Tsunami Maritime Response and Mitigation Strategy:

Westport Marina, Port of Grays Harbor

Westport, Washington

2022

Prepared for:

Westport Marina

Port of Grays Harbor

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Front Cover: Westport Marina, Port of Grays Harbor

Table of Contents

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Executive Summary

The State of Washington has the second highest earthquake risk and one of the highest tsunami risks in the nation. Western Washington has dozens of active local crustal faults and a subduction zone fault. These faults, along with local landslides and distant earthquakes across the Pacific Ocean (i.e. Alaska, Japan, Chile, etc.) can generate dangerous tsunamis that could severely impact coastal communities along the outer Pacific coast and inland waters of the Salish Sea, including Puget Sound.

The highest risk “local source” tsunami for Grays Harbor, WA is from the seven-hundred-mile-long Cascadia Subduction Zone (CSZ), which lies just off the Pacific Ocean coastline of Washington and runs from northern California up to Vancouver Island, BC Canada. The CSZ can generate a powerful magnitude 9+ earthquake, which could cause severe ground shaking for 3 to 6 minutes. A CSZ earthquake can generate 60+ foot high tsunami waves that hit the Pacific coast of Washington within just 10-20 minutes after the earth starts to shake. These tsunamis waves can last 12-24 hours or longer.

The highest risk “distant source” tsunami is from a magnitude 9.2+ Alaska subduction zone earthquake (similar to the one in 1964), which we refer to as the Alaska Maximum WA (AKMaxWA). An AKMaxWA earthquake can generate about 20-foot-high tsunami waves that hit the Pacific coast of Washington within 3 hours and 30 minutes. The tsunami waves can also last 12-24 hours or longer.

Among the most vulnerable facilities to tsunami impacts are ports, harbors, and marinas, which are typically located along shorelines in developed areas. They are often built on land created from dredged soil and are thus susceptible to liquefaction in addition to tsunami impacts. Ports are a vital component of the maritime industry, which is comprised of key infrastructure for transportation, travel, and commerce. Ports provide and operate commercial marine transportation facilities that ship a wide spectrum of commodities ranging from grain (bulk) to container cargoes. Ports also maintain and operate airports, commercial and pleasure boat marinas, subsidized space for start-up businesses, cold-storage plants, log-export yards, boat launch ramps, and even short-haul railroads. The maritime industry in Washington is a $21.6 billion industry contributing directly and indirectly to 146,000 jobs and $30 billion in economic activity.

The ability of ports, harbors, and marinas to withstand a disaster and resume operations quickly will be a major factor in the recovery of the local community and economy in the short and long term. One way to help is to develop a strategy with recommended actions that can be implemented to increase port resilience. Contained within this document is the tsunami maritime response and mitigation strategy for the Port of Grays Harbor’s facilities at Westport Marina, including response guidance in the event of tsunamis for Small Craft (vessels under 300 gross tons) such as recreational sailing and motor vessels, and commercial fishing vessels.

Document Layout

Section 1: Introduction begins by explaining what a tsunami is and the differences between local source and distant source tsunamis. It then provides an overview of the hazards the maritime community faces from tsunamis. Finally, it provides an overview of Westport Marina.

Section 2: **Tsunami Maritime Risk and Guidance** covers the maritime risk from local and distant source tsunamis and provides an overview on how to respond during a tsunami. It then explains the different tsunami alert levels and the different ways people can get alerted for tsunamis, including natural warning signs.

Section 3: Response Guidance for Westport Marina, Port of Grays Harbor focuses on recommended response actions for the Westport Marina and the agencies or entities responsible for performing them. Some examples include evacuating people to high ground and restricting people from entering the tsunami inundation zone.

Section 4: Mitigation Guidance for Westport Marina, Port of Grays Harbor provides recommended mitigation actions for the Westport Marina. It covers site-specific mitigation actions that can be undertaken to allow the marina to become more resilient in the event of a tsunami. Some example mitigation actions include strengthening cleats and moorings, installing tsunami signs, and increasing the height of dock piles.

Section 5: Conclusion and Next Steps summarizes actionable next steps that Westport Marina, Port of Grays Harbor can take to improve their tsunami response capabilities and incorporate tsunami mitigation efforts into their infrastructure planning.

The Appendices provide additional information and resources, some of which are specific to Westport Marina. These resources include response checklists, harbor information, site-specific mapping and other data, graphics, and detailed information.

Section 1: Introduction

An earthquake strikes. The ground shakes. If you are on land, windows and doors rattle. If you are on your vessel near shore, you see trees, telephone poles and buildings sway dangerously back and forth. Windows break and bricks fall off the sides of buildings. You are in the marina and know how dangerous this can be, so without delay you dock and secure your vessel, leaving to follow your tsunami evacuation route. The streets are cracked and buckled. Trees and power lines have fallen, so you move as quickly and safely as you can inland to high ground. Because you and the maritime community have implemented a tsunami maritime response and mitigation strategy, you and your family know what to do to protect yourselves when you are in your vessel and/or at Westport Marina, Port of Grays Harbor. You get to high ground. As you look out towards the water, you see a powerful tsunami wave racing to shore, smashing everything in its path, the first of several life-threatening waves. Thankfully, you, your family, and your neighbors are safe.

The introductory scenario demonstrates the value of developing and implementing a tsunami maritime response and mitigation strategy. This strategy provides practical guidance to assist your maritime community in reducing your tsunami risk. You may be a community leader, an elected official, a concerned resident, a business owner, an employee, a government worker, or some other member of the community. Whatever your role in the community, we hope this strategy will assist you in your efforts to make your community safer.

Tsunamis

Tsunamis are the result of a sudden, large-scale displacement of water. They can be caused by landslides under or into water, large submarine earthquakes, eruptions of coastal volcanoes, and by meteor impacts into a body of water. In Washington State the most likely sources of tsunamis are earthquakes and landslides. Earthquakes create tsunamis when the seafloor deforms abruptly and vertically displaces the overlying water column. The displaced water travels outward in a series of waves that grow in intensity as they encounter shallower water near coastlines, as shown in figure 1. Tsunami wave impacts are greatest in and around ocean beaches, low-lying coastal areas, and bounded water bodies such as harbors and estuaries. The first waves may not be the largest in the series, nor the most destructive. The tsunami's effects include not only rapid flooding of low-lying land, but also dangerously strong currents. As the water travels inland, it scours the ground and picks up large debris, which gives the waves an additional element of destructive force.

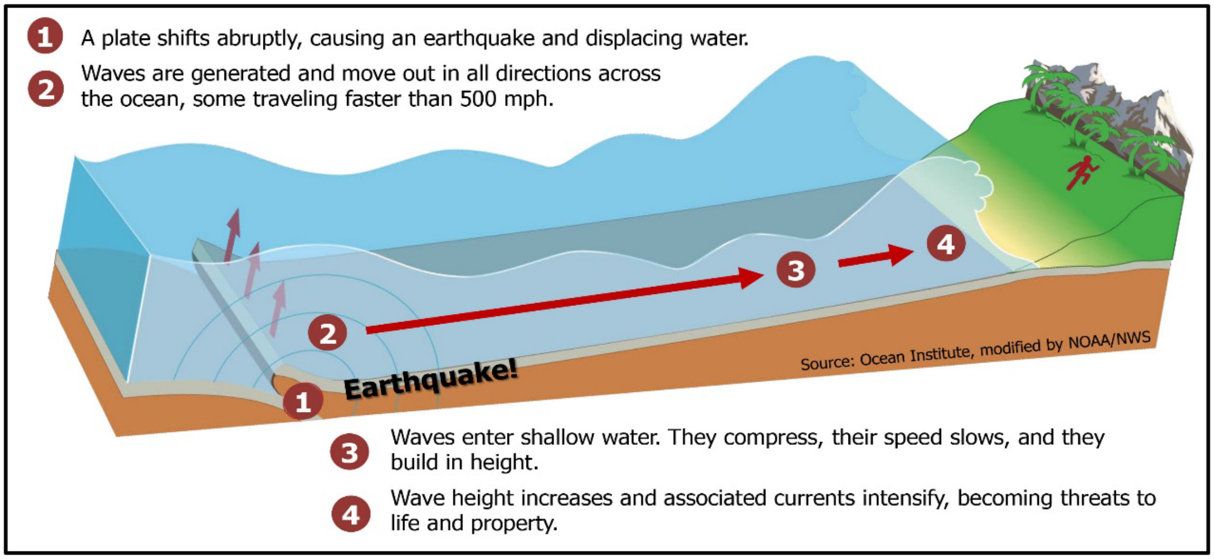
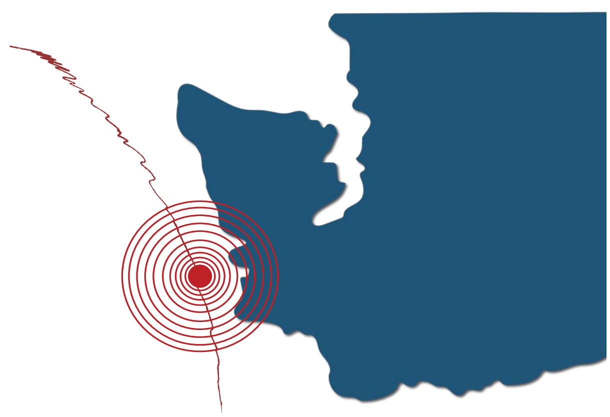


Figure 1: Earthquake generated tsunami diagram.

Tsunamis triggered by earthquakes pose the greatest risk to Washington's coasts. The location of the earthquake plays a key role in determining the tsunami travel time to a coastal community, as well as its impact on the community. Washington is at risk from both local source and distant source tsunamis.

Local Source Tsunamis

Local source tsunamis are tsunamis for which the first waves arrive at a location in under 3 hours, and you will most likely feel shaking from the earthquake. These tsunamis are caused by large underwater earthquakes along the Cascadia Subduction Zone (CSZ) fault, and local faults, and or landslides. The risk from a local source tsunami tends to be very high due to the first waves arriving within minutes to a couple of hours. The waves can be 60+ feet high and the current speeds are very fast, which can cause significant damage to everything along the coast. There is very little time for local authorities to respond and for people to evacuate to high ground.



An earthquake along the CSZ could produce catastrophic tsunami waves that hit the outer coast within 10-20 minutes. These waves would then hit low-lying parts of the northern inland waters and Puget Sound within two hours. Strong currents and water level changes would continue for 12-24 hours or longer. Additionally, the earthquake shaking has the potential to cause slope failures, leading to landslide-induced tsunamis with no warning and immediate impacts.

Aftershocks of sufficient size may also produce tsunamis in the days, weeks, and months following a major CSZ earthquake.

Distant Source Tsunamis

Distant source tsunamis are tsunamis for which the first waves arrive at a location in over 3 hours, and you will not feel shaking from the earthquake. These tsunamis are most frequently caused by large underwater earthquakes in other parts of the Pacific Ocean basin. The risk from a distant source tsunami is lower than from a local source tsunami because it takes longer for the tsunami waves to arrive, the waves are usually not as high, and the speed of the currents is usually slower. This varies greatly depending upon the location and magnitude of the earthquake that generates the tsunami. For example, tsunami waves originating in or near Japan would take 9-10 hours to arrive, which provides much more time to get to high ground than a tsunami originating off the coast of Alaska where waves would arrive within 3.5-4 hours.

Alaska is Washington's closest and therefore highest risk for a distant source tsunami. A magnitude 9.2+ earthquake off the coast of Alaska, such as an Alaska Maximum WA (AKMaxWA) scenario, can generate 20+ foot high tsunami waves off Washington's coast that can last 12-24 hours or longer. This has the potential to cause widespread damage along Washington's outer coast. People located in Washington will not feel the earthquake and must rely on other alert methods to know when a distant source tsunami is on the way.

Tsunami Hazards for Mariners and Vessels

Figure 2: Damage in Crescent City, California, from the 2011 Japan tsunami, about 10 hours after the initial earthquake.

Tsunamis pose many significant hazards for boaters and their vessels. Sudden large fluctuations in water level can cause unprepared and unaware vessels to become quickly swamped with water and/or washed onto the shore. In shallow areas these fluctuations can also ground vessels on the sea floor when water rapidly recedes, only to be overtopped by water when the next wave rapidly arrives (Figure

Figure 3: Standing tsunami bore wave in Sunaoshi River, Miyagi Prefecture, Japan 2016. Miyagi Prefectural Police/Kyodo/via Reuters

2). These incoming and receding surges of water can also create large tsunami bores that can capsize boats, and complex coastal waves that pose a danger to navigation (Figure 3).

Tsunamis can create strong and dangerous currents with speeds greater than 9 knots that pose serious risk to vessels and maritime facilities. These currents can be amplified by the geography and bathymetry of the surrounding area. Narrow waterways and areas around islands are especially dangerous, as well as areas where water is shallower. These strong currents can lead to the formation of large whirlpools and eddies (Figure 4) which can cause vessels to become trapped and unable to escape under their own power. These complex fast-moving tsunami waves can quickly change direction making them extremely unpredictable. This creates increased risk in areas of waterway congestion that can cause vessels to crash into each other. Tsunamis also drag massive amounts of dangerous debris into the water (Figure 5).

Figure 4: Whirlpools forming off Japan's coast after the 2011 tsunami. Yoiumri / Reuters

Figure 5: Tsunami debris in the water after 2011 tsunami in Ishinomaki, Japan. Koyodo News / AP

All the above risks also exist inside of harbor and port areas. The extreme water level fluctuations during a tsunami have the potential for docks to overtop pilings, become detached from the shore or sea floor, or break apart in sections (Figure 6). Vessels can be grounded when water recedes. Large, deep keeled vessels can experience strong enough drag sufficient to rip them from their moorings or lift them on top of docks or the shore (Figure 7). Narrow entrances to harbors can amplify current speeds and cause water to move in unexpected directions. The confined nature and amount of infrastructure and vessels in harbors can lead to a massive amount of debris moving through the area, creating dangerous conditions. All these hazards can exist for 12-24 hours or more.

Figure 6: Docks broken from Japan 2011 distant tsunami in Brookings, OR. USCG Photo by Group Air Station North Bend

Figure 7: Ship lifted on to land by tsunami waves in Japan. US Navy photo

Summary of Tsunami Hazards that can Directly Affect Marine Vessels:

- Severe water-level fluctuations
  - Docks could overtop piles as water level rises
  - Vessels could be washed onto shore and grounded
  - Grounding of vessels as water level suddenly drops
- Capsizing from incoming surges (bores), complex coastal waves, and surges hitting grounded vessels
- Strong and unpredictable currents that can change direction quickly
- Eddies/whirlpools
- Drag on large-keeled vessels
- Collision with other vessels, docks, and debris
- Dangerous tsunami conditions can last 12-24 hours or longer after the first wave arrives, causing problems for inexperienced and unprepared boaters who take their boats offshore

Boater Considerations During a Tsunami

Mariners and vessel captains will need to take into consideration many factors if they are at sea during a tsunami. Captains will need to decide whether to remain at sea and search for safer locations (deep water away from other vessels and debris) to attempt to ride out the tsunami or to instead return to shore, secure their vessel and evacuate to high ground. These decisions largely depend on the type of tsunami and these 5 major considerations:

- How much **time** before waves arrive
- How much **time** it will take to reach a safe location
- The **preparedness** and **readiness** of the vessel and its captain
- The **weather** conditions at sea as they could be as dangerous as the tsunami itself
- The **congestion** on roads and boat ramps

Within those considerations, it’s important to know: the distance to shore or deep water (100 fathoms or 600-foot depth); the skill level of the captain and crew; the vessel speed and capability; the draft of the vessel; the amount of provisions, fuel, and equipment on board; tide stage and conditions on the sea; and whether the vessel has adequate communication with other nearby vessels and authorities on shore, too (Figure 8).

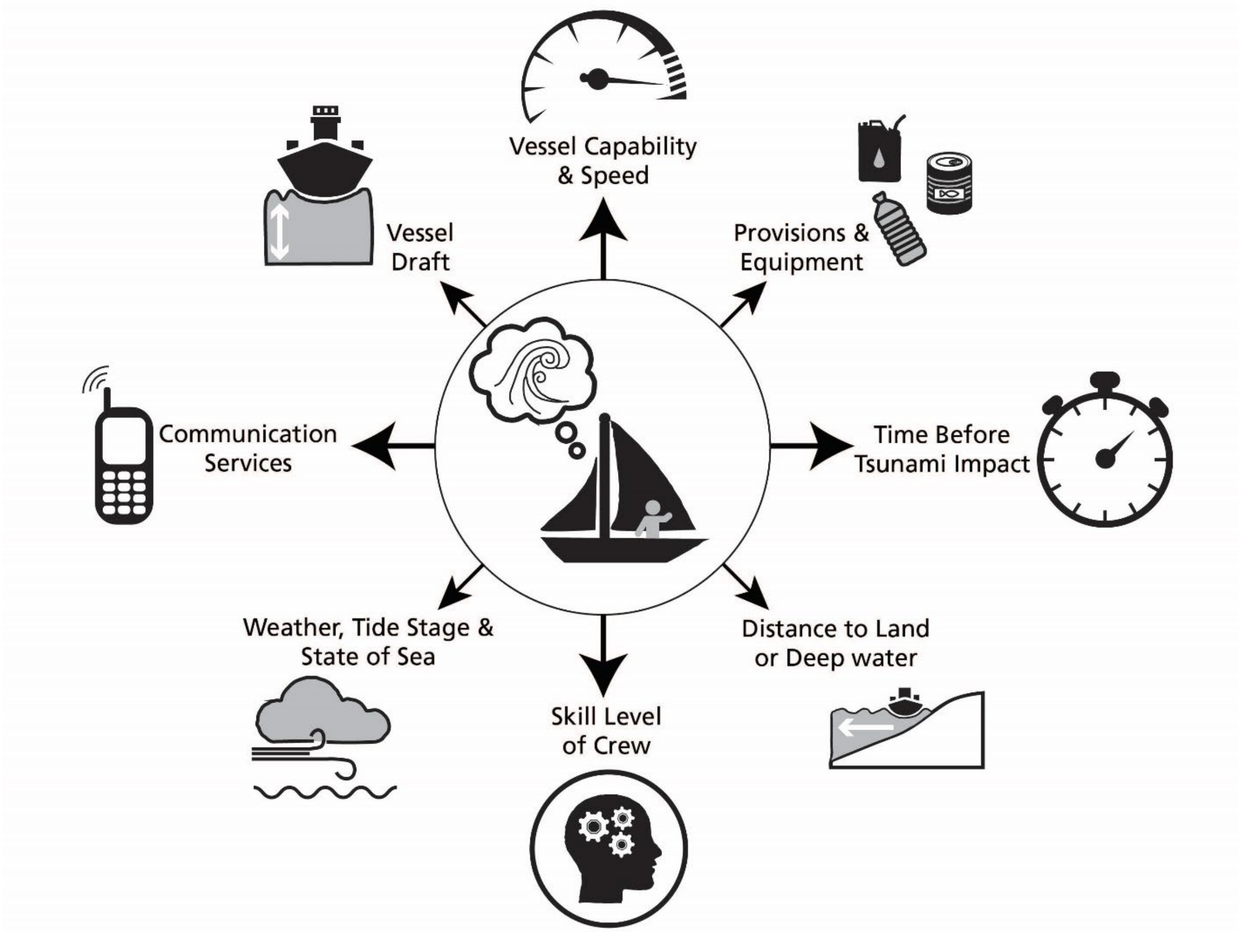


Figure 8: Considerations for boaters who are already offshore during a tsunami.

Westport Marina, Port of Grays Harbor

Located on Washington State's Pacific Coast, the Port of Grays Harbor operates seven lines of business throughout Grays Harbor County including 4 deep-water marine terminals with dual Class 1 rail service and available marine terminal uplands, the Westport Marina, the Satsop Business Park, and a suite of available industrial properties. In 2021 96 deep-water ships and barges called in to the Port of Grays Harbor's docks, 31,000+ railcars moved through the Port, and 3.2 metric tons of cargo were handled. The Port of Grays Harbor ranks in the top 50 export ports and the top 100 overall tonnage ports in the US.

Westport Marina is the largest coastal marina in the Pacific Northwest and home to Washington State's largest charter fishing fleet. It is also among the top commercial fishing ports by volume on the West Coast. Each year, 100+ million pounds of seafood cross the docks to reach domestic and international markets around the globe. The hundreds of fishermen whose boats are moored in the Westport Marina are the irreplaceable link between quality seafood and those who want to enjoy it. The commercial vessels in the marina range from 35 feet– 100+ feet long, harvesting Dungeness crab, salmon, albacore tuna, shrimp, oysters, prawns, pacific whiting, and more throughout the year. Vessels enter the marina to offload, purchase fuel, bait, and ice, and find safe harbor.

Figure 9: Westport Marina, Port of Grays Harbor

Westport Marina's facilities and upland facilities include 550 boat slips on 17 floating docks, 5 parking lots, bathrooms and showers, vessel pump-out stations, a 3-lane boat launch ramp and associated upland amenities, trailer storage, fuel docks, wheelchair-accessible viewing tower and platform, and a 1,000-foot boardwalk. In addition to port-managed facilities, there are numerous small businesses, 5 seafood processing facilities, multiple break walls and jetties maintained by the US Army Corp of Engineers, and 6 privately leased fixed piers. The Westport Marina is also home to the United States Coast Guard Station Grays Harbor.

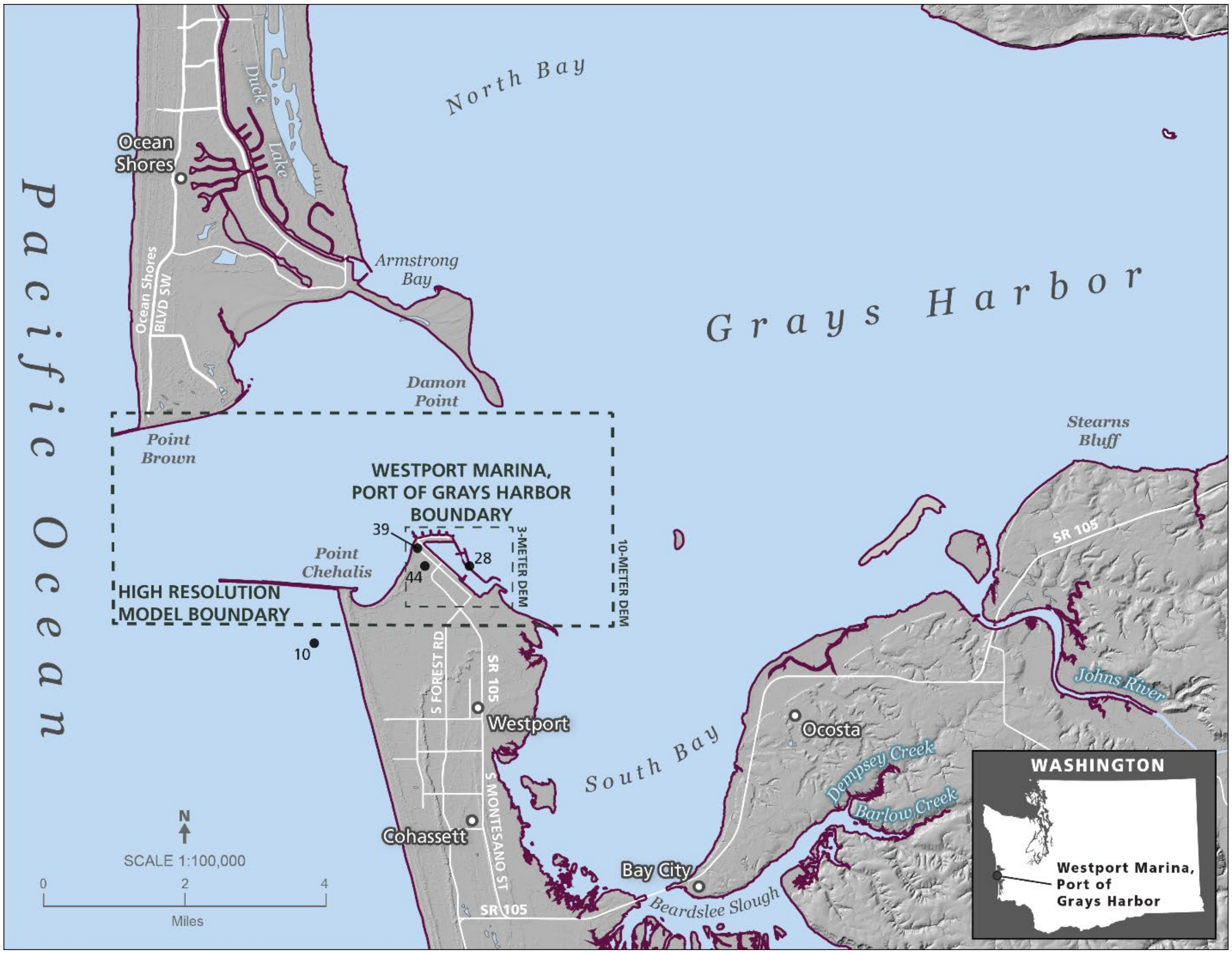


Figure 10: Overview of Port of Grays Harbor, Westport Marina study area. Dashed boxes represent either 10-meter or 3-meter model resolution boundaries. Black dots represent approximate location of simulated tide gauges: 10—Offshore Westport Light State Park; 28—Westport Marina, Port of Grays Harbor; 39—Westport Viewing Tower; and 44— Proposed vertical evacuation structure (VES). Refer to Tables 1—4 for tide gauge summaries.

