haven*. Potential homebuyers may also value properties that have access to vertical evacuation given a rising awareness of coastal hazards.

    - **Evaluate High 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.

- **E**xplore 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 Chapter 4.3: Structure Types and Considerations.*

- **H**ire 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 essential for determining the forces that a structure will need to resist. An architect and structural engineer may also be hired to do an initial conceptual design for grant applications. *Go to Chapter 3.2: Tsunami Modeler and Chapter 3.3: Geotechnical Engineer.*

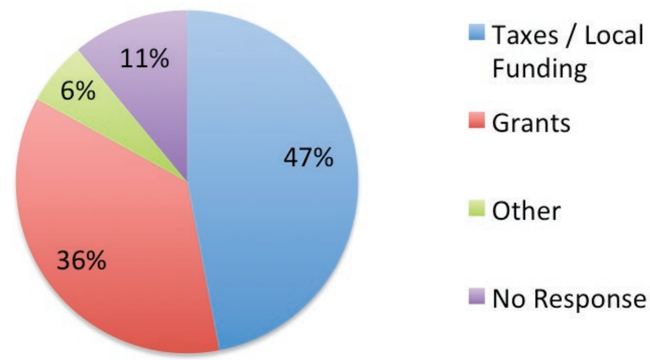
- **H**ire a project management consultant to help with facility planning, cost estimation, bond planning, architect selection, and construction services. This step can occur at this point in the process or later, depending on circumstances. The Ocosta Elementary School District benefited from project 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

Community representatives, emergency managers, and planners said that it was important to develop a funding plan that allows for alternative sources. Community leaders supported first engaging the community, doing research, and putting forth specific recommendations before diving into funding. There was consensus that grants are a desirable funding option but are currently competitive and will generally not cover all costs. In two public meetings in the cities of Ocean Shores and Aberdeen, participants filled out survey cards and indicated support for local funding options as shown in *Appendix B*. For these reasons, those interviewed suggest that you:

- **A**ssess potential funding sources. By this point, your community has selected a potential site and structure type and completed initial geotechnical and tsunami studies. You may have also completed initial design. As a result, you are able to determine a budget working with your project management consultant, architect, and structural engineer. It is helpful to already have a fleshed-out proposal and budget when reviewing funding options. Federal grants are available, but local funds will also be required. Local funding mechanisms include bonds, property taxes, special districts, and a number of other options. *Go to Chapter 5: Tools to explore all these options and more.*

- **A**pply for grants. It is best for projects to have grants secured before major design starts. The grant process takes time, so get started early. Grants are not guaranteed but can be applied for multiple times. There are grants to cover the costs of initial site studies and to prepare larger grant applications. There are grants that cover a portion of the design and construction costs. Most grants will only help you to fund the tsunami evacuation component of a larger multi-use project (i.e., school or parking garage). The city of Long Beach received a Hazard Mitigation Grant Program (HGMP) grant to design a berm. In 2018, the Shoalwater Bay Tribe was awarded a federal Pre-Disaster Mitigation Grant (PDM) to build a tsunami evacuation tower. The EMD Hazard Mitigation Officer is an essential guide in navigating the grant process. *Go to Chapter 2.4: State Hazard Mitigation Officer and Federal Grants.*

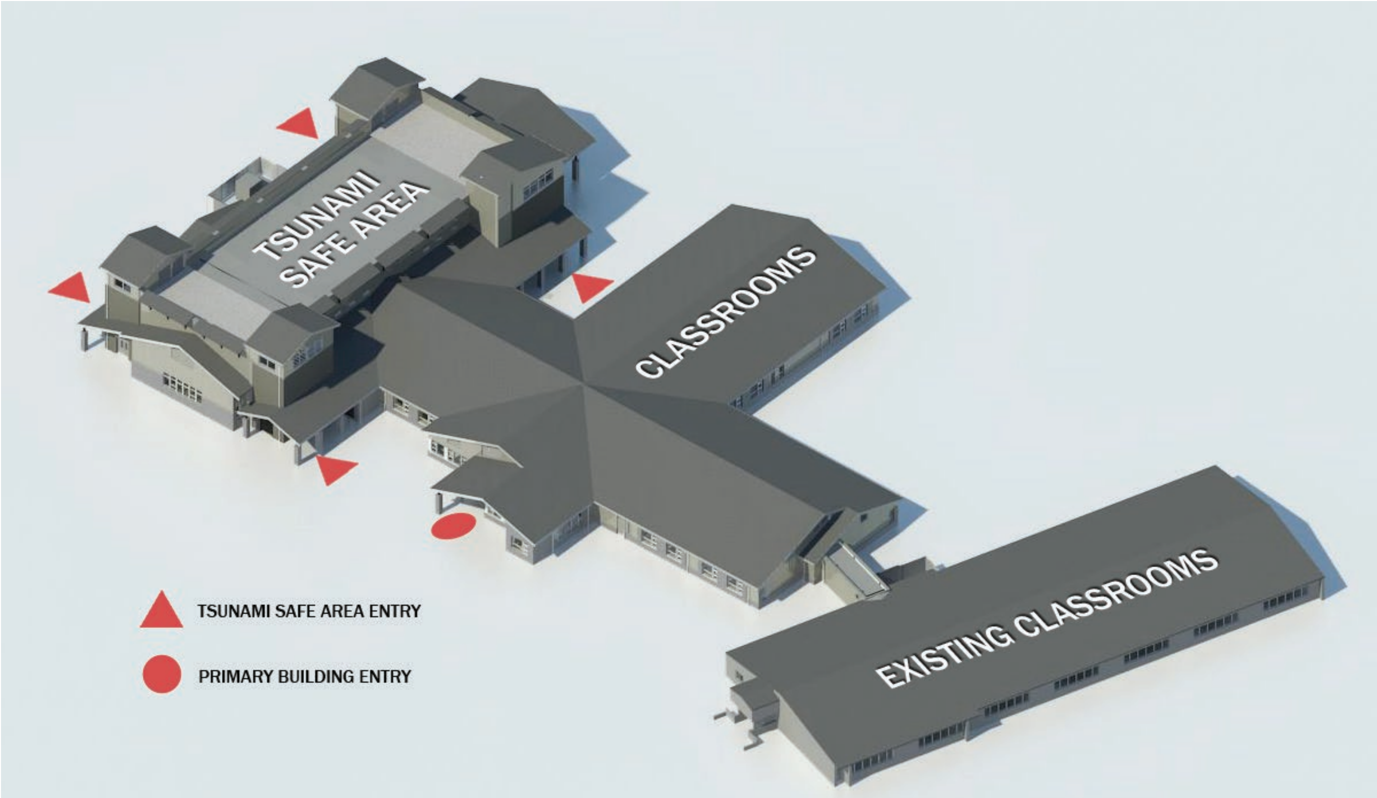


Survey results from the Ocean Shores public meeting. The question asked was: What is your first preference for funding tsunami vertical evacuation structures? There were 53 respondents. Go to Appendix B: Public Meetings for the complete findings. Photo Credit: UW Project Team

- **P**repare 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.

- **B**uild 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 to eventually provide everyone with safe evacuation options. Your community must start somewhere.

- **M**aintain open and frequent communications with your community. You should have plans to go back to your community with another funding 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. Similarly, if a grant application does not succeed, your community will be in a better position for the next attempt.



Computer rendering of Ocosta Elementary School with tsunami safe area above the auditorium. Image Credit: TCF Architecture

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

Those interviewed all agreed that it is essential to select a capable project team that maintained good communication. Those with project management experience emphasized the importance of having a community leader who was in charge of overseeing the project from start to finish. Continual tracking of the budget and scope was also stressed. Community representatives, emergency managers, and planners strongly believed that it is critical to be transparent and share progress updates with the community. Project team consultants and tsunami experts emphasized that reassessment should not only be expected but encouraged. Those interviewed suggest that you:

- **C**reate 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 Chapter 3: Tsunami Experts and Project Team Roles.*

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

- **C**onfirm 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. This is a job that should not be delegated down given the complexity of these projects. *Go to Chapter 2.2: Internal Project Manager.*

- **C**onduct further tsunami modeling. As the architect and structural engineer design the structure, 3D 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 and the tsunami modeler. *Go to Chapter 3.2: Tsunami Modeler, 3.4: Structural Engineer, and 3.5: Architect.*

- **E**xercise strong oversight with 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.

- **C**onfirm the design and capacity considerations for the evacuation structure. All of these elements will impact costs. It is more than likely that trade-offs will need to be made 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 Chapter 4.4: Structure Design Criteria.*

- **I**dentify 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 Chapter 4.4: Structure Design Criteria.*

- **C**onduct a peer review during the design phase of the project. The building code requires peer review for all tsunami vertical evacuation structures to ensure a thorough review process. Peer review is also required for all federal grants. The peer-review team will likely include a tsunami modeler, structural engineer, and geotechnical engineer to review the design at key points in its evolution. Qualified experts should be chosen in each area, and this collaborative process can help improve the end product for the community.

Drilling rig preparing to install one of 160 piles for the Ocosta Elementary School. Photo Credit: Degenkolb Engineers

Phase 7. Construct, Complete, and Operate

Community representatives and project team consultants said that the construction phase presents new challenges that can be successfully managed through good communication and oversight. Emergency managers and planners emphasized that the job is not done when the structure has been built. They view evacuation structures as part of a larger evacuation planning strategy and overall community resilience. All interviewees agreed that completing your first structure is a great springboard for continued momentum. For these reasons, those interviewed suggest that you:

- **H**ire 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 have unanticipated challenges. With the Ocosta Elementary School, budget constraints required that some program elements be eliminated. The Superintendent and Stakeholder Committee decided to eliminate the elevator to the roof because it would not be operable after an earthquake anyway.

- **S**chedule 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.

- **S**et up a maintenance plan and a security plan for your evacuation structure. This will differ depending if your evacuation structure is a building, tower, or berm and where it is located. This will assure that your evacuation structure will be durable and used appropriately.

Ocosta Dedication Ceremony Cake. Photo Credit: UW Project Team

- **C**elebrate your newly constructed tsunami vertical evacuation structure by having an open house. Your community can take pride in this achievement. The completed project is a valuable legacy and an inspiration to other communities.

Next Steps.

- **C**onduct community outreach and training. Practice tsunami evacuation drills with structure occupants (if applicable) and nearby residents. A tsunami can strike at any time of day. If a tsunami strikes at night, a building may be used by nearby residents and not daytime occupants (i.e., school kids). The New Zealand research team interviewed Westport residents living near the Ocosta Elementary School and discovered that residents were unaware that the tsunami evacuation area on the roof of the school was intended for their use as well, not just the school children. Ongoing outreach by the local government and other stakeholders is necessary to get this information out to the public.

- **C**onsider ongoing improvements to the evacuation structure that may not have fit into the original project budget. Add emergency supplies, sanitation facilities, and other enhancements.

- **E**ngage 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 evacuation structure. This might include strengthening bridges and adding signage.

- **S**tart planning efforts for your next tsunami vertical evacuation structure if your community needs more structures. With one completed project, you now better understand the process including the barriers and issues you overcame the first time. Each completed project will provide the people in your community with more knowledge, confidence, and increased safety.

2 COMMUNITY AND EMERGENCY MANAGEMENT ROLES

From left to right: Keily Yemm (EMD), Maximilian Dixon (EMD), and Daniel Eungard (DNR). Photo Credit: EMD

There are a variety of roles within your community that are important to a successful tsunami vertical evacuation structure project. Emergency managers are key partners for your community throughout the whole process. The 7 Phase Process describes these roles within the overall process. This section provides further detail about each role.

I. 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 manual.

Community Leaders:

Your community leader may be a superintendent, tribal leader, emergency manager, fire chief, 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 new and 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; 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.

Paula Akerlund, former Superintendent of Ocosta School District. Photo Credit: Washington State National Guard

Stakeholder Committee Members:

The Committee is composed of stakeholders in the community with diverse perspectives. Committee members should stay with the process from start to finish. They assist in decision-making and provide a sounding board. Through their work on the committee, they become experts on the project who can credibly inform the wider community.

How these roles fit into the overall process:

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 it is easy for the process to stall. There may be individuals who lead certain parts of the process such as the efforts to go door-to-door to pass a ballot initiative. However, there should be one point person for the overall process that is recognized as such by the consultant project team, partners, and the community.

The Stakeholder Committee should be first assembled in the early stages of the project. The Committee and leadership work together to first research and analyze the issue and then to make recommendations. They help determine if the community truly needs evacuation structures and what sites might make the best sense. 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 on budget and on schedule.

2. 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.

This internal project manager will need to work with a project management consultant that will help them with facility planning, cost estimation, bond planning, architect selection, and construction services. In the case of the Ocosta Elementary School project, the superintendent was the 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.

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. The Shoalwater Bay Tribe's emergency manager is leading their efforts to build a tsunami evacuation tower. She is both the community leader and the internal project manager. The emergency manager has been an active and visible leader working with her community and the neighboring community that will also benefit from this tower. In 2018, the Shoalwater Bay Tribe secured a Pre-Disaster Mitigation (PDM) grant working with the Washington State Emergency Management Division (EMD). After receiving the grant, they hired a project management consultant to help with construction services.

3. 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 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 Earthquake, Volcano, and Tsunami Program Manager:

The Earthquake, Volcano, and Tsunami Program Manager and staff are experts in tsunami and earthquake risk and the steps communities might take to improve their resiliency. 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 such as the annual *Tsunami Roadshow.* They also coordinate the *Great Washington ShakeOut* that involves both earthquake and tsunami preparedness. They are also the lead agency for publishing guidance materials such as this manual. *Go to 2.4: The State Hazard Mitigation Officer and Federal Grants,* later in this chapter, for more information on the funding portion of EMD's work.

County or Tribal Emergency Manager:

Lee Shipman, Emergency Manager for the Shoalwater Bay Tribe. Photo Credit: Dan Hammock in The Daily World

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 the fire and police departments. The county or tribal emergency manager assists local governments in their preparedness, mitigation and response, and recovery efforts regarding disasters.

The county or tribal emergency manager works closely with the EMD program manager 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 in 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 manager 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, EMD can assist your community in finding appropriate grants to apply for and assisting 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.

4. State Hazard Mitigation Officer and Federal Grant Funding

The State Hazard Mitigation Officer works closely with the State Program Manager to help communities identify federal grant funding opportunities. Grants are an important funding source to help communities complete tsunami vertical evacuation projects.

Role:

The EMD Hazard Mitigation Officer and staff assist communities to identify and apply for federal grant funding. They administer grants once they have been awarded. The grant programs are described below. The Hazard Mitigation Officer and staff's role is to support communities in becoming more resilient to natural disasters.

The planning, design, and construction of tsunami vertical evacuation structures are eligible for grant funding. Examples of grants received by Washington State coastal communities are indicated under the specific grant types in the grants section below. 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. There may be other grant funding opportunities besides those offered by FEMA, but FEMA is a well-recognized source for these types of grants.

How this role fits into the overall process:

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

The Hazard Mitigation Officer and staff are resources to help a community to determine whether their project is eligible for grant funding. They can also guide a community in preparing the application and review the application for completeness. Even if a community's grant request is turned down the first time, they can always reapply. Unfunded grant applications may be given a higher priority in future funding rounds.

Since grants are competitive and funding limited, a community should have an alternative funding plan to move forward in the event they do not get a grant.

The city of Long Beach, the Pacific County Ocean Park Fire District, and the Shoalwater Bay Tribe have all received federal grants for evacuation structures. After grants are awarded, the Hazard Mitigation Officer and staff will monitor work progress, release funds, answer questions, and serve as an intermediary with FEMA.

Grants:

FEMA provides two types of Hazard Mitigation Assistance (HMA) Grants to eligible communities. 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, and jurisdictions require a Hazard Mitigation Plan (HMP) to be eligible.

Hazard Mitigation Grant Program (HMGP): Only after a statewide federal disaster declaration do federal funds flow into this program. The larger the state 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. After this funding is available, communities are able to apply for hazard mitigation projects. FEMA provides 75% of the funds with a 12.5% state match and a 12.5% local match. EMD recommends to FEMA which applications should be given priority, but FEMA makes the final determination of who gets awarded. The city of Long Beach and the Pacific County Ocean Park Fire District both received HMGP grants.

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. In 2018, $249 million in funds were available nationally. EMD recommends to FEMA which applications should be given priority, but FEMA makes the final determination. FEMA provides 75% of the funds with a 25% local match. The Shoalwater Bay 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% and FEMA will provide the other 90%.

