17. TSUNAMI

17.1 HAZARD PROFILE

17.1.1 HAZARD DESCRIPTION

Overview

Tsunamis are a series of extremely long waves caused by a large and sudden displacement of the ocean. While they are most commonly triggered by powerful undersea earthquakes, tsunamis can also be generated by landslides, volcanic activity, and possibly, near-earth objects (e.g., asteroids, comets) colliding with or exploding above the ocean. A tsunami can happen any time, any season, and during any weather. A tsunami can happen any time, any season, and during any weather.

Tsunamis radiate outward in all directions from their source and can travel hundreds of miles per hour in the open ocean, crossing entire ocean basis. When they reach the coast, tsunami waves slow down and build in height and ocean currents intensify. When they strike land, most tsunamis are less than 10 feet high, but in extreme cases, can exceed 100 feet when they strike near their source.

Tsunamis will arrive as a series of waves, not a single wave, and tsunami impacts can last hours or days. The first wave may also not be the largest – it could the second, or third, or fourth, that may arrive hours later. The first part of the wave may be a drawdown of the sea – a natural warning sign, but the high part of the wave may also arrive first without this warning sign.

A wave's size, or height, is not the defining factor of a tsunami; rather, it is the wavelength – the distance from one wave crest to the next. Tsunami wavelengths are much, much longer than the ocean depth. They may be more than 100 miles long in mid-ocean. As a consequence, they cause all the ocean water from the sea surface to the seafloor to move back and forth as they propagate. Tsunamis are only generated by large-scale ocean disturbances that can create these very long waves. Further, because the waves are so long, they have very long periods; periods are the time between one wave crest and the next. Tsunami periods may range from 5 minutes to an hour. Contrast this with surf waves that typically have periods between a few seconds and 30 seconds. The tsunami's long period contributes to them being a hazard. A 10-foot surf wave washes up the beach for a few seconds and then washes back. A 10-foot tsunami causes sea level to rise by 10 feet for several minutes or longer, allowing all that water to flood sometimes miles inland. Wave height is an indicator of the danger and damage a tsunami may cause but is not the sole defining characteristic of the tsunami.