How to Use This Strategy

The Washington Emergency Management Division encourages maritime communities to utilize this strategy to help reduce their risk from tsunamis and save lives. The information within this strategy can be used to learn about maritime tsunami risk, incorporate real-time response actions into standard operating procedures, determine and prioritize mitigation actions, and identify additional resources. These response and mitigation actions could greatly reduce the number of casualties and amount of damage from future tsunamis and speed up the time it takes to recover in Washington maritime communities. For detailed information on tsunami hazards in your area, check out the Washington Department of Natural Resources Washington Geological Survey (WGS) webpage. For detailed information on tsunami alerting, preparedness and mitigation, check out the Washington Emergency Management Division (WA EMD) webpage. For additional information on tsunami maritime hazards consult tsunami.noaa.gov.

Section 2: Tsunami Maritime Risk and Guidance

Tsunamis can strike without warning and the danger can be even higher for those at sea when a tsunami is coming. Dangerous currents, extreme water level changes, debris in the water, and damage to ports and shoreside infrastructure can all lead to potentially fatal situations. The safest place to be when a tsunami strikes is on land at an elevation above the tsunami inundation zone. It's therefore vital to know the natural warning signs a tsunami may be coming, as well as have multiple ways to receive official alerts of a distant source tsunami.

A local tsunami will leave very little time for mariners at sea to take protective action, which is why knowing the natural warning signs is so important. Upon seeing or experiencing any of the natural warning signs that could indicate a tsunami, immediate action should be taken to reach shore, safely dock your vessel, and evacuate the inundation zone.

A distant tsunami will leave more time for protective action to be taken, but there will be no natural signs (such as earthquake shaking) to warn mariners about the approaching tsunami. The only warning for a distant tsunami will come from official sources. For that reason, mariners should always be equipped with a way to receive alerts while at sea. While having a single way to obtain alerts is good, having multiple redundant ways to receive alerts is recommended.

This document provides response guidance in the event of tsunamis for **small craft** (vessels under 300 gross tons) such as recreational sailing and motor vessels, and **commercial fishing vessels.**

Natural Tsunami Warning Signs

For both local and distant source tsunamis, there is a possibility that you may not receive an official alert and specifically for a distant source tsunami, you will not feel shaking. You therefore need to be able to recognize the natural warning signs of a tsunami and respond immediately when you experience any one of them:

- **If you are ONSHORE, you might:**
    - Feel strong ground shaking (local source tsunami only)
    - Hear a loud roar from ocean
    - See water rapidly receding, possibly exposing the sea floor
    - See water surging towards the shore faster than any tide
- **If you are OFFSHORE, you might:**
    - Feel shaking through the hull of your vessel (local source tsunami only)
    - See a rapid or extreme shift in currents and simultaneous changes in wind wave heights

Official Tsunami Alerts

Tsunami alerts for Washington are originated by the National Oceanic and Atmospheric Administration's (NOAA) National Tsunami Warning Center (NTWC) in Palmer, Alaska. The Center detects, locates, sizes, and analyzes earthquakes throughout the world 24 hours a day. Figure 11 shows a summary diagram of how tsunami alert dissemination works.

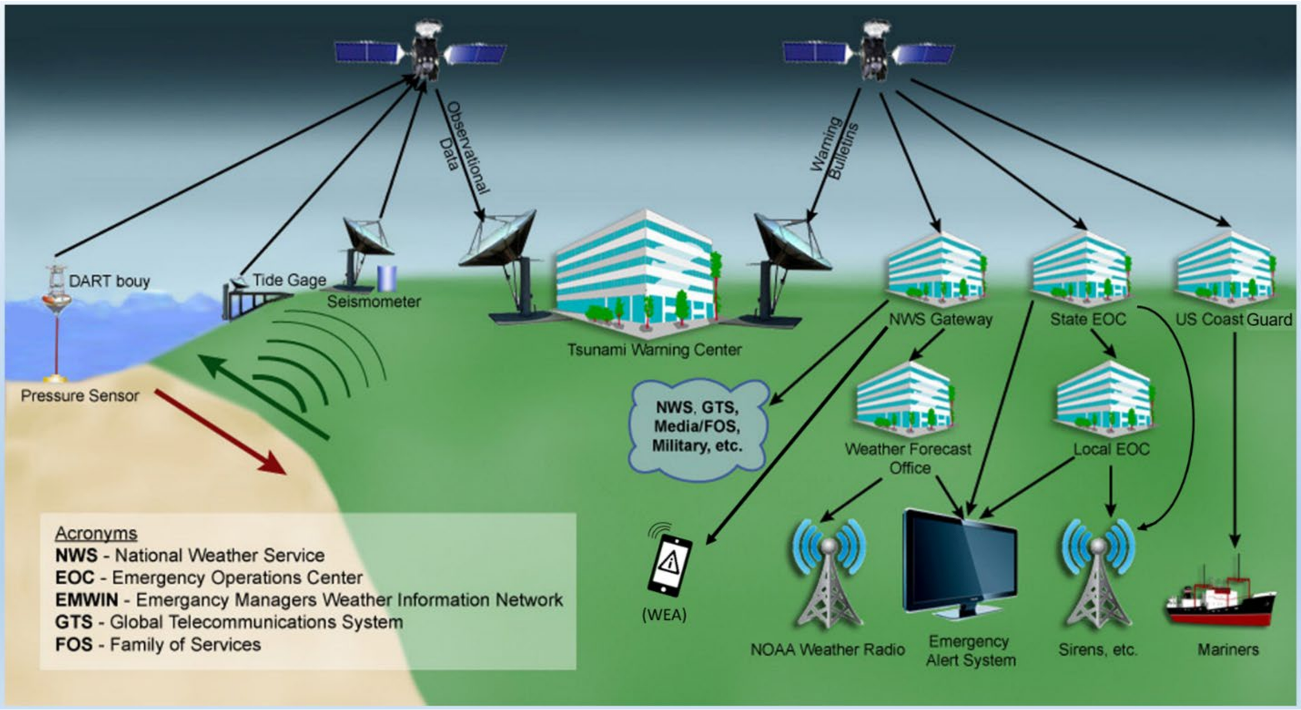


Figure 11: Diagram of tsunami alert dissemination.

When an earthquake occurs with the potential to generate a tsunami:

- The NTWC will evaluate the tsunami based on set parameters and determine the level of alert necessary.
- The NTWC will then use data from deep ocean tsunami detectors to judge the size, speed and severity of the tsunami and alter the alert levels as appropriate.
- Once the NTWC issues an alert, that information is sent to the appropriate federal and state authorities to be disseminated to the public.
- In the event of a warning the National Weather Service will send an alert through NOAA Weather Radios in the affected area.
- The Washington State Emergency Operations Center (SEOC) will activate the tsunami All Hazards Alert Broadcast (AHAB) sirens. The city of Westport currently has four sirens. One is located at the water treatment plant and is audible from the Westport Marina.
- The SEOC will also send an alert though the wireless emergency alert system (cell phone alerts), as well as through the Emergency Alert System (broadcast alerts on television and radio).
- The Grays Harbor County Division of Emergency Management will also issue alerts as described in the, in cooperation with the SEOC.

These types of alerts are most important for distant tsunamis and can also be useful for those further from the source of a local source tsunami. For those individuals near the source, such as people on the outer coast for a CSZ tsunami, the impacts could occur too quickly to receive official alerts. Individuals in those locations should be prepared to recognize the natural warning signs and act on them immediately.

Determining Whether a Tsunami Could Be Generated

In most cases the first sign of a potential tsunami is an earthquake. Seismic waves travel about 100 times faster than tsunamis, so information about an earthquake is available before information about any tsunami it may have generated. Three key pieces of information about an earthquake help the tsunami warning centers determine if it was tsunamigenic (capable of generating a tsunami): location, depth, and magnitude. The warning centers use this preliminary seismic information to decide if they should issue a tsunami message and at what alert level(s).

Once a message is issued, the warning centers conduct additional seismic analysis and run tsunami forecast models using information from the seismic and water-level networks as it becomes available. These numerical models use the real-time information and pre-established scenarios developed from historical tsunami information to simulate tsunami movement across the ocean and estimate coastal impacts, including wave height and arrival times, the location and extent of coastal flooding, and tsunami duration. The resulting forecasts help the warning centers decide if they should issue an updated alert or cancellation message.

Tsunami Alert Messages

The National Tsunami Warning Center (NTWC) issues tsunami Warnings, Advisories, Watches, and Information Statements. Each has a distinct meaning relating to local emergency response. In summary:

Warning	→	**Inundating wave possible**	→	**Full Evacuation Suggested**
Advisory	→	**Strong currents likely**	→	**Stay away from the shore**
Watch	→	**Danger level not yet known**	→	**Get ready to take action**
Information	→	**Minor waves at most**	→	**No action suggested**

Figure 12: Official tsunami alerts, associated effects, and protective actions to be taken.

Based on seismic data analysis or forecasted amplitude (dependent on whether the Center has obtained sea level data), NTWC will issue the appropriate message. Warnings and advisories suggest that action be taken. Watches are issued to prompt people to get ready to take action. Information Statements are issued to let people know that there was a large earthquake, but there is little to no danger. Once the danger level is determined, the watch is upgraded to a warning or advisory, or canceled. The full definition of each message is given below:

Tsunami Warning - A tsunami warning is issued when a tsunami with the potential to generate widespread inundation is expected, imminent, or occurring. Warnings alert the public that dangerous coastal flooding accompanied by powerful currents is possible and may continue for several hours after initial arrival. Warnings alert emergency management officials to take action for the entire tsunami hazard zone. Appropriate actions to be taken by local officials may include the evacuation of low-lying coastal areas, and the repositioning of ships to deep waters when there is time to safely do so. Warnings may be updated, adjusted geographically, downgraded, or canceled. To provide the earliest possible alert, initial warnings are normally based only on seismic information.

Tsunami Advisory - A tsunami advisory is issued when a tsunami with the potential to generate strong currents or waves dangerous to those in or very near the water is expected, imminent, or occurring. The threat may continue for several hours after initial arrival, but significant inundation is not expected for areas under an advisory. Appropriate actions to be taken by local officials may include closing beaches, evacuating harbors and marinas, and the repositioning of ships to deep waters when there is time to safely do so. Advisories are normally updated to continue the advisory, expand/contract affected areas, upgrade to a warning, or cancel the advisory.

Tsunami Watch - A tsunami watch is issued to alert emergency management officials and the public of a tsunami which may later impact the watch area. The watch area may be upgraded to a warning or advisory or canceled based on updated information and analysis. Therefore, emergency management officials and the public should prepare to take action. Watches are normally issued based on seismic information without confirmation that a destructive tsunami is underway.

Tsunami Information Statement - A tsunami information statement is issued to inform that an earthquake has occurred, or that a tsunami warning, advisory, or watch has been issued for another section of the ocean. In most cases, Information Statements are issued to indicate there is no threat of a destructive basin wide tsunami and to prevent unnecessary evacuations as the earthquake may have been felt in coastal areas. Information Statements may indicate for distant regions that a large tsunami is being evaluated and could be upgraded to a warning, advisory, or watch.

Receiving Tsunami Alerts

Those in the maritime community should be aware of both the types of alerts issued, and the actions they could need to take when an alert is received. All of those in the maritime community should be equipped with a way to receive official alerts through as many means as possible. Cell phone, text and internet-based alerts may be able to be received in locations near shore, in port, and other areas normal communications work properly. Boaters at sea or in locations where reliable cell phone signals and internet access is limited or nonexistent will need to have alternate forms of receiving emergency alerts such as a marine radio, a NOAA weather radio or both.

Tsunami alerts can be received by officials and the public in several ways which are outlined in the appendices, along with a more detailed look into alerting dissemination responsibilities. In Grays Harbor County, The Grays Harbor County Division of Emergency Management will issue alerts in cooperation with the SEOC. One of the most important things to remember about alerting is that you should have multiple methods of receiving alerts to ensure important alerts are received. Vessel captains and boat owners/operators should ensure their vessel is equipped with a marine radio that will receive emergency alerts, and ensure they have an alternate method to receive alerts that will work on the water such as a NOAA weather radio.

You can learn more about how to receive alerts for tsunamis and other types of hazards at mil.wa.gov/alerts.

Actionable Tsunami Alert Levels

Tsunami warnings and advisories are the two actionable alert levels for maritime communities. For both advisory and warning level incidents, it is important that clear and consistent directions are provided to the entire boating community and to waterfront businesses.

Sign up to receive notifications from the National Tsunami Warning Center in Palmer, Alaska at the following website: https://ntwc.ncep.noaa.gov/?page=productRetrieval. The Center issues two types of bulletins that require action by the Washington maritime community:

⚠ Tsunami Warnings	⚠ Tsunami Advisories
Tsunami wave heights could exceed 3 feet in harbors near the open coast, indicating very strong, dangerous currents and inundation of dry land is anticipated.	**Peak tsunami wave heights of 1 to 3 feet are expected, indicating strong and dangerous currents can be produced in harbors near the open coast.**
SIGNIFICANT tsunami currents or damage are possible. Depending on the tidal conditions, docks may overtop the pilings.	**SIGNIFICANT** tsunami currents or damage are possible near harbor entrances or narrow constrictions.

Figure 13: Actionable tsunami alert levels and associated effects.

Current Velocity, Areas of Dangerous and Unpredictable Currents, and the Relationship Between Current Speed and Harbor Damage

Damage occurring from tsunamis inside harbors can be directly attributed to strong currents. These currents are in excess of existing or 'normal' currents in the area, meaning their speed is added on top of the base, or normal tidal current speed. Damage varies based on the current speed and direction, as well as the age and location of docks and boats, yet some generalities about the relationship between tsunami currents and damage can be noted (Figure 14).

One such generality is that the faster the current speeds are the greater the chance and severity of damage. Beginning at ~ 3 knots (1 knot = 1.15 miles per hour) there is risk of minor to moderate damage to docks and smaller boats. Beginning at ~6 knots the risk increases to moderate to major damage and could impact larger boats. Once current speeds reach ~9 knots or greater the risk of complete destruction becomes extreme to all maritime infrastructure and vessels.

Currents = Damage

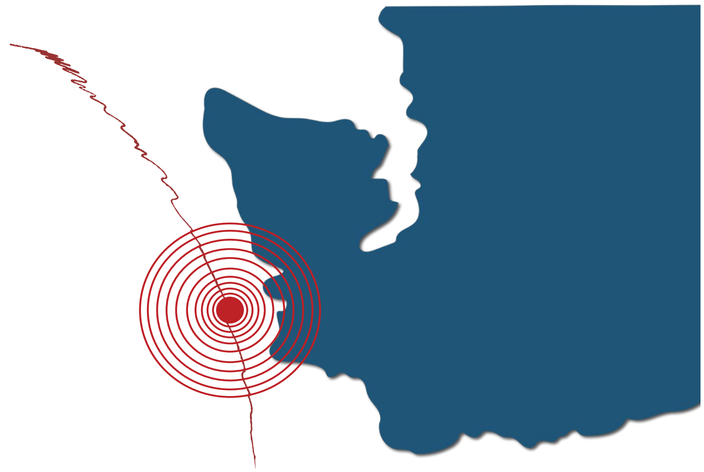
0-3 Knots = No Damage
3-6 Knots = Minor/Moderate damage
6-9 Knots = Moderate/Major Damage
>9 Knots = Major/Complete Damage

Current Speed	Damage Type
0 Knots	No Damage
>0-3 Knots	Small buoys moved
3-6 Knots	Docks/small boats damaged, Large buoys moved
6-9 Knots	Moderate dock/boat damage, Mid-sized vessels off moorings
>9 knots	Major dock/boat damage, large vessels off moorings
>>9 Knots	Complete destruction

Figure 14: Current velocity and associated damage.

It should be noted that the 3-6-9 knot current speed thresholds are appropriate for newer (<30-40 years old) and well-maintained docks and harbor infrastructure. For estimating damage to older (>40-50 years old) and less maintained docks, it may be more appropriate to use current speed thresholds of 2-5-7 knots.

Guidance for Local Source Tsunamis



Maritime response guidance in this section is based on the risk from a tsunami generated by a magnitude 9.0 Cascadia Subduction Zone (CSZ) earthquake, which is the maximum considered local source scenario. Other local source tsunamis generated on other faults may also occur and are likely to have different effects, depending on source and distance, than the maximum considered scenario. Always check with local authorities for more specific guidance that may be appropriate for other local tsunamis.

For a local source tsunami, it is necessary to evacuate the tsunami inundation zone as soon as possible. Any response actions taken should be prioritized based on life safety preservation.

Local Source Tsunami Risk for the Westport Marina, Port of Grays Harbor

The risk of casualties and damage from a tsunami generated by a M9.0 CSZ earthquake is very high for the Westport Marina. Some key risk factors include:

- Extreme water level changes
- Extensive inundation of dry land
- Major drawdown of water levels exposing the sea floor near shore
- Rapid and powerful current flows
- The first wave may not be the largest or most dangerous
- Significant amounts of debris moving unpredictably in the water

To better understand the hazard and risk from a tsunami generated by a CSZ M9.0 earthquake, a hypothetical tsunami model was created. This model uses a surface-rupturing splay fault along the CSZ. Washington State has adopted this scenario (called the CSZ L1 Extended L1 model, and in some areas we also use the CSZ L1 model) as the "maximum considered" tsunami hazard scenario and uses it for preparedness, mitigation, response, and recovery planning. The scenario represents a full rupture of the CSZ extending northward past the entrance of the Strait of Juan de Fuca. The CSZ Extended L1 model creates very large waves along the Pacific coast, in addition to substantial waves that propagate through the Strait of Juan de Fuca and into the Strait of Georgia, eventually affecting the entire Salish Sea, including Puget Sound. The waves can be about 15-20 feet high as they move over land and reach the Westport Marina area about 25-30 minutes after the earthquake. These waves can last 12-24 hours or longer. This model was used to develop maps of inundation, minimum water levels, and current velocity for the areas around Westport Marina.

The following maps were generated to visualize the hazard and risk to the Westport Marina from this local source CSZ Extended L1 tsunami. Additional maps are available for reference in the appendices. It's important to note that Westport is planning on building a vertical evacuation structure (VES) in the Westport Marina District and is awaiting FEMA funding (as of publication of this strategy in 2022). In the subsequent maps, you will see the site location marked as "Proposed VES."

Pre- and Post-CSZ Earthquake Mean High Water Shoreline

During large subduction zone earthquakes there is usually coseismic (during the earthquake) land-level change as a result of the large shift in tectonic plates. Past CSZ earthquakes (and other large subduction zone earthquakes around the world) have generated coseismic subsidence, a permanent drop in the existing shoreline. The CSZ Extended L1 model incorporates estimated subsidence into the earthquake and tsunami modeling. The model we use generates around 7 feet of coseismic subsidence during the earthquake in Westport (Figure 15). This means that the coastline at the Westport Marina area will drop around 7 feet during the earthquake. This is a permanent land-level change that will take hundreds to thousands of years to recover.

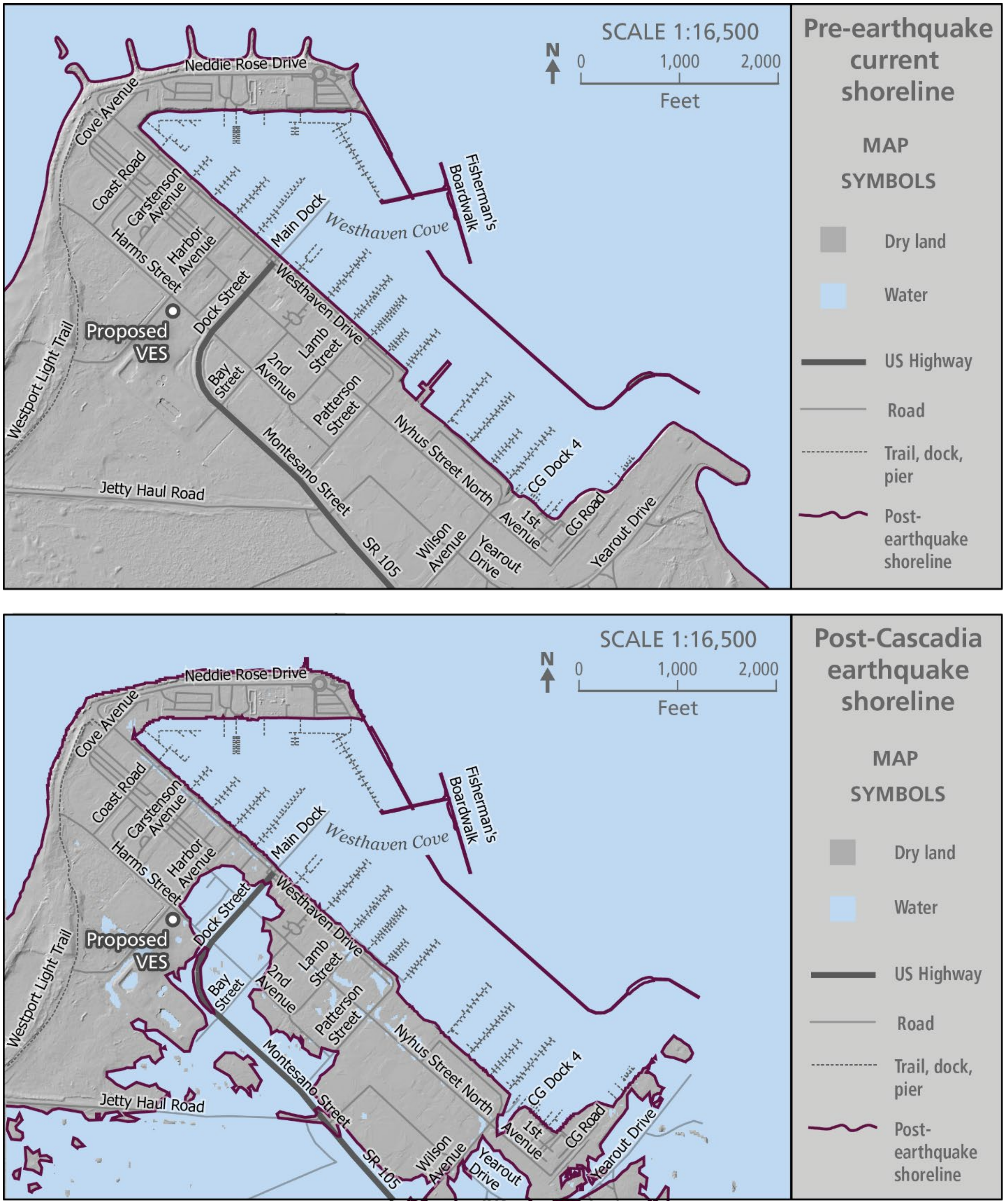


Figure 15: Pre- versus post-Cascadia earthquake mean high water shoreline based on the Extended L1 earthquake scenario, which assumes approximately 7 feet of subsidence at Westport Marina.