To be awarded federal grants, it is essential to have an eligible project and a strong and complete application, and to work closely with your local, county, tribal, and state partners.

For more information on federal Hazard Mitigation Grants:

https://mil.wa.gov/emergency-management-division/grants/hazard-mitigation-grants

https://www.fema.gov/hazard-mitigation-grant-program

https://www.fema.gov/pre-disaster-mitigation-grant-program

3 TSUNAMI EXPERTS AND PROJECT TEAM ROLES

Ground breaking for Ocosta Elementary School. From left to right: Brian Ho (architect), Brian Fitzgerald (architect), Cale Ash (engineer), Randall LeVeque (tsunami modeler), Loyce Adams (tsunami modeler), Paula Akerlund (superintendent), Tim Walsh (DNR geologist), John Schelling (EMD program manager). Photo Credit: Pete Eckert of Eckert and Eckert Photography

There are a variety of roles for tsunami experts and project team consultants in the planning, designing, and construction phases of a tsunami vertical evacuation structure. The 7 Phase Process describes these roles within the overall process. This section provides greater detail about each role.

1. 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 (DNR) works closely with the State's Emergency Management Division (EMD)and other partners to help communities with their decision-making and mitigation efforts. DNR produces tsunami inundation maps for Washington State. These maps show the amount of flooding or inundation depth 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. DNR has published 13 inundation maps since 2000 with three more in the process of being released in 2018. About 50% of Washington's coastline has been mapped to date.

Utilizing tools created by the USGS with input from local emergency managers, 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.

How this role fits into the overall process:

The DNR geologist is an important partner for communities, particularly in the initial assessment and planning stages of the project. The DNR geologist also assists in producing community tsunami evacuation maps that utilize USGS evacuation modeling and research findings.

Earthquake Tsunami Scenarios:

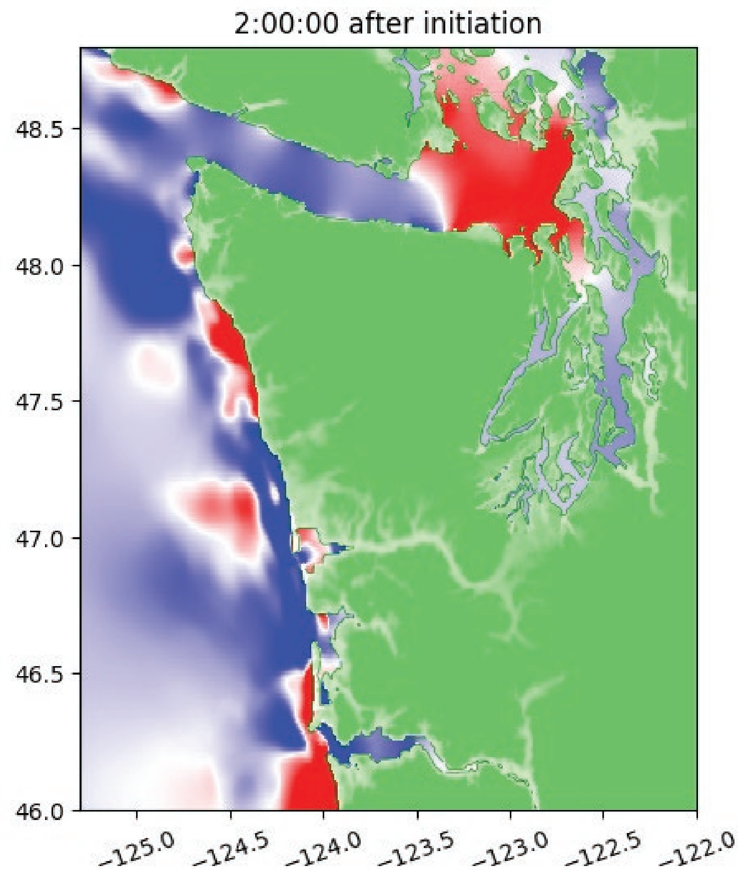
In the last 10,000 years, there have been roughly 19 earthquake events rupturing the entire length of the Cascadia Subduction Zone (CSZ). These earthquakes had magnitudes estimated between 8.5-9.1 Mw. The time between events has been as short as 80 years and as long at 1,100 years with an average of ~300 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 and produced a tsunami event recorded in Japan that establishes the date as January 26, 1700.

The 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 10-20% chance to occur in 50 years, much higher than the L1 but causing less inundation than the L1. There is a 95% confidence that the next event will not be larger than L1. The extra-large (XL1) events are very rare and researchers do not think there is enough accumulated strain on the fault to produce an extra-large event. Western Washington also has a number of local crustal faults known or suspected of producing tsunamis. Tsunami scenarios for these local fault sources are limited and a topic of ongoing research.

The simulated ~2,500 year L1 event scenario is used in setting design standards when building tsunami vertical evacuation structures. Ultimately, for the design of tsunami vertical evacuation structures, structural engineers must adhere to the requirements of American Society of Civil Engineers (ASCE) *7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures* which defines a probabilistic tsunami model.

2. 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. The tsunami modelers interviewed emphasized the importance of revisiting models throughout the whole process, especially if there are changes to the shape and location of the evacuation structure.



Tsunami simulation snapshot. Image Credit: Randall LeVeque

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 will need to be able to withstand. 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 EMD and 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.

Modeling Process:

Tsunami vertical evacuation structures are designed to withstand earthquakes, aftershocks, liquefaction, and multiple tsunami waves. Modeling is essential before and during the design of an evacuation structure to understand the impact of wave forces.

DNR issues tsunami inundation maps based on modeling. For a particular tsunami scenario, these maps show how far inland the water travels and the height of the waves. Inundation maps are peer reviewed by tsunami experts. These maps are available to the public and need to be part of your planning efforts. They do not, however, contain the detailed site-specific modeling required for the design of evacuation structures.

All modeling relies on Digital Elevation Models (DEMs). These models 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. NOAA's National Center for Environmental Information (NCEI) develops and shares DEM information that is used in tsunami modeling.

The DNR 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 other natural or man-made feature (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 currents in and immediately surrounding the site. These 2D results are essential as input to the three-dimensional (3D) model that can provide a more accurate prediction of tsunami forces on the structure. 3D models are more complex and costly to create. However, 3D models are more accurate 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 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 would be difficult to model.

Most tsunami models assume Mean High Water (MHW) for the entire 12-24 hour 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. Modeling continues to develop and improve and is based on a strong foundation of research.

3. Geotechnical Engineer

The geotechnical engineer is critical for investigating site conditions, verifying the appropriateness 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 the typical coastal sandy soils, lack of bedrock, and combined earthquake and tsunami forces.

How this role fits into the overall process:

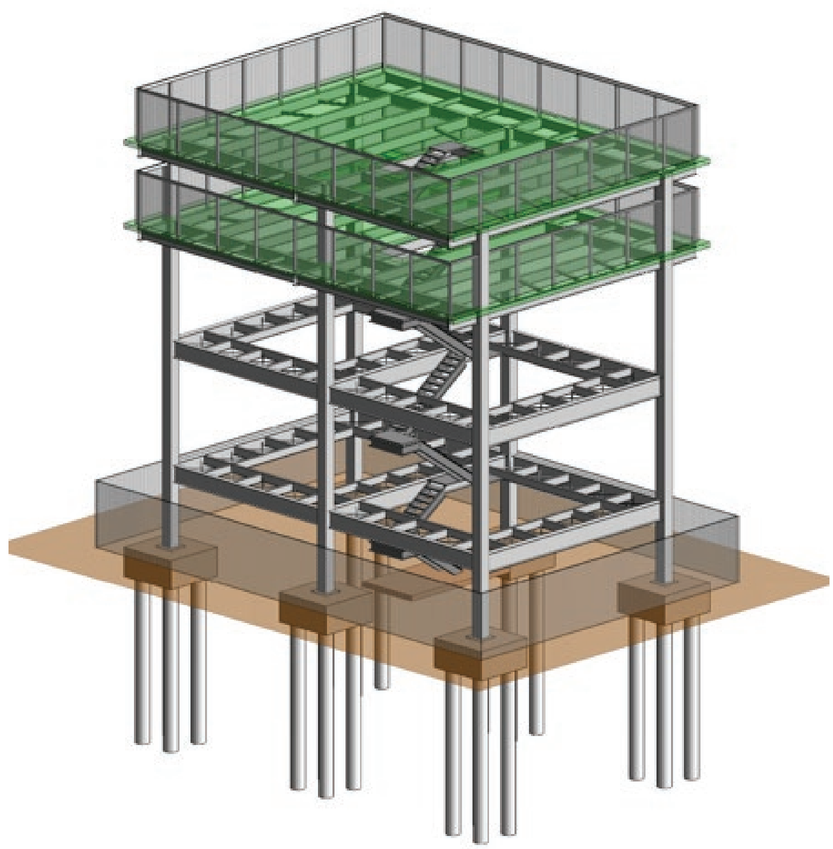
A geotechnical engineer should be hired to investigate conditions for potential sites. Geotechnical engineers can also assist with the initial siting alternatives analysis. Once there is a preliminary design for the evacuation structure, the geotechnical engineer will work with the structural engineer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

4. 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 recently adopted International Building Code (IBC) tsunami building codes 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.



Computer rendering of Shoalwater Bay Tribe tower. Image Credit: Degenkolb Engineers

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 project budget for bond measures and large grant applications. Generally this represents approximately 15% of design completion, and the community may pay for this work with local funding or with grants.

The next step would be 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. Even evacuation berms may require significant ground improvement to minimize the impacts of liquefaction and protect against tsunami scouring.

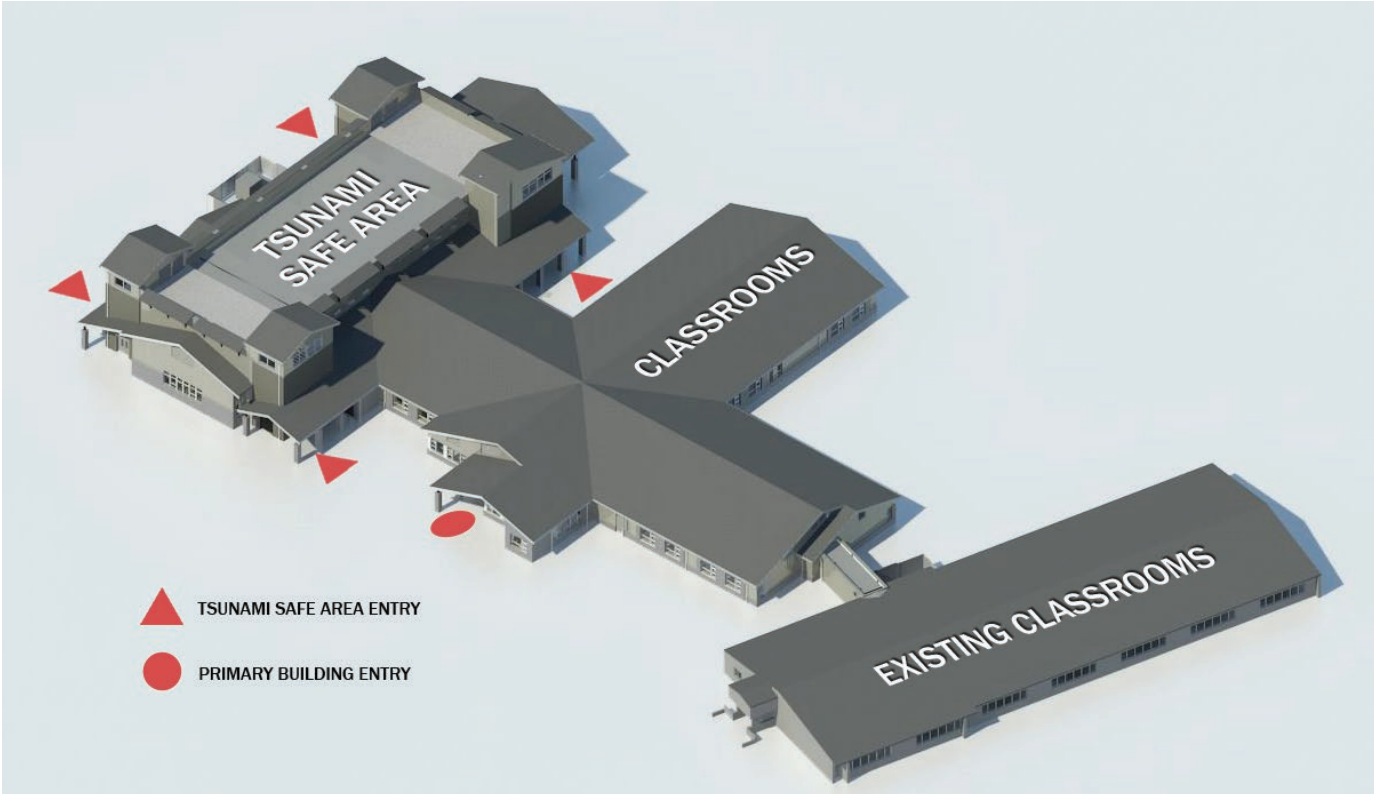
Building Codes:

Tsunami vertical evacuation structures must withstand a major earthquake, aftershocks, liquefaction and several tsunami waves. They have to survive ground liquefaction, the scouring of waves and the impact of floating debris. Consequently, they must be designed to be very resilient structures.

In 2017, the American Society of Civil Engineers (ASCE) published *ASCE 7-16 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. ASCE 7-16 has been adopted by reference as part of the 2018 International Building Code (IBC), which guides design of structures in Washington State. Washington State may officially adopt ASCE 7-16 in early 2020. Fire and police stations, hospitals, and commercial buildings over 65 feet will be required to meet these standards but are not required to be a public evacuation structure. The Ocosta Elementary School, completed in 2016, was designed using the final draft version of ASCE 7-16. The IBC is utilized by structural, geotechnical, and civil engineers and architects for their work.

The ASCE 7-16 guidance requires a factor of safety for vertical evacuation structure height. The initial tsunami wave height at the building location is determined from the tsunami modeling. This model takes into account the 3 to 6 feet the ground level will drop (subsidence) after a CSZ earthquake. The model also includes estimated future sea level rise. A safety factor is then added to this wave height as follows: the inundation height above sea level is first increased by 30% and then 10 feet is added to this height. In addition, ASCE 7-16 designates IBC-adopted tsunami inundation zones and provides design guidance and requirements for structures within inundation zones.

Prior to 2008, there was no design guidance developed for tsunami structures in the United States. In 2008, the Federal Emergency Management Agency (FEMA) published the *646 Report: Guidelines for the Design of Structures for Vertical Evacuation from Tsunamis*. This report was followed by an update in 2012. Impetus for this work came from the 2004 Indian Ocean Tsunami and the 2011 Japan Tsunami. FEMA 646 is not used for engineering design of vertical evacuation structures but still provides a valuable overview of tsunamis and structures for the United States with examples from around the world. It also includes community guidance on site selection for evacuation structures.



Computer rendering of Ocosta Elementary School with tsunami safe area above the auditorium. Image Credit: TCF Architecture

5. 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:

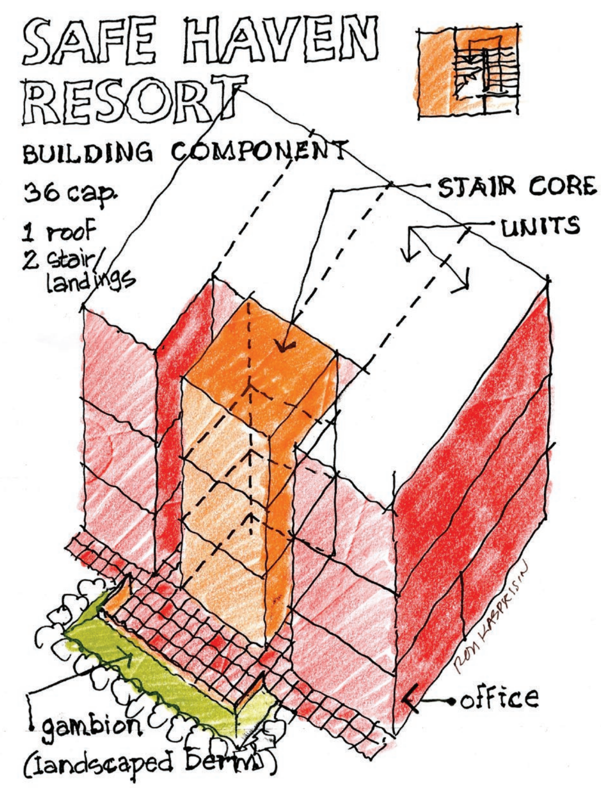
The architect is responsible for designing a building that is functional, attractive, and meets the clients' needs and budget as well as various code requirements. The architect is often the project team lead and coordinates with all the other disciplines and the community. The architect works directly 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:

When a site has been identified and initial tsunami modeling and geotechnical work has been carried out, it is a good time to bring in the architect. An architect working with a structural engineer can develop alternative studies for the proposed structure. This work may be paid for with available 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 further 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.