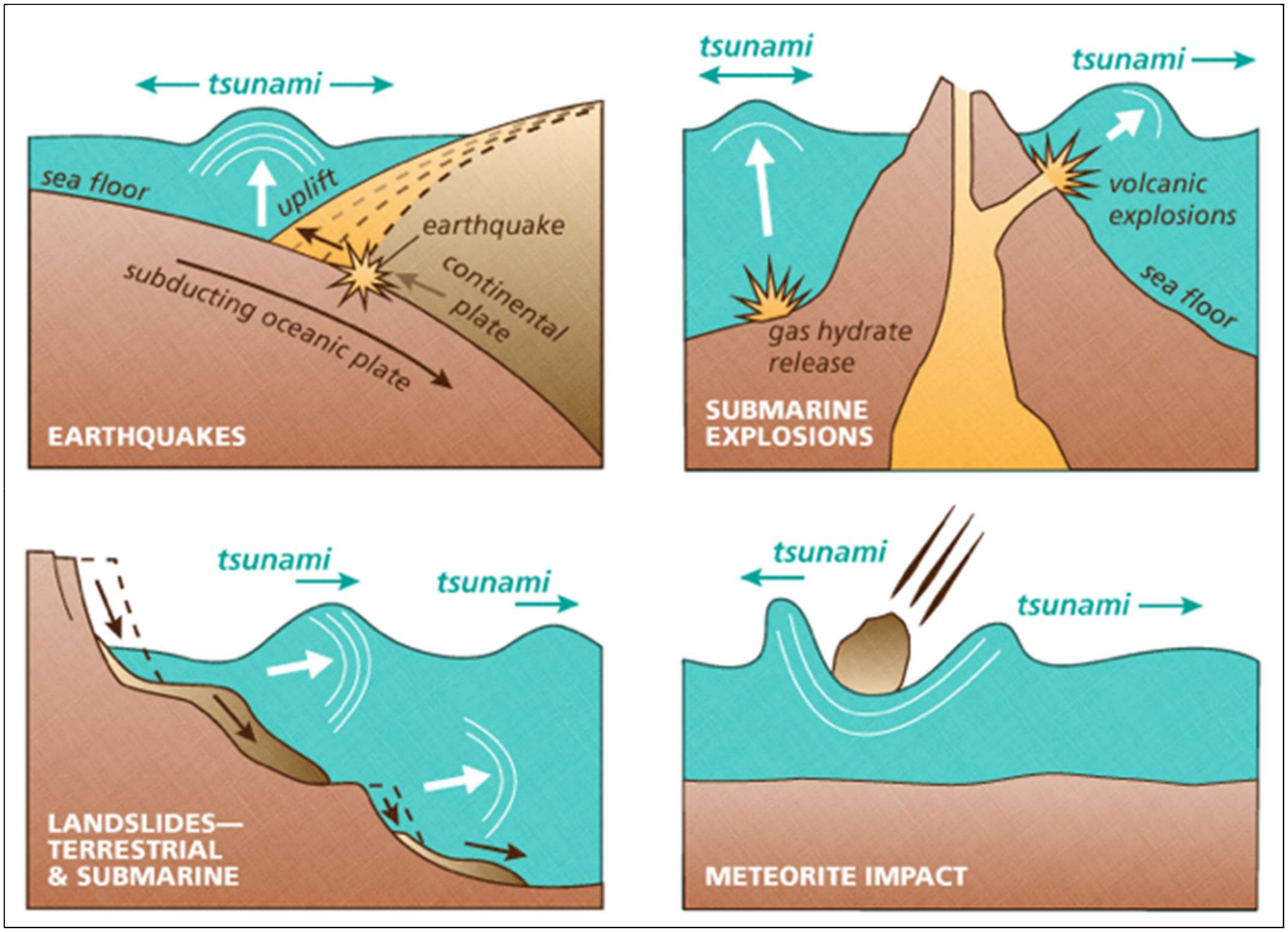
The amplitude of a tsunami is the measurement of how much above or how much below normal sea level the water will rise and fall. A tsunami with an amplitude between about a foot and three feet (0.3 to 1 meter) relative to normal sea level is a hazard in the nearshore marine environment due to it creating strong and unusual currents, and also to the low-lying immediate shoreline – beaches, harbors, marinas, etc. – that may be flooded. A tsunami with an amplitude of more than about three feet (more than a meter) poses a greater threat due to inland flooding and an even stronger offshore effect. And as tsunami size increases, so does the corresponding hazard. The most common cause of death in a tsunami is by drowning, but persons can also be crushed by debris as it is picked up and carried in the moving water. Later arriving tsunami waves will also include the floating debris generated by earlier waves.

Tsunami Causes

Generating Event

Figure 17-1 shows the various types of events that have been known to generate tsunamis (WDNR 2025). The sections below provide summary descriptions of each of these types of event.