Anticipated Water Level Changes from a Local CSZ Tsunami

Modeling from a CSZ M9.0 earthquake-generated tsunami indicates that all portions of Westport Marina and surrounding areas will be inundated by water. While there are deeper areas of inundation along the outer coastline, the flow depth of the inundation on land ranges between 15-20 feet in most areas.

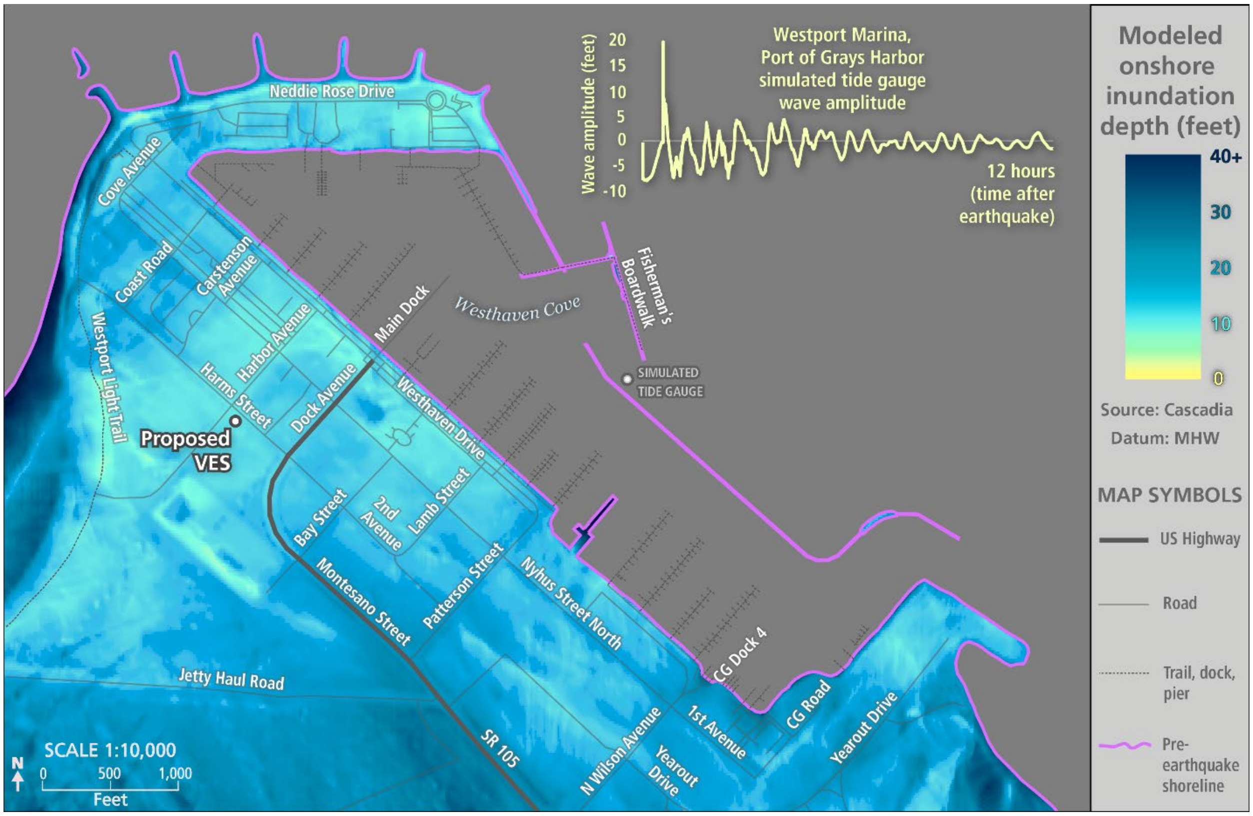


Figure 16: Maximum onshore inundation depth from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, at mean high water (MHW) in Westport Marina. Simulated tide gauge graph shows tsunami wave amplitude over time relative to MHW elevation datum (0) at marked location and records ~7 ft of co-seismic subsidence.

Evacuation from the Inundation Zone

Given the amount and extent of inundation from a locally generated tsunami, all people should immediately evacuate the inundation zone. Evacuees should always plan to evacuate on foot due to the potential for damage to road infrastructure, downed powerlines, and congestion and confusion on the roadways. Pedestrian evacuation maps with approximate walk times (based on a walking speed of 2.46 miles per hour, roughly a 24 minute per mile pace) have been developed for the Westport area (Figure 17). Those who work, live, or frequent this area should study these maps to determine the quickest route to safety, which is high ground. Once the optimal routes are determined they should be practiced often to understand the amount of time evacuation will take, and to ensure that evacuation can be performed without delay at any time, day or night, and in any type of weather conditions. For full-sized inundation and evacuation maps be sure to visit the Washington Department of Natural Resources [Tsunami Evacuation Maps webpage.]

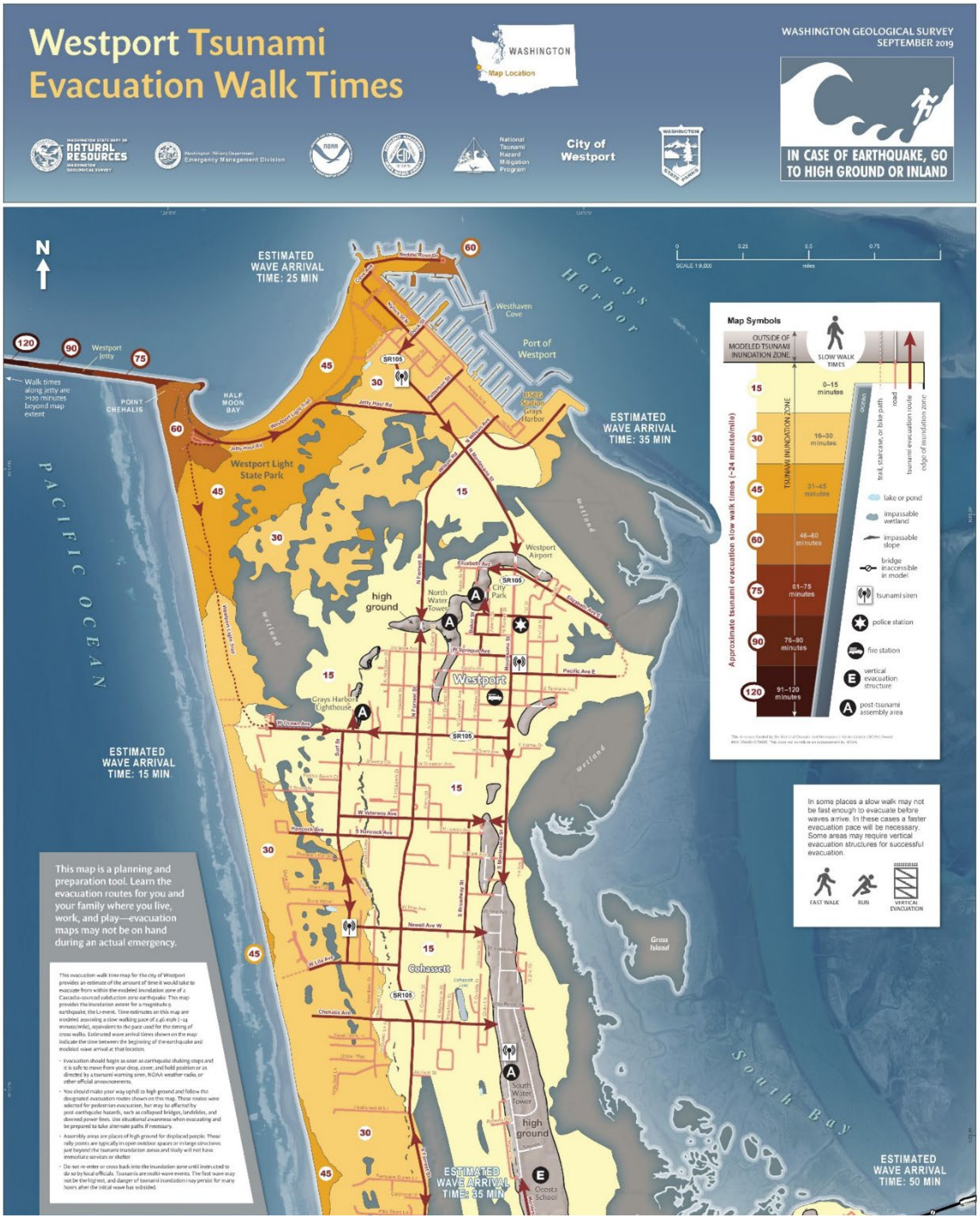


Figure 17: Evacuation routes, walk times, and designated assembly areas in Westport, Washington.

Once Westport's vertical evacuation structure is built, this will be the optimal place to safely evacuate to in Westport Marina for a local CSZ tsunami and the map below will be updated to reflect anticipated walk times to reaching high ground.

Anticipated Current Changes from a Local CSZ Tsunami

The following maps were generated to visualize the hazard from currents to Westport Marina from a CSZ Extended-L1 maximum considered tsunami. Tsunamis last for many hours and the waves will continue to arrive during tidal cycles. We provide modeling to show maximum speed at both mean high water (high tide) and mean low water (low tide) to show the difference in current speed at both tidal stages. Additional maps, graphs, and charts are available for reference in the appendices. Current velocities are catastrophic in the entire Marina completely destroying infrastructure and vessels.

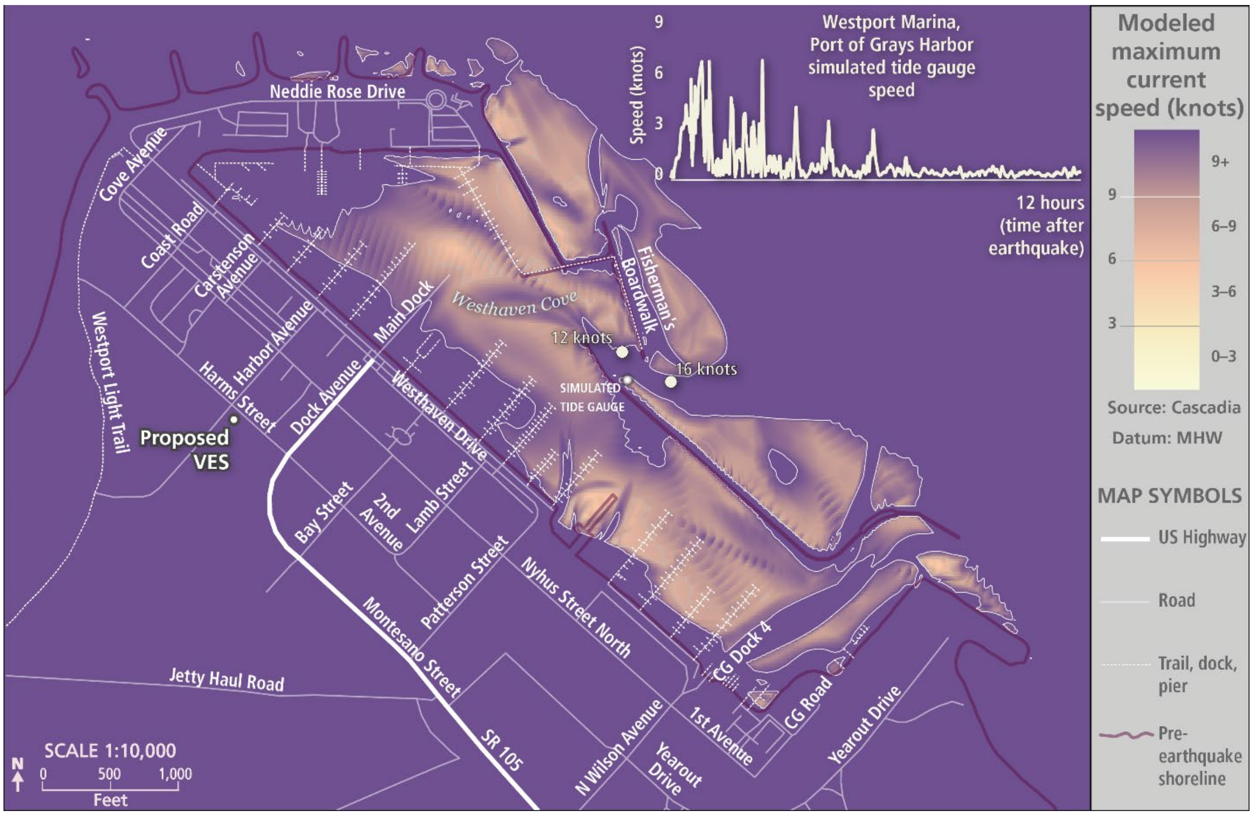


Figure 18: Maximum current speeds from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, at mean high water (MHW) in Westport Marina. Simulated tide gauge graph shows speed over time at marked location. Recorded speeds do not account for normal tidal currents. Current speeds become faster at lower tidal gauges in comparison to higher tidal stages as shown in this figure.

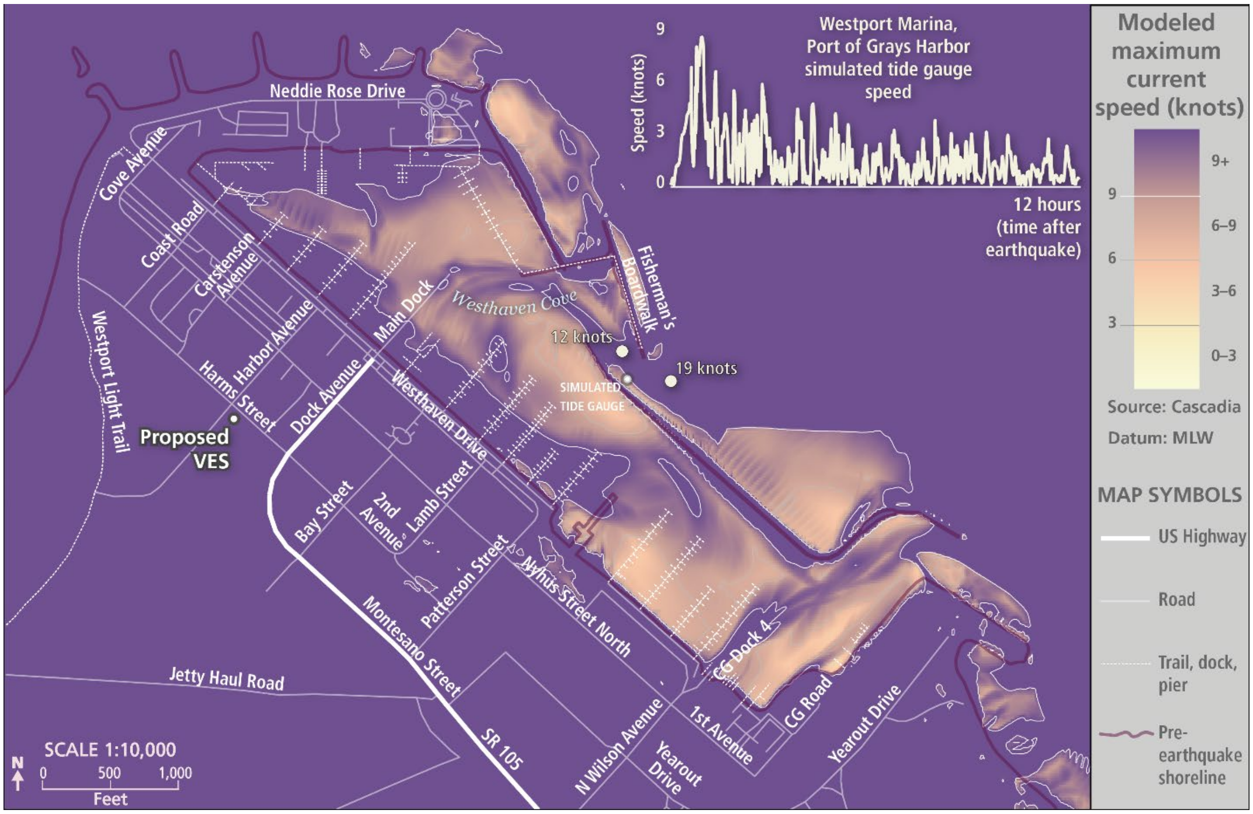


Figure 19: Maximum current speeds from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, at mean low water (MLW) in Westport Marina. Simulated tide gauge graph shows speed over time at marked location. Recorded speeds do not account for normal tidal currents. In some areas, you can see currents ranging up to 19 Knots over normal current speeds. Current speeds are faster at lower tidal stages.

Minimum Water Level Leading to Possible Exposure of Sea Floor

Figure 20 was generated to visualize the hazard from drawdown in Westport Marina from a CSZ Extended L1 tsunami. Prior to wave arrival of a CSZ Extended L1 tsunami, there is expected to be an initial trough, pulling the water out of the Marina and exposing the seafloor in some areas. This map (Figure 20) shows the maximum drawdown that is expected at mean low water. The subsequent graphs (Figures 21-24) show how water depth and wave amplitude vary over time in both Westport Marina and Offshore of Westport Light State Park. Additional maps, graphs, and charts are available for reference in the appendices.

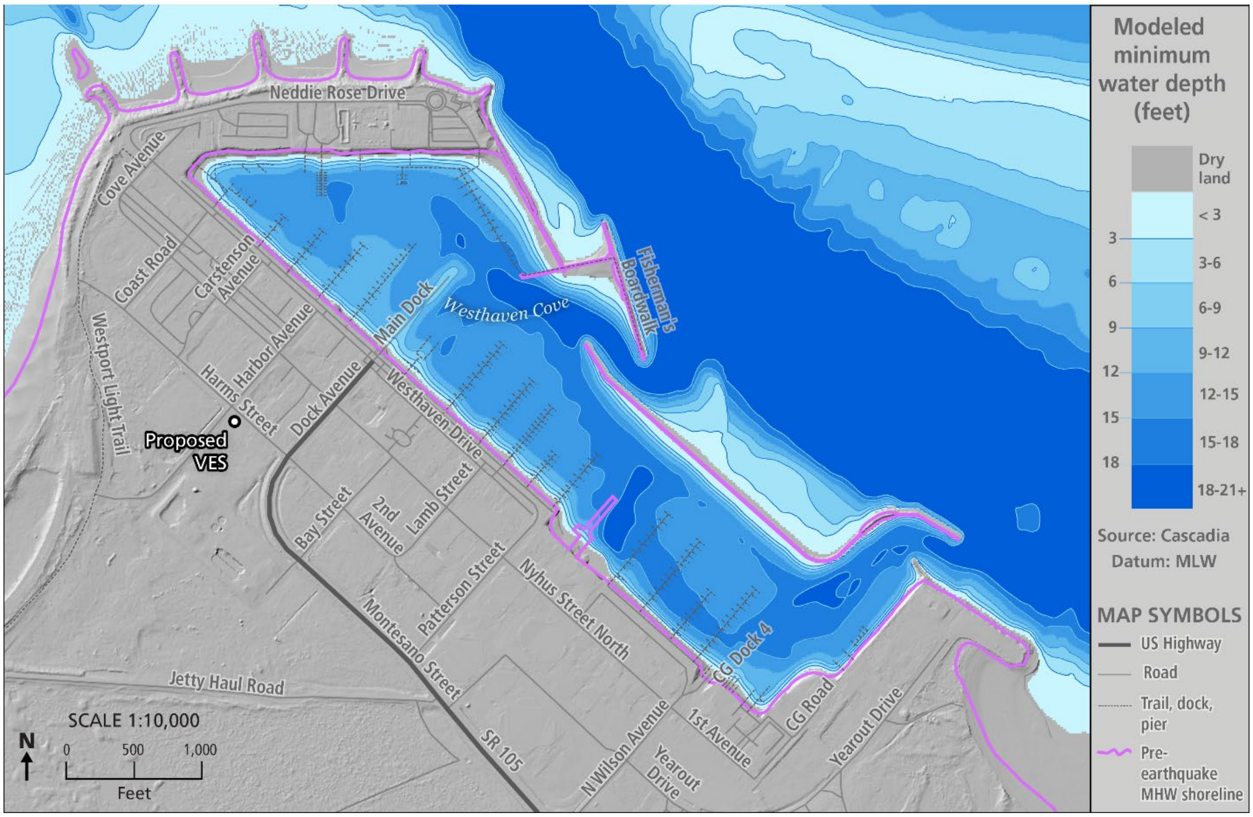


Figure 20: Minimum offshore water depth (maximum drawdown) from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, at mean low water (MLW) in Westport Marina. Each colored zone has a 3-foot water depth interval.

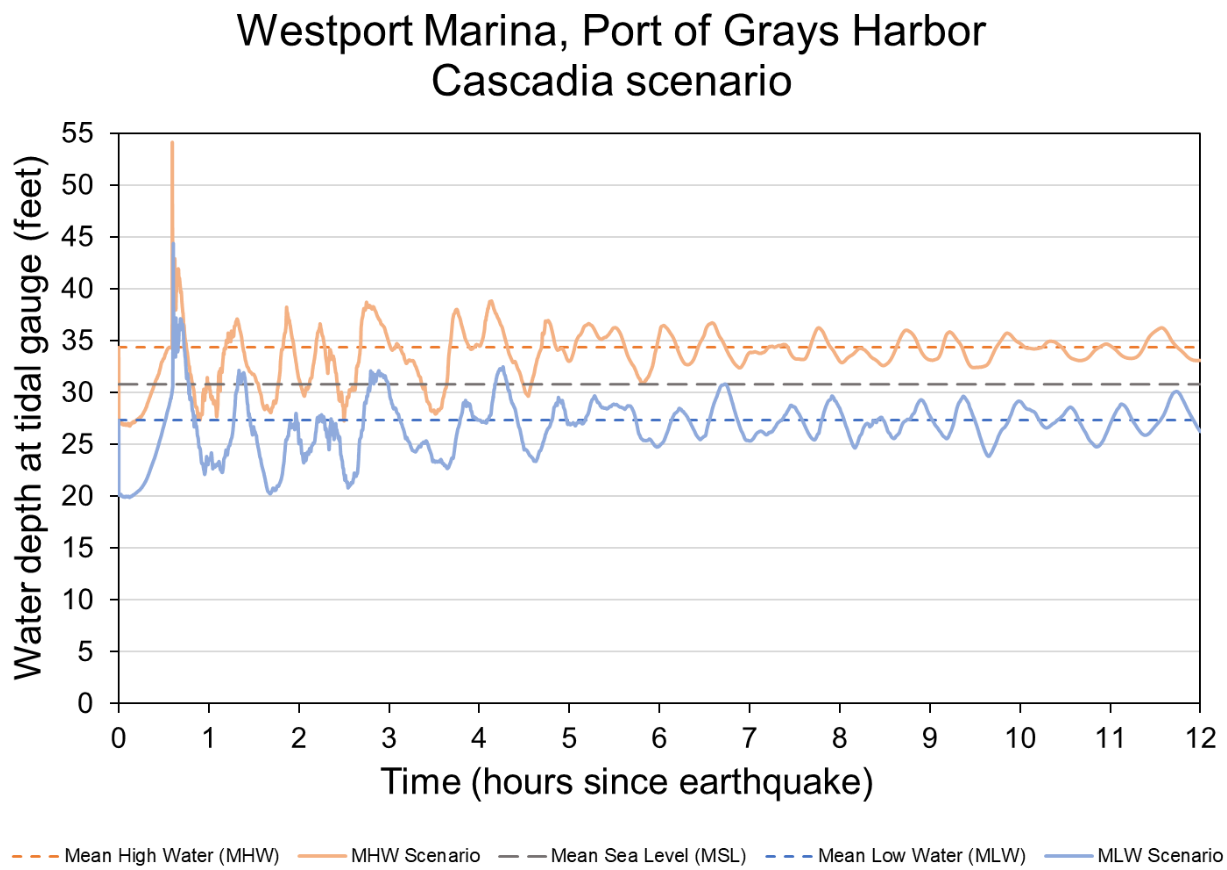


Figure 21: A comparison of offshore water depth, the actual water depth to the sea floor, at Westport Marina, Port of Grays Harbor over time from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, using either the mean high water (MHW) (orange) or mean low water (MLW) (blue) vertical elevation datum. Tsunami wave amplitudes deviate from the MHW and MLW tidal datum horizontal lines, respectively. Waveform shows ~7 feet of coseismic subsidence.