For the Ocosta Elementary School, the architects had to design a building that served all the required school functions. It worked out that the height of the gymnasium roof was 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. The doors to these towers can be opened remotely but also have large safety glass windows that can be broken to gain access. Following community feedback, the architects worked to design the building 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 is an inspiration to other coastal communities in Washington State and beyond.



Project Safe Haven Sketch. Image Credit: Ron Kasprisin of the UW Project Team

4 TSUNAMI EVACUATION PLANNING GUIDES

Shoalwater Bay Tribe annual Yellow Brick Road tsunami walk event. Photo Credit: Dan Hammock in The Daily World

The following guides can assist communities in preparing for tsunamis, developing a public process and in the siting and design of evacuation structures. These guides supplement and distill the *7 Phase Process in Chapter 1*.

I. How to Respond to and Prepare for a Tsunami

In assessing your community's evacuation planning needs, it is important first to understand how people are recommended to respond when faced with a tsunami. This training is essential for community members to make the most of their evacuation options and to assess the need for further efforts. Preparedness efforts are also outlined that improve post-event outcomes for your community.

Washington State coastal communities are 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 or within the Puget Sound from a crustal earthquake on the Seattle Fault, Tacoma Fault, or other fault, and/or from landslides. Distant source tsunamis can come from as far away as Alaska (1964) and even Japan (2011).

Generally speaking, Washington State Emergency Management Division (EMD) identifies the following warning signs and action to take:

- FEEL: If you feel the ground shaking severely.
- SEE: Tsunamis may be preceded by a rapid fall in the sea level. If you SEE fast receding water, or a wall of water coming towards you.
- HEAR: If you HEAR a loud roar like a train or jet.
- RUN: Move quickly inland to high ground.

How to respond to a local source tsunami:

For local source tsunamis, the waves will often arrive with shaking from an earthquake. Evacuation times can vary from minutes to over an hour.

1. When you feel shaking: 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 to high ground or inland. The earthquake is your warning. 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 guide).

3. The earthquake may have buckled the roads, knocked down power-lines, and caused landslides, making driving nearly impossible. You will most likely need to evacuate on foot, taking care to avoid hazards along the way.

4. Children, the elderly, people with access and functional needs, and those with health issues may move more slowly and will likely need assistance.

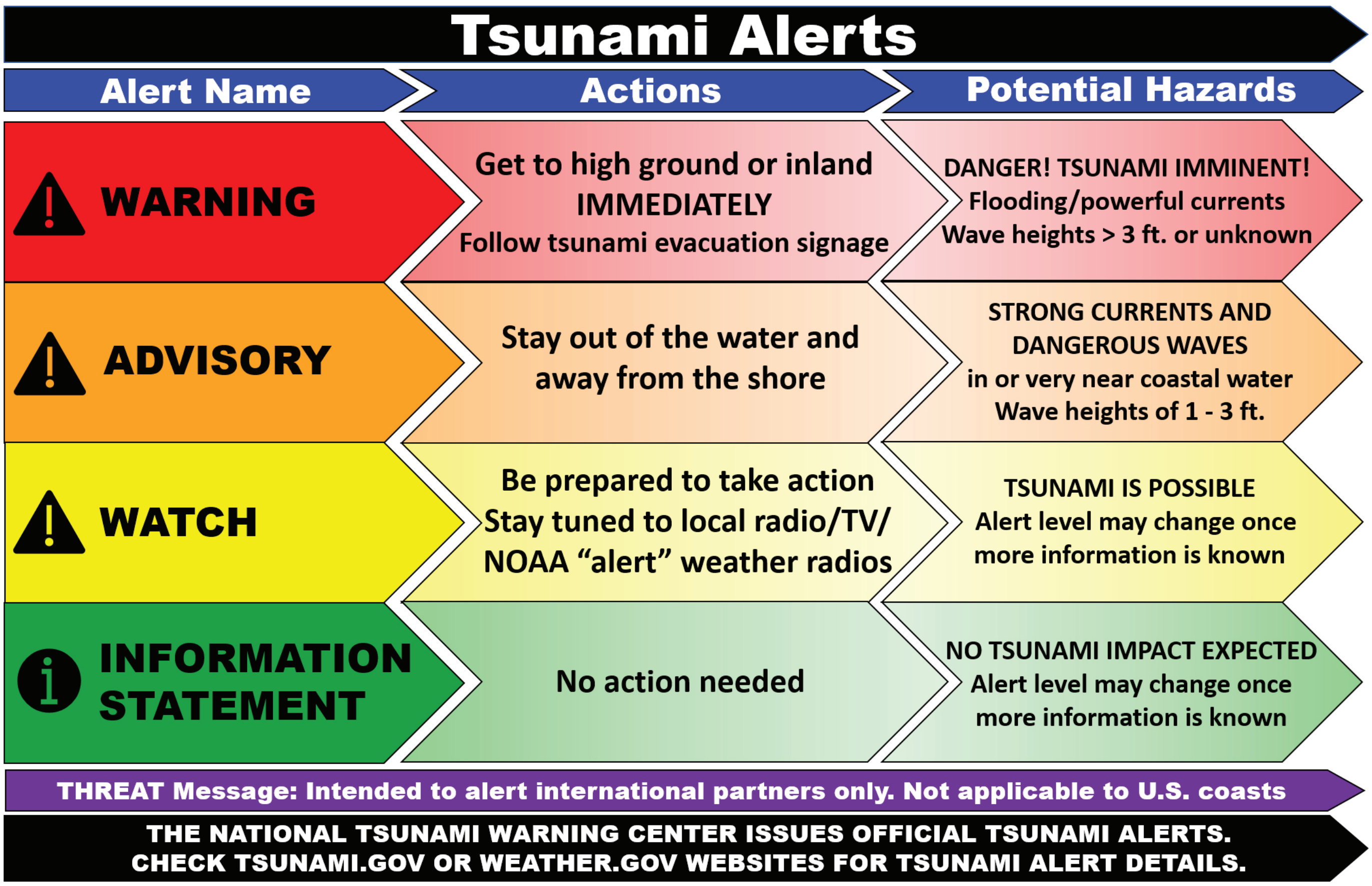
5. Tsunamis consist of multiple waves that could impact coastal areas for 12 to 24 hours or longer. The first wave is often not the highest. Once you reach high ground, do not come down until local authorities notify you to do so.

How to respond to a distant source tsunami:

From a distant source tsunami, you are unlikely to feel shaking from the earthquake. Distant tsunamis can come from as far away as Japan and Alaska. Because of early warning systems, people will likely have several hours to evacuate.

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 Alert Levels. Image Credit: EMD

Alerts:

There are a variety of ways to receive alerts about tsunamis:

- All Hazard Alert Broadcast (AHAB) Tsunami Sirens.
- NOAA Weather Radios.
- Wireless Emergency Alerts (WEA) via cell phone, a text via SMS, or message via NTWC Twitter feed. You can send a text message to 40404 with "Follow NWS_NTWC" as the message.
- Email service via UNESCO/IOC email service tsunami-information-ioc@lists.unesco.org.

Preparedness Efforts:

1. All communities need to become better informed about their tsunami risk in order to make the best decisions for the safety of their family based upon the information provided.

2. Ongoing community education builds awareness and support. One of the outreach programs used to support tsunami awareness is the EMD *Tsunami Roadshow* held yearly in many coastal communities. Other efforts could involve inviting a panel of tsunami experts to a public meeting to present and answer questions.

3. Perform evacuation drills in your community so everyone knows where to go before the tsunami hits. These drills also help to raise awareness and increase support for building vertical evacuation structures. The Washington State *Great ShakeOut* drill is held every October. Many communities and tribal nations hold evacuation walks, such as the *Yellow Brick Road* evacuation drill conducted by the Shoalwater Bay Tribe each summer. In Washington State, schools located in tsunami inundation zones must now conduct annual tsunami evacuation drills.

4. Work on a community-wide tsunami evacuation plan. This plan should include information on existing evacuation routes, high ground, signage, and warning siren locations. 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, that can help your community reach the goal of providing everyone with access to safety.

AHAB siren on the Washington coast. Photo Credit: EMD

5. Create a family emergency plan. Build your go-bag and work on getting at least two weeks of supplies ready. A go-bag/kit is a bag that you can carry with you during an emergency that contains essential supplies that will help you to get where you need to go. 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. A go-bag should contain: 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.

- The following website provides a PDF of the 2 Weeks Ready Brochure and a video on how to prepare a kit: https://www.mil.wa.gov/preparedness

- The following website provides a wide variety of information concerning tsunamis and includes information on preparedness: https://www.mil.wa.gov/tsunami

- The following website provides general guidance on family emergency plans: https://mil.wa.gov/uploads/pdf/Publications/english%20family%20emergency%20plan.pdf

2. Condensed 7 Phase Process

This condensed version of the 7 Phase Process provides a brief description of the elements under each phase. To support a most compact version, explanations and references to other sections of the manual have been removed. This condensed version is intended to be a quick reference, but you are strongly encouraged to consult the full *7 Phase Process in Chapter 1*.

Phase 1: Involve Emergency Management Partners

- Contact your county or tribal emergency manager and the EMD Earthquake and Tsunami Program Manager.
- Ask your emergency manager 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. Consider also evaluating:
    - The identified sites in the *Project Safe Haven* reports
    - Incorporating vertical evacuation into upcoming new projects
    - Sites near population densities and children (i.e., schools)
    - Neighborhood sites
    - Sites that are on high ground and inland
- 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, Completion, and Operation

- Hire a construction contractor.
- Schedule regular project meetings and reviews during construction.
- Set up a maintenance plan and a security plan for your evacuation structure.
- Celebrate your newly constructed structure by having an open house.

Next Steps.

- Conduct community outreach and training.
- Consider ongoing improvements to the evacuation structure.
- Improve routes, bridges, and signage that assist with access to the evacuation structure.
- Start planning efforts for your next tsunami vertical evacuation structure.

3. 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 population density might consider a berm for that location. Other sites may be best suited for a tower. There are many considerations in choosing a structure type. This section seeks to describe the various structure types and some considerations that may go into choosing one over the other. There are four general vertical evacuation structure types:

Buildings

New buildings and significant additions and retrofits to existing buildings may offer a good opportunity for vertical evacuation. Examples of buildings include schools, city halls, community centers, conference centers, parking garages, apartment buildings, and resorts and hotels. Buildings may also allow for more consistent maintenance and security. The Ocosta Elementary School is an example.

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 would also require an engineering review to determine if they met tsunami and earthquake structural requirements. In addition, these buildings would have to meet height requirements based on tsunami modeling for the site. Small coastal communities generally do not have existing buildings of this construction type.

Considerations:

- 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 site that would be hard to modify?

Towers

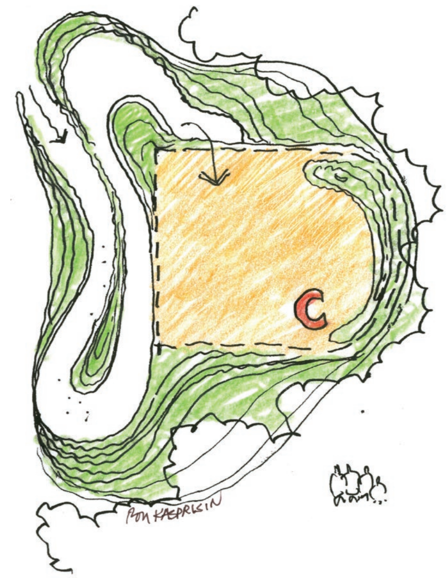
Towers are generally stand-alone structures with a platform at the top for people to gather. Towers can be single purpose but can also support multiple uses such as viewing and bird-watching platforms. Towers generally require less land than other options. The Shoalwater Bay Tribe is currently designing a tower that would serve both the Tribe and the nearby town of Tokeland. Tsunami towers have been built in Japan.

Considerations:

- 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.



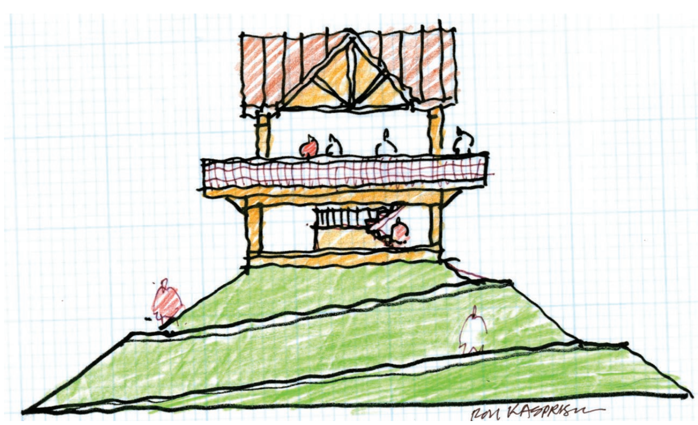
Potential Berm Design. Sketch Credit: Ron Kasprisin UW Project Team

Considerations:

- 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.



Potential Hybrid Tower Berm Design. Sketch Credit: Ron Kasprisin UW Project Team

4. Structure Design Criteria

This guide can assist communities in the design of their tsunami vertical evacuation structures. The following criteria are also a valuable back-check at different points in the design process. Project team consultants and community representatives felt these criteria were important in assessing designs. At this phase in the process, you will have already hired an architect and structural engineer.

- Confirm the required height of the evacuation structure. The height is based on the tsunami modeler and geotechnical engineer findings in combination with the building code requirements.
- Confirm the total occupant capacity of the evacuation structure. Consider nonresidents such as visitors, tourists, and employees who may need to use the structure. Compare this with the number of people that are within walking distance during the appropriate evacuation timeframe.
- Confirm the estimated cost of the evacuation structure within the budget constraints for your community. This will need to be done multiple times during the design and construction phases.
- Does your evacuation structure fit with the surrounding landscape and neighboring buildings while also being recognized by visitors as a tsunami vertical evacuation structure?
- Have you considered multiple uses for your evacuation structure? How might a structure support other needed community functions?
- Is the design of your evacuation structure attractive and well proportioned? Will this be a building that the community can take pride in?
- 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 more easily flow around.
- What other program elements have you considered for your evacuation structure? Is there storage space for supplies and water? Do you have emergency sanitation facilities? Do you have a backup power source?
- 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.
- 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 for the community to know about and access the evacuation structure during a tsunami evacuation?

5. Project Safe Haven Community Planning Process

Washington State's *Project Safe Haven* was a community planning process that took place from 2010-2011. It was the first of its kind to identify sites and potential structure design concepts for tsunami vertical evacuation structures. *Project Safe Haven* was a joint effort of communities, several state and federal agencies, and the University of Washington. Through public meetings and workshops, communities created a tsunami vertical evacuation plan, including the selection of potential sites. The findings of these workshops were published in 2011 in reports that are available online, *Go to Appendix D: Resources*.

The multidisciplinary planning process was held in eight Washington State coastal communities, including the Long Beach peninsula, Grays Harbor County, Clallam County, Shoalwater Bay Tribe, Macah Tribe, and others. Local elected and tribal officials invited *Project Safe Haven* into their communities and supported the process. An effective planning process must work with the support of local officials.

A series of at least four meetings were held in each community, by county. This process is still highly relevant to communities that are seeking to plan for evacuations structures. Outlined below is the process followed by *Project Safe Haven* that can be used in your community's planning process:

A Steering Committee was assembled by EMD and the University of Washington and included local and state agencies, emergency managers, and tsunami experts to guide the project. Many of the steering committee members led or participated in each community meeting and workshop.

Site visits were organized to explore preliminary locations for evacuation structures, the community's general landscape and built environment, and tsunami risk considerations. This was the first visit to each community for many steering committee members, while others members were local or already familiar.

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

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. 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.

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.

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.

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 drawing 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.