Figure 17-1. Tsunami-Generating Events

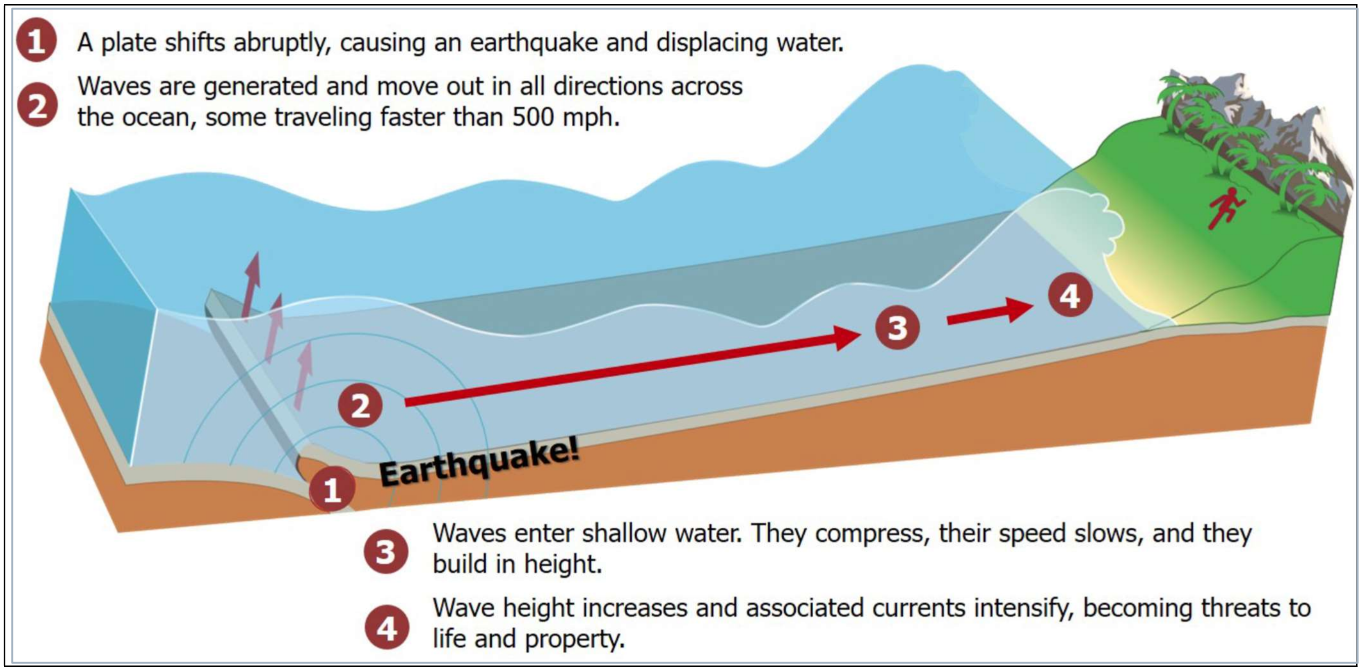


Source: (WDNR 2025)

Earthquakes

The most common source is a large shallow undersea earthquake. About 80% of all known tsunamis worldwide are triggered by earthquakes. Not all earthquakes create tsunamis. An earthquake must be big enough and close enough to the ocean floor to cause the sudden vertical movement of the ocean floor that typically sets a tsunami in motion. As the ocean floor rises or drops, so does the water above it. As the water moves up and down, seeking to regain its balance, the tsunami radiates in all directions. The size of the resulting tsunami depends on the amount of movement of the ocean floor, the size of the area over which it occurs and the depth of the water at the source. Generally, an earthquake must exceed magnitude 8.0 to generate a dangerous distant tsunami. Figure 17-2 shows how an earthquake generates a tsunami.

Figure 17-2. How an Earthquake Generates a Tsunami



Source: NOAA NTHMP Tsunami Information Guide, 2009

In Hawaiʻi, local tsunami warnings are automatically issued for earthquakes of magnitude 6.9 and greater. Chapter 9 provides details on the earthquake hazard.

Landslides

Tsunamis can be generated when a landslide enters the water and displaces it from above (subaerial) or when water is displaced ahead of and behind an underwater (submarine) landslide. Whether a tsunami is generated depends on the amount of landslide material that displaces the water, the speed it is moving and the depth it moves to. Most landslides that generate tsunamis are caused by earthquakes, but other forces (like gravity, wind and increased precipitation) can cause overly steep and otherwise unstable slopes to suddenly fail.

Landslide-generated tsunamis may be larger than seismic tsunamis near their source and can impact coastlines within minutes with little to no warning, but they usually lose energy quickly and rarely affect distant coastlines.

Volcanic Activity

Although not as frequent, tsunamis can be generated by underwater or ocean-adjacent volcanic eruptions. Like landslide-generated tsunamis, tsunamis generated by volcanic activity usually lose energy quickly and rarely affect distant coasts. Volcanic tsunamis can result from violent submarine explosions. They can also be caused by caldera collapses, tectonic movement from volcanic activity, flank failure into a water source or pyroclastic flow discharge into the sea.

Meteorite Impacts

If large objects from space hit earth, they have the potential displace water and cause a tsunami. To date, no asteroid impact-generated tsunamis have been recorded during historical times. There is evidence that such events may have happened in the geologic past.

Source Distance

Tsunamis are often characterized as local or distant based on where they are generated compared to where they will impact land

Local-Source Tsunamis

Local-source tsunamis originate from a source close to the coast, with waves impacting nearby coastal areas in within minutes to an hour. In Hawaii, any tsunami generated by a source located within the state is considered to be a local-source tsunami. Local-source tsunamis are also called local tsunamis and near-field tsunamis