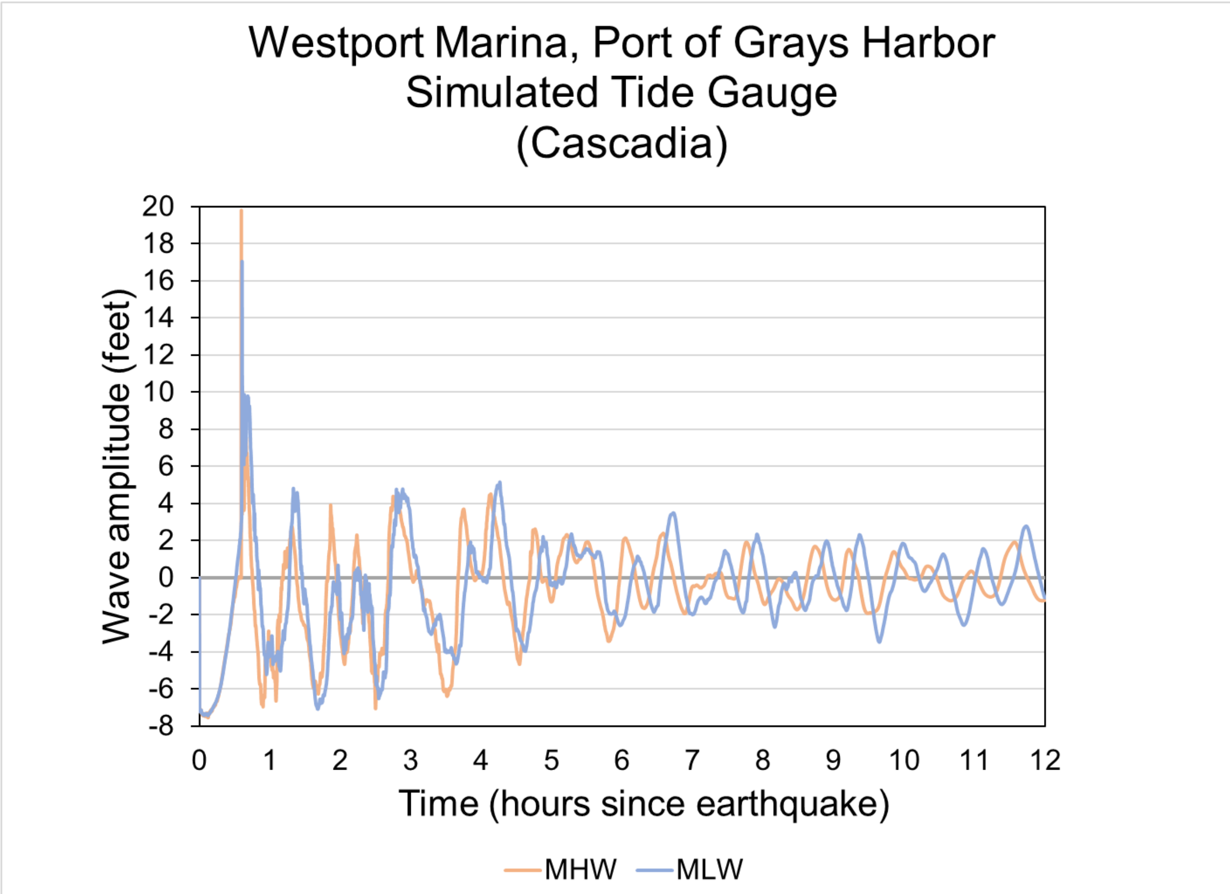


Figure 22: Tsunami wave amplitude range, representing the net change of water level and not depth, over time from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, relative to the mean high water and mean low water vertical elevation datum (MHW; MLW; both corrected to 0) at Westport Marina, Port of Grays Harbor. Waveform shows ~7 feet of coseismic subsidence. Water depths during MHW and MLW at this location equal ~34 feet and ~27 feet, respectively.

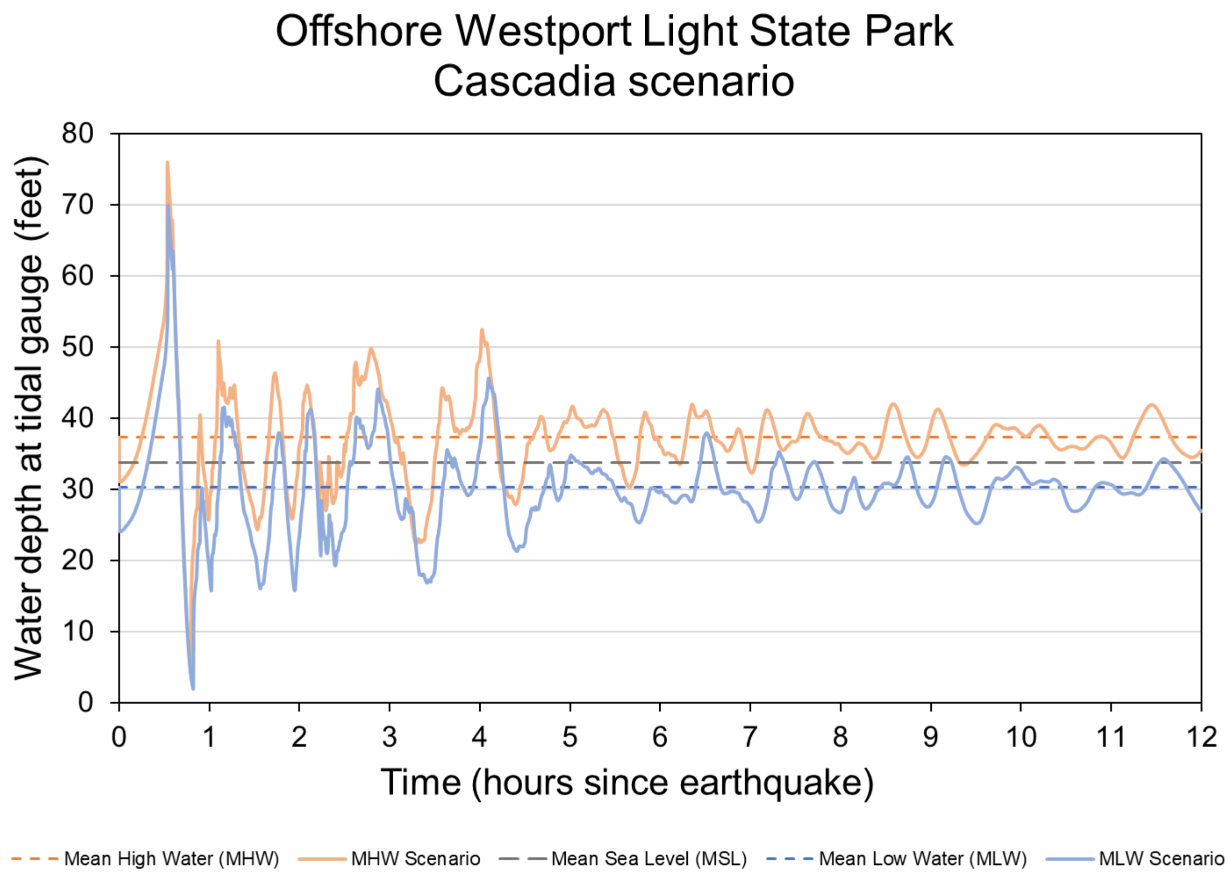


Figure 23: A comparison of water depths, the actual water depth to the sea floor, over time offshore Westport Light State Park from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, using either the mean high water (MHW) or mean low water (MLW) vertical elevation datum. Tsunami wave amplitudes deviate from the MHW and MLW tidal datum horizontal lines, respectively. Waveform shows ~5 feet of coseismic subsidence. Note that the location of this tide gauge is outside of the high-resolution modeled area (modeled with ~60 m [2 arc-second] resolution).

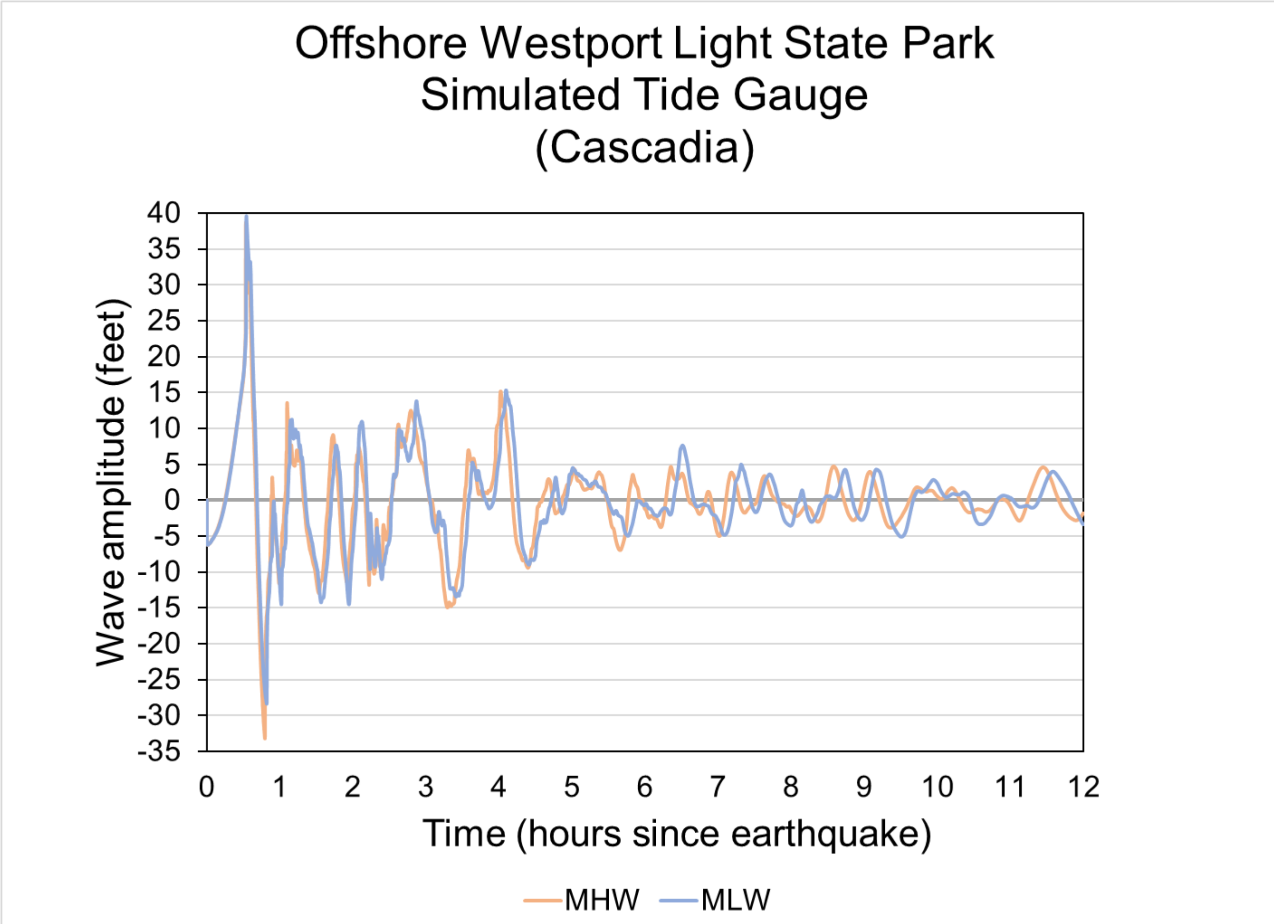


Figure 24: Tsunami wave amplitude range, representing the net change of water level and not depth, over time from a tsunami generated by a maximum considered Cascadia subduction zone scenario, Extended L1, relative to the mean high water and mean low water vertical elevation datum (MHW; MLW; both corrected to 0) offshore Westport Light State Park. Waveform shows ~5 feet of coseismic subsidence. Water depths during MHW and MLW at this location equal ~37 feet and ~30 feet, respectively. Note that the location of this tide gauge is outside of the high-resolution modeled area (modeled with ~60 m [2 arc-second] resolution).

Actionable Natural Warning Signs for a Local Source Tsunami

The earthquake itself is the warning for a local tsunami. There may not be enough time to receive an official tsunami warning. Be alert for the earthquake and other tsunami natural warning signs:

- **Onshore**
  - Strong and/or long ground shaking
  - Loud roar from ocean
  - Water rapidly receding, possibly exposing the sea floor
  - Wall of water surging towards shore faster than any tide
- **Offshore**
  - You may feel the earthquake through the hull of your vessel
  - You may see a rapid or extreme shift in currents and simultaneous changes in wind wave heights

General Guidance on Response to Natural Warning Signs or Official

Because you may have only minutes to take action it is important to have a plan in advance that includes a quick way to release commercial fishing gear so that your boat is not dragged down by currents, and having at least 3 days of food, fuel, and water stored on your vessel.

Tsunami Warning or Natural Warning Signs	**During the tsunami** • **If you are on land or tied up at the dock:** ○ Leave your vessel and head for high ground or inland on foot as soon as possible. You **do not** have time to save your vessel in this situation and could die trying to do so. • **If you are on the water but near shore:** ○ Use your best judgement to decide between the two options – safely beach/dock your vessel and evacuate on foot to high ground **or** get to minimum offshore safe depth. ○ Attempting to beach your vessel could be challenging and dangerous due to wave conditions, water levels, or the presence of bars. It is easy for a boat to run aground or capsize before reaching the shore only to be swept up by the coming tsunami wave. ○ However, if you can safely beach or dock your vessel and evacuate to high ground before the tsunami arrives, this is your best option. If that is not possible head to deep, open water as quickly as possible and stay away from other vessels. • **If you are on the water and not near the shore:** ○ **Aim to get to at less than 100 fathoms (600 ft):** Stop fishing operations immediately, freeing the vessel from any bottom attachments (cut lines if necessary). If you can beach or dock

Tsunami Warning or Natural Warning Signs	your vessel within 10 minutes of a natural warning and evacuate on foot to high ground, this is your best option. If that is not possible, head to water that is deeper than 100 fathoms, keeping in mind the following: ▪ Proceed as perpendicular to the shore as possible ▪ Sail directly into wind waves, keeping in mind that wind waves opposed by tsunami currents will be greatly amplified ▪ Maintain as much separation as possible from other vessels ▪ Synchronize movements with any other vessels to avoid collisions o **At 100 fathoms (600ft) or deeper:** If you are already at a location where the water depth is 100 fathoms or deeper, you are relatively safe from tsunamis. **After the tsunami** • If you are in an offshore staging area, check with the United States Coast Guard (USCG) for guidance before leaving the staging area; conserve fuel by drifting until you know what actions you need to take. • If you are at an onshore assembly area, check with local authorities for guidance before returning to the inundation zone. • Do not return to local ports until you have firm guidance from the USCG and local authorities. • Local ports could sustain heavy damage from a local tsunami and may not be safe for days, weeks or months. • If at sea, check to see if you can reach an undamaged port with your current fuel supply and watch for floating debris or survivors that may have been washed out on debris. • If at sea, consider checking with the USCG about your role in response and recovery.

Lessons Learned in Alaska from the March 28, 1964 Alaska Tsunami

The first wave is not always the largest for tsunamis. At Kodiak, Alaska during the 1964 tsunami the first wave was 3.4 m (11 ft) at the Naval Air Station, while the fifth wave was 7.6 m (25 ft) at high tide (Lander, 1996). The tsunami arrived within 10 minutes of the earthquake.

The primary lesson was that there was INSUFFICIENT time for harbor personnel or vessel captains/owners to do any response actions (i.e., remove vessels offshore or out of the harbor) prior to the arrival of the tsunami. Evacuation inland and to high ground out of the tsunami inundation zone was the only possible action.

Guidance for Distant Source Tsunamis

Maritime guidance in this section is based on the hazard and risk from a maximum considered distant source tsunami from Alaska. Other distant source tsunamis may also occur but are likely to cause less damage than the maximum considered scenario.

A distant source tsunami will allow some time for local agencies and residents to take response actions to reduce casualties and damage to vessels. The most important action is to save lives by moving quickly to a safer area before the tsunami waves arrive, whether that be deep water or inland to high ground. There may not be enough time to take action to reduce damage to vessels. Local response activities could be extensive and may involve large numbers of people, resulting in congestion and delayed actions. Therefore, the actions to be taken must be prioritized and based on life-safety preservation. Only those actions assured to be successful should be attempted.

Distant Source Tsunami Risk for Westport Marina, Port of Grays Harbor

The risk of casualties and damage from a tsunami generated by a distant earthquake, while not as great as a local source tsunami, is still high for the Westport Marina. Some key risk factors include:

- Significant water level changes
- Potential for inundation of dry land
- Significant drawdown of water levels with the potential to expose the sea floor in shallow areas
- Strong and unexpected currents
- The first wave may not be the largest or most dangerous

To better understand the hazard and risk from a tsunami generated by a distant earthquake, a tsunami model of a M9.2 Alaska-Aleutian Subduction Zone (AASZ) megathrust earthquake was created. Washington State has adopted this scenario called the Alaska Maximum WA (AKMaxWA) model as the “maximum considered" distant source tsunami hazard and uses it for preparedness, mitigation, response, and recovery planning. This simulated tsunami has a similar magnitude to the 1964 Alaska earthquake (M9.2). The waves can be about 3-5 feet high (yellow to green gradient in Figure 25) as they move over land and reach the Westport Marina area at approximately 3 hours and 50 Minutes following the earthquake. These waves can last 12-24 hours or longer.

The following maps were generated to visualize the hazard to Westport Marina from a AKMaxWA distant source tsunami. Additional maps are available for reference in the appendices.

Anticipated Water Level Changes from a Distant Alaska Tsunami

Modeling from an AKMaxWA earthquake-generated tsunami indicates that significant portions of Westport Marina and surrounding areas may be inundated by water (Figure 25). While there are deeper areas of inundation along the outer coastline, the flow depth of the inundation on land ranges between 3-5 feet in most areas.

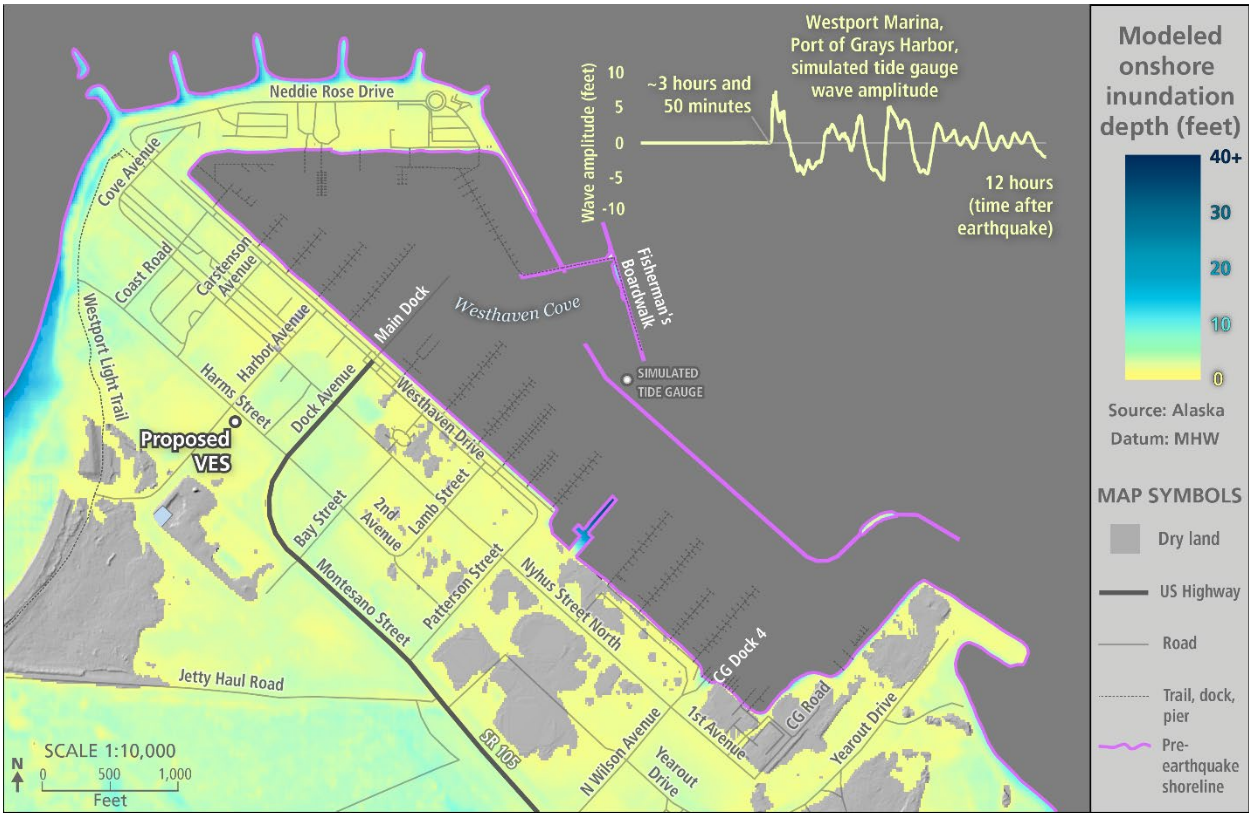


Figure 25: Maximum onshore inundation depth from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, at mean high water (MHW) in Westport Marina. Simulated tide gauge graph shows tsunami wave amplitude over time relative to the MHW elevation datum (0) at marked location.

Anticipated Current Changes from a Distant Alaska Tsunami

The following maps (Figure 26 and Figure 27) were generated to visualize the hazard from currents to Westport Marina from a distant AKMaxWA tsunami. Tsunamis last for many hours and the waves will continue to arrive during tidal cycles. We provide modeling to show maximum speed at both mean high water (high tide) and mean low water (low tide) to show the difference in current speed at both tidal stages. Additional maps, graphs, and charts are available for reference in the appendices. Current velocities are high reaching speeds of up to 15 knots in the Marina having the potential to destroy infrastructure and severely damage vessels.