5 TOOLS

Ocosta Elementary School was funded by local bonds. Photo Credit: Pete Eckert of Eckert and Eckert Photography

Building tsunami vertical evacuation structures and implementing a tsunami evacuation plans requires creativity, financial resources, determination, and community buy-in. The following tools and approaches represent a comprehensive, yet not exhaustive, list of options.[1] Upgrade"]

1. Many of the definitions provided in this section are 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."

1. Revenue Generating

Local governments commonly use revenue generating tools to fund community infrastructure and other necessary amenities. As such, the following tools identify a wide range of local fund-generating options. Those that share benefits also share costs. To fund tsunami vertical evacuation structures, local funding will be necessary.

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.[2] The Ocosta Elementary School including the vertical evacuation component was financed through a municipal bond.

Property Tax

Property taxes are imposed at regular intervals on land and improvements to the land. A property tax is tax levy on the value of property that the owner of the property is required to pay to a government in which the property is situated.[3]

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 government.

Special Assessment and Local Improvement Districts

Special Assessment and Local Improvement Districts include property owners who benefit from a specific public improvement. These owners are charged a fee, which can be based on an attribute(s) of the property that is proportional to the benefits received from the improvement, and which is charged to both new and existing development. There are numerous possibilities, from temporary creations designed simply to raise revenue for a specific improvement, to independent, special-purpose governmental entities. Since this is not a tax, special assessment districts are free from constitutional requirements of uniformity, equality, and double taxation. This technique shifts the financial burden from the general public to those directly benefiting.[4] This type of tool assesses an additional tax on the full value of a property, usually paid by property owners within a defined special assessment district that will benefit from specific public improvement(s).

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. The appealing aspects of this type of tool are that it expands the available capital budget and aligns incentives of payees and beneficiaries.[5]

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2. https://www.investor.gov/introduction-investing/basics/investment-products/municipal-bonds
3. https://tax.findlaw.com/federal-taxes/the-property-ad-valorem-tax.html
3. https://www.oas.org/cdmp/document/mitiplan/mittools.doc
5. https://urban-regeneration.worldbank.org/node/19

Excise Taxes

Excise taxes are taxes paid when purchases are made on a specific good, such as gasoline. 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. Taxes on tobacco may be used to promote health programs.[6]

A dedicated tourist tax could help fund tsunami vertical evacuation projects. Several communities along the Washington Coast with the greatest tsunami risk also have high levels of tourism during the summer months. This is an asset and could be leveraged to support vertical evacuation structures for year-round residents and tourists alike.

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.

Developer Extractions

Developer extractions are fees to offset the burdens of new development on the community. Extractions contribute to regional equity by ensuring that a new development pays a fair share of the public costs that they generate and typically consist of a developer's payment of "impact fees." These fees are used to fund new schools and parks, construction or maintenance of public infrastructure directly connected to the new development, and off-site improvements and services. Exactions are levied on developers in exchange for the approvals to proceed with a project.

Service Areas

The taxing authority of a government can designate areas that will receive services and those that will not, and it can tax the former at a higher rate. This technique will be more effective if used in conjunction with a regulatory program, which limits development in areas with lower, more attractive tax rates. A capital program will make the designation more equitable and less open to legal challenge.

2. Partnerships and Other Options

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 increase the likelihood that your community identifies the total money needed to fund vertical evacuation. The following identify a wide range of creative tools that may work for your community.

6. https://www.irs.gov/businesses/small-businesses-self-employed/excise-tax

Public Private Partnerships (P3)

A public-private partnership (P3) is a contractual arrangement between a public agency (i.e., federal, tribal, state, or local) and a private sector entity (i.e., business, non-profit organization, etc.). 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.[7] 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 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.

Affordable Housing Tax Credits

The Low Income Housing Tax Credit (LIHTC) program was created in 1986 and is the largest source of new affordable housing in the United States. There are about 2,000,000 tax credit units today and this number continues to grow by an estimated 100,000 annually. The program is administered by the Internal Revenue Service (IRS). The LIHTC program does not provide housing subsidies. Instead, the program provides tax incentives, written into the Internal Revenue Code, to encourage developers to create affordable housing. Long Beach, Washington, for example, is struggling to provide affordable housing. LIHTC could be used to fund affordable housing projects with a vertical evacuation component.[8]

Coastal Alliance Network

Washington coastal communities are vulnerable to a host of hazards such as seismic and tsunami events, erosion, severe storms and flooding, sea level rise, and ocean acidification. A network may advocate for state and federal funding, including working directly with state legislators and their staff. Successful advocacy efforts may lead to upgrading schools, providing money for tsunami structures, and enhancing evacuation and mitigation planning.

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

Tsunami-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.

7. https://www.agc.org/public-private-partnership-p3-basics
8. http://wshfc.org/mhcf/4percent/index.htm

3. Grants

Grants can be a valuable component of vertical evacuation projects. At the same time, grants are often hard to get due to competitiveness, timing of grant cycles, etc. Contact EMD early if your community is interested in applying for a grant. The following grants offer a range of potential sources for funding from FEMA to foundations. *Go to Chapter 2.4: State Hazard Mitigation Officer and Federal Grant Funding.*

FEMA Mitigation Grant Programs

FEMA's vision is to serve as a catalyst that drives increased understanding and proactive action to help people in communities reduce their losses from natural hazards. FEMA funds Hazard Mitigation Assistance grant programs including the Floodplain Management Assistance Program (FMA), Pre-Disaster Mitigation program, Hazard Mitigation Grant Program and the Severe Repetitive Loss program. Local matching funds are typically required for these programs. *Go to Chapter 2.4: State Hazard Mitigation Officer and Federal Grant Funding.*

Community Development Block Grant Program (CDBG)

The CDBG Program is focused on economic development, housing rehabilitation, and neighborhood rehabilitation. 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% of eligible projects for organizations like non-profits that provide social services or youth recreational facilities.[9]

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.

Earmarks

Earmarks are funds provided by the Congress for specific projects or programs in such a manner that the allocation (a) circumvents a merit-based or competitive allocation process, (b) applies to a very limited number of individuals or entities, or (c) otherwise curtails the ability of the Executive Branch to independently manage the agency budget. Earmarks have been used to fund a very wide variety of project ranging from planning and project development to the construction of dams.[10]

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9. https://www.commerce.wa.gov/building-infrastructure/capital-facilities/
10. http://uspolitics.about.com/od/politicaljunkies/g/what_is_earmark.htm

NOAA Regional Coastal Resilience Grants

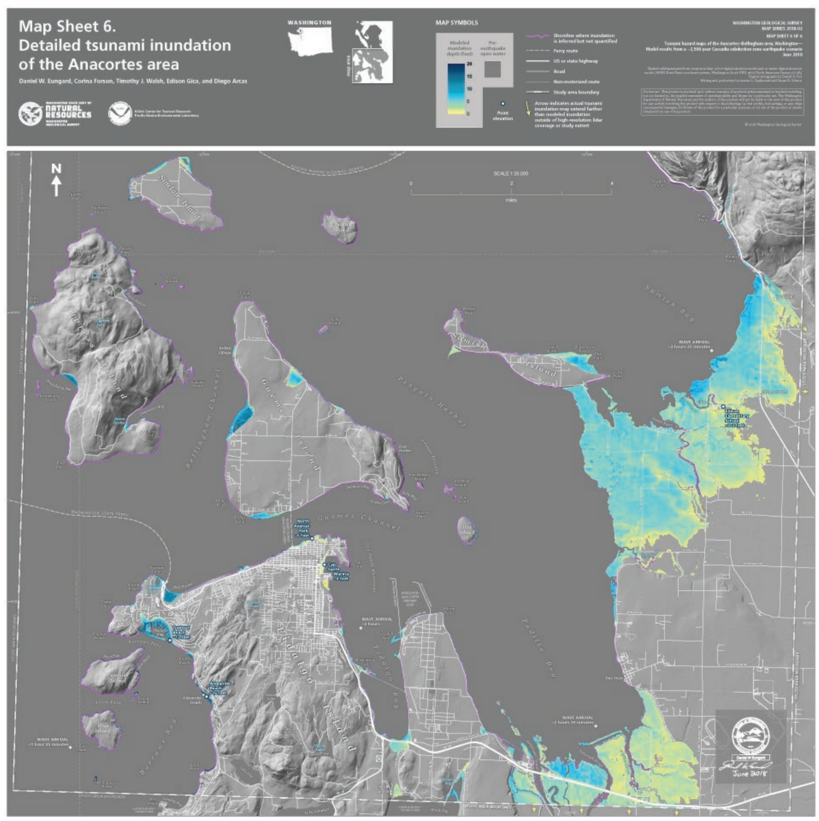
NOAA grants aim to improve coastal community disaster preparedness, response, and recovery. The grant awards priority to comprehensive science-based solutions and collaborative partnerships to help state and local government agencies and non-governmental organizations improve their ability to prepare for and recover from a variety of coastal threats, including hurricanes, tsunamis, and sea-level rise. A local match is required for these grants.

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.

4. 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 your city to support tsunami evacuation planning. Additionally, there are plans already in place that your community can look to for inspiration, guidance, and technical assistance. The 2010-2011 *Project Safe Haven* community planning process and associated reports is one example. The following planning tools identify a range of resources and planning documents to support vertical evacuation in your community.



Anacortes area inundation map. Map Credit: DNR

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 risk 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 Improvement Plan (CIP)

A CIP is a plan that identifies capital projects and equipment purchases, provides a planning schedule, and identifies options for financing the plan. CIP projects range from roads to facilities. The CIP provides a link between a municipality, school district, parks and recreation department, and/or other local government entities, comprehensive and strategic plans, and the entity's annual budget.[11] CIP decisions are important and need to take a number of concerns and priorities into consideration including funding and resource allocation in support of vertical evacuation. For example, the construction of a vertical evacuation structure could be a line item within a capital budget.

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 Indian tribal governments as a condition of mitigation grant assistance.[12] 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 an approved HMP are eligible for FEMA grants. The recommendations of the HMP should be integrated into the comprehensive plan and the capital improvement plan.

Focused Public Investment Plan (FPIP)

A Focused Public Investment Plan (FPIP) coordinates and concentrates investments in a designated Public Investment Area (PIA), such as water, sewer, streets, schools, and parks. FPIPs limit growth in what would otherwise be dispersed or inadequately served by public services. Such a plan could provide a vehicle whereby communities limit growth with risk area until risk reduction measures are present.[13]

Silver Jackets

The Silver Jackets team, sponsored by the United States Army Corps of Engineers (USACE), facilitates collaborative solutions to state flood risk priorities. Different agencies wear different colored jackets when responding to emergencies. For example, the Corps wears red and FEMA wears blue jackets during flood response events. The name Silver Jackets is used to underscore the common mission of the diverse agencies involved. These teams work across the United States to bring together multiple state, federal, and sometimes tribal and local agencies to collaborate and share best practices. Silver Jacket teams generally consist of members from FEMA, USACE, USGS, the National Weather Service, and various state agencies.[14]

The goal of each Silver Jackets team is to leverage a state-led interagency team in every state that integrates multiple programs and perspectives to provide cohesive solutions to flood and other disaster risks. While each state team is unique; they generally increase local collaboration and information-sharing

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11. https://opengov.com/article/capital-improvement-plans-101
12. https://www.fema.gov/media-library/assets/documents/4596
13. http://www.oas.org/cdmp/document/mitiplan/mittools.pdf
14. https://silverjackets.nfrmp.us/Home/About-The-Silver-Jackets-Program

across agencies. By applying their collective knowledge, the teams enhance response and recovery efforts when such events do occur. Coastal communities in need of vertical evacuation structures could benefit from a Silver Jackets team approach.

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, such as a right of access, or restrict the landowner's right to use the property in a particular way. By owning development rights, the government has a very high level of control while allowing the land to remain in private hands.[15] This tool has been used to limit development within a risk area and promote construction in safer locations. King County, Washington, for example, purchased hundreds of acres of development right within the Cedar River watershed to better control water discharge and limit flooding. In tsunami risk zones, the tool could also be used to confirm rights of access to a vertical evacuation space in a privately owned building in the event of a tsunami.

5. 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, for example, 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. Currently, the ASCE Chapter 7-16 provides the most current building code guidance for tsunami vertical evacuation structures. This guidance is included in the 2018 IBC by reference.

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. Bonus and Incentive Zoning is most commonly used in metropolitan areas. 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.[16]

15. https://realestate.findlaw.com/land-use-laws/easement-basics.html
16. http://www.mass.gov/envir/smart_growth_toolkit/pages/glossary.html#incentivezoning

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.

Coastal Construction Control Line (CCCL)

The CCCL defines an area seaward of which there are additional regulations. For example, Florida established a CCCL to protect beaches and dunes from improperly sited and designed developments. The CCCL represents the projected landward limit of significant damage to upland structures from water forces from a one-hundred-year coastal storm. Structures located seaward of the CCCL are required to be designed and built to withstand the high winds and storm surges.

Transfer of Development Rights (TDR)

TDR programs use the market to implement and pay for development density and location decisions. 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 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 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 vertical evacuation element.

6. Retreat, Protection, and Accommodation

The following tools are not directly linked to funding vertical evacuation, but may help increase the resilience of your community and therefore reduce the risks posed to your community by a tsunami. Approaches like dune restoration may reduce tsunami wave run-up by filling in existing dune cuts. Vulnerable communities, like the Quinault Indian Nation, are looking at options for community relocation out of the tsunami and climate change risk zone. The following tools and approaches identify a range of smart mitigation options.

Dune Restoration (Protection)

Along the Washington coast there are a number of dune cuts that have been created over time to accommodate cars on the beach. Unfortunately, dune cuts also create an ideal path for a tsunami wave. Dune restoration may mitigate the concentrated tsunami wave pathway that the dune cuts produce.

Spit or Sand Spits (Protection)

A spit or sand spit is a depositional land form. At one end, spits connect to land and extend into the sea. A spit is a type of bar or beach that develops where a re-entrant occurs, such as at cove's headlands. This is created by the process of long-shore drift or littoral drift that occurs due to waves meeting the beach at an oblique angle, and backwashing perpendicular to the shore, which moves sediment down the beach in a zigzag pattern.[17]

Barrier islands and spits play an enormous role in mitigating ocean swells and other storm events for the mainland side of the barrier island. This effectively creates a very unique environment of relatively low energy, brackish water. Multiple wetland systems such as lagoons, estuaries, and/or marshes can result from such conditions depending on the surroundings. Without such structures, these wetlands could not exist and would be destroyed by daily ocean waves and tides as well as ocean storm events. Spits can weaken wave energy including that caused by tsunami waves. Japan has employed artificial barriers, such as the placement of concrete tetrapods, to temper wave energy and help protect coast communities.

Community Relocation, Advance Site Acquisition, and Land Banking (Retreat)

Entire communities have been relocated in the United States and throughout the world following a disaster or to mitigate the impacts of anticipated future hazards. In Washington State, the Quinault Tribe in Taholah made the decision to relocate their downtown buildings and facilities to high ground due to increasing climate change impacts like sea-level rise.[18]

Advance site acquisition and land banking involves the purchase of land by the government for eventual use or resale to the private sector in order to influence the character or timing of future growth.

Retrofitting (Accommodation)

Retrofitting refers to changing existing buildings to withstand a hazard. These changes can be structural or nonstructural. Nonstructural measures include anchoring bookcases to structural members to survive earthquakes. Structural measures include anchoring the building to the foundation to better withstand seismic forces or raising the entire structure above a level of expected flooding.

Currently the State of Hawaii is assessing certain existing coastal building to determine if they might be suitable for tsunami vertical evacuation. Unlike Hawaii, Washington coastal communities generally do not have concrete and steel frame buildings of sufficient height that could be retrofitted for vertical evacuation.

17. https://www.bbc.com/bitesize/guides/z3ndmp3/revision/6
18. https://earthjustice.org/blog/2018-march/climate-change-forces-the-quinault-tribe-to-seek-higher-ground

6 FIVE RECOMMENDATIONS

Dunes at Long Beach. Photo Credit: UW Project Team

These recommendations support the building of tsunami vertical evacuation structures as well as overall community resiliency. The recommendations outline an integrated approach that touches upon partnerships, planning, project guidance, and technical assistance.

The following recommendations are the result of interviews with those listed in *Appendix A: Interviewing Process*. These interviews included elected officials, school district representatives, emergency managers, tsunami modelers, engineers, geologists, coastal residents, and others. There was general support for these recommendations among those interviewed.

Recommendation 1: Develop a Coastal Alliance Network

Tsunami-impacted communities along the Washington coast are also vulnerable to a host of coastal hazards as described in the 2017 William D. Ruckelshaus Center *Final Report Washington State Coast Resilience Assessment.* From Washington to California, communities are vulnerable to seismic and tsunami events, erosion, severe storms, and flooding, sea-level rise, and ocean acidification. All Western Washington coastal communities are at-risk from tsunamis. Several of these communities or portions of these communities have no reliable access to natural or artificial high ground. Many of those interviewed felt strongly that coastal communities must form alliances to achieve their resiliency goals.