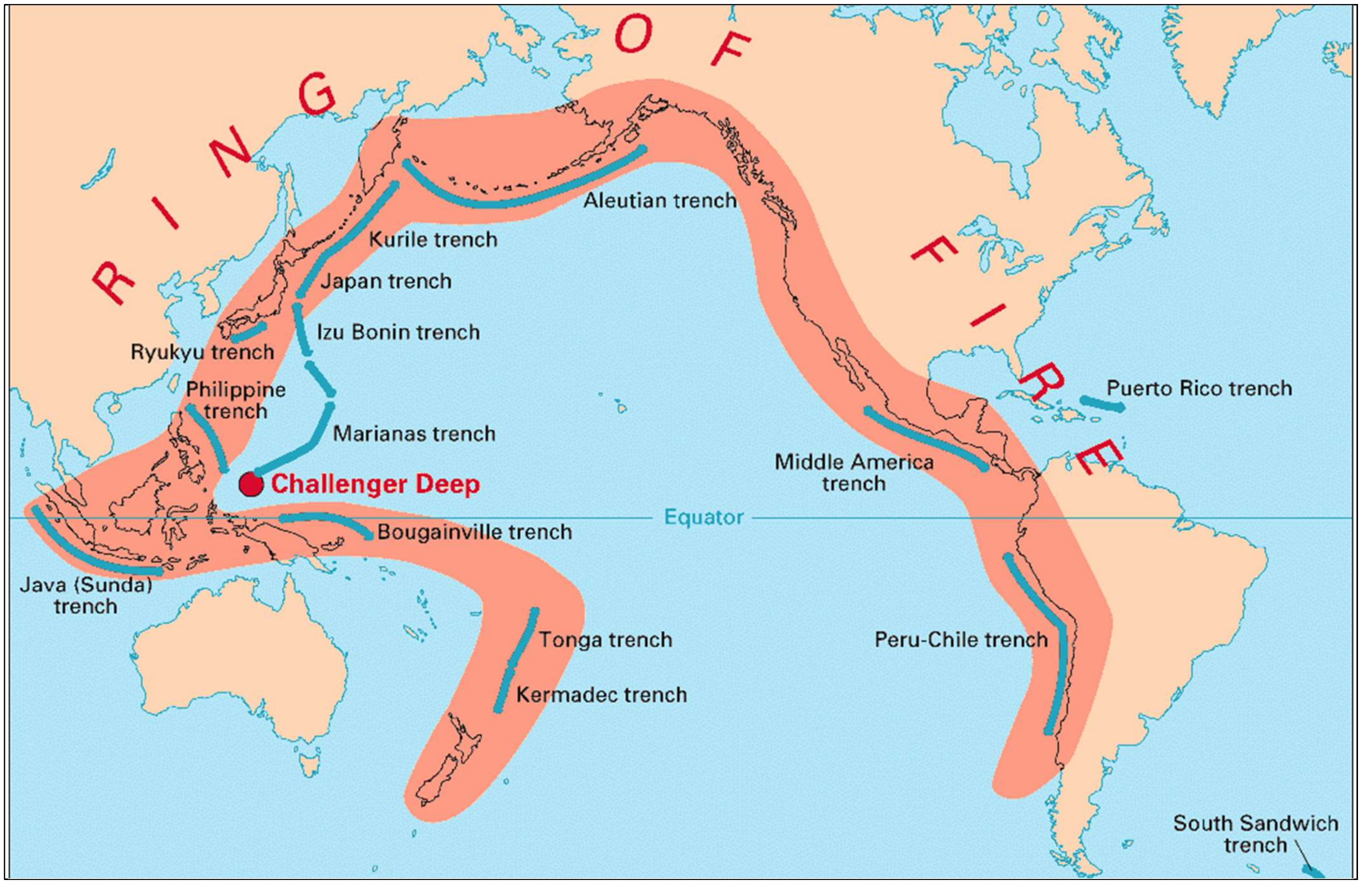
In Hawaii, local tsunamis are most likely to be generated from a source near the County of Hawaiʻi, primarily from earthquakes and large-scale collapse events along the south flank of Kīlauea volcano or the active Mauna Loa or Hualalai volcanoes. The southeast coast of the island, from Cape Kumukahi to South Point, is the region most likely to suffer a large basal-slip earthquake capable of generating a tsunami. The west coast of Hawai`i Island, from South Point to Keahole Point, could also suffer a major earthquake that generates a tsunami.

Distant-Source Tsunamis

Distant-source tsunamis originate from a source far from the coast, usually over 600 miles away, with the first wave arriving more than 3 hours later. The source could be as far as the other side of the ocean. In Hawaii, tsunamis that result from sources located outside the state are considered distant tsunamis. Distant-source tsunamis are also called distant tsunamis, far-field tsunamis, and tele-tsunamis.