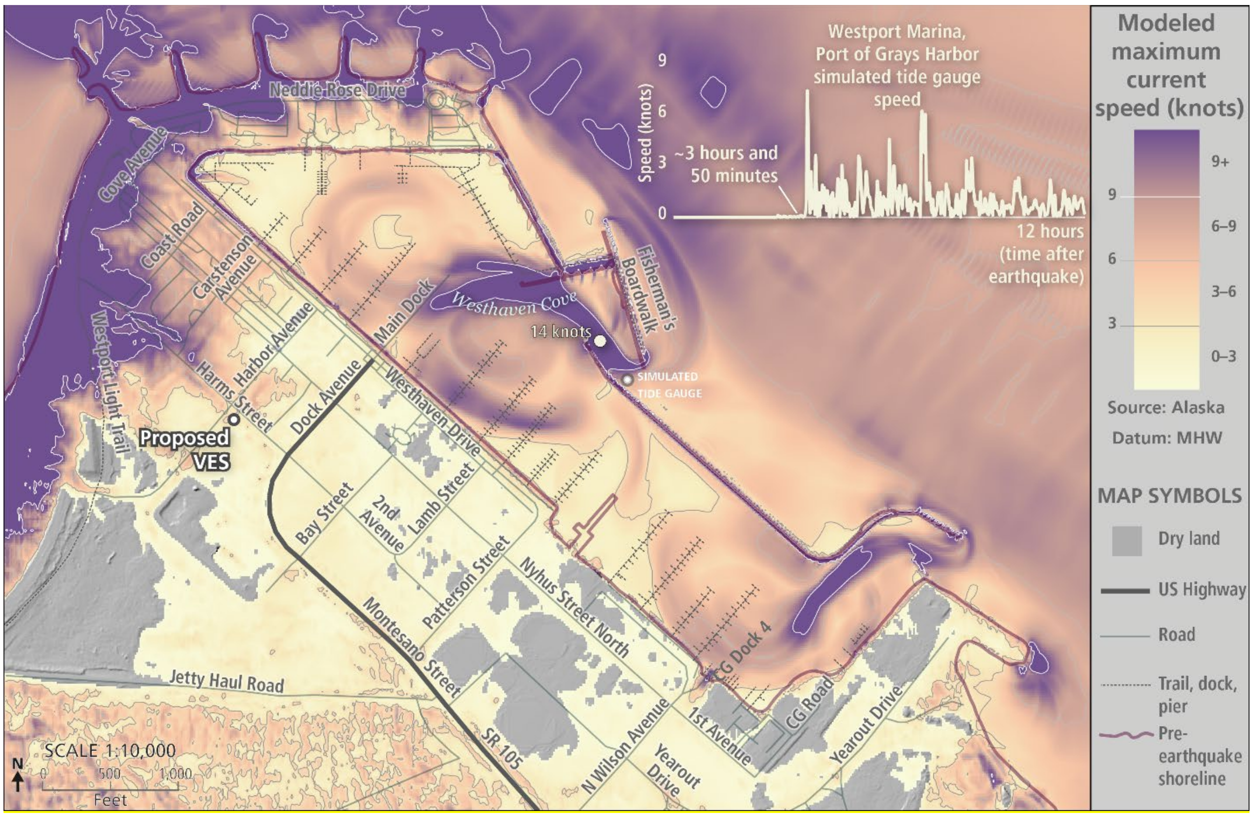


Figure 26: Maximum current speeds from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, at mean high water (MHW) in Westport Marina. The four assigned current speed ranges approximate hazards to ships and docking facilities and represent the following amounts of damage: no expected damage (0–3 knots); minor/moderate damage possible (3–6 knots); major damage possible (6–9 knots); and extreme damage possible (>9 knots). Simulated tide gauge graph shows speed over time at marked location. Recorded speeds do not account for normal tidal currents. The maximum modeled current speed in the Marina peaks at 14 knots over normal tidal current conditions.

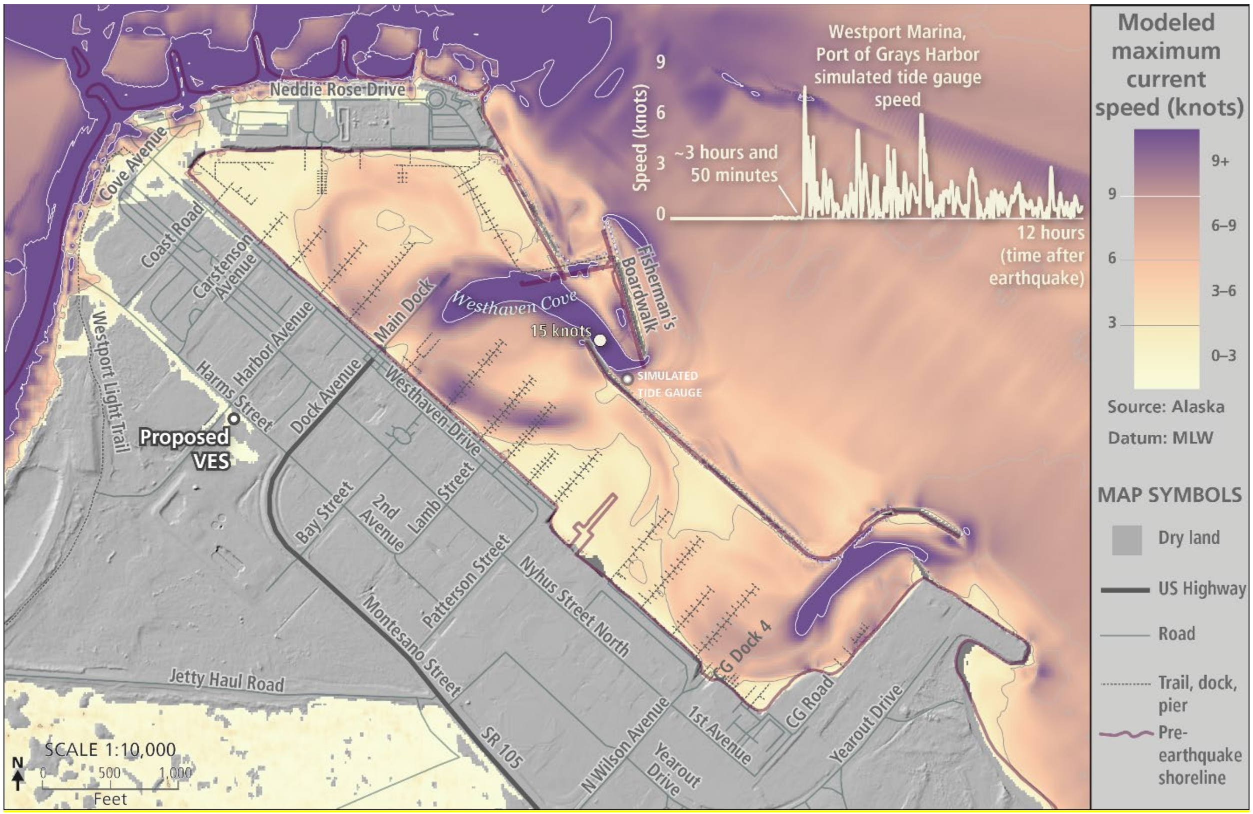


Figure 27: Maximum current speeds from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, at mean low water (MLW) in Westport Marina. The four assigned current speed ranges approximate hazards to ships and docking facilities and represent the following amounts of damage: no expected damage (0–3 knots); minor/moderate damage possible (3–6 knots); major damage possible (6–9 knots); and extreme damage possible (>9 knots). Simulated tide gauge graph shows speed over time at marked location. Recorded speeds do not account for normal tidal currents. The maximum modeled current speed in the Marina peaks at 15 knots over normal tidal current conditions.

Water Level Drawdown Leading to Potential Exposure of Sea Floor

Figure 28 was generated to visualize the hazard from drawdown in Westport Marina from an AKMaxWA tsunami. Unlike a CSZ Extended L1 tsunami, there is no leading trough or initial drawdown prior to wave arrival. An AKMaxWA tsunami, along with any tsunami generated along the Alaskan Aleutian Subduction Zone, would lead with a wave crest. This map (Figure 20) shows the maximum drawdown that is expected at mean low water. The subsequent graphs (Figures 29-32) show how water depth and wave amplitude vary over time in both Westport Marina and Offshore of Westport Light State Park. Additional maps, graphs, and charts are available for reference in the appendices.

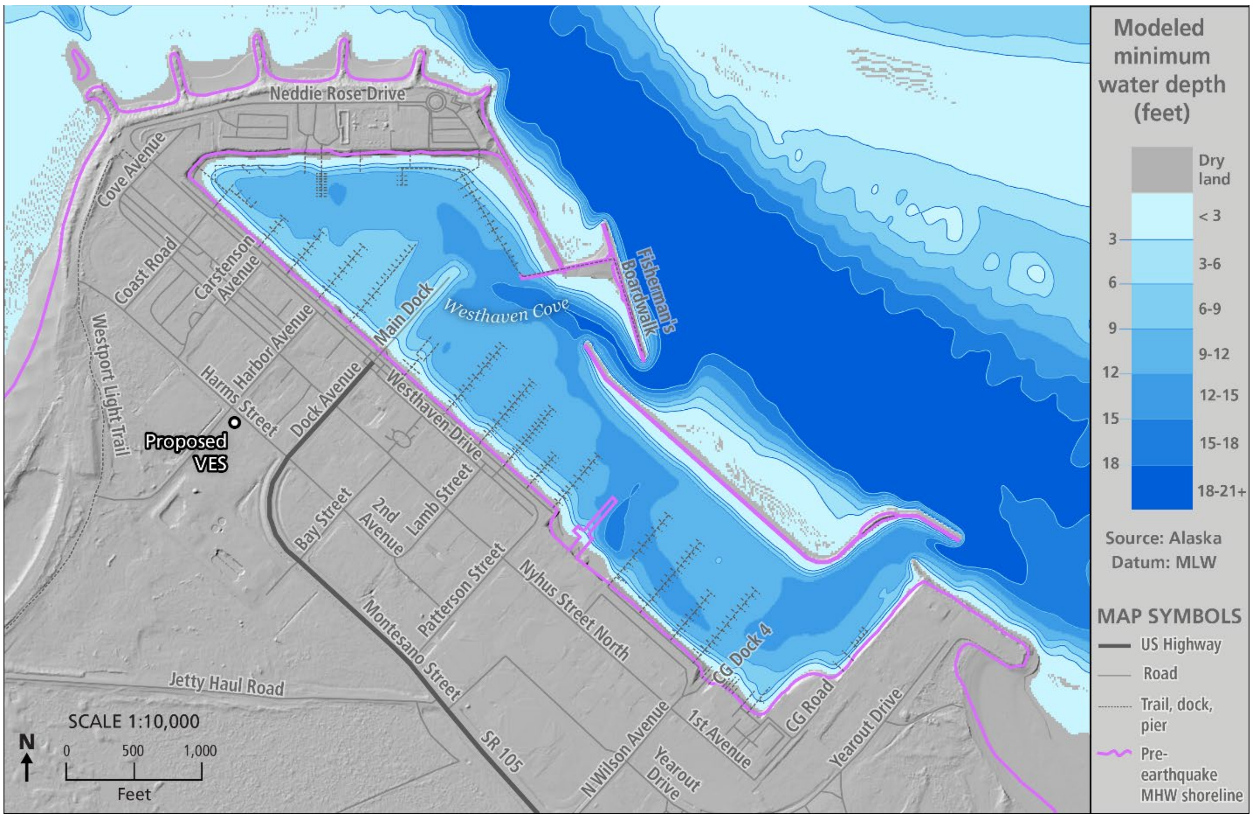


Figure 28: Minimum offshore water depth (maximum drawdown) from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, at mean low water (MLW) in Westport Marina. Each colored zone has a 3-foot water depth interval.

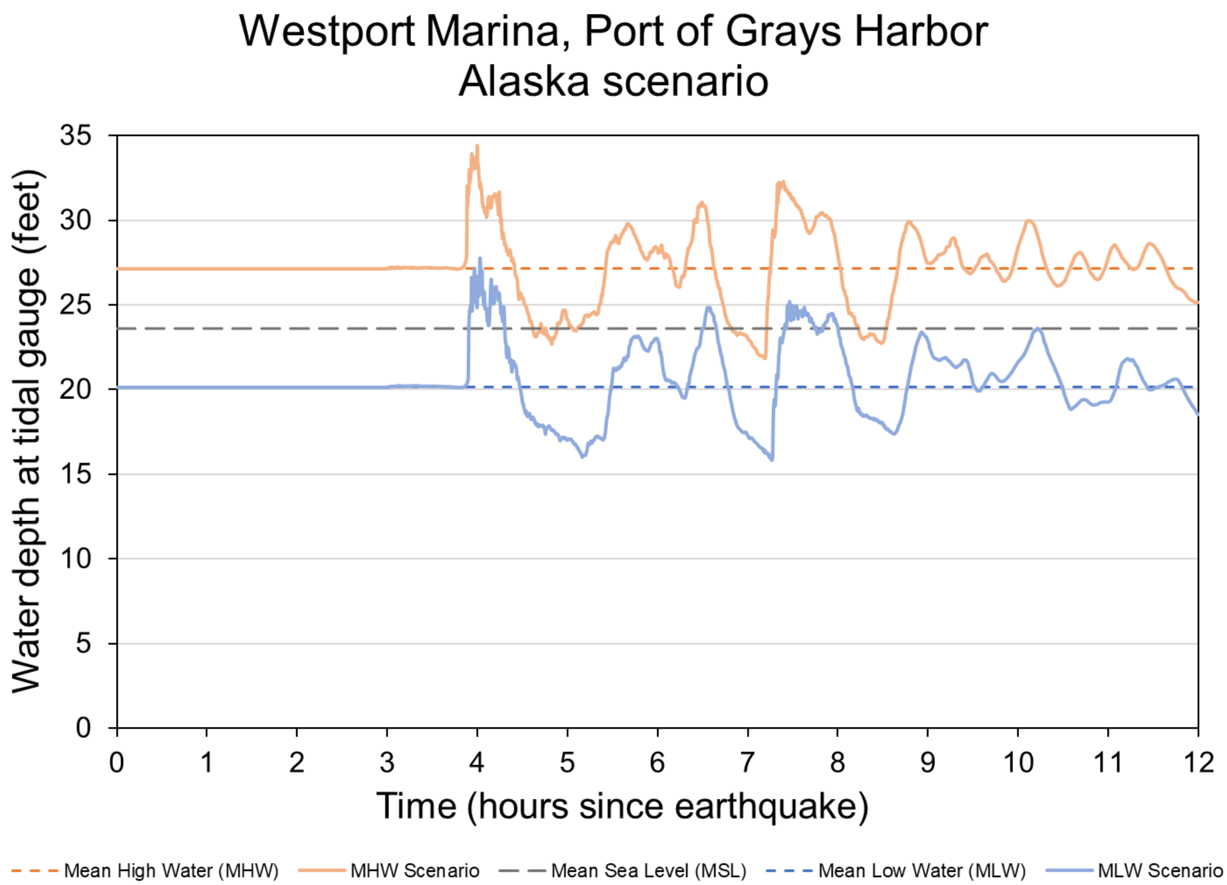


Figure 29: A comparison of offshore water depth, the actual water depth to the sea floor, at Westport Marina, Port of Grays Harbor from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, using either the mean high water (MHW) or mean low water (MLW) vertical elevation datum. Tsunami wave amplitudes deviate from the MHW and MLW tidal datum horizontal lines, respectively.

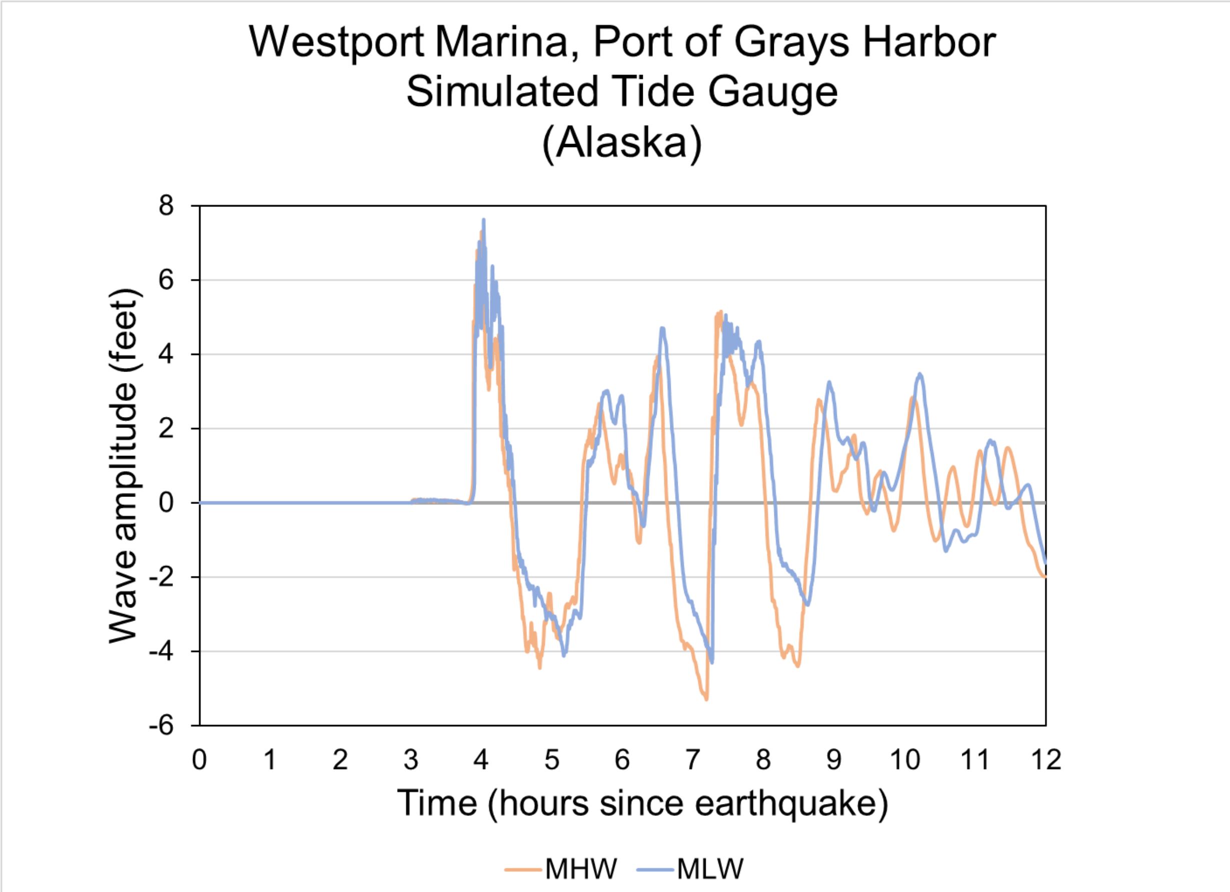


Figure 30: Tsunami wave amplitude, representing the net change of water level and not depth, range over time from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, relative to the mean high water and mean low water vertical elevation datum (MHW; MLW; both corrected to 0) at Westport Marina, Port of Grays Harbor. Water depths during MHW and MLW at this location equal ~34 feet and ~27 feet, respectively.

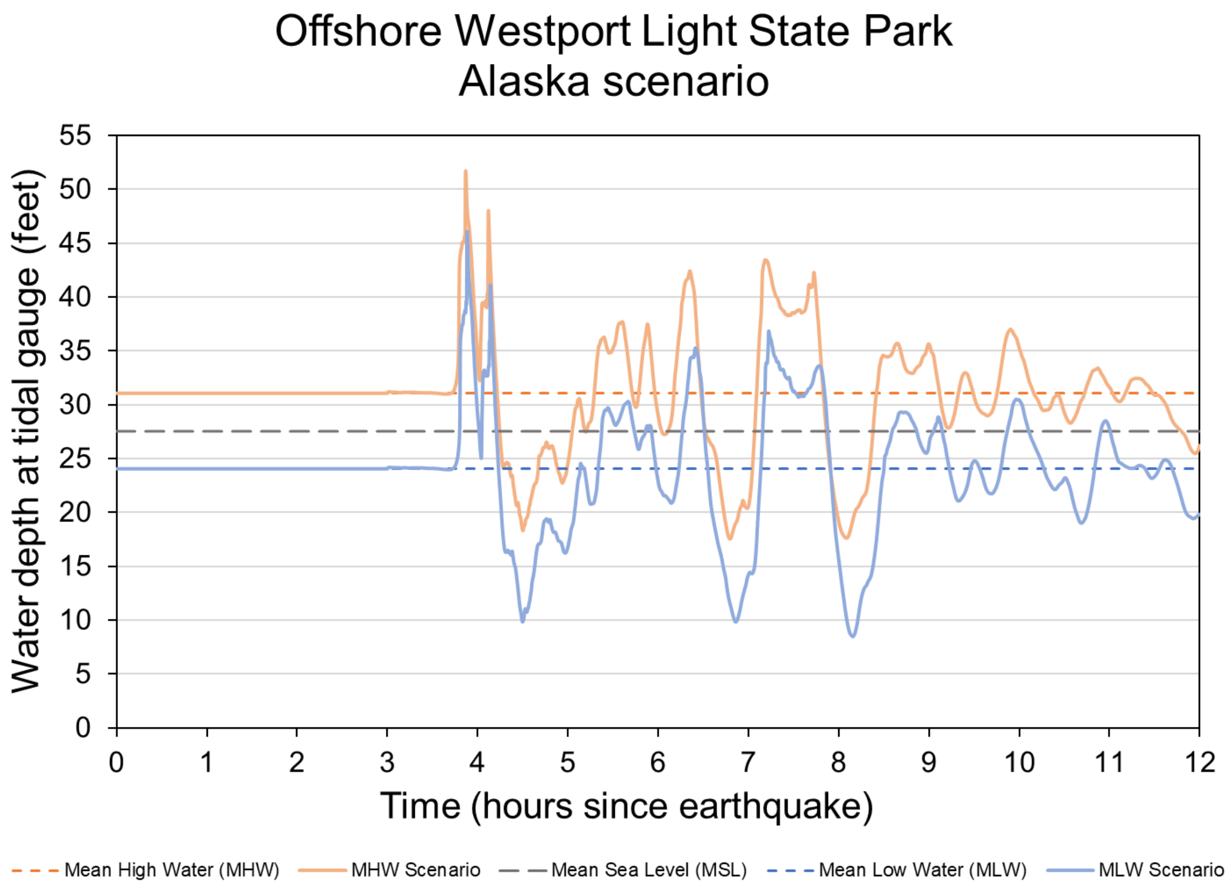


Figure 31: A comparison of water depths, the actual water depth to the sea floor, over time offshore Westport Light State Park from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, using either the mean high water (MHW) or mean low water (MLW) vertical elevation datum. Tsunami wave amplitudes deviate from the MHW and MLW tidal datum horizontal lines, respectively. Note that the location of this tide gauge is outside of the high-resolution modeled area (modeled with ~60 m [2 arc-second] resolution).