Although the states of Washington, Oregon, and California have similar coastal risks, Washington State coastal communities have fewer resources and need additional support. In Washington State, major ports and development are located on the Puget Sound and Columbia River and not the outer Pacific Ocean coastline. As a result, the outer coast does not have the economic, infrastructure and governance resources typical of many other West Coast communities.

Coastal communities are an essential part of the cultural character, quality of life, and natural heritage of Washington State. Coastal communities must work together to advocate and share information in addressing a variety of coastal hazards including tsunamis. By working together, coastal communities can raise public awareness, gain support for state and federal funding and identify opportunities for collaboration on shared projects, such as tsunami evacuation planning and structures, to improve overall coastal resiliency. This recommendation ties into three recommendations outlined in the Ruckelshaus Report:

- R1: Establish a Coast-Wide Resilience Initiative to Enhance and Integrate Efforts.
- R5: Develop an Advocacy Strategy for the Coast.
- R9: Increase Opportunities for Collaboration, Coordination, and Partnerships.

A coastal alliance network will likely build upon existing networks and stakeholders such as the Washington Coastal Advisory Council. The Silver Jackets approach is good example of a multi-stakeholder approach to hazards as described in *Chapter 5.4 Planning / Silver Jackets*. Important stakeholders include elected officials, local communities and tribes, agencies and universities, planners, and emergency managers among others. Given limited resources, this effort would seek to coordinate with existing groups and avoid duplicating efforts. Advocacy could also establish a state-level planning directive with dedicated funding to support comprehensive coastal hazard planning. The goal is to move from a model of reactive crisis management to proactive risk reduction.

Recommendation 2: Integrate Tsunami and Seismic Risk into All Planning Efforts

Risk reduction measures should be fully integrated into all planning documents, codes, procedures, and policies. These include community comprehensive plans, capital improvement plans, building and development codes and ordinances, environmental and coastal regulations, and other planning and policy tools. Risk is typically defined as a relationship between impacts and event frequency. Tsunamis may be very infrequent, but for at-risk communities, the impact is intolerably high. Assuring adequate access to natural and artificial high ground must be integrated into planning efforts for all at-risk communities.

In Washington State, the Growth Management Act (GMA) is the primary planning framework for all 39 counties. The GMA establishes 13 goals that should guide all comprehensive plans and also establishes mandatory and optional plan elements. Hazard risk reduction is not mentioned in either the goals or the mandatory and optional elements. The GMA requires all counties and cities to plan under the Critical Areas Ordinance (CAO) that does make some mention of 'geologically hazardous areas.' Yet, the CAO's primary function is to protect critical natural areas and does not address communities at risk from natural hazards.

The GMA process requires community growth to drive such elements as land use, transportation, housing, and ports. Yet, for some communities, risks are so great that reducing them to a tolerable level should be a primary planning driver. Risk reduction should be factored into land use designations, including transportation corridor access to safe areas, housing density within risk areas, and port facility life cycles as related to expected increases in sea levels. Even in extremely hazard-prone communities, such as those on the Washington State's outer coast, the GMA does not support the integration of comprehensive risk reduction into community development.

Communities tend to address natural hazards in their Hazard Mitigation Plans. These plans are required of communities that want to receive federal grant funds. HMPs are sometimes referenced in comprehensive plans but need to be better integrated into all planning documents. The National Flood Insurance Program (NFIP) is an example of an effort to integrate hazards into overall planning. NFIP participating communities are required to establish regulations that reduce future flood damages. Those interviewed felt that risk reduction should be a planning priority and should be better integrated into overall planning efforts.

Recommendation 3: Support Tsunami Risk Reduction and Continuity Planning

Tsunami vertical evacuation structures in coordination with other evacuation planning efforts can help coastal residents to survive a major tsunami. Impacts to coastal communities will vary depending on their location and the type and severity of the tsunami. Outer coast and Puget Sound coastal communities have similar and different challenges. A major Cascadia Subduction Zone earthquake and tsunami will significantly impact coastal communities, particularly those on the outer coast that lack sufficient access to natural and artificial high ground. Many of those interviewed felt is was critical for communities to support risk reduction and continuity planning.

As discussed in *Recommendation #2*, current planning efforts can support risk reduction. This can be done by building evacuation structures and improving evacuation routes. Risk reduction can also 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. Home owners can reduce their risk of loss by purchasing insurance through the National Flood Insurance Program.

All at-risk communities and businesses should also follow sound government and business continuity of operations practices including storing data off-site and developing response capabilities and communication systems outside of tsunami inundation zone. Since coastal communities may need to be relatively self-sufficient for several weeks following a major event, these practices can make a vital contribution.

Recommendation 4: Develop Approaches that Reduce Project Costs

Tsunami vertical evacuation structures have only recently been seen as a risk-reduction solution for coastal communities with a lack of natural and artificial high ground. At this point, the process for designing and building these structures is still relatively new. As more structures are completed, there will be more available cost information and a better understanding of the process. These are costly projects for communities with limited resources, and some communities will require multiple structures. Those interviewed expressed support for approaches that could reduce project costs.

For example, towers may provide the most commonly used vertical evacuation option, particularly for communities that need many structures. Developing a prototype tower design could reduce project costs. Such a tower design could be appropriately modified for various site conditions, height requirements, and appearance criteria. The design could be optimized to use common steel shapes and connections to increase efficiency during design and construction. Similarly, tsunami modelers could be commissioned to model a variety of typical coastal sites and to determine tsunami depth and velocity for design purposes. These approaches may also work with berm design. Funding for such efforts could come from state and federal sources and would require advocacy work as described in *Recommendation #1*.

Recommendation 5:
Provide Vertical Evacuation Structure Project Management Assistance

Washington State coastal communities often lack the dedicated staff and comprehensive expertise needed for project and construction management. Project management services include facility planning, cost estimation, and bond planning. Construction management services include on site quality control, budget management and schedule management during the construction phase. At-risk communities should not be expected to have the full internal capacity to manage projects from start to finish. The community's responsibility is to facilitate an open community engagement process that selects sites and funding options. Those interviewed supported project management assistance for communities.

Designing and constructing vertical evacuation structures is still relatively new and complex and uses the latest available science. The building code sections dealing with tsunami design was adopted into the 2018 International Building Code (IBC) after undergoing over a decade of research and development. Tsunami modeling continues to evolve on a strong foundation of scientific research. Tsunami vertical evacuation structures must be built to the highest design standards to survive an earthquake, aftershocks, liquefaction, and multiple tsunami waves. Only one structure has been completed so far in North America. All of these factors point to the need for project management assistance.

An oversight entity could be assigned the responsibility of providing guidance to local communities on project management expertise. The agency that takes on this role could create an oversight support team. This team might include construction managers, engineers, public works representatives, community planners, emergency managers and others. Those interviewed felt that this oversight entity could assist communities with their choice of lead consultants and contractors and to also assure that feasible projects could be built within a local community's budgetary and other constraints.

The Washington State Emergency Management Division (EMD) might be the best agency to coordinate these efforts. EMD could draw upon the construction management expertise from other state agencies. The Educational Service Districts, for example, under the Washington State Office of Superintendent of Public Instruction provided project management services for the Ocosta Elementary School Project. The Washington State Department of Transportation and the United States Army Corp of Engineers might also be able to provide project management support.

APPENDICES

Appendix A: Interviewing Process

Interviews were essential to producing this manual. Interviewees included elected, tribal, and school district officials, emergency managers, structural and geotechnical engineers, tsunami modelers, an architect, a USGS researcher, and others. All those interviewed were connected in one way or another to the planning, designing, and building of tsunami vertical evacuation structures. Interviewees were very generous with their insights and time. This manual would not have been possible without them. All interviewees were given an opportunity to comment on the manual and many provided comments on various sections at multiple times throughout the review process. Appendix A includes a list of interviewees, questions asked in the formal interviews, and some selected findings from those interviews.

List of Interviewees

All interviewees were interviewed over the phone or in person. Interviews usually took place with two or three staff members from the University of Washington Institute for Hazards Mitigation Planning and Research. Interviewees were told they would not be directly quoted without their express permission.

- Paula Akerlund, former Superintendent, Ocosta School District
- Cale Ash, Office Director and Principal, Degenkolk Engineers
- Tim Cook, Hazard Mitigation Officer, Washington State Emergency Management Division
- Scott McDougall, Director, Pacific County Emergency Management Agency
- Crystal Dingler, Mayor, City of Ocean Shores
- Steve Ensley, Councilmember, City of Ocean Shores
- Maximilian Dixon, Earthquake/Tsunami/Volcano Program Manager, Washington State Emergency Management Division
- David Glasson, City Administrator, City of Long Beach
- Frank Gonzales, Tsunami Modeler, University of Washington
- Brian Ho, Managing Principal, TCF Architecture
- Randall LeVeque, Tsunami Modeler, University of Washington
- Mike Motley, Engineer, University of Washington
- John Schelling, Emergency Management and Safety Administrator, Washington State Department of Commerce
- Lee Shipman, Emergency Management Director, Shoalwater Bay Tribe
- Dan Trisler, Principal Geotechnical Engineer, Hart Crowser
- Timothy Walsh, Assistant State Geologist, Washington State Department of Natural Resources
- Charles Wallace, Deputy Director, Grays Harbor Emergency Management
- Nathan Wood, Research Geographer, United States Geological Survey

Charles Wallace.
Photo Credit: Washington State National Guard

The following is a list of people who were consulted about different parts of the process but not with the specific questions listed below:

- Daniel Eungard, Geologist, Washington State Department of Natural Resources
- Jon Martin, Councilmember, City of Ocean Shores
- Chris Moore, Oceanographer and Systems Analyst, National Oceanic Atmospheric Administration
- Amanda Murphy, Project and Research Lead, The William D. Ruckelshaus Center
- Doug Nichols, Project Management and Facility Planning, Nichols Consulting
- Bobbak Talebi, Coastal Planner, Washington State Department of Ecology

Questions to Interviewees

These questions were asked to all people who participated in the in-depth interview process. Their names are listed in the previous section.

1. What is/was your role in this process?

2. Why did you support/not support this process?

3. What are the key steps in this process?

4. Why was this site chosen?

5. What went well for this process? Why?

6. What did not go well for this process? Why?

7. What are the biggest lessons learned from this process?

8. How can this process be most successful going forward?

9. What were/are funding sources for these structures?

10. What else would you like to add?

Interview Findings

This section provides a sampling of the responses from the various interviews and is not intended to include all comments. Reference to specific projects was avoided to maintain the anonymity of interviewees. The interviews were a critical foundation for this manual.

1. Public Engagement

- Keep the faith in this work long-term. Keep conversation going for future actions.
- Involve the public throughout the entire process! Don't leave them out.
- Explain in basic language was the risks are, costs, options.
- Emphasize that there is no one-size-fits-all; this will vary by community.
- Tried really hard not to scare people. Very factual and matter-of-fact. Talked about what might happen but did not make it the centerpiece.
- Having a team of subject matter experts at public meetings was important.

- Communities need to continuously be educating themselves about the risk and impacts. Especially in communities where there has been turnover.
- Communication about uncertainty of modeling has to be iterative, not alarmist.
- Process focus on positive outcomes, be clear about options, balance complexity with clarity.
- In NW culture, communities want to partner and not be treated in a top down way.
- Risk is a decision, not just a loss estimation. People may decide to live with the risk as a choice.
- Supportive of process that provides solutions because otherwise all they have is fear.
- Social media can be very valuable to raise awareness and rally support.

2. Partnerships

- Welcome experts in and work with them.
- The state can be a great partner.
- Leverage all existing resources and experts in the State of Washington. There is expert advice available for these projects for free.
- Some communities are small and realize they can't do it alone. As such, they have to reach out, ask for help.
- Partnership with state, FEMA, and sister communities, etc., is critical.
- Schools are good partners for evacuation structures.
- In small communities, you can't get anything done without having the right people in the community who have credibility and influence.
- Need to coordinate with local officials, not blindside them.

3. Leadership

- Need a leader who can bring in the resources and be a problem solver. Must be persistent.
- People need to trust and believe in the leader. Identify what skills people can bring to committee.
- Good leadership establishes credibility. They bring in experts, never fail to answer a question, and came back with information. Also, they admit what is not known.
- Confirmed that there was community buy-in and support regardless of FEMA money. The community was determined to find a way no matter what.
- You need a person that is going to own and facilitate the process from beginning to end.
- Trust has to be established with the community. Leverage experts and elected officials to build that trust.
- The leader has to protect the resources and interests of their organization.
- The work of the committee is to research, develop recommendations, reach consensus.

4. Coordination

- Assemble a strong team of consultants (structural, geotech, architect).
- This is really new territory and requires close collaboration between project team disciplines, local government, and agencies.
- There is an iterative nature of design between geotech, modelers, architect and structural.
- Bring geotech on as soon as possible.
- Professionals must recognize these projects are different from anything else they have ever done: they do not compare to past design development projects done for municipalities.
- Geotech findings will have significant cost impacts on structures, particularly the foundations.
- Modelers are going to help set the structure height, but their input is also subject to the design.
- Modelers should be consulted throughout the design particularly when there is a change in location and geometry.

5. Planning and Design

- Local governments need to look at any upcoming building and critical infrastructure replacement projects to see opportunities. Look where buildings are located relative to evacuation needs. Prioritize what projects to move forward with.
- Make sure we have as much due diligence as possible early in the process. Site conditions are often underestimated.
- The state inundation maps are good for initial site review.
- Select more than one site to review and test.
- Identify clusters of population and overlap with sites of opportunity.
- Do not make the building design look like a fortress.
- Local communities have a preference for community-owned structures, especially schools.
- Work with the University partners to do site-specific modeling and community outreach.
- It's important for these to be multi-use with public benefit.

6. Funding and Budget

- Identify all possible funding but have a plan B if some of the funding does not work out.
- Understand cost impacts before going public.
- The community needs to be presented with the full range of realistic funding options.
- Break it down to cost per person per year do help with sticker shock.
- Public has to see value for their taxes. There is a reluctance to pay full cost, so grants are needed.
- Continue emphasis on funding from FEMA when available.
- Don't talk about funding until there is a project proposal and recommendations in mind.
- Advocate for funding from congressional delegation.
- Private sector dollars are needed. The public sector money will not do it alone.
- These communities are cash strapped. Site selection is based on opportunity and convenience.
- Look for partners to use the facility and to offset costs.

Future Actions

- Coastal communities need to work together to advocate for funds from the state and feds.
- EMD and FEMA could provide funding to model ideal structure types, berms and towers.
- Silver Jacket Committee: Planner, Public Works, Emergency Manager, Elected meet to discuss opportunities and cut through barriers.
- Need a go-to person that can help cut through bureaucracy and confusion.
- Create a data and information repository to add data and lessons learned to. Make this open to all governments in the area/risk zone for knowledge sharing.
- Ride success after one completed project. Continue building structures, inspired by implemented projects until it is an expectation that Washington coastal communities will all have Safe Havens.
- Vertical Evacuation Structure Academy: Specific education and outreach towards community officials, involve WA Chapter Planners and Public Works Association and others.
- State agency and university partners must coordinate together with any release of new information for modeling. Public confusion can hurt the process.
- The process needs to be streamlined, made easier. Even FEMA funding involves a lot of red tape.

Appendix B: Public Meetings

Two public meetings were held in two Washington coastal communities as part of the process to develop this manual. The first meeting was held 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, but also included the adjacent cities of Hoquiam and Cosmopolis.

Each meeting featured a series of presentations by tsunami experts. Time was allotted for audience questions and survey cards were handed out to gather audience responses to a series of questions. In this section, the meeting agenda, survey card results, and other supporting materials are provided.

Ocean Shores Public Meeting

Ocean Shores public meeting on tsunami vertical evacuation structures. Screenshot credit: TVW

The city of Ocean Shores is one of the most heavily impacted communities on the west coast from a major Cascadia Subduction Zone (CSZ) earthquake and tsunami. A CSZ earthquake will generate multiple tsunami waves, the first making landfall approximately 20 minutes after ground shaking stops. Due to a lack of natural and artificial high ground, Ocean Shores requires many vertical evacuation structures. Ocean Shores was also one of the communities included in the original *Project Safe Haven* reports that identified numerous potential sites for evacuation structures. Ocean Shores is a growing community that includes a large population of retirees and hosts a large tourist population during the summer months. The public meeting focused primarily upon vertical evacuation structures. Between 80 and 90 people attended this meeting.