Distant tsunamis that impact Hawaii are most likely to be generated by a source located in the Pacific Ring of Fire, also known as the Circum-Pacific Belt (see Figure 17-3). The Ring of Fire is a ring of volcanoes and earthquakes along the edges of the Pacific Ocean and, is the most seismically and volcanically active zone in the world. The Hawaiian Islands are not part of the Pacific Ring of Fire but can be impacted by tsunamis generated from sources in that region. Earthquakes originating from the coasts of Alaska's mainland and Aleutian Islands, the U.S. West Coast, Chile, Japan and Russia's Kuril Islands and Kamchatka Peninsula, have generated tsunamis that impacted Hawai`i.

Figure 17-3. Pacific Rim of Fire



Tsunami Characteristics

Difference Between Tsunamis and Wind-Generated Waves

Tsunamis are unlike wind-generated waves. In addition to being generated by different sources, tsunamis move the entire water column, from the ocean surface to the ocean floor, while wind waves only affect the uppermost part of the ocean, as illustrated in Figure 17-4. There are also important differences in their wavelength (horizontal distance between wave crests), period (time between wave crests), and speed, as summarized in Table 17-1 and described in the sections below.

Figure 17-4. Wind-Generated Waves vs. Tsunami Waves

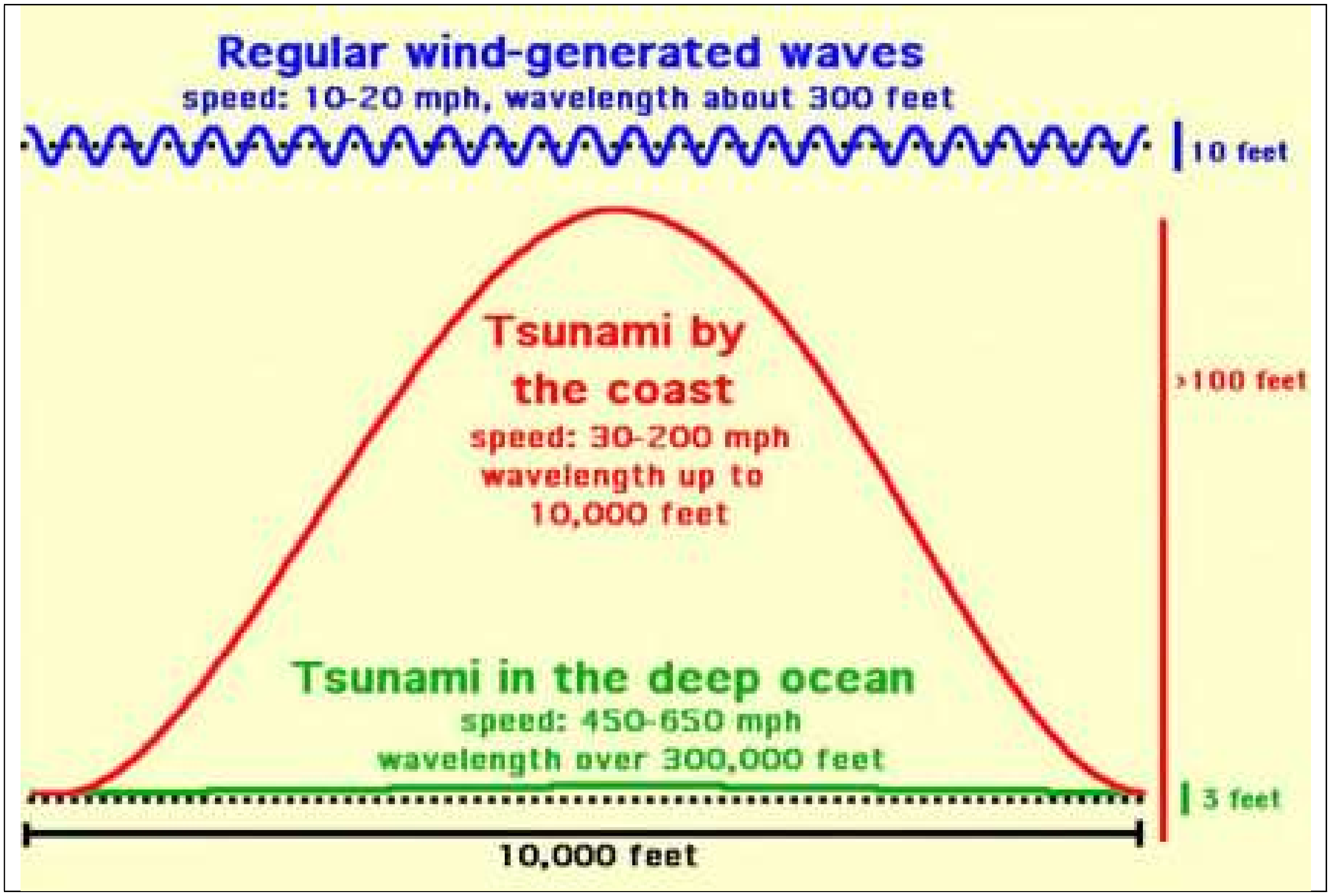


Table 17-1. Differences Between Tsunamis and Wind-Generated Waves

	Tsunami	Wind Wave
Source	Earthquakes, landslides, volcanic activity, certain types of weather, near earth objects	Winds that blow across the surface of the ocean
Location of energy	Entire water column, from the ocean surface to the ocean floor	Ocean surface
Wavelength	60-300 miles	300-600 feet
Wave Period	5 minutes – 2 hours	5-20 seconds
Wave Speed	500-600 miles per hour (in deep water) 20-30 miles per hour (near shore)	5-60 miles per hour

Source: (NWS 2025)

Period

Wind driven waves arrive at the shore every few seconds. In contrast, tsunami waves arrive over tens of minutes, typically from five (5) minutes to one (1) hour apart.

Wavelength