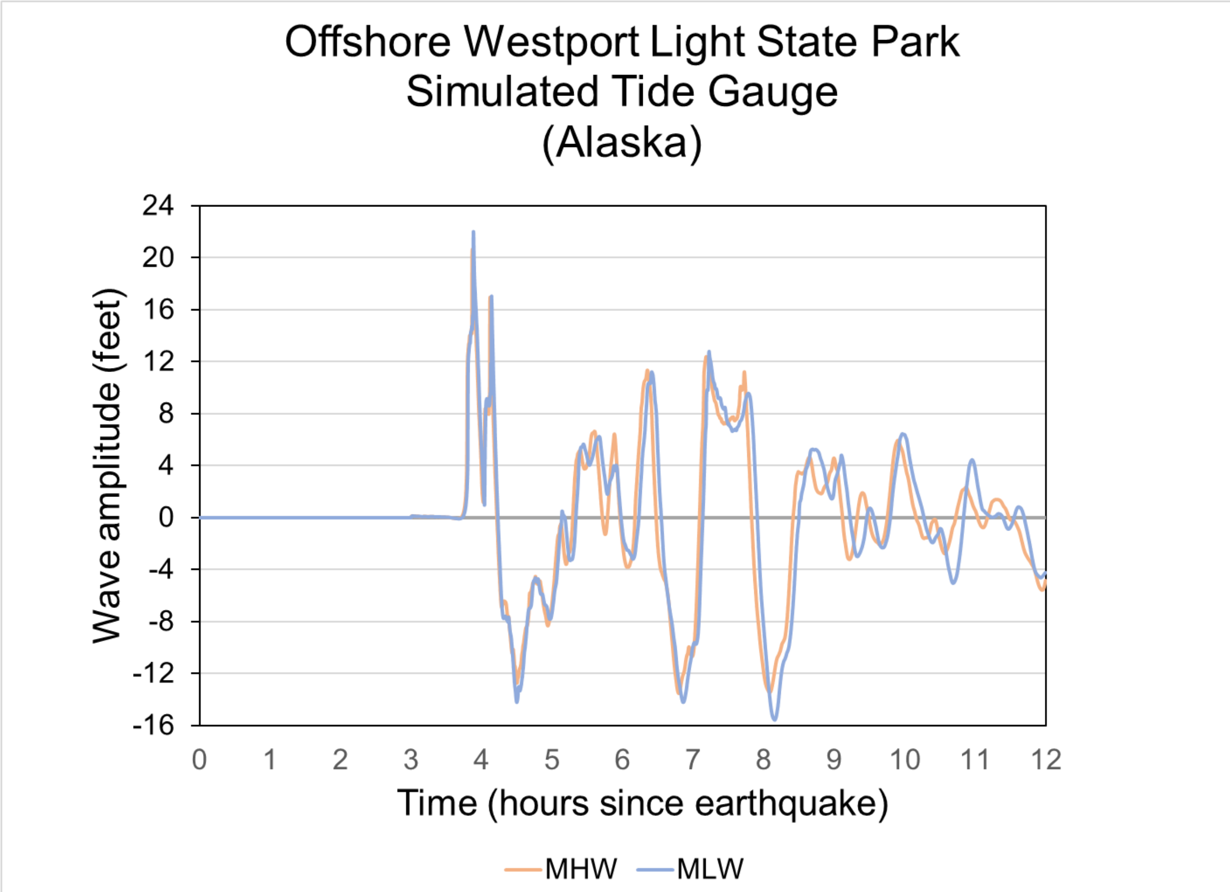


Figure 32: Tsunami wave amplitude, representing the net change of water level and not depth, range over time from a tsunami generated by a maximum considered Alaska-Aleutian subduction zone scenario, AKMaxWA, relative to the mean high water and mean low water vertical elevation datum (MHW; MLW; both corrected to 0) offshore Westport Light State Park. Water depths during MHW and MLW at this location equal ~37 feet and ~30 feet, respectively. Note that the location of this tide gauge is outside of the high-resolution modeled area (modeled with 60 m [2 arc-second] resolution).

Lessons Learned in Northern California from the March 11, 2011 Japanese Tsunami

Prior to the arrival of the March 11, 2011 tsunami in Crescent City, California, many commercial fishing boats headed to sea. Once the tsunami hit and they realized they were unable to return to Crescent City Harbor due to its damage, decisions had to be made as to where to go because of a huge storm approaching the coast. Some vessels had enough fuel to make it to Brookings Harbor in Oregon or to Humboldt Bay, California. Some smaller vessels did not have enough fuel and made the choice to re-enter Crescent City Harbor to anchor. Some of the captains had never been to Humboldt Bay and some were running single handed as they did not have enough time to round up crew. The captains kept in close contact with each other for safety and for moral support. Even though the tsunami initially impacted the west coast on the morning of March 11, 2011, the largest surges in Crescent City did not arrive until later in the evening, when the waves coincided with high tide.

The primary lesson is: if you plan to take your boat offshore during a tsunami, only do so if you have the experience, supplies, and fuel to stay offshore or travel long distances to other harbors because dangerous tsunami activity could last for more than 24 hours and damage within harbors might prevent reentry.

Actionable Natural Warning Signs for a Distant Source Tsunami

As a reminder, for a distant source tsunami you will not feel shaking and there is a possibility that you may not receive an official alert. You therefore need to be able to recognize the natural warning signs of a tsunami and respond immediately when you experience any one of them:

- **If you are ONSHORE, you might:**
    - Hear a loud roar from ocean
    - See water rapidly receding, possibly exposing the sea floor
    - See water surging towards the shore faster than any tide
- **If you are OFFSHORE, you might:**
    - See a rapid or extreme shift in currents and simultaneous changes in wind wave heights

General Guidance on Response to Tsunami Advisories and Warnings for a Distant Tsunami

Tsunami Advisories	**During the tsunami** • Evacuate from all structures and vessels in the water. • Access of public along waterfront areas will be limited by local authorities. • All personnel working on or near the water should wear personal floatation devices. • Port authorities will shut off fuel to fuel docks, and all electrical and water services to all docks. • Secure and strengthen all mooring lines throughout harbor, specifically areas near entrances or narrow constrictions. **After the tsunami** • Port authorities will not allow public to reenter structures and vessels in the water until Advisory is cancelled and conditions are safe.

Tsunami Warnings

During the tsunami

- Access of public along waterfront areas will be limited by local authorities.
- Port authorities will shut off fuel to fuel docks, and all electrical and water services to all docks.
- If you are on the water:
  - Prepare for heavy seas and currents. Maintain extra vigilance and monitor VHF Channel 16 for possible Urgent Marine Information Broadcast from the US Coast Guard.
  - Monitor VHF FM Channel 16 and the marine WX channels for periodic updates of tsunami and general weather conditions; additional information will be available from NOAA Weather Radio.
  - **It is not recommended that captains take their vessels offshore during a tsunami** because they could put themselves at greater risk to injury. However, if they do decide to go offshore, they should proceed to a staging area **greater than 30 fathoms (180 ft) & at least 1/2 mile from shore** and have the experience, fuel, and supplies to stay offshore for more than 24 hours or possibly have the resources to travel to a different port if extensive damage occurs to their home port.
  - **If conditions do not permit, dock your boat and head for high ground or inland.**
  - **VESSELS considering leaving** the harbor and heading to sea, should consider the following:
    - Make sure your family is safe first
    - Check tide, bar, and ocean conditions
    - Check the weather forecast for the next couple of days
    - Ensure you have enough fuel, food, and water to last multiple days at sea
    - **If you do not have time to accomplish your goal, you should not make the attempt.**
    - **PLEASE REMEMBER:** There may be road congestion. There may also be vessel congestion in the harbor as ships, barges, and other vessels attempt to depart at the same time. All vessels should monitor VHF Channel 16 and use extreme caution. NEVER impede another vessel.
  - **VESSELS that stay in port** should check with local port authorities for guidance on what is practical or necessary with respect to vessel removal or mooring options, given the latest information on the tsunami; then exit the tsunami inundation zone.

Tsunami Warnings

	After the tsunami
	After the tsunami • The **"CAUTIONARY RE-ENTRY" DOES NOT MEAN THAT THE HARBOR IS OPEN**. The **"CAUTIONARY RE-ENTRY"** message is for land entry only. • Mariners at sea should monitor VHF Channel 16 for possible US Coast Guard Safety Marine Information Broadcasts regarding conditions and/or potential restrictions placed on navigation channels and entrances to harbors. • Check with your docking facility to determine its ability to receive vessels. Adverse tsunami surge impacts may preclude safe use of the harbor. Vessels may be forced to anchor offshore or travel great distances to seek safe harbor. An extended stay at sea is a possibility if the Harbor is impacted by debris or shoaling. Make sure your vessel is prepared to stay at sea. Where possible Mariners should congregate for mutual support while at sea, anchor, or during transit elsewhere. • If in an onshore assembly or evacuation area, check with local authorities for guidance before returning to the inundation zone.

Section 3: Response Guidance for Westport Marina, Port of Grays Harbor

Response actions taken in the initial minutes and hours of an emergency are critical for protecting lives and property. It is essential to understand which actions are recommended and who is responsible for taking them. Most response actions that are discussed are feasible for Westport Marina. Some will need to be evaluated and expanded upon and others are not feasible. Each action is also rated on its estimated feasibility for implementing the action at Westport Marina. Given the wave arrival time of a Cascadia Subduction Zone (CSZ) earthquake-generated tsunami, these actions were **ONLY considered for a distant source tsunami** (i.e. Alaska). During a CSZ generated tsunami there is not enough time for actions other than personal protective actions and heading inland to high ground as quickly as possible.

Distant Source Tsunami Response Actions	Feasibility for Westport Marina
Shut Down Marina Infrastructure Before Tsunami Arrives	Yes
Evacuate Public/Vehicles from Waterfront Areas	Yes
Secure Moorings of Marina Owned Vessels	Yes
Remove or Secure Hazardous Materials	Yes
Informing and Coordinating with Key First Responders During a Tsunami	Yes
Personal Floatation Devices for Marina Staff	Yes
Identify Boat Owners/Individuals Who Live Aboard Vessels and Establish Notification Processes	Yes
Pre-Identify Personnel to Assist in Rescue, Survey and Salvage Efforts	Yes
Activate Incident Command at Evacuation Sites	Needs Review
Move Vessels Out of the Marina	Needs Review
Restrict Traffic Entering the Marina by Land and Aid in Traffic Evacuation	Needs Review
Activate Mutual Aid System as Necessary	Needs Review
Reposition Ships Within the Marina	Needs Review
Pre-Stage Emergency Equipment Outside Affected Area	Needs Review
Remove Small Vessels from the Water	Not Feasible
Remove Buoyant Assets Out of and Away from the Water	Not Feasible
Restrict Boats from Moving and Prevent Ships from Entering the Marina During a Tsunami	Not Feasible

Analysis of Distant Source Tsunami Response Actions and their Feasibility for Westport Marina, Port of Grays Harbor

Shut Down Marina Infrastructure Before Tsunami Arrives

Description of Response Action

The challenges in tsunami recovery go beyond repairing docks and clearing debris from the water. Torn fuel or sewage pump out lines can leak into the water during and after the tsunami, leading to extensive environmental cleanup. Additionally, if facilities are inundated while the power systems are on, this could cause dangerous conditions and increased damage to those systems. Having procedures and plans in place to shut down infrastructure, including water supply valves and power to facilities, quickly and efficiently, in the event of a tsunami can help mitigate impacts. Ensuring there are shutoffs in appropriate locations that are easy to access, clearly labeled, and/or able to be shut off remotely would save time and improve likelihood of success.

Feasibility for Westport Marina: Yes

Currently, Westport Marina staff plan to shut off the water supply valves at each float and facility before the first waves arrive from a distant source tsunami. This step is briefly outlined in the Marina's emergency procedures but requires more specificity considering there is limited staff capability and additional training may be needed for tsunami response. Staff availability outside of normal business hours for tsunami response is challenging and there may not be a 24/7 solution to address it. As the Marina moves on with improvements, the necessity for these valves and a detailed response procedure for shutting them off should be emphasized.

The Marina should consider including power shut off as part of their current tsunami response procedures. This includes assessing and prioritizing power shut off locations based on their vulnerability to a distant source tsunami. Another consideration is to work with the City of Westport to include procedures to shut off main water supply valves to Marina facilities.

Both the City and the Marina could also investigate the potential for remote controlled or automatic shut off valves and switches. This would help address after business hours staffing constraints and improve response times and effectiveness. Similar systems have been implemented within Washington that utilize ShakeAlert Earthquake Early Warning. A funding source would need to be identified to install automatic systems and/or could be included as part of the current process for replacing valves and updating systems. Additional review would be needed to determine resources needed to accomplish this.

Evacuate Public/Vehicles from Waterfront Areas

Description of Response Action

Limiting the number of people and vehicles in the inundation area when dangerous tsunami waves arrive will help to limit the amount of damage, debris, and casualties associated with the incoming waves. The fewer people and vehicles in/around the inundation zone, the lower the overall risk and danger to life safety. Developing a detailed evacuation plan for these dangerous areas is the first step to ensuring a comprehensive evacuation of people and vehicles from the area during a tsunami.

Feasibility for Westport Marina: Yes

Westport Marina, Port of Grays Harbor owns several parking lots around the marina but does not own or have any authority to regulate traffic or order evacuations. The Marina should coordinate with the City, Regional Fire Authority, and County to request the development of evacuation procedures. The Marina has coordinated with the City, Regional Fire Authority, and County during recent distant tsunamis. Marina staff should disseminate key response information to users of their facilities before and during a tsunami. The Marina should assess ways to improve its ability to communicate with the public and specifically marina tenants and users. This can include providing information to users on existing warning and public information systems like Grays Harbor County's opt-in emergency notification system.

The City of Westport plans to coordinate with local agencies like the Regional Fire Authority to better understand roles and responsibilities for emergency events. For example, traffic control, street closures, and revision most likely fall under the City of Westport Public Works Department. Other evacuation responsibilities may be shared among several City departments such as Public Works, Police, and the Fire Authority. Once these have been identified and outlined in the associated agencies' response plans, this provides an excellent opportunity for the city, local agencies, and the Marina to conduct an exercise on tsunami evacuation.

Secure Moorings of Marina owned Vessels

Description of Response Action

If boats and ships are properly and securely moored during a distant source tsunami, there is a higher chance they will be able to withstand the fluctuating currents and not become dislodged. Prior to the initial wave arrival, boat owners and harbor personnel can visually check that vessels are properly and securely moored. Given the size of some harbors and number of slips and vessels to check, it may not be possible in the time available to check the entire area and every vessel. Given this limitation the check should begin in the areas identified as most at risk of strong currents and other hazardous conditions. Vessel captains and owners should be encouraged to securely moor their vessels every time they dock, allowing a visual check to be conducted quickly. If owners and captains are vigilant about their mooring lines and security, then very few vessels would need to be additionally secured.

Feasibility for Westport Marina: Yes

Due to staffing limitations, it is not feasible for Westport Marina to plan to secure all moorings for the approximately 500 vessels which could be moored at any given time. However, the Marina does keep a list of any derelict vessels in the harbor and "vessels of concern" which have questionable seaworthiness. It would be much more feasible for Marina staff to check the moorings of these smaller lists and leave the privately owned vessels to the responsibility of their owners. The Marina should also consider including the importance of proper mooring in public education materials and other communications so their stakeholders understand how taking a few extra seconds to secure their vessels can help save lives and property. Washington Emergency Management Division plans on working with the Marina to provide tsunami response recommendations for boaters.

Remove or Secure Hazardous Materials

Description of Response Action

Tsunamis become even more dangerous when their debris carries hazardous chemicals and materials. As tsunamis inundate port facilities, barrels of petroleum fuel, manufacturing chemicals, or any other types of waste products including remains of paints, oils, and/or solvents can be spilled, dislodged, and spread out of containment. This will compound existing damage and debris cleanup by creating dangerous health conditions for port users and staff while having significant ecological consequences impacting the local fishing economy. The ability to move portable hazardous materials out of the expected tsunami inundation zone and/or the ability to secure containment of them depends on the tsunami's wave arrival time. While there may be enough time to remove or secure hazardous material for distant source tsunamis, there will not be enough time to do so during most local source tsunamis.

Feasibility for Westport Marina: Yes

Westport Marina will address and update emergency response plans to include procedures and review mitigation possibilities in securing Marina controlled chemical storage. In Westport Marina, there is one Marina owned chemical storage tank that can be capped in during tsunami incidents to mitigate the spill of hundreds of gallons of used oil, but a procedure to do so needs to be established. There would need to be a clearly established standard operating procedure (SOP) developed for this response outlining who determines when the chemical storage tank should be capped, when it should be capped, and that there is enough time to cap it prior to tsunami wave arrival. This SOP would need to be reviewed and tested regularly, and updated if the Marina acquires additional chemical storage, to ensure effective response during a tsunami incident. Privately owned vessels, assets, and facilities in the Marina may also contain similar hazardous materials. During ongoing outreach with users, boaters, and tenants, the Marina can better inform them of personal response actions they can take to secure these materials.

Informing and Coordinating with Key First Responders During a Tsunami

Description of Response Action

Local first responders play a key role in alerting, evacuation, closures, incident management, and post-tsunami response. Ensuring that responders are aware of both the imminent risk to the Marina, its facilities, tenants, and users, and what tsunami response actions the Marina is taking is essential for effective coordinated response and communication. This coordination can help save lives. Response capability for a local source tsunami would be challenging given the short time of wave arrival, inundation depths, and current speeds, but there are still opportunities to coordinate. It would be prudent to identify and practice communication and coordination processes between the Marina and first responders before the next tsunami and apply lessons learned. This will help avoid confusion or duplication of effort and will improve overall response capability.

Feasibility for Westport Marina: Yes

Regardless of whether a tsunami impacting Westport is local or distant, many local agencies will be involved from the beginning in protective actions, response, and recovery. The Marina itself have very limited decision-making authority when it comes to emergencies and disasters. With this said, the Marina and its staff can be an asset to other jurisdictions around the Marina during response even if they are not the primary decision makers or response agency. Each of the agencies are responsible for different geographic locations, decision-making, and/or response actions and it is therefore vital that all are communicating frequently to avoid confusion and duplication of effort. During tsunamis, much of this communication takes place hourly on the Grays Harbor County Department of Emergency Management's conference calls. The Port of Grays Harbor does have representatives on the County's emergency and law enforcement committees that participate in the conference calls during a tsunami. Westport Marina needs to review if the Port's current and future structure informs the participants on the call of issues related to the Marina and that information is being passed to the Marina following those calls.

Personal Floatation Devices/Vests for Marina Staff

Description of Response Action

Ideally, before the first waves arrive all port staff have evacuated to high ground and thus are out of any danger. However, during a local source tsunami there may not be enough time to reach high ground, and during a distant source tsunami staff may remain in the inundation zone to perform response activities. In such an event, having floatation devices or vests easily available for port staff could reduce casualties. Any persons in the inundation zone when waves arrive are in extreme danger and while floatation devices will not guarantee safety, they at least offer a better chance of survival.

Feasibility for Westport Marina: Yes

All Westport Marina crew are issued personal floatation jackets, which they are required to wear when on or near the water, and the marina has sufficient additional jackets for all office staff. The Marina will need to impress upon all staff the importance of wearing these devices if responding during a tsunami.

Identify Boat Owners/Individuals Who Live Aboard Vessels and Establish Notification Processes

Description of Response Action

During tsunamis, alerting boaters will be essential, especially liveaboards. Notifications could be simply an alert that there is potential for damaging waves incoming or could include instructions about protective action recommendations. For those that live aboard their vessels, this may be challenging because their vessel is their home, and they will be reluctant to leave and/or want to return as soon as possible to check on their vessel. Tsunami waves may persist for many hours and/or days creating dangerous conditions that will restrict them from safely returning. They will be temporarily, or possibly permanently, displaced.

Having a list of boat owners, including liveaboards, would improve alerting capability so they can be rapidly informed and more quickly take protective actions during tsunamis. It is worth noting that it can be challenging to account for all liveaboards due to housing instability and potentially an influx of international seasonal fishermen. Notifications can be delivered many ways: through phone trees, email notifications, text messages, or even by personnel in the harbor using loudspeakers. Remember, boaters may not be able to receive any one method of notification so the redundancy of multiple methods of notification should always be preferred.

Feasibility for Westport Marina: Yes

Westport Marina used to have a texting program, but it proved unreliable and so was discontinued. The Marina does have a social media presence which it launched in April 2022. The biggest challenge with mass notification to marina stakeholders is that the userbase of the Marina is always changing and many people choose not to sign up for the opt-in communication system. Along with a better method for reaching Marina users, the Marina should consider educating their userbase about the many options for receiving tsunami alerts such as NOAA Weather Radios, marine radios, WEA, EAS, Twitter, and third-party mobile applications. The Marina could educate users about the Grays Harbor County public notification system that will call, leave voicemails, and text anyone who opts-in so they will receive local alerts during emergencies, including tsunamis.

Pre-Identify Personnel to Assist in Rescue, Survey and Salvage Efforts

Description of Response Action

A major part of the post-tsunami response will be the rescue, survey, and salvage operations in the area. Once the waves recede, first responders will need to conduct search and rescue if people did not make it out of the inundation zone in time as there may be survivors trapped under debris or even pulled out to sea. Personnel will need to conduct survey safety assessments to determine what port facilities are not safe to enter and use. Port entrances, shipping lanes, and navigation channels will also need to be assessed to determine if they are safe for vessel reentry due to potential risk from debris, scouring, and movement of sediment. Finally, personnel will need to determine what facilities or equipment can be salvaged. Whatever is not salvageable will need to be removed.

Feasibility for Westport Marina: Yes

The subject of survey and salvage is mentioned in Westport Marina's Emergency Response Plan. This section of the plan needs a thorough review and expansion, both of internal roles and external agency coordination for these efforts. Marina staff will need to coordinate with and assist agencies that are involved in conducting survey safety assessments for their own facilities. The Marina will need to ensure that proper training and exercising is provided to accomplish this. The channel into the harbor and marina is federal jurisdiction and the Corp of Engineers will be responsible for surveying and determining its condition. The Coast Guard has the authority, just like after a hurricane, to restrict all traffic until it determines it is safe for navigation.

Activate Incident Command at Evacuation Sites

Description of Response Action

During and after a tsunami, evacuation sites will likely be crowded with evacuees. People may be injured, scared, and eager for answers and explanations. Activating an Incident Command at the evacuation area(s) can help to provide clear and direct leadership, chains of command, and span of control. It will be important to have qualified authorities who understand the Incident Command System (ICS) and how it operates filling those positions of leadership. Having an organized and structured command at these locations can help reduce confusion, organize and calm evacuees, and prepare for response activities after the tsunami is over.

Feasibility for Westport Marina: Needs Review

While there will be staged supplies at the proposed vertical evacuation structure in Westport Marina, incident command will not be activated at this location. For a distant source tsunami, like AKMaxWA, there will be more time for response and evacuation and therefore evacuation sites outside of the inundation zone and the proposed vertical evacuation structure will be utilized. Using the tsunami inundation maps provided in this study for a distant AKMaxWA scenario (Figure 25), the City of Westport could explore the possibility of determining additional evacuation sites outside of the inundation zone and activating incident command at those sites. For a local source CSZ generated tsunami, there would not be other viable evacuation areas other than the proposed vertical evacuation structure due to limited response time.

It would be beneficial for Marina staff to be trained in ICS so they can better understand its use during tsunamis and provide more knowledgeable, experienced assistance to responding agencies. ICS training is not currently required for Westport Marina staff but should be considered for at least those personnel with decision-making authority and other key responsibilities so they are better able to coordinate with and support responders. Many ICS classes are free, can be completed online at your own pace, and do not require a huge time commitment. Even a basic understanding of ICS will improve the Marina staff's effectiveness during a tsunami.

Move Vessels Out of the Marina

Description of Response Action

For ports and marinas that lie on the coast of the open ocean, relative safety for ships can be found at depths of 30 fathoms (180 feet) for a distant source tsunami and 100 fathoms (600 feet) for a local source tsunami. In some locations the distance to these depths is short and, depending on the time it will take for the first wave to arrive, evacuation of ships and boats to sufficient depths may be possible. The evacuation effort would need to be planned, orderly, and controlled to avoid dangers associated with congestion in the waters. Some jurisdictions, such as the island of Oahu in the state of Hawaii, have already implemented such plans.

Feasibility for Westport Marina: Needs Review

To determine if this process could take place, additional study and review would be necessary. Westport Marina would have to coordinate with other local, state, and federal agencies to determine feasibility of staging areas for both commercial and recreational vessels. This coordination would be essential since the Marina does not have the authority to handle vessels or require vessels to move during a tsunami. It is more feasible to share tsunami protective action guidance with vessel owners and operators through ongoing outreach and education initiatives.