Meeting Agenda

June 12th, Tuesday, 6pm – 8pm
Ocean Shores Convention Center

6:00 – 6:15 Welcome & Opening Comments: Mayor Pro Tem Jon Martin
Chuck Wallace, Deputy Director, Grays Harbor County Emergency Management

6:15 – 6:20 Panel Introductions: Maximilian Dixon, Earthquake Program Manager, Washington State Emergency Management Division (Moderator)

6:20 – 7:00 Panelists

- Jeana Wiser, Project Safe Haven Planner, University of Washington
- Daniel Eungard, Geologist, Washington Geological Survey
- Randall LeVeque, Tsunami Modeler, University of Washington
- Christopher Moore, Oceanographer and Systems Developer, National Oceanic Atmosphere Administration
- Cale Ash, Principal Engineer, Degenkolb Engineers
- Tim Cook, State Hazard Mitigation Officer, Washington State Emergency Management Division

7:00 – 7:50 Questions from Audience

7:50 – 8:00 Closing: Chuck Wallace

Afterwards: Maps with tsunami refuge locations in the back, indicate your top choices.

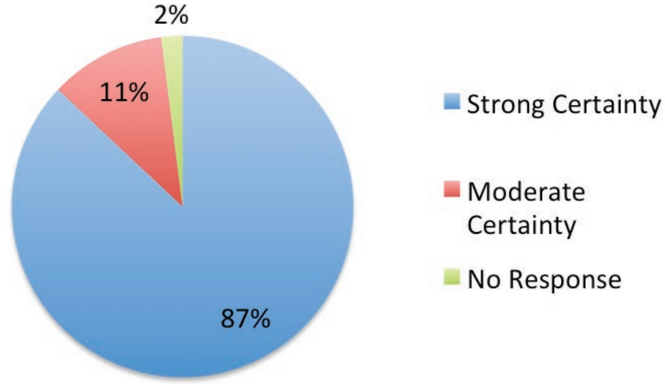
Ocean Shores Survey Card Results

Total Responses: 53

- Key Survey Card Findings by participants:
- Almost 90% felt a strong certainty that vertical evacuation structures could save their life.
- Between 40-50% identified local funding options.
- Near 50% looked to their elected officials and emergency managers for leadership.
- 55% said that the public awareness of the tsunami hazard was a key opportunity.
- 57% cited the cost/funding as the biggest barrier.

Question 1: How certain are you that tsunami refuges could save your life and/or the lives of people in your community?

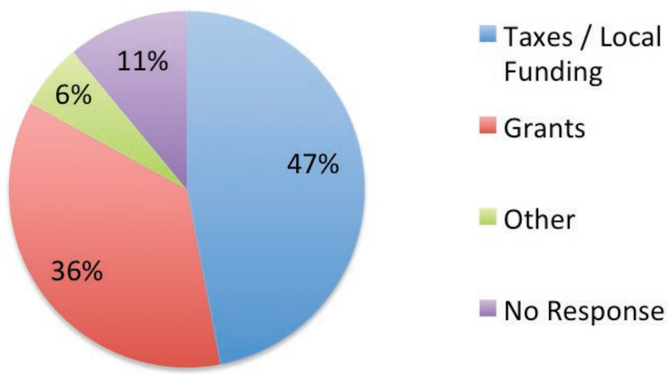
- Strong Certainty: 46/53: 87%
- Moderate Certainty: 6/53: 11%
- No Response: 1/53: 2%



Question 2: What are your top 2 preferences to help fund tsunami vertical evacuation refuges in Ocean Shores, given limited state and federal funds?

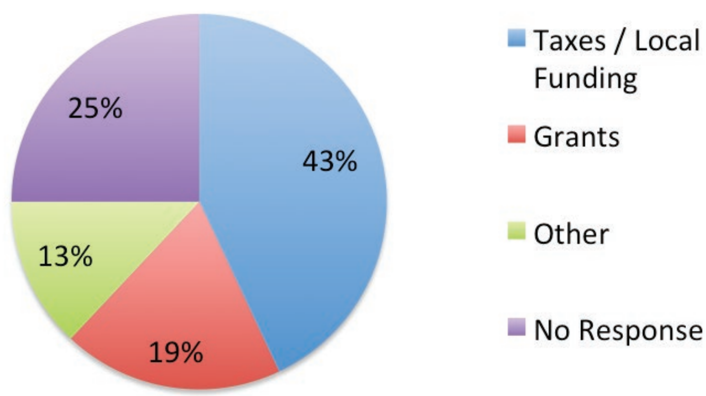
Preference 1:

- Property Tax / Local Tax / Taxes / Bonds / Levy / Assessments / Sales Tax / General Funds / Reserve Funds: 25/53: 47%
- Grants: 19/53: 36%
- Other (*): 3/53 6%
- No Response: 6/53: 11%



Preference 2:

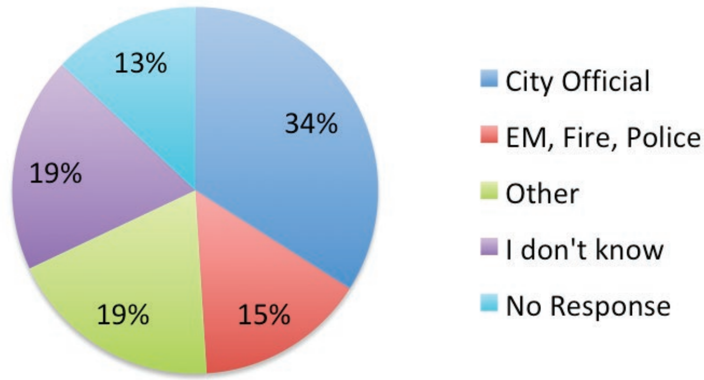
- Property Tax / Local Tax / Taxes / Bonds / Levy / Assessments / Sales Tax / General Funds / Reserve Funds: 23/53: 43%
- Grants: 10/53: 19%
- Other (*): 7/53: 13%
- No Response: 13/53: 25%



(*) *Includes: funding raising, private donations, corporations, labor match, county funding, etc.*

Question 3: Who do you trust in your community to lead a tsunami vertical evacuation refuge process?

- Council, Mayor, Admin: 18/53: 34%
- EM, Fire, Police: 8/53: 15%
- Other (*): 10/53: 19%
- I don't know: 10/53: 19%
- No Response: 7/53 13%

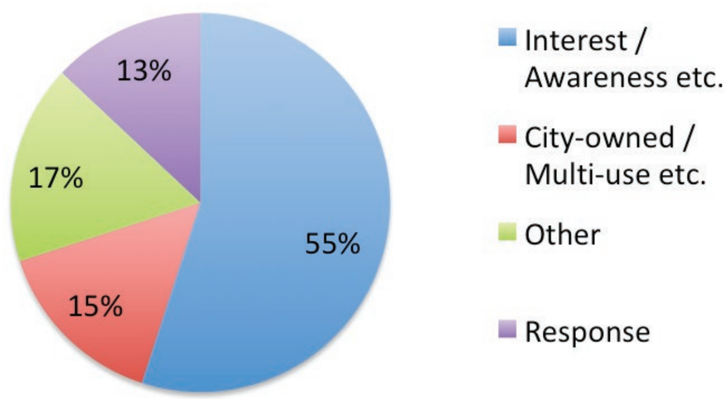


(*) *Includes: local citizens, community organizations, business groups, lack of trust in elected officials, etc.*

Question 4: What do you see as the biggest opportunities & barriers to building tsunami refuges in Ocean Shores?

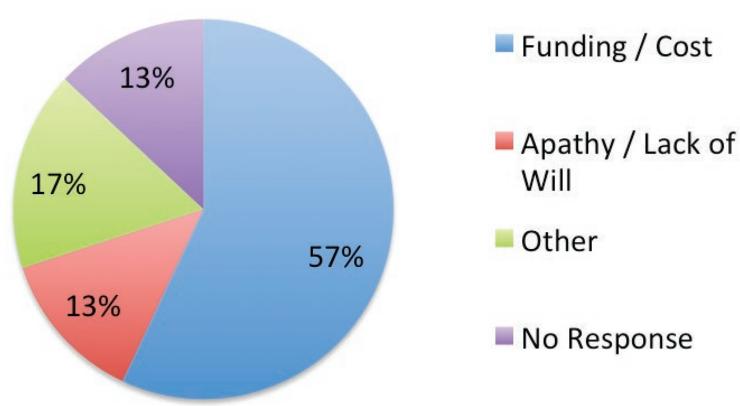
Opportunities:

- Interest / need / awareness: 29/53: 55%
- City owned land / multi-use: 8/53: 15%
- Other (*): 9/53: 17%
- No Response: 7/53: 13%



(*) *Includes: early design, help with grants, shipping containers, jobs, etc.*

- Barriers:
- Funding / Cost: 30/53: 57%
- Apathy / Lack of Will: 8/53: 13%
- Other (*): 8/53 17%
- No Response: 7/53: 13%



(*) *Includes: no public visualization of event, elected officials resistance, bureaucracy, etc.*

Comments: (Written in comment section on back of survey card)

- "Clear instruction on who/what is allowed in the evacuation structure - can all animals be allowed in? How much personal property would be allowed - both these items consume space. Historical view @ large US hurricanes provide examples of what can be expected without guidelines."
- "Until we get structures built - please educate what we should do?"
- "Will pets be allowed in structures?"
- "I'm interested in the topic but live in Olympia, so my comments don't really apply for that reason."
- "Survival after tsunami - food, shelter, medical care. After all my stuff washes around, then what?"
- "Great presentations!"
- "Great speakers!! Well prepared."
- "I wanted to spend more time to give thoughtful answers, but I wanted to listen to Q & A."
- "It was very informative. Thank you."
- "Area's already Islands - Bridge damages – How do these people get to the evacuation above area? Liquefaction, how do people walk on ground that is already jelly form?"
- "More smaller structures."
- "Very well done! Thank you."
- "Did not hear a plan for how to handle those w/ disabilities; especially if non-mobile. How would they be able to ascend a 'tower' or vertical evac. structure?"

Ocean Shores Map Results

Several maps of the city of Ocean Shores with locations for potential vertical evacuation structures were posted on the walls outside the meeting rooms. The maps were put up before the meeting and taken down after the meeting ended and all the attendees had left. Each participant was given two stars to put on a map of Ocean Shores with evacuation structure locations. Participants were told 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. A handful of attendees put stars on these maps. Estimated number of participants 12 to 14. (*)

Map 1:
- 8 Silver Stars
- 6 Colored Stars

Map 2:
- 6 Silver Stars
- 3 Colored Stars

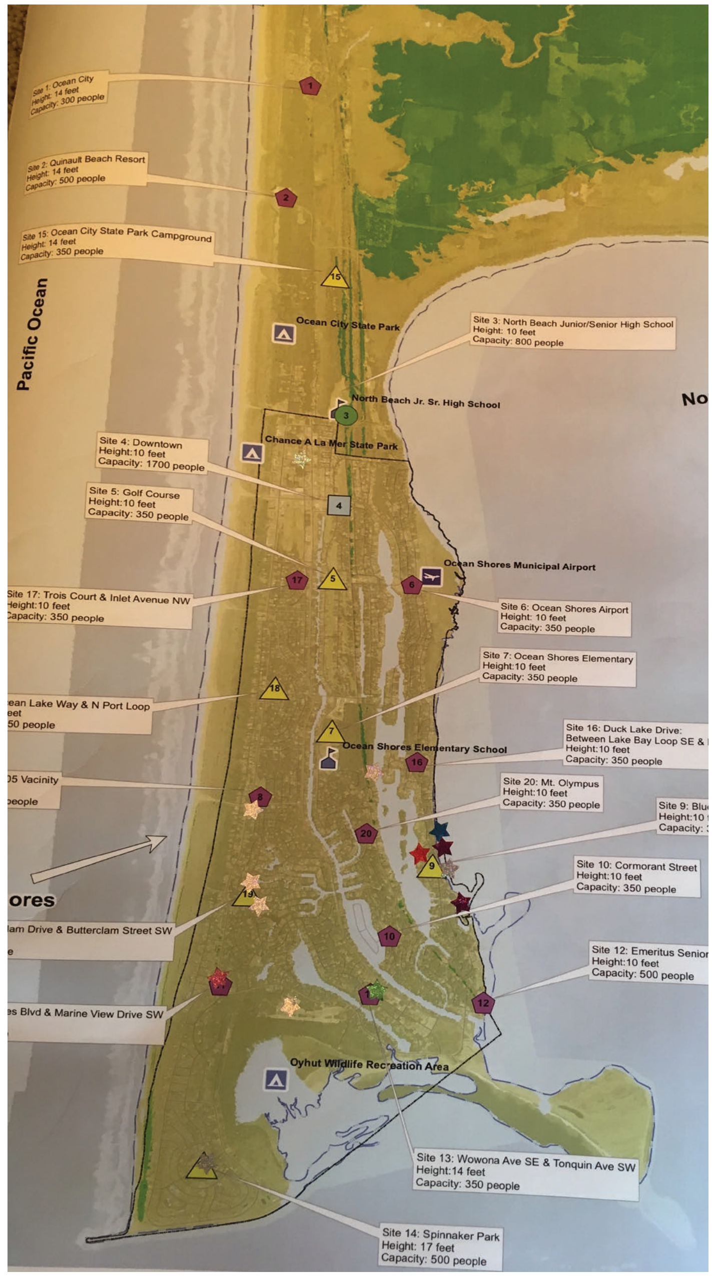
(*) *For both maps, it is possible a person used two silver stars rather than 1 silver star and 1 colored star.*

<u>Findings</u>

- The findings are probably not representative of the whole community but do provide an interesting sampling.

- The stars tend to cluster in the southern portion of Ocean Shores. This is also the area of the community with the farthest distance to natural high ground.

- Map 1 shows silver and colored stars grouped together indicating that participants may have thought that the first community site should be the one near their home.
- Map 2 shows silver stars on the west side and colored stars on the east side. Participants seem to have not located the first community right next to their home. West-side locations would also more likely serve tourists and more seasonal residents.
- Only one silver star was placed on the downtown site for both maps.



Map 1 of Ocean Shores with evacuation structure locations. Silver Stars on first site to be built for community. Colored Stars on site nearest to your home. Photo Credit: UW Project Team

Map 2 of Ocean Shores with evacuation structure locations. Silver Stars on first site to be built for the community. Colored Stars on site nearest your home. Photo Credit: UW Project Team

Aberdeen, Hoquiam, Cosmopolis Public Meeting

The Cities of Aberdeen, Hoquiam, and Cosmopolis are located at the mouth of the Chehalis River at the east end of Grays Harbor. A CSZ earthquake will generate multiple tsunami waves, the first making landfall approximately 50-70 minutes after ground shaking stops. Much of the built-up portions of these cities are low lying and will be inundated. These cities also have ample access to natural high ground, although horizontal evacuation routes may need improvement. There are sections of these cities that may benefit from building vertical evacuation structures or including a vertical evacuation component in a new building. Aberdeen, Hoquiam, and Cosmopolis were not part of the *Project Safe Haven* reports. The public meeting covered overall tsunami preparedness and both horizontal and vertical evacuation options. Between 40 and 50 people attended this meeting.