Wind waves have short wavelengths, which can be measured in feet. In contrast, tsunami wavelengths in the open ocean can be measured in miles. Tsunamis are characterized as shallow-water waves, meaning the wavelength is much, much greater than the water depth. Even in deep ocean water, tsunamis are shallow-water waves because their wavelength in the open ocean is so long. Tsunamis can travel vast distances with little energy loss and dramatically increase in height as they approach shallow coastal waters. In the open ocean, a tsunami's wave height (vertical distance between trough and crest) is usually much smaller than the wind waves and swell, but it is moving a tremendous amount of water and energy as it approaches the shore.

Speed

Tsunamis are also travel faster than wind waves. Wind waves are surface phenomena and their speed is related to the wind speed and direction. Because the energy in tsunami waves reaches all the way to the bottom of the ocean, the depth of the sea floor is the primary factor that determines how fast they move. The deeper the water; the faster the tsunami. In the deep ocean, tsunamis can move as fast as a jet plane, over 500 mph, and can cross the entire Pacific Ocean in a day.

Coastal Impact Characteristics

The topography of the ocean floor as a tsunami wave shoals influences the size of the wave. Reefs, bays, entrances to rivers, undersea features and the slope of the beach all help to modify the tsunami as it approaches the shore. Tsunamis can travel up rivers and streams that lead to the ocean and wrap around headlands, islands, and sand spits. Unlike storm waves, tsunami waves may be very large in coastal bays, actually experiencing amplification in long funnel-shaped bays. Tsunami wave energy can also become trapped in bays or partially enclosed bodies of water and be dangerous for many hours or even days.

Shorelines protected by substantial reefs typically do not sustain extensive damage from tsunamis as the reefs reflect some of the wave energy. Low coral islands with steep offshore slopes may experience smaller tsunami waves as the tsunami wavelength stays long because the deep water offshore will not cause the wave height to increase as much.

A tsunami may come onshore like a fast-rising flood, or a wall of water. Its appearance may differ at different points along a coast. It will not look like a normal wind wave. Tsunamis rarely become great towering breaking waves that are surfable. Sometimes, before the water rushes on land, it will suddenly recede, showing the ocean floor, reefs, and fish like a very low, low tide - this is a natural warning that a tsunami is coming.