Restrict Traffic Entering the Marina by Land and Aid in Traffic Evacuation

Description of Response Action

During a tsunami advisory or warning, one of the main life safety actions is to help people evacuate to high ground and/or vertical evacuation structures. To facilitate this, ports and marinas should develop a strategy to coordinate with local government officials to restrict vehicular and foot traffic from entering port/marina owned property that is in the inundation area and assist in the safe and orderly evacuation from those areas. If applicable, response actions that could restrict entry include closing gates to port entrances and blocking roadways with port/marina owned vehicles. Personnel could aid in local government evacuation efforts by utilizing flags, hand gestures, or temporary signage. If staff can assist in evacuation efforts, it is important to provide them with high visibility clothing or vests and flashlights to improve their safety and effectiveness.

Feasibility for Westport Marina: Needs Review

Responsibility for evacuating people from the waterfront area of Westport falls under the City of Westport, not Westport Marina. The Marina will evacuate people from vessels and direct them to high ground, at which point those evacuees would then fall under the direction of the City or County. Currently, there is not a process in place for restricting traffic from entering the Marina or aiding traffic out of the Marina during tsunamis so the City will need to review and coordinate with other agencies to establish a plan. Efforts to prohibit entry may be difficult due to limited staff and their availability during different times of day. When a plan is established, the Marina should work with the City to identify any tasks which its staff could assist with in the Marina area during the evacuation process. The Marina should educate personnel, tenants, and users about the ways in which they may receive communications from the City of Westport and Grays Harbor County during emergencies like evacuations. The Marina should also train their staff on tsunami evacuation processes and test these processes by conducting regular drills.

Activate Mutual Aid System as Necessary

Description of Response Action

Activation of a Mutual Aid System can help locations experiencing an emergency receive additional assistance from nearby jurisdictions that are not part of the emergency. Activating this type of system allows authorities in an area struck by a disaster access to additional resources that may be scarce during the initial response or may be needed in numbers that exceed the amount available in the disaster area.

Feasibility for Westport Marina: Needs Review

While Westport Marina is part of The Port of Grays Harbor, which is a government agency, the Marina is under the jurisdiction of the City of Westport. This means Marina does not have response authority or capability but is still responsible for managing the infrastructure of Westport Marina. The City of Westport has law enforcement authority and South Beach Regional Fire Authority has emergency medical service (EMS) authority for the Marina. They are not considered mutual aid systems but responsible agencies. As such, they would be the entities that are able to request mutual aid on behalf of the Marina. During any emergency incident the Port's primary role, and by proxy the Marina's primary role, is to provide information to boaters and users, notify the proper authorities, and work with responders as needed.

There is a Grays Harbor Tsunami Action Plan that is in development through Grays Harbor County Emergency Management which will highlight and determine what mutual aid systems are needed for tsunamis. The Marina should consider training their staff in how these systems work, what agreements are in place, and how mutual aid can be requested through the City of Westport and the South Beach Regional Fire Authority to improve effectiveness during an actual tsunami.

Reposition Ships Within the Marina

Description of Response Action

Using tsunami current velocity maps, ports and marinas can identify areas that are most likely to encounter strong currents during tsunamis. Once identified, they can then determine if moving ships out of those areas of danger and placing them in locations less likely to experience strong currents would be beneficial. What ships would need to be moved and to where is something that should be determined well ahead of a tsunami and detailed in a plan. Ideally the Marina would focus on large ships with deep keels in dangerous areas that may be more likely to experience sufficient drag to rip them free of moorings, damaging infrastructure and leaving the ships free floating to cause additional damage. There would need to be clearly established standard operating procedures (SOPs) developed for this response which detail specific instructions as: who determines that a vessel should be moved; that there is enough time to safely move the vessel; and ultimately who is responsible for moving the vessel. These SOPs would need to be reviewed, tested, and updated on a regular basis to ensure an effective response during a tsunami incident.

Feasibility for Westport Marina: Needs Review

This process could potentially take place at Westport Marina during a distant source tsunami if the Marina were to focus efforts on large steel commercial vessels (85 to 105 feet in length) rather than all commercial and recreational vessels. These vessels are most likely to cause significant infrastructure damage due to their size, especially due to risk from high current velocities (refer to Figures 26 and 27) and thus are most important to move to a safer location – in this case out of the marina entirely and into deeper water off the coast. They are also most likely to have resident crew members on board, which increases the need to get these ships to a safe location before the first wave arrives. While the Marina does not have the authority to handle these vessels or require them to move during a tsunami, they should communicate with large commercial vessel operators and provide instructions and guidance as necessary. Westport Marina should include protective action guidance and procedures in their emergency response plans to communicate with these vessels and ensure that proper training and exercising is provided for that communication.

Pre-Stage Emergency Equipment Outside Affected Area

Description of Response Action

The aftermath of a destructive tsunami requires a significant number of emergency responders and their equipment to show up at the affected area to begin search and rescue, salvage, and clean up. If any emergency response equipment normally resides within the inundation zone, it should be pre-staged out of the area before the waves arrive so it is not damaged and remains operable for the post-incident response. Any necessary equipment should be identified in advance and a plan made to determine what equipment needs to be pre-staged outside of the tsunami inundation zone before a tsunami were to take place. This would save time, resources, and staffing for response during a tsunami where resources may already be limited.

Feasibility for Westport Marina: Needs Review

Currently Westport Marina does not have any emergency equipment of its own. The Marina applied for funding for an oil spill response vessel but was recently denied. They will continue to advocate for getting emergency equipment of this kind that can be trailered; when or if this occurs, the Marina should consider pre-staging this equipment permanently outside of the inundation zone if possible since there is already limited staff available during response. A tentative location where the Marina could store future emergency equipment would be at the City of Westport's Water Maintenance facility which is designed to be the Emergency Operations Center during incidents.

Remove Small Vessels from the Water

Description of Response Action

Tsunamis can generate an extensive amount of debris which in turn can damage vessels and other marine assets due to fluctuating current speeds, inundation, and drawdown. Prior to tsunami wave arrival, ports and marinas may be able to remove their assets and smaller vessels from the water and encourage its users to do the same. This could reduce the potential for these vessels and assets to be damaged by debris or become drifting debris themselves. However, the ability to remove vessels and assets from the water is dependent on the tsunami's estimated wave arrival time. While there may be enough time to execute this process for distant source tsunamis, there may not be enough time to do so during most local source tsunamis. Removal would also be a time-consuming and labor-intensive process which would require adequately trained personnel and may require specialized equipment such as shoreside boat lifts and trailered vehicles to remove vessels from the water. To effectively coordinate this process amongst a port or marina and its users, proper training and exercise would need to be provided for port staff and its users would need to be informed of those processes and recommendations. If a port or marina owns vessels essential to life safety, such as equipment used for search and rescue operations, fire and spill response, and law enforcement activities, they should be prioritized for removal from the water.

Feasibility for Westport Marina: Not Feasible

Westport Marina does not have the equipment necessary for removing assets or small vessels from the water, such as a haul-out facility or public hoists. Vessels moored at the Marina are privately owned and it is the responsibility of the vessel owner to provide the means of removal from the water. As with other recommended response actions in this strategy, the Marina can help educate vessel owners of recommended protective actions they can take to protect themselves, their crew, and their vessels during tsunamis.

Remove Buoyant Assets Out of and Away from the Water

Description of Response Action

Buoyant assets such as floats, buoys, empty drums, barrels, and other manufacturing or fishing supplies can become debris during tsunamis. Any items that will easily float and are not needed near the water for normal operations should be moved to an area outside of the inundation zone when possible. Similar assets that need to remain in the inundation area should be secured as much as possible. While a large local source tsunami is likely to dislodge and damage even moderately secured buoyant assets, they may remain secured during a smaller distant source tsunami.

Feasibility for Westport Marina: Not Feasible

Currently Westport Marina does not have any buoyant assets which fit this recommendation. However, the Marina should consider providing education to their tenants about securing their buoyant assets so items outside the Marina's control can also be secured. These public education efforts can be completed in tandem with recommendations provided by WA EMD to complement existing educational resources.

Restrict Boats from Moving and Prevent Ships from Entering the Marina During a Tsunami

Description of Response Action

Due to the strong, unpredictable currents and massive amounts of debris in the water during a tsunami, vessels in motion on the water can be in extreme danger. Eliminating or severely restricting vessels from being occupied and in motion on the water reduces the danger to life safety and can help to limit casualties. Since the narrow entrances of most harbors are where tsunami-caused currents can be strongest, vessels should not enter or leave the harbor during a tsunami. While boaters should be encouraged to return to the harbor if possible before tsunami waves arrive, entering the harbor should not be attempted once the initial wave crest or trough has arrived. These locations will be highly dangerous to navigate during a tsunami, and when currents are at their strongest may prove impossible to pass through at all.

Feasibility for Westport Marina: Not Feasible

For Westport Marina, the Grays Harbor Pilots handle the movement of all ships and would make the decision whether to bring vessels into or out of the Harbor. These pilots should be trained on what to do to protect vessels during a tsunami. The Coast Guard can restrict the entrance of recreational traffic into or out of the Harbor, which they do for hazardous bar conditions. Unless it is included in an emergency declaration by the Governor, or possibly the County, no one can prevent commercial craft that don't require a pilot to be on board to enter or leave Grays Harbor. The Marina can recommend vessel owners take certain protective actions depending on their location and wave arrival time, but they cannot specifically require certain actions to be taken. Instead, the Marina will work with WA EMD to provide these recommendations through a combination of ongoing public education and outreach initiatives to inform boaters of protective actions to take during tsunamis and better understand how to protect themselves and their crew. Coordinating with WA EMD, the Marina could also investigate disseminating information (signs, published, and online/social media) to inform users where to go for information such as Coast Guard Marine Broadcasts, NWS Radio, etc., in during a distant tsunami.

Section 4: Mitigation Guidance for Westport Marina, Port of Grays Harbor

Mitigation actions are taken to reduce risk and protect lives and property before an emergency happens. They can require a significant amount of time, investment, and expertise, but are essential for reducing the impact of a tsunami on maritime infrastructure. Some examples include strengthening cleats and moorings and installing stronger or taller dock piles. Here are common maritime mitigation actions with visuals to help you understand what they would look like after completion, as well as identify the parties responsible for undertaking those actions. Each action is also rated based on its estimated feasibility for implementation at Westport Marina, Port of Grays Harbor.

Mitigation Actions	Feasibility for Westport Marina
Install Tsunami Signs	Yes
Increase Size and Stability of Dock Piles/Increase Height of Piles to Prevent Overtopping	Yes
Reduce Exposure of Petroleum/Chemical Facilities and Storage	Yes
Strengthen Cleats and Single Point Moorings	Needs Review
Improve Movement of Dock Along Dock/Pilings	Needs Review
Acquire Equipment/Assets to Assist in Response Activities	Needs Review
Improve Floatation Portions of Docks	Needs Review
Fortify and Armor Breakwaters	Not Feasible
Deepen or Dredge Channels Near High Hazard Zones	Not Feasible
Move Docks and Assets Away from High Hazard Zones	Not Feasible
Widen Size of Harbor Entrance to Prevent Jetting	Not Feasible
Construct Floodgates	Not Feasible
Construct Breakwaters Farther Away from the Marina	Not Feasible
Increase Flexibility of Interconnected Docks	Not Feasible
Debris Deflection Booms to Protect Docks	Not Feasible

Analysis of Tsunami Mitigation Actions and their Feasibility for Westport Marina, Port of Grays Harbor

Install Tsunami Signs

Figure 33: Tsunami evacuation kiosk in Oceanside, California.

Mitigation Action Description

Installing tsunami signs is the easiest and most cost-effective mitigation action that a port can take to reduce tsunami injuries and casualties. The simple signage can help to educate harbor users of the danger of tsunamis in the area and can help direct individuals to higher ground during an evacuation of the area. Signs are cheap, installation is easy, and upkeep is minimal. Signage can be posted along roadways and trails to alert people that they are entering or leaving a tsunami inundation zone, so individuals entering the area know of the need to evacuate if a tsunami warning is issued. Signage designating the location and direction of evacuation routes can be posted to help people find and follow the established evacuation routes quickly during an evacuation. Standardized signage has been created to designate the extent of inundation areas as well as to designate and define evacuation routes. Additionally, signage can be created to educate and inform people of anticipated tsunami inundation extent in the area, evacuation route maps, and even general tsunami information. Many states, counties, and cities that face tsunami danger have built informational kiosks to inform the public of tsunami dangers, such as the evacuation kiosk shown in figure 33.

Feasibility for Westport Marina: Yes

This is an easy action for Westport Marina, Port of Grays Harbor to address and there is a high need for additional signage in the Marina district. The City of Westport and Westport Marina plan to work with Washington Emergency Management Division in the future on the placement of wayfinding signage (tsunami evacuation route, tsunami arrows, evacuation route information) and informational signage educating Marina users about tsunami risk, alerts, and evacuation information. There currently is no educational signage in the Marina and very limited wayfinding signage. As part of a larger statewide tsunami wayfinding project, Washington Emergency Management division will inventory locations of existing signage, provide recommendations for placement of additional signage, and work with local jurisdictions to provide signage. Additionally, with the new proposed vertical evacuation structure in Westport, there is an opportunity to educate the public about the structure and navigate them to the structure through signage. While it may be expensive, investigating options that employ the use of electronic signage could be beneficial where information about local emergencies, like tsunami warnings, could be updated and disseminated quickly. Information about recommended evacuation routes, protective actions to take, and other general information could be displayed as well.

Increase Size and Stability of Dock Piles/Increase Height of Piles to Prevent Overtopping

Figure 34: Docks lifted off pilings due to extreme water level changes.

Mitigation Action Description

Structurally, the pilings are one of the most important components of a dock. The pilings act as the dock's foundation, keeping the structure attached to the sea floor while allowing vertical movement as water levels change with waves or tides. Tsunami inundation has the potential to be sufficiently high enough to float docks off the top of the pilings, leaving them unattached and floating freely (Figure 34). The strong currents from tsunamis can also, through scouring or drag on the docks and vessels attached to them, pull pilings from the ground. Pilings that are pulled loose also lead to a dock unattached to the sea floor and floating in the dangerous waves. Untethered, freely floating docks pose a danger in a tsunami, essentially becoming massive pieces of debris moved by the waves, possibly with vessels still attached to them. To help ensure docks remain attached to the sea floor during a tsunami, ports and harbors may choose to increase the size and stability of the pilings. Installing pilings taller than the expected potential inundation levels will help ensure docks do not float off the top of the pilings. Thicker pilings will resist the shearing forces from the extreme drag of the tsunami waves much better than thinner ones. Installing pilings deeper into the sediment of the sea floor can help them remain foundationally solid, more resistant to scouring, and keep them from pulling out of the soil.

Feasibility for Westport Marina: Yes

Westport Marina has hundreds of 60-foot, 12-inch diameter wood creosote pilings which are being replaced over time with more resilient 60-foot, 12-inch steel pilings. To determine which wood creosote pilings need to be replaced, staff evaluate the wood wear, age, and stability, and can replace up to 18 wood creosote pilings a year following permitting requirements. While it is feasible to replace the pilings, the steel pilings are cost prohibitive. In the update of the 2022 Marina Modernization plan, the Marina could advocate more aggressively for additional funding to replace up to 18 pilings every year or every other year. While pilings are replaced, staff could prioritize the replacement of wood pilings in areas with increased tidal flow and expected high tsunami current speeds (refer to Figures 26 and 27). The Marina could also consider increasing the height of newly replaced pilings so they are not overtopped by reviewing modeled water depths during tsunamis provided in this strategy (refer to Figure 25).

Additionally, the Marina could evaluate the need of placing dolphins in areas of increased flow conditions, during normal tidal fluctuations, and tsunami flows. While this option would be an expensive one, it could be considered in future upgrade and replacement projects as well to strengthen the ends of the floats.

Reduce Exposure of Petroleum/Chemical Facilities and Storage

Mitigation Action Description

Since ports and harbors are where ships go for refueling and many routine maintenance procedures, these areas will have several facilities that utilize and store petroleum and chemical products. Damage to or destruction of these facilities or the locations and containers that store petroleum or chemicals during a tsunami can cause a widespread hazardous material spill and contamination. Some ports may even have chemical processing facilities or oil refineries in addition to normal vessel fueling facilities and manufacturing plants that utilize chemicals. Petroleum products and many other chemicals are less dense than water and will float on top of the inundating waves to be left on shore or pulled out to sea as the waves recede. Petroleum products have been known to combust even on top of the water; the fuels can also catch floating debris on fire. An inferno on top of an inundating tsunami wave or pulled onto the open sea can swiftly become an even larger disaster than the original destructive wave.

Ideally major chemical processing facilities as well as refineries and extremely large fuel storage tanks should be located well outside the inundation zone. If that is not possible then the next best solution would be to construct or retrofit those facilities to withstand a major earthquake and resulting tsunami. Smaller holding tanks and storage facilities should be considered for relocation out of the inundation zone if possible, moved to locations at less risk for damage or destruction, or hardened as much as possible to withstand earthquake shaking and tsunami waves.

Figure 35: Chemical storage tank in Westport Marina.

Feasibility for Westport Marina: Yes

At the Westport Marina, there is one Port-owned chemical storage tank that can be capped in the event a tsunami is on the way (Figure 35). Creating an emergency procedure to have Marina staff cap the storage tank prior to wave arrival could mitigate the potential spill of hundreds of gallons of used oil which could compound existing debris and spill clean-up. While there is not a feasible location to place the storage tank out of the inundation zone for a local CSZ tsunami, since inundation is expected throughout the entire area, it is possible to elevate the storage tank above AKMaxWA inundation levels at its current location (refer to Figure 25). Marina staff would need to assess potential retrofits, including elevating the storage tank, to withstand impacts from tsunami waves and other hazards. Many of the other chemical facilities and storage are owned, maintained, and operated by tenants of Westport Marina. The Marina could help provide general information and recommendations for the safe storage and elevation of chemicals to tenants that could mitigate spillage during tsunamis. Westport Marina will update emergency response plans to include procedures, and review mitigation possibilities, for securing chemical storage controlled by the Port of Grays Harbor.

Strengthen Cleats and Single Point Moorings

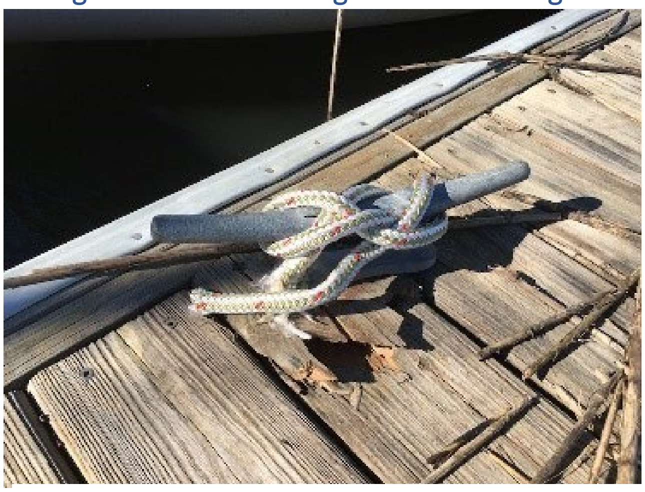


Figure 36: Cleat ripped from dock.

Mitigation Action Description

The cleats and mooring points used to anchor vessels to docks need to withstand extreme forces during a tsunami. Vessels that are pulled free from their moorings during a tsunami quickly become part of the massive amount of debris moving in the water, potentially destroying other vessels and infrastructure. Cleats and mooring points that are poorly installed or are of insufficient size for the vessels moored to them will not be able to withstand the forces exerted on them during a tsunami and could be ripped free (Figure 36). Lag bolts attaching cleats can snap or be pulled free from the dock structure; worn and rusty cleats can break off or bend, releasing lines. To ensure that the mooring points remain secure even in extreme scenarios, cleats need to be rated strong enough to hold not just the weight of the vessels they secure, but also withstand the additional forces from the drag on those vessels due to the extreme currents of a tsunami. Such cleats and moorings should be secured to the dock structure with high tensile bolts and a backing plate so pulling forces are spread over a larger surface area, as shown below in Figure 37.

Feasibility at Westport Marina: Needs Review

Figure 37: Bollard with backing plate to distribute force.

There are thousands of cleats in Westport Marina and each slip typically has 3-4 cleats. The cleats are not secured to concrete; rather, they are fastened to wood whalers and coverboards. Some of the wood in Westport marina is the original wood dating back to the early 1980s and needs to be replaced. The Marina should inventory the number, types, approximate ages, and relative condition of the wood and mooring points to better understand their condition and suitability. Rather than replace the cleats themselves, the Marina can prioritize the replacement of aging wood first where the cleats are attached to strengthen them against high drag and pull from fluctuating waves. Focusing on wood replacement in commercial areas of the Marina could be considered first for future work plans and capital improvement. Additionally, while replacing the cleats with single point moorings is not feasible for the entire Marina, the Marina could investigate the use of stronger cleats and alternative moorings during dock upgrade and replacement projects as feasible for large commercial vessels that are 80 feet or greater. To accomplish this on a broader scale, The Marina would need to identify external sources of funding.

Improve Movement of Dock Along Dock/Pilings

Mitigation Action Description

As with the flexibility of dock connections, one of the dangers in the rapid water level changes that come with a tsunami wave is docks not freely moving vertically along the guide of the pilings. The unpredictable waves and rapid water level changes have been known to cause the connection between docks and piles to bind. This can cause the docks to get 'jammed' against the pilings, leaving the dock unable to float up with the water. When docks get stuck on the piles the water level can quickly overtop the dock surface, causing major damage. Some hardware used to connect docks with pilings, such as simple metal hoops with little space between the dock hardware and piling, can be more prone to binding. As docks lift rapidly on one side, the other side can become wedged against the piling at an angle. The force of the water against the dock surface can bend these hoops, trapping the dock even more, or can cause the connection hardware to break, leaving the dock unattached to the piling and allowing it to float freely and become debris. Dock connections to piles that run through a hole in the dock surface are less likely to bind or break, and utilization of guide wheels or rollers helps to avoid binding issues and promote smooth movement even more (Figure 38).

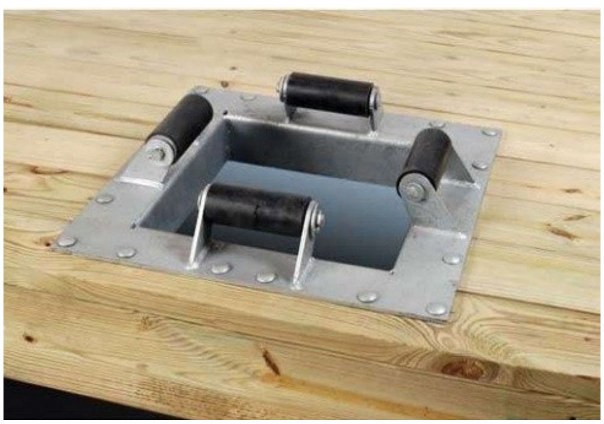


Figure 38: Through deck piling hardware with rollers to promote smooth movement.

Feasibility for Westport Marina: Needs Review

To improve the movement of the docks along the pilings in the Marina, connection hardware that incorporates the use of rollers should be considered as pilings' hoops are replaced during future Marina modernization efforts. Currently piling hoops slide along the pilings, thus increasing the wear on the wood pilings themselves, accelerating their need for replacement. Additionally, dock connection hardware in the Marina that doesn't use rollers could be prone to breaking or binding. Westport Marina should inventory the types of hardware used to connect docks to the pilings to determine areas that could be prioritized for replacement and/or upgrade to include rollers. The hardware that is replaced should be of sufficient strength to withstand extreme wave action and able to move smoothly as much as is feasible for the intended use.