Meeting Agenda

August 8th, Wednesday, 6pm – 8pm
Aberdeen High School

6:00 – 6:10 Welcome and Opening Comments

- Dr. Alicia Henderson, Superintendent, Aberdeen School District
- Chuck Wallace, Deputy Director, Grays Harbor County Emergency Management

6:10 – 7:20 Speakers

- Maximilian Dixon, Earthquake Program Manager, Washington State Emergency Management Division
- Daniel Eungard, Geologist, Washington Geological Survey
- Cale Ash, Principal Engineer, Degenkolb Engineers
- Tim Cook, State Hazard Mitigation Officer, Washington State Emergency Management Division
- Bob Freitag, Director, University of Washington Institute for Hazards Mitigation Planning and Research
- Chuck Wallace, Deputy Director, Grays Harbor County Emergency Management

7:20 – 7:50 Question and Answer

7:50 – 8:00 Closing

- Dr. Alicia Henderson, Superintendent, Aberdeen School District
- Maximilian Dixon, Earthquake Program Manager, Washington State Emergency Management Division

Aberdeen, Hoquiam, Cosmopolis Survey Card Results

Total Responses: 32

Key Survey Card Findings by participants:

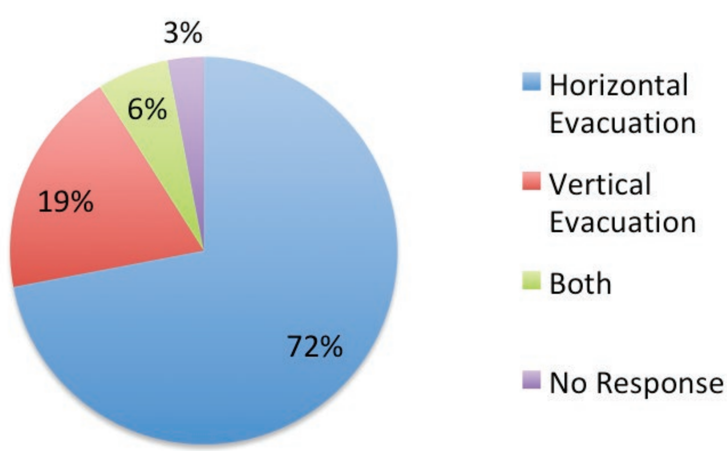
- 72% said horizontal evacuation provides greatest safety.
- For both funding preference #1 (35%) and #2 (47%), local taxing came in first.
- 50% chose local officials and emergency management to lead this effort.
- 50% said a combination of partnerships, leadership, research, and the new school levy are the biggest opportunities.
- 76% said a combination of lack of funding, low-income area, lack of leadership, and community involvement and lack of awareness are the biggest obstacles.

Aberdeen public meeting on tsunami survival options. Photo Credit: UW Project Team

Question 1: What provides the greatest safety for your community?

Horizontal evacuation access to high ground outside of the risk area – trails, bridges, roads.
Vertical evacuation opportunities above the level of flooding – tall structures or towers.

- Horizontal evacuation (23/32): 72%
- Vertical evacuation (6/32): 19%
- Both (2/32): 6%
- No Response (1/32): 3%

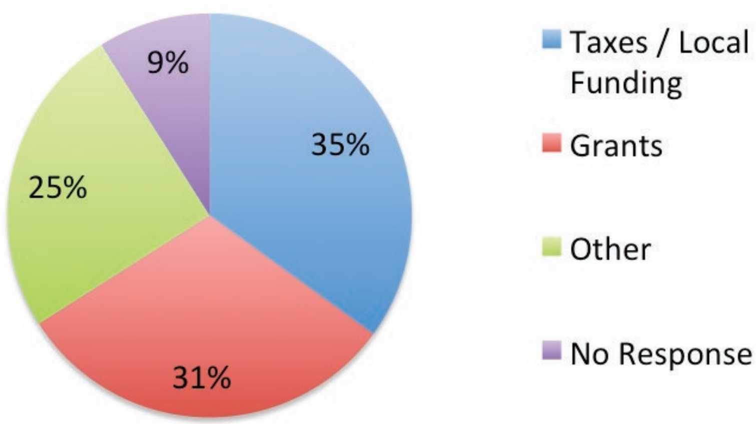


Comments:

- (Chose (a) horizontal evacuation) "When there are no vertical evacuation structures."
- (Chose (a) horizontal evacuation) "Both apply."
- "Uncertain - I will need to walk two miles to the closest high ground from the Chehalis River."
- "I live on Lawrence Drive in Hoquiam. I'm on bedrock but my best friend lives on Chenault, a landslide area and tsunami zone. I can go up to Sunset Cemetery but she will be stuck with no where to go. I need horizontal evac. She needs vertical evac. We live about 2.5 minutes away from each other."
- "Until we have enough vertical evacuation sites."
- "Lots of existing routes and public lands available = less money."
- "Aberdeen has options if they can be accessed."
- "Not enough trails and bridges."
- "All we got!"
- "Both - depending on location in community."
- "S. Evans Street Evac. route is unsafe."
- "We have not horizontal evac. in Ocean Shores."
- "I've been here 6 weeks and trying to learn."
- "Some evacuation routes unsafe for walking."
- "Lots of bridges and bluffs that could fail causing no where to go."

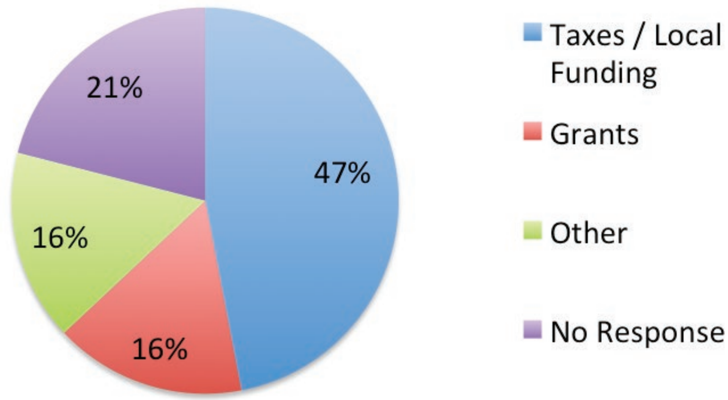
Question 2: What are your top 2 preferences to fund access to evacuation opportunities given limited state and federal funds?

Preference 1:
- Property Tax / Bonds / Special Assessments / Local Improvement District / Excise Tax (11/32): 35%
- Grants (10/32): 31%
- (*) Other (8/32): 25%
- No Response (3/32): 9%



Preference 2:

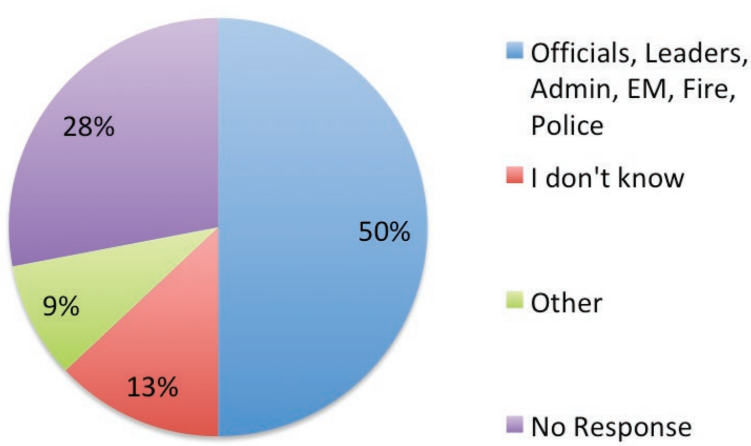
- Property Tax / Bonds / User Tax / Sales Tax: (15/32) 47%
- Grants (5/32): 16%
- (*) Other (5/32): 16%
- No Response (7/32): 21%



(*) *Includes: vertical evacuation structures; trails and bridges; clear access to horizontal evacuation sites; roads and trails; community information; I don't know.*

Question 3: Who do you trust in your community to lead the effort?

- Elected Officials / School District Leader / City Staff / Emergency Management, Fire, Police (16/32) 50%
- I don't know (4/32): 13%
- (*) Other (3/32): 9%
- No Response (9/32): 28%

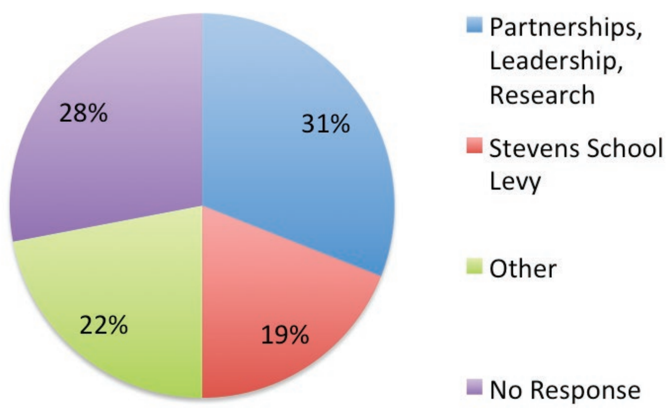


(*) *Includes: Shoalwater Tribe; collaborative efforts with local shareholders; no one.*

Question 4: What do you see as the biggest opportunities & barriers to funding evacuation projects?

Opportunities:

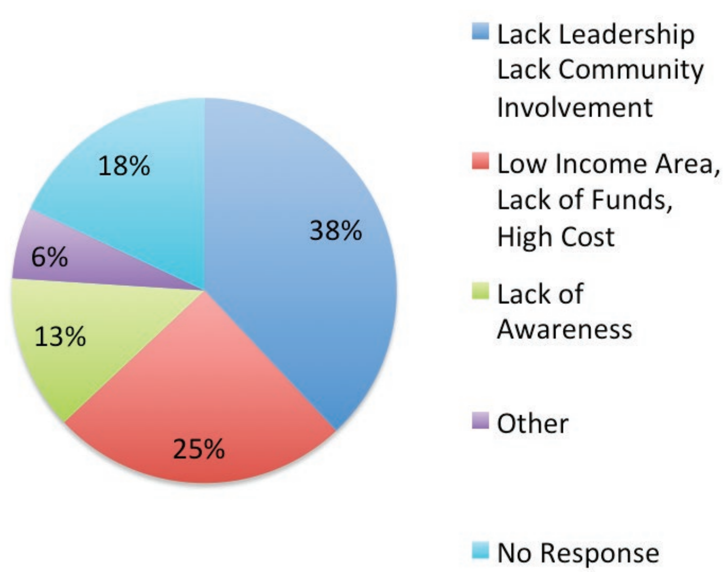
- Partnerships / Leadership / Research (10/32): 31%
- Stevens new school levy (6/32) 19%
- (*) Other (7/32): 22%
- No Response (9/32): 28%



(*) *Includes: cranberry bogs (open ground, roads and dikes); roads; available properties; taxes and grants.*

Barriers:

- Lack of leadership & community involvement (12/32) 38%
- Low income area / lack of funds / high cost (8/32): 25%
- Lack of awareness (4/32): 13%
- (*) Other (2/32) 6%
- No Response (6/32): 18%



(*) *Includes: limited crossings of drainage ditch; logging roads at times are gated/locked.*

Comments: (Written in comment section on back of survey card)

- "Not that I can think of at this time. Thank you!"
- "Excellent. Very informative. Thank you."
- "Data for further inland; up the Chehalis River!"
- "Who maintains the vertical structures? Keep clean and ready, not taken over by homeless or drug addicts. How much does it cost to develop higher ground areas for evacuation, cheaper than buildings?"
- "Great Presentation."
- "Educate us on what does not work so we do not repeat these efforts."
- "Great information in a lot of areas."
- "There are some real sharp young people working on this issue. My take away is Hooray!"
- "Good show, learned a lot."
- "Survivability of the earthquake has not been addressed. Preparedness should include hard decisions including (1) leave as help trapped individuals (2) leave or assist injured individuals (3) carry on infant or a prepared kit. / In Grayland the need to talk/run to the hills is the only option. The lack of bridges across the drainage ditch limits routes and increases distances."
- "Great Job! Thank you!
- "Fuel storage tank above and below ground are not protected from tsunami flood fuel contamination. Ocosta School is vulnerable to debris accumulation and fire. Advanced communication should be mandatory for EMD including satellite Internet. Local National Guard and others have very few members living locally. Why not cross train Air National Guard?"
- "With evacuation on foot, how are electric lines managed to reduce risk of electrical hazards/ downed lines? Is there protocol to cut power?"
- "I enjoyed the presentation and found it very informative."

Appendix C: New Zealand Report

A research team from New Zealand conducted interviews with several Washington State coastal community residents in the summer of 2018. They asked residents a variety of questions about tsunami vertical evacuation structures. Several of these findings are integrated into the manual.

Understanding community participation of tsunami vertical-evacuation planning in the coastal Washington communities: key findings from 2018 focus groups and interviews

David Johnston, Caroline Orchiston, Lucy Carter, Kate Boersen, Carla Jellum

Background

Improving the response capacity of coastal communities with high tsunami risk presents an on-going challenge. Since 2001, Washington State Emergency Management Division has sought to meet this challenge with implementation of its tsunami education and preparedness programs, and monitoring and evaluation of such initiatives (Johnston et al. 2014; Johnston et al. 2018). This study presents preliminary results of the most recent effort to explore community participation in tsunami vertical-evacuation planning and understanding on the Washington coast. This work will contribute to on-going Project Safe Haven initiatives led by the University of Washington, which is designing a Manual to provide practical guidance for local leaders in building tsunami vertical evacuation structures.

The aim of this qualitative research undertaken on the Washington coast is to investigate community perspectives and understanding of local vertical evacuation developments. The four selected communities for this study; Long Beach, Tokeland, Westport and Ocean Shores are each at different stages in the planning and development of vertical evacuation structures.

- Long Beach developed an initial plan for a vertical evacuation structure in the form of an earth berm. However, after a scoping and design phase, the plan was rejected and withdrawn due to a number of factors. Both the community and City administration had a number of concerns about cost, engineering and proposed location.

- Tokeland has a proposed vertical evacuation structure in the final stages of funding approval from FEMA. This initiative has been driven by Shoalwater Bay Tribe in close collaboration with a range of agencies.

- Westport completed the redevelopment of Ocosta School which included a tsunami evacuation tower as part of the dual purpose design. This structure can accommodate 2,000 people, and is available for use by the whole Westport community.

- Ocean Shores is at a community consultation stage around options for vertical evacuation structures.

These four communities offer insights into the process of developing community-led, agency-supported vertical evacuation developments which firstly, will assist with the development of the Manual, and secondly, will be useful for other community-led vertical evacuation initiatives in and beyond Washington.

Methods

Data collection took place in both Pacific and Grays Harbor Counties on the Washington coast between the 19th and 21st of June 2018. Two focus group meetings were held at Long Beach and one at Tokeland. Semi-structured focus group discussion sessions were conducted with a total of 15 participants, and were based around nine key questions (see Appendix 1). Permission was sought to digitally record the sessions for later transcription, and all participants agreed.

The focus groups were followed by 42 semi-structured interviews with members of the public in Westport and Ocean Shores. Participants were asked a subset of the nine questions used in the focus groups, and one additional question about their knowledge of tsunami risk in their community. It was necessary to ask fewer questions in the context of approaching people in public places, because we didn't want to take up too much of their time. The questions included:

1. How long have lived on the Washington coast?
2. What do you understand about about tsunami risk in your community?
3. What do you know about the tsunami vertical evacuation structures that have been built or are proposed in your community?
4. How certain are you that tsunami vertical evacuation structures could save your life, and/or the lives of people in your community?
5. Do you support the proposed structures and/or the idea of structures being built in your community?
6. Who is paying / should pay for them? Who do you think is responsible for paying?

A preliminary thematic analysis was then undertaken, and key themes extracted from the data. Preliminary results for both the focus groups and semi-structured interviews are presented below.

This research was conducted following the guidelines as outlined in Massey University's (New Zealand) code of ethics. Project Identification Code: 4000019715.

Results

Preliminary results for focus groups and semi-structured inteviews are presented. As noted above, each of the four communities are at different stages in the process, hence the wording of each question was adapted, depending on location.

1. **How long have you lived on the Washington coast?**

    - All participants were included in the sample if they had resided within close proximity of the Washington coast over the last year or longer. Visitors were not included, because the research was designed to target local opinion and understanding of community-led tsunami vertical evacuation processes.

2. **What do you know about the tsunami vertical evacuation structures that have been built (or are proposed) in your community?**

    - Long Beach: People were aware of the earlier berm proposal and referenced media (local newspaper) coverage on this. There was some confusion, however, on where the proposal was at and who had proposed it.

    - Tokeland: People were aware of the structure but there were varying degrees of knowledge on the details of the proposed structure (how many people it will hold, location, whether animals can access it, disabled accessibility).

    - Westport: Everyone knew about the school but there was confusion over who would be allowed to use the structure.

    - Ocean Shores: People understood that there is a risk and while many were fatalistic about their opportunity to escape from a major event, they had evacuation plans. There was some acknowledge that Ocean Shores is at the beginning of a process of investigating the development of vertical evacuation, and a few individuals (2) were aware of the Tsunami Roadshow workshop on June 12th.

3. **What are the top two things that you would like to know about vertical evacuation structures to help you understand them?**

There were a range of responses to this question, but three key questions were most frequently asked.

- What type of structure is being (will be) built?

- Who is going to pay for it?

- Where is it going to be built?

4. **How certain are you that tsunami vertical evacuation structures could save your life, and/or the lives of people in your community?**

    - Yes they could, but there were concerns over the ability of community members to get to the structure in time (i.e. more communication on routes and timing).

    - Mistrust of the engineering and design (particularly in reference to the berm in Long Beach).