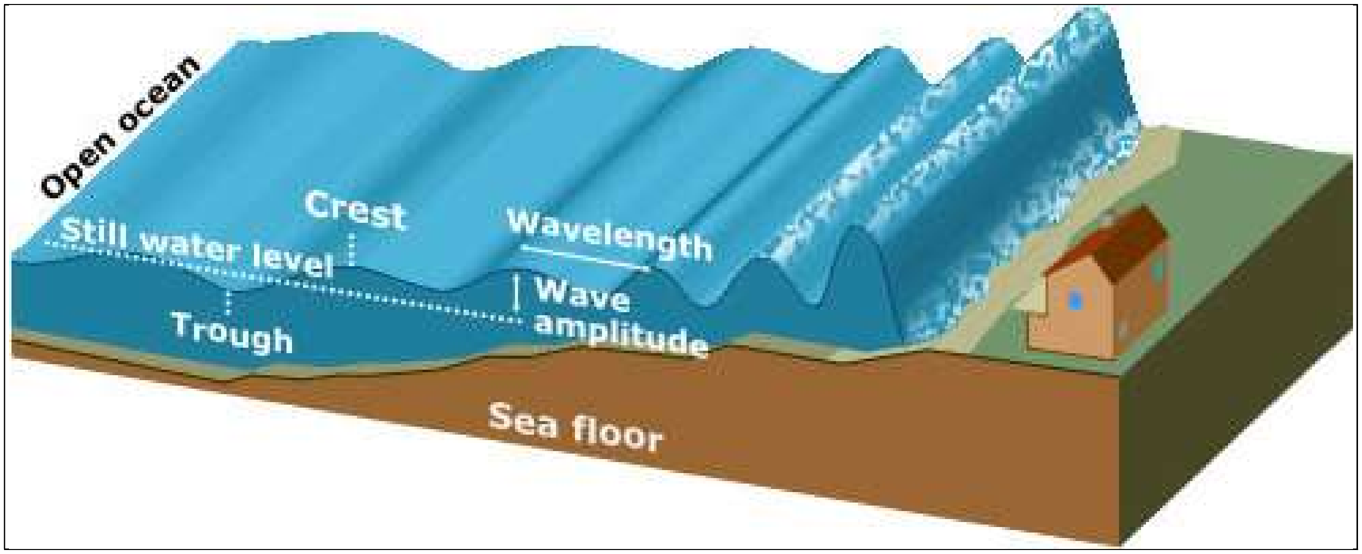
Tsunami Behavior in Deep Water and Shallow Water

Tsunamis behave differently in deep versus shallow water and as they impact the coast (see Figure 17-5):

- **Deep Water Characteristics:** In deep water, tsunamis move quickly, moving hundreds of miles per hour, with long wavelengths. The vertical height of the wave in the open ocean is relatively small, typically only a few feet at most. Tsunami waves in the deep open ocean are usually undetectable by people on a boat or ship at the surface.

- **Shallow Water Characteristics:** Because tsunami waves lose such little energy as they travel across the ocean, they still have tremendous energy as they approach the shore. As a tsunami wave enters shallower water near the shore, it slows down (to 20-30 mph), its wavelength decreases, and the wave energy is compressed and directed upward, increasing the wave height (amplitude) significantly (from a few feet to over 100 feet).

Figure 17-5. Changing Tsunami Behavior with Water Depth



Potential Impacts

Because of their speed, their long period, and the immense volume of water they can displace, large tsunami waves can cause inundation (flooding) that extend further inland than typical tides or storm surges, causing catastrophic flooding and destruction. A large tsunami can flood low-lying coastal areas more than a mile inland.

Even small tsunamis can pose a threat. They can produce strong currents, can injure and drown swimmers, and can damage and destroy boats in harbors. Relatively small waves measuring just 6 feet in height can generate powerful currents strong enough to knock individuals off their feet (USGS n.d.).

Most tsunami damage and destruction are caused by flooding, wave impacts, strong currents, erosion, and debris. Aside from the tremendous hydraulic force of the tsunami waves themselves, floating debris carried by a tsunami can endanger human lives and batter inland structures.

The water can be just as dangerous as it returns to the sea, carrying debris and people with it. Tsunamis are comprised of multiple waves and each successive wave will carry debris from the previous one.

In addition to loss of life and mass injuries, other potential impacts include damage to and destruction of homes and businesses, cultural and natural resources, infrastructure, and critical facilities in coastal areas.

17.1.2 LOCATION

Tsunami Inundation and Evacuation Areas

The entire coast of Oʻahu can be impacted by tsunami events triggered by local or distant sources that are capable of causing injury or death and damaging or destroying property. Low-lying areas such as beaches, bays, lagoons, harbors, and areas along rivers and streams leading to the ocean are the most vulnerable. In general, areas at greatest risk are those less than 25 feet above sea level and within a mile of the shoreline.

Figure 17-6 shows areas that would be inundated by a standard or extreme tsunami event, defined as follows

- The standard tsunami inundation area is based on the historical tsunami impacts on the Island of Oʻahu over the past 100 years. Much of Honolulu, including Waikīkī and the international airport, is located in this area.
- The extreme tsunami inundation area is based on the more extensive inundation that would occur in the event of an earthquake in the Eastern Aleutian Islands with a magnitude 9.0 or greater. This scenario is called the Great Aleutian Tsunami. Its expected recurrence interval is 1,500 years. Almost all of Kailua and Waimanalo are in the extreme tsunami evacuation zone, as well as significant portions of Kapolei and downtown Honolulu.

The City developed evacuation zone mapping based on peer review of the inundation area mapping developed by University of Hawaiʻi researchers and the operational needs of Honolulu's first responders and the emergency management community. Figure 17-7 shows evacuation zones for the standard and extreme tsunami scenarios.

For both the inundation area mapping and the evacuation zone mapping, the area covered for an extreme tsunami event includes all of the are in the standard tsunami area plus additional land further inland.

Figure 17-6. Standard and Extreme Tsunami Inundation Areas

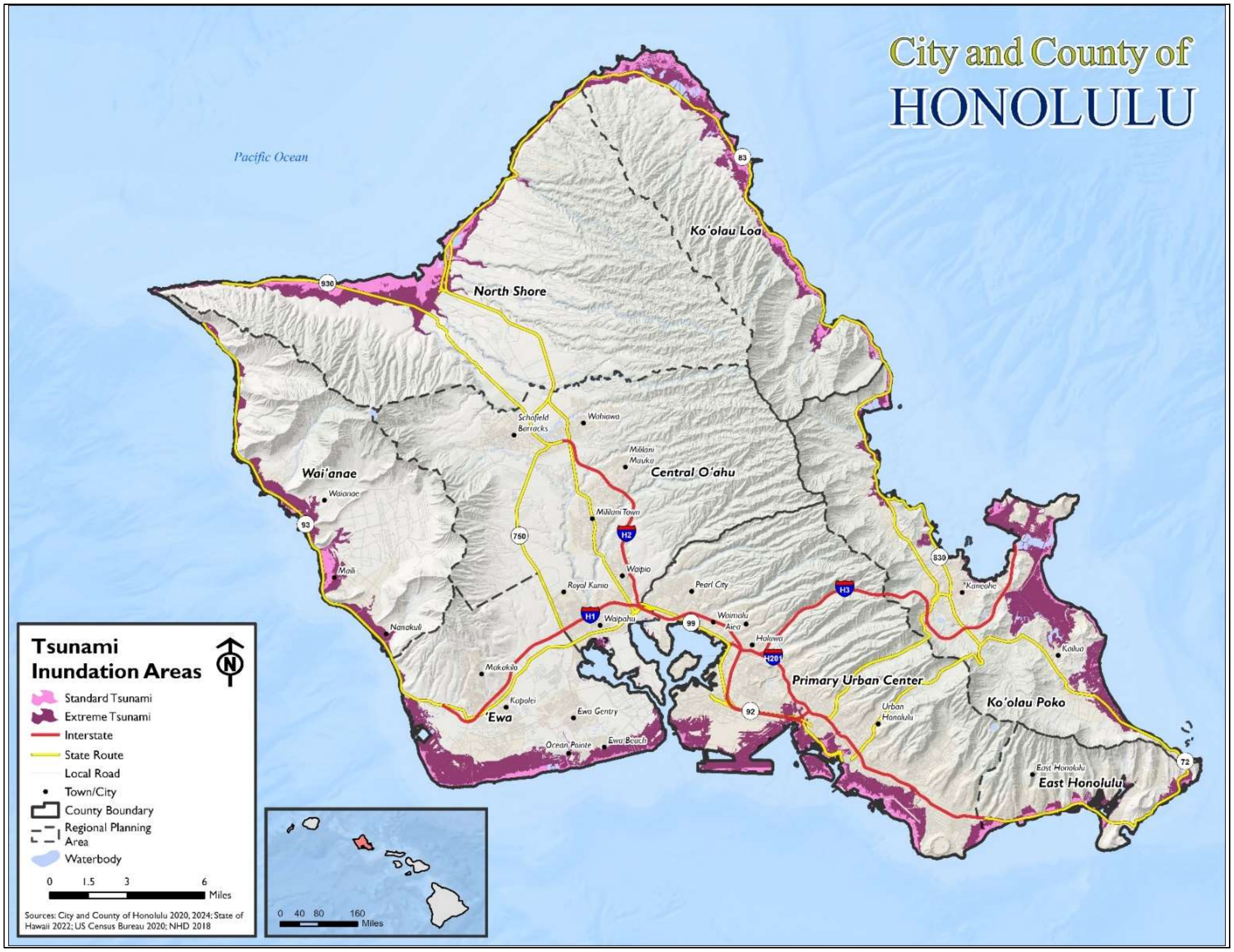