Acquire Equipment/Assets to Assist Response Activities

Mitigation Action Description

Post-tsunami response will be a complicated effort involving many personnel and equipment. Vessels will be needed to patrol and search the water for survivors or casualties, as well as to tow or move damaged vessels, broken or detached docks, and other large debris in the area. Fireboats and other firefighting equipment will be needed to extinguish any fires that start among vessels, facilities, or on floating debris. Cranes may be needed to hoist and move large debris either in the water or elsewhere on the port property. Other equipment may also be required such as loaders, bulldozers, or other earth moving equipment to clear debris and allow access to all the port property. Large ports and marinas may already have some of this equipment on site; smaller ports may have less equipment or may rely on equipment owned or operated by other entities. Regardless, response will require equipment, and the more of that equipment that is either owned by or prearranged for use by the port or marina, the faster the response can begin and clean up can start. If a port does not have equipment or the means to purchase it, they should consider developing a plan, including agreements with local entities to rent, borrow, or have use of any equipment that would be needed to respond after a tsunami in their port.

Feasibility for Westport Marina: Needs Review

Assets that are currently owned by the Port of Grays Harbor could potentially be used for tsunami response at Westport Marina, if necessary, but further review of available assets and procedures would need to be established. Currently, there are no Marina specific assets, including fireboats, that can be used in any emergency response at the Marina, including spill response. However, the Marina is in the process of seeking funding for a response boat that can be used in a broad variety of emergency response and clean-up capabilities. When considering securing emergency response assets, the Marina should take into consideration inundation and current velocity mapping provided in this document when choosing a storage site to mitigate damage of the assets. While this would not be possible for a CSZ tsunami, there are locations within Westport Marina of reduced tsunami current and areas of dry land during an Alaska tsunami.

Improve Floatation Portions of Docks

Figure 39: Docks built on floating blocks.

Mitigation Action Description

The rapid onset of tsunami waves can rapidly over-top docks causing them to sink and break apart if the docks are not sufficiently buoyant. It may appear that since they are floating and rise and fall with the tides and waves, that all docks have sufficient floatation portions under them. However, certain styles and materials of floating dock structures are in fact much more buoyant than others. Many docks are made 'pontoon' style where tubes of buoyant materials (sometimes filled with foam) run in a parallel track with a platform built on top. Another common dock construction technique is to use solid floating 'blocks' either at the ends of the dock structure or at widely spaced distances along the entire length (Figure 39). These styles, while common, will not prove to be as buoyant as docks with a floatation section that spans the entire underside of the dock area. The most buoyant docks are built on top of sturdy, sealed 'blocks' made from High Density Polyethylene (a strong, impact resistant plastic) filled with buoyant foam such as Expanded Polystyrene (like Styrofoam) which spans the entire dock width and length (Figure 40). The increased buoyancy of full floatation docks will do the best at handling the extremely fast changes in the water depths that accompany tsunami waves.

Figure 40: Docks built on full flotation system.

Feasibility at Westport Marina: Needs Review

When considering new design and rehabilitation projects, the Marina explore options that increase the overall resilience for the flotation of docks in the Marina. Additional review with engineering personnel would be needed for the assessment of current dock conditions as with other ongoing maintenance and replacement projects. If there were to be significant upgrades to improve the floatation of docks, additional funding sources would need to be identified.

Fortify and Armor Breakwaters

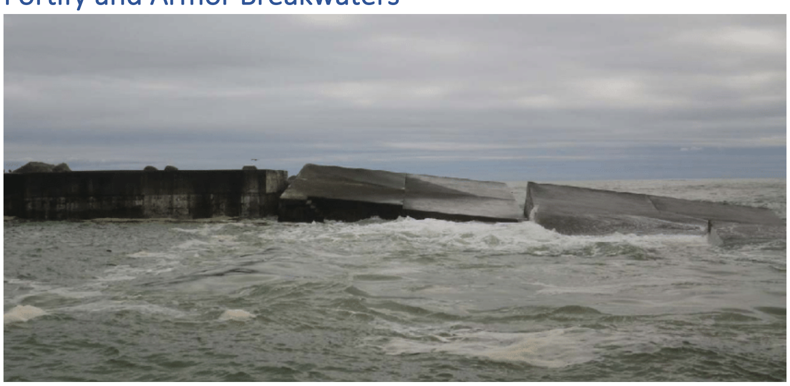


Figure 41: Breakwater failure in Japan after 2011 Tohoku Tsunami.

Mitigation Action Description

Breakwaters are designed to absorb and deflect strong wave action to protect ships and vessels from rough seas. Unless built to extreme heights, breakwaters are unlikely to block tsunami waves. The waves would likely overtop the structure, allowing inundation to enter the normally protected area. The strong waves and currents from a tsunami could also cause extreme scouring on infrastructure like breakwaters. The wave action can remove the soil that acts as the foundation of the structure and could even strip away sections of the breakwater itself. Scouring and damage during a tsunami could cause the breakwater to fail, as pictured in Figure 41, allowing even more water to flow into the area. Sudden gaps in the breakwater can also create new unpredictable and dangerous currents.

Any damage to breakwaters will also need to be repaired post-tsunami, and if damage is severe enough could require full replacement of the structures at considerable time and cost. The concept behind armoring or fortifying breakwaters is simple; the entire structure is further

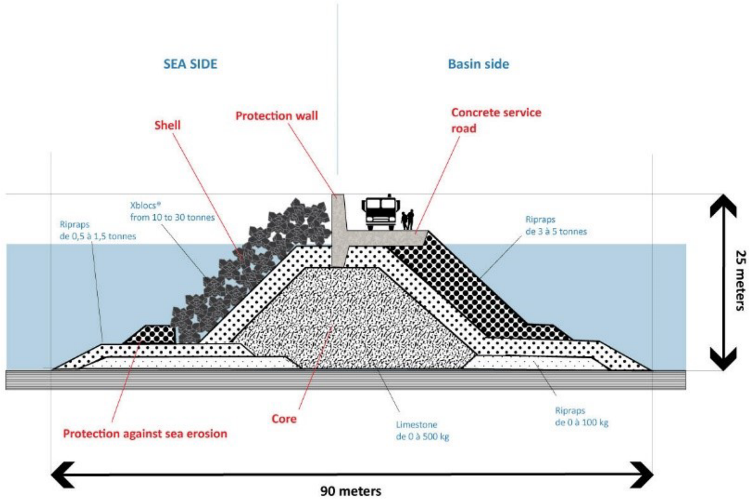


Figure 42: Cross-section of a fully fortified breakwater.

reinforced to make it stronger, thicker, and sturdier. These enhancements are made to create more resilient structures that would be able to withstand the effects of a tsunami. Fortification implies strengthening the entire structure through the addition of material like rubble or concrete, increasing the size and strength of the foundation, and overall creating a larger and more sturdy structure as seen in Figure 42. Armoring implies covering the seaside of the breakwater with additional materials to help in strengthening the structure. Armoring can be done with actual rock like rubble or using wave dissipating blocks, large pre-formed concrete blocks built to be placed in an interlocking pattern less likely to break loose in strong wave and current action as shown in Figure 43.

Both armoring and fortifying breakwaters are time, resource, and cost intensive efforts which likely requiring extensive engineering, environmental assessment, approval, and construction processes. If a port has the means in the long term to engage in such a process, the benefits extend beyond just the potential to lessen tsunami damage. However, the amount of cost and effort may lead this option to only be seriously considered when building new breakwaters or when the span of life is over for current breakwaters, and they require replacement.

Figure 43: Armored breakwater.

Feasibility for Westport Marina: Not Feasible
This mitigation action is not possible for Westport Marina, Port of Grays Harbor to accomplish on its own since modifying a breakwater would require federal authorization. While there could be benefits for making the breakwaters more resilient to tsunamis, they are managed and maintained by the US Army Corps of Engineers. With this said, it is possible for the Marina to have discussions with the US Army Corps of Engineers on the benefits of this and to support efforts like obtaining funding and securing authorization for this work to be done. If the US Army Corps of Engineers were to take this task on, it would be a long and resource intensive process.

Deepen or Dredge Channels Near High Hazard Zones

Mitigation Action Description

The effects of a tsunami wave will always be strongest and most pronounced in shallower waters. Just as the wave rises higher as it enters shallower waters, pushing the water further onto dry land, the other effects are similarly more pronounced in locations where the depth is less. In harbor areas scientific mapping and modeling can identify specific locations where tsunami hazards are highest. Deepening these locations through dredging or other means will not eliminate the hazards but can help to lessen their effects. The process of dredging or otherwise deepening channels is a complicated, involved process that will require significant inputs of time and money. Given the benefit from deepening channels will only alleviate some of the effects of the tsunami hazard, it is most likely not going to be worthwhile as a standalone action. However, sedimentation builds over time and eventually all harbors, ports, and channels will require dredging for maintenance purposes. It is more likely that ports would choose this time of regular maintenance to utilize hazard maps to determine the areas of high hazard and deepen them as much as feasible.

Feasibility for Westport Marina: Not Feasible

The hazard maps developed for Westport Marina identify a few key locations in the Marina where there is an increased risk tsunami risk. Specifically, the entrance of Westport Marina has a high risk for currents exceeding 9 knots above normal tidal flow during an Alaska-source tsunami. It is likely that the "jetting" effect of the water is an effect of the narrow entrance to the harbor and not the depth. As with the breakwaters, the entrance channels are federally maintained and would be subject to the same restrictions for changing them. Westport Marina would not advocate for deepening or dredging channels in high hazard zones for it could undermine the integrity of the Marina's infrastructure. Many of the areas in the Marina are at depth with the native materials at the Marina's Sea floor level. If this area were to be dredged, it would dig into the bedrock beneath the Marina and would be an exorbitant cost the Marina is not willing to advocate for, especially if the stability of the Marina's infrastructure cannot be ensured during the process.

Move Docks and Assets Away from High Hazard Zones

Mitigation Action Description

Once a port has been able to identify the areas that are more likely to experience significant tsunami hazards, they can consider relocating port infrastructure away from these areas. Docks and vessels in the highest hazard areas are at the most risk of damage or destruction during a tsunami. Moving this infrastructure away from high hazard areas and into areas that are anticipated to face a lower hazard risk can help save infrastructure and vessels from becoming broken or detached, adding to the debris moved around in the water. Moving docks and infrastructure in a port or harbor is a substantial undertaking involving careful planning. New construction may be required shoreside to reroute walkways or build new shore anchoring systems. Old pilings would need removal and, if of sufficient size and strength, repositioning in the new location, or replacement with piles of greater height, strength, or thickness. Despite all the work involved, if a port has the space and ability to reconfigure the layout of a harbor area to eliminate docks from high hazard zones, there would be a large benefit in the reduction of damaged or destroyed vessels and infrastructure if a tsunami were to occur.

Feasibility for the Westport Marina: Not Feasible

This is not a feasible action for Westport Marina. Westport Marina is currently at capacity for sheltering vessels in the space that is owned by the Port of Grays Harbor. To create additional space in the Marina to be able to move assets out of high hazard areas, there would need to be a reduction of the number of vessels which would have a significant economic impact on the marina and will not be considered. As this kind of reduction is economically unfeasible, the Marina at large should instead focus its mitigation efforts on strengthening and improving the infrastructure in the high hazard areas rather than moving it.

Widen Size of Harbor Entrance to Prevent Jetting

Mitigation Action Description

The narrow entrances of harbors act as a funnel to channel moving water into and out of harbor areas depending on wave and tide action. Typically harbor entrances are built as an opening between breakwaters and are kept narrow to limit the amount of rough seas that can pass through them. While the narrow design helps keep the harbor areas calmer during typical rough conditions, they become much more dangerous during a tsunami. The extreme water level changes and surges of water that are produced by a tsunami will become amplified at the narrow entrance points. Here the water will speed up dramatically while passing through these funnel areas to enter or leave the harbor. Most tsunami modeling shows the highest current velocities occur in areas constricted by narrow points the water must pass through. In some harbors this jetting of water through the constricted areas can be lessened by widening the harbor entrances. Widening harbor entrances is a delicate balance between mitigating the risk of extreme currents during infrequent events and providing shelter and lessening rough seas entering the harbor during frequent storm events. Additionally, changing or altering the size of entrances to harbors is an involved process to alter the size and shape of the breakwaters that form each side of the entrance. Changing or altering the size and shape of harbor entrances will also change how the tsunami waves interact within the harbor, so proposed changes should be evaluated through tsunami modeling to understand how the changes will affect the harbor and vessels in the harbor.

Feasibility for Westport Marina: Not Feasible

This is not a feasible action for Westport Marina. The Marina is on the cusp of the entrance of the Port of Grays Harbor and there are two jetties engineered to ensure the longevity of the shipping channel. These jetties at the entrance of the mouth of the Port of Grays Harbor help to maintain water speed and channel depth while keeping sediments out. Additionally, Point Chehalis and the groins protect Westport Marina so modifying these structures is not feasible.

Construct Floodgates

Figure 44: Floodgates in Fudai, Japan.

Mitigation Action Description

The construction of floodgates has proven successful in several locations to lessen or eliminate inundation from tsunami waves. While the largest and most powerful tsunamis can overtop or otherwise breech floodgates, they have proven extremely effective during smaller tsunamis, and even during large tsunamis in locations with less inundation. Japan has constructed several massive floodgates that proved effective against tsunami waves, like the floodgate pictured in Figure 44. Construction of floodgates is likely the most complicated and labor and time intensive mitigation project listed here. Additionally, there are potential issues with installing floodgates: they can disrupt natural tidal movements, they require a massive footprint, they need to be operable after a major earthquake, and they need to be able to be closed before the waves arrive to be effective. Floodgates are the most effective when waterways have a narrow entrance to a bay, port, or harbor, allowing one set of gates to protect the entire area.

Feasibility for Westport Marina: Not Feasible

Constructing floodgates is not a feasible action for Westport Marina as there are not any locations to construct them based on the geography of the area. Westport Marina is located on a peninsula, eliminating the possibility of floodgate construction.

Construct Breakwaters Farther Away from the Marina

Figure 45: Breakwater protecting the harbor in Hilo, Hawaii built far out from harbor area.

Mitigation Action Description

Breakwaters confine and shelter harbors, providing protection from storm surges, strong waves, and ordinary floating debris. During a tsunami, however, these same breakwaters constrict extreme and rapidly changing water levels and current movements. Tsunami effects are amplified in confined and restricted areas, the smaller space forcing the currents to move faster, and refracting waves are created as the water sloshes within the enclosed basin. Constructing breakwaters farther from harbors allows more unrestricted movement of the water during an extreme tsunami (Figure 45). Enlarging the entire protected area will help slow down the extreme currents and reduce the sloshing effect by creating a larger basin for the water to move through. The locations of breakwaters for harbors are often determined by the shape of the land around them, with harbors in deep but narrower bays easier to build farther out than harbors situated on land that sticks out or runs straight.

Feasibility for Westport Marina: Not Feasible
Constructing breakwaters farther away for Westport Marina would be an unnecessary and unfeasible mitigation action. Since Westport Marina is on an inward facing cove, it is not getting the brunt of the ocean's currents and waves.

Increase Flexibility of Interconnected Docks

Figure 46: Broken dock in California from tsunami waves.

Mitigation Action Description
The rapidly changing water levels, extreme waves, and unpredictable currents associated with tsunamis will test the flexibility of any dock system. When an interconnected dock cannot handle the extreme changes during the tsunami, it will likely break at the joints connecting two dock sections, as in Figure 46. The refracting waves move docks in both horizontal and vertical directions in ways docks will not have been subjected to prior. Post-tsunami, any docks that are torn apart or broken will need extensive repairs at best and full replacement at worst. Increasing the amount of movement between sections of docks at their joining points can help ensure docks remain connected and intact after tsunami waves recede. Increasing flexibility of the dock sections can involve lengthening gaps between the sections to allow for increased movement or utilizing more flexible types of hardware to make the attachments.

Feasibility for Westport Marina: Not Feasible
The docks in Westport Marina are already constructed with flexibility in mind for fluctuating tides and currents. Increasing the flex of the docks in the Marina could compromise the docks' structure, which could introduce debris and added repair/replacement costs following a tsunami.

Debris Deflection Booms to Protect Docks

Figure 47: Debris deflection boom.

Mitigation Action Description
Debris deflection booms are installed in harbors to protect the dock structures from damage caused by floating debris. The booms are installed between the open water and the docks to deflect any floating debris in a different direction and keep the debris from striking and damaging the dock structures or the vessels moored there. Debris deflection booms are typically made from floating interconnected pieces of formed plastic filled with foam (much like smaller dock floats) to ensure they do not sink, as shown in Figure 47. These individual floats are strung together with a cable and attached on each end to a foundational piling that allows the floats to rise and fall with tides and waves. Debris deflection booms would likely be overwhelmed by large local tsunami waves carrying immense amounts of debris but would function well to protect docks from smaller tsunami waves and lighter amounts of debris from a distant tsunami. Even a partial reduction in the amount of debris carried on tsunami waves would help to reduce damage from collisions between debris and vessels or dock structures. Debris booms need to be able to rise much higher than typical tidal changes to accommodate the extra rise of water from tsunami waves, so they do not become over topped, eliminating their effectiveness.

Feasibility for Westport Marina: Not Feasible
Overall, this is a mitigation option that would not be feasible for Westport Marina. While deploying deflection booms could be useful for protecting the docks, they could impede travel for vessels in and out of the Marina. This restriction of movement could impede response and protective action maneuvers for vessels as well. There are limited options for long term storage of the deflection booms and they would be challenging to deploy in an emergency. Currently, the Marina has a limited capacity for response with only 3 operational staff members that will be assisting with other response related activities. Additionally, the Marina doesn't have vessels that could be used in deploying booms. While there is a desire to acquire response vessels that could be used for a multitude of emergency actions, including spills, there would be a greater return on focusing on other mitigation and response actions.

Section 5: Conclusion and Next Steps

The dangers posed from a tsunami to the maritime community in general, and Westport Marina, Port of Grays Harbor specifically, are extreme. A locally generated tsunami has the potential to decimate port infrastructure, destroy many vessels, and cause a high number of casualties within the tsunami inundation zone. This level of damage could lead to Westport Marina, Port of Grays Harbor being unable to operate in any capacity for a significant length of time, disrupting a key location used by the maritime community and leading to a significant loss of economic revenue for the surrounding area. A maximum considered distant source tsunami from Alaska, while posing less of a risk, still has the potential to cause significant damage to Marina infrastructure such as docks and could lead to damage or destruction of many vessels located in the harbors. There could be significant variations in wave amplitudes and wide-spread inundation in Westport Marina, much more than previously anticipated for distant source tsunami from Alaska. The time, money, and effort it will take to restore the Marina to pre-event conditions will be significant.

This highlights the importance of assessing and understanding the hazard and risk posed by tsunamis. With this understanding, actions can then be taken to improve response capability and mitigate the risk as much as possible. These response and mitigation actions can help save lives, make the Marina more resilient, and reduce the time it takes for the Marina to recover, thus restoring an integral part of the maritime infrastructure and economy. They can also enhance the Marina's resiliency to more frequent hazards such as extreme storms, unusually high tides (i.e., King Tides), sea level rise from climate change, and floods. Given the tsunami risk and the importance of the Marina to both the maritime community and the local economy, every action taken to reduce this risk is a step toward creating a more resilient community.

Going forward, the Westport Marina can take steps and engage in actions in both mitigation and response that will make the Marina more resilient and its customers, tenants, and the public safer in the event of a tsunami. Some of these actions are relatively simple and easy to undertake, while others require more time, planning, and outside assistance.

To help mitigate the potential damage to Marina infrastructure and tenant property and reduce potential casualties, **it is recommended that the Marina consider taking or augmenting these simple mitigation actions:**

- Install Tsunami Signs
- Increase Size and Stability of Dock Piles/Increase Height of Piles to Prevent Overtopping
- Reduce Exposure of Petroleum/Chemical Facilities and Storage

These mitigation actions are relatively simple and will provide substantial benefits in reducing potential damage, injuries, and casualties for those who live, work, and recreate on the Marina's properties. Some review, advocacy, and coordination may be needed to help identify existing or additional funding streams for these actions to be executed.

The Marina should also **review the following mitigation actions and decide if they are appropriate to further enhance Marina resiliency:**

- Strengthen Cleats and Single Point Moorings

- Improve Movement of Dock Along Dock/Pilings
- Acquire Equipment/Assets to Assist in Response Activities
- Improve Floatation Portions of Docks

These mitigation actions will be more resource intense to undertake and fully implement, often requiring consultation with engineers or other experts. Despite the increased resource inputs to achieve these actions, the benefit of reduced damage to facilities and potential reduction in casualties make these larger mitigation actions worth evaluating and implementing wherever possible. The Marina should evaluate these options and where appropriate work them into the Marina's long-term planning for ongoing maintenance, rehabilitation, and future upgrades to its infrastructure.

Additionally, **the Marina can enhance its mitigation efforts through planning, and education of and outreach to its tenants and those using its facilities.** By integrating mitigation methods into the Marina's long-term planning, the Marina can ensure that the more complicated mitigation actions stay on track to be completed in a reasonable time frame. This can also help with budgeting allocation which will allow the Marina to ensure there will be funds to cover the costs for more expensive actions. Engaging in outreach and education with tenants and other users of the Marina's facilities will help ensure that tsunami hazards and risks are widely understood by those who occupy and or utilize the Marina's property. Helping tenants understand the dangers posed by tsunami waves and encouraging them to take steps to mitigate that risk will help the Marina become more resilient overall and assist in recovery efforts.

Some of the easiest response actions the Marina is recommended to take are:

- Shut Down Marina Infrastructure Before Tsunami Arrives
- Evacuate Public/Vehicles from Waterfront Areas
- Secure Moorings of Marina Owned Vessels
- Remove or Secure Hazardous Materials
- Informing and Coordinating with Key First Responders During a Tsunami
- Personal Floatation Devices for Marina Staff
- Identify Boat Owners/Individuals Who Live Aboard Vessels and Establish Notification Processes
- Pre-Identify Personnel to Assist in Rescue, Survey and Salvage Efforts

These response actions require little in the form of planning, time inputs, or other resources to accomplish. Some of these actions may already be in the planning stages or implemented in some form, but every attempt to enhance and improve on these actions will assist the Marina's response to a tsunami.

Once the Marina has exhausted all the easier actions to create a more robust response to a tsunami, they should review some of the more difficult or resource intense response actions to develop the most comprehensive response possible.

Some response actions the Marina should review to determine if they are appropriate include:

- Activate Incident Command at Evacuation Sites
- Move Vessels Out of the Marina
- Restrict Traffic Entering the Marina by Land and Aid in Traffic Evacuation
- Activate Mutual Aid System as Necessary
- Reposition Ships Within the Marina
- Pre-Stage Emergency Equipment Outside Affected Area

These response actions will need to be reviewed to determine if they are appropriate for the Marina, and if they should be undertaken for either a local or distant source tsunami, or for both. These response actions will require more time, research, and planning to be effective. Some actions may be determined by the Marina to not be feasible, however creating the most robust and comprehensive response plans and processes that are feasible will help to reduce risk, save lives, and increase resiliency.

Further, **the Marina should continue to expand its planning for a tsunami over time as much as possible.** Conducting regular exercises and training will help ensure that response procedures are followed in an effective manner during a tsunami and can help identify areas for improvement prior to an actual incident. Education and outreach to Marina tenants and other users of the Marina's facilities will help them understand the tsunami hazards and risks, how to get tsunami alerts, and what to do to protect themselves and their property. The Marina may even determine some response actions are the responsibility of tenants, in which case, education and outreach to those individuals can help them better understand their risks and what actions they should take to reduce those risks. Much like mitigation efforts, every additional step taken to improve response capability for a tsunami will help the Marina save lives, protect property, and shorten recovery times.

Please be sure to check out the appendices for additional information and other valuable resources that can be used to assist in developing and implementing tsunami maritime response and mitigation actions. These include:

- Detailed alerting information and information about the Vessel Traffic Service including channels and service area map
- Alerting response checklist for boaters
- Detailed tsunami alerting timeline and response roles
- Detailed explanation of modeling conducted for this strategy
- Stand-alone versions of all maps and graphics developed for this strategy