5. **Do you support the proposed structures and/or the idea of structures being built in your community?**

    - There was almost universal support for the development of vertical evacuation across all communities. Many participants identified their preference for structures to be dual or multi-purpose. They also had concerns about cost, engineering and location.

6. **What do you see as the biggest opportunities and challenges (barriers) to building tsunami vertical structures in your community?**

    - Opportunity: co-design to ensure dual or multi-purpose.
    - Challenge: local geology (concern that foundations into sand would not be strong enough).
    - Challenge: mixed expectation of funding from local, state and federal leadership.
    - Challenge: height restriction in the building code (this relates to existing or new buildings becoming vertical evacuation structures).

7. **What support is needed for them to be built?**

    - Community
    - Science
    - Engineering
    - Local leadership
    - Education
    - Financing

8. **Who is paying for / should pay for them? Who do you think is responsible for paying?**

    - Mixed attitudes towards local taxation: The majority of participants were supportive of contributing through property tax. Business owners in Ocean Shores brought up the recent cost of road improvements which they had to contribute to as a concern.

    - Despite the ballot passing, some Westport participants said that they didn't vote for it and weren't asked about it.

    - Long Beach brought up the class divide in the area, with wealthy communities in the (tsunami safe) hills, and poorer residents residing at sea level.

9. **Who do you trust in your community to lead a tsunami VE process or project?**

    - Issues around trust were explored in the focus groups in Long beach and Tokeland.

    - Long Beach: participants struggled to identifiy a specific person, group or agency to drive a future development.

    - Tokeland: "Us, we're doing it". One non-Tribal resident said she thought they were doing a good job and trusted they were making good decisions.

Recommendations

- Funding: We suggest communicating the approximate annual or monthly cost of the structure for an individual person, rather than the total cost of the structure. Additionally, discussing the 'additional' cost of vertical evacuation to proposed structures (i.e. 25% more to incorporate vertical evacuation standards into a building that is already planned vs. the total cost).

- Dual or Multi-purpose Designs: There was strong support for dual purpose design and language and messaging needs to reflect these aspirations for the community i.e. a berm also being referred to as an opportunity to build a children's play area, or open space/park.

- Leadership: The community sees emergency management as the role of existing leaders in the community as opposed to emerging from the community itself, therefore communities need more local empowerment.

- Communication and Education: A range of on-going communication and engagement is required to continue to build awareness, and to promote vertical evacuation into the future. For example, the Ocosta School evacuation tower is widely known by the local community, however there is some confusion about how to access it, and its capacity to host the community. In addition, an enhanced strategy is needed to improve knowledge on tsunami evacuation, including drills, which could use messaging such as 'Long, strong, get gone' since participants are currently reliant on sirens and local messaging (radio and apps) to tell them to evacuate. Few people described the natural warning (strong ground shaking) that would motivate them to evacuate. Such efforts should remain a part of on-going County and State (including school) engagement programmes.

- Trust: Open and honest conversations need to continue throughout the development of future vertical evacuation structures. Long Beach is an example of a community that has currently lost trust in the process, however a positive future outcome can help regain trust. In contrast, Tokeland has built strong relationships over a long time before starting the process, which should be encouraged in other communities.

References

Johnston D, Orchiston C, Dixon M, Terbush B, Becker J, Leonard G. 2018. Community understanding of tsunami risk in coastal Washington, USA. Proceedings of the 11th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Los Angeles, CA. 2018.

Johnston, D, Johnson V, Becker J, Leonard G, Fraser S, Saunders W, Wright K, Paton D, Gregg C, Houghton B, Schelling J, Nelson D, Crawford G, Walker B, Wood N. 2014. Evaluating tsunami education in coast Washington, USA: A 2001-2012 review. Proceedings of the 10th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Anchorage, AK, 2014.

Note: This report will be released as GNS Science Report No. 2018/30

Appendix I: Semi-structured interview questions

Date: Mon Tues Weds Thurs
Location: Long Beach Tokeland Ocean Shores
Interviewer: DJ CO LC KB

1. How long have you lived on the Washington coast?

2. What do you know about the tsunami vertical evacuation structures that have been built or are proposed in your community?

3. What are the top two things that you would like to know about vertical evacuation structures to help you understand them?

4. How certain are you that tsunami vertical evacuation structures could save your life, and/or the lives of people in your community?

5. Do you support the proposed structures and/or the idea of structures being built in your community?

6. What do you see as the biggest opportunities and challenges (barriers) to building tsunami vertical structures in your community?

7. What support is needed for them to be built?

8. Who is paying for them? Who do you think is responsible for paying?

9. Who do you trust in your community to lead a tsunami vertical evacuation process or project?

Tsunami Evacuation Sign in New Zealand. Photo Credit: David Johnston

Appendix D: Resources

The Resources section provides a description of partner-organization and related websites, key reports, articles and videos, and the contact information for state and county emergency management staff. This section supports coastal communities in connecting with the people, resources, and information that will allow them to be most successful in their tsunami evacuation planning efforts.

Organizations

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: https://www.ready.gov/tsunamis
- Tsunami Information Sheet: https://www.fema.gov/media-library/assets/documents/162057

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: https://www.tsunami.gov
- NOAA Center for Tsunami Research and Forecasting: https://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. These grants are the primary funding source for projects that further the efforts of the NTHMP and NOAA's TsunamiReady program.

- NTHMP website: https://nws.weather.gov/nthmp/index.html
- 2018-2023 Strategic Plan: https://nws.weather.gov/nthmp/documents/NTHMPStrategicPlan.pdf

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: https://www.tsunami.gov
- Text: https://twitter.com/NWS_NTWC
- Facebook: https://www.facebook.com/NWSNTWC

Pacific Tsunami Warning System: https://www.tsunami.gov/?page=productRetrieval
- Text: https://twitter.com/NWS_PTWC
- Facebook: https://www.facebook.com/UsNwsPacificTsunamiWarningCenter

UNESCO's Intergovernmental Oceanographic Commission (UNESCO/IOC)
The IOC is the only UN body specialized in ocean science and services. It provides a focus for other UN organizations and agencies with regard to ocean science, observations and data exchange, and services such as global tsunami warning systems.
- Email: tsunami-information-ioc@lists.unesco.org

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): https://pubs.er.usgs.gov/publication/pp1707
- Earthquake Notification Service: https://earthquake.usgs.gov/ens/register
- Pacific Coastal and Marine Science Center: https://walrus.wr.usgs.gov
- Can It Happen Here?: https://earthquake.usgs.gov/learn/topics/canit.php
- Coastal and Marine Geology Program: https://marine.usgs.gov/research/hazards.php
- USGS Earthquake Resources Links: https://earthquake.usgs.gov/learn/topics/all.php

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

State

Washington State Emergency Management Division (EMD)
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. EMD is the lead agency in helping coastal communities understand and prepare for tsunamis. EMD assists with public outreach and information, funding, and coordination with a variety of federal, state, and local partners.
- Preparedness: https://www.mil.wa.gov/preparedness
- Tsunami: https://www.mil.wa.gov/tsunami
- Mitigation Grants: https://www.mil.wa.gov/HMAgrants
- FEMA's Hazard Mitigation Assistance: https://www.fema.gov/hazard-mitigation-assistance

- FEMA's Hazard Mitigation Assistance Guidance and Addendum: https://www.fema.gov/media-library/assets/documents/103279 and email HMA@mil.wa.gov for questions.

Washington State Department of Natural Resources (DNR)

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

- Washington Geologic Information Portal: https://geologyportal.dnr.wa.gov/
- Geologic Hazard Maps, Tsunami Inundation: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/geologic-hazard-maps#tsunami-inundation
- Tsunamis: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/tsunamis
- 3D web map of flood/tsunami hazard in Aberdeen, Hoquiam, and Cosmopolis: https://fema.maps.arcgis.com/apps/Styler/index.html?appid=6bccc9c8386748b08d20f08626856fed

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): https://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.

- http://www.wacoastalnetwork.com

Washington Coastal Resilience Project (WCRP): Bolstering Resilience to Coastal Hazards

WCRP is a three-year effort to rapidly increase the state's capacity to prepare for natural events that threaten the coast. The project will improve risk projections, provide better guidance for land use planners, and strengthen capital investment programs for coastal restoration and infrastructure. These are the tools that coastal communities need to become more resilient to disasters.

- http://www.wacoastalnetwork.com/washington-coastal-resilience-project.html

Reports

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. To find out more, *go to Chapter 4.5: Project Safe Haven Planning Process*.

- Clallam County Final Report PDF: https://www.mil.wa.gov/uploads/pdf/emergency-management/haz_safehavenreport_clallam.pdf

- Makah and Quileute Tribes Final Report PDF: https://www.mil.wa.gov/uploads/pdf/emergency-management/haz_safehavenreport_makahquileute.pdf

- Grays Harbor County Final Report PDF: https://www.mil.wa.gov/uploads/pdf/emergency-management/haz_safehavenreport_graysharbor.pdf

- Pacific County Final Report PDF: https://www.mil.wa.gov/uploads/pdf/emergency-management/haz_safehavenreport_pacific.pdf

FEMA P-646 Report: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis
This document, produced in coordination with NOAA, provided the first report for tsunami vertical evacuation structures in North America when it was published in 2008. The report provides information on tsunami hazards, modeling, evacuation structure planning, and structural considerations. In 2009, an abbreviated guide was produced for elected officials. In 2012, the overall report was updated and another update is currently underway.

- 2009 Community Officials Report: https://www.fema.gov/media-library-data/20130726-1719-25045-1822/fema_p646a.pdf
- 2012 Full Report: https://www.fema.gov/media-library-data/1426211456953-f02dffee4679d659f62f414639afa806/FEMAP-646_508.pdf

Resilient Washington Subcommittee Report (2017)
The Resilient Washington Subcabinet was 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 and includes nine recommendations and three directives. This report is cited in the Executive Summary in this manual.

- https://mil.wa.gov/uploads/pdf/resilient-wa-subcabinet/rw-subcabinet-draft-reprt-with-appendices-9.22.17.pdf
- Meeting of the Subcommittee: https://www.tvw.org/watch/?eventID=2017091073

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, some of which are cited in *Chapter 6: Five Recommendations* in this manual.

- https://s3.wp.wsu.edu/uploads/sites/2180/2013/06/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.

- https://www.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.

- http://www.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.

- https://www.sciencedirect.com/science/article/pii/S2212420914000387

Slide Presentations

American Society of Civil Engineers (ASCE) PowerPoint Presentation
This slide presentation provides information on the *ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Its *Chapter 6: Tsunami Loads and Effects* is the current standard for designers of tsunami vertical evacuation structures. ASCE 7-16 has been adopted for reference as part of the 2018 International Building Code (IBC), which guides design of structures in Washington State. Washington State may officially adopt ASCE 7-16 in early 2020.

- https://www.asce.org/uploadedFiles/News_Articles/ASCE-Press-Event-Presentations.pdf

Videos

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. For more information on findings from this public meeting, *go to Appendix B: Public Meetings*. The event was recorded and televised by TVW and is available here:

- https://www.tvw.org/watch/?eventID=2018061070

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.

- https://www.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.

- https://www.youtube.com/watch?v=otI7bUrUOmI

Washington Tsunami Roadshow (April 2018)
The EMD visits coastal communities and provides presentations on tsunami hazards as part of the annual Washington Tsunami Roadshow. The presentations highlight resident preparedness and alert messaging. The event was recorded and televised by TVW and is available here:

- https://www.tvw.org/watch/?eventID=2018041007

Washington Tsunami Roadshow Presentations (PDF):

- EMD: https://mil.wa.gov/uploads/pdf/emergency-management/180410_waemd_tsunami-roadshow.pdf
- NOAA: https://mil.wa.gov/uploads/pdf/emergency-management/washington-state-tsunami-roadshow_noaa-nws_2018.pdf
- DNR: https://mil.wa.gov/uploads/pdf/emergency-management/eungard_science_modeling_overview.pdf
- Sea Grant: https://mil.wa.gov/uploads/pdf/emergency-management/tsunami_roadshow_cegl.pdf

National Geographic Tsunamis 101 (2015)
This video provides an overview of tsunamis.

- https://www.youtube.com/watch?v=_oPb_9gOdn4

Climate Change and the Jersey Shore: Impacts on Coastal Communities, Ecosystems, and Economies (2016)
This video by Rutgers University reviews the variety of impacts on coastal communities from global warming. Although the video focuses on the Jersey shore, many of the same impacts are of concern for Washington State coastal residents.

- https://www.youtube.com/watch?v=G7YJgsliy1g

Washington State Contacts

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https://www.pacificcountysheriff.com/emergency-management.html

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https://www.co.pierce.wa.us/104/Emergency-Management

San Juan County
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mmestas@sjcounty.net / 505.334.7700 / https://www.sjcoem.com

Skagit County
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https://www.skagitcounty.net/Departments/EmergencyManagement/main.html

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https://snohomishcountywa.gov/180/Emergency-Management

Whatcom County
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jgargett@co.whatcom.wa.us / 360.676.6681
https://www.whatcomcounty.us/201/Emergency-Management

Washington State Tribal Emergency Management Contacts

Hoh Tribe
360.374.6582 / http://hohtribe-nsn.org/?page_id=1010

Jamestown S'Kallam Tribe
360.683.1109 / http://www.jamestowntribe.org/

Lummi Nation
360.312.2000 / https://www.lummi-nsn.gov/Website.php?PageID=384

Makah Tribe
360.645.2201 / http://makah.com/

Port Gamble S'Kallam Tribe
360.297.2646 / https://www.pgst.nsn.us/contact-info-a-directions

Puyallup Tribe
253.573-7800 / http://www.puyallup-tribe.com/directory/

Quileute Tribe
360.374.6163 / https://quileutenation.org/contacts/

Quinault Nation
360.276.8215 / http://www.quinaultindiannation.com/contactus1.htm

Samish Nation
360.293.6404 / http://www.samishtribe.nsn.us/contact/

Shoalwater Bay Tribe
360.267.0119 / http://shoalwaterbay-nsn.gov/home/about-the-tribe/contact-us/

Skokomish Tribe
360.426.4232 / http://www.skokomish.org/tribal-directory/

Squaxin Island Tribe
360.432.3945 / http://squaxinisland.org/info/contact-information/

Suquamish Tribe
360.598.3311 / https://suquamish.nsn.us/

Swinomish Tribe
360.466.7280 / http://www.swinomish.org/contact.aspx

Tulalip Tribe
360.716.4000 / https://www.tulaliptribes-nsn.gov/Home/ContactUs.aspx

Appendix E: Glossary

American Society of Civil Engineers (ASCE) and ASCE 7-16

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. In 2017, ASCE published *ASCE 7-16 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. ASCE 7-16 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.

Bathymetry

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

Cascadia Subduction Zone (CSZ)

The CSZ stretches from Vancouver Island, Canada, to Northern California and measures over 600 miles in length. The CSZ is beneath the Pacific Ocean, just off North America's west coast and is at the juncture of the Juan de Fuca and North American tectonic plates. In the last 10,000 years, there have been at least 23 earthquake events rupturing the entire length of the Cascadia Subduction Zone (CSZ). These earthquakes had magnitudes estimated between 8.5-9.1 Mw. The time between events has been as short as 80 years and as long at 1,100 years, with an average of ~300 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, and produced a tsunami event recorded in Japan that establishes the date as January 26, 1700.

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 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.

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.

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 the earthquake shaking, 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.

Local Source and Distant Source Tsunamis

A local tsunami is from a nearby source that can arrive in less than an hour and as little as a few minutes. A distant tsunami comes from a far away source and has a travel time of over three hours. Washington State is at-risk from both tsunami sources. 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. Distant source tsunamis can come from as far away as Alaska (1964) and even Japan (2011).

Pedestrian Evacuation Model

Utilizing tools created by the United States Geological Survey with input from local emergency managers, the Department of Natural Resources (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.

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. Multiple tsunami waves will be generated following a CSZ earthquake.

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

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 often too damaged for vehicle travel. Horizontal evacuation routes can lead out of the inundation zone or to natural or artificial high ground within the inundation zone, such as a tsunami vertical evacuation structure.

Vertical Evacuation

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.

Tsunami Inundation Map

DNR produces tsunami inundation maps for Washington State. These maps show the amount of flooding or inundation depth 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. DNR has published 14 inundation maps since 2000 covering about 50% of Washington's coastline. Tsunami inundation maps are essential for mitigation and evacuation planning.

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.

Tsunami and earthquake advisory. Image Credit: Great ShakeOut

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, engineering berms (artificial hills), or be integrated into buildings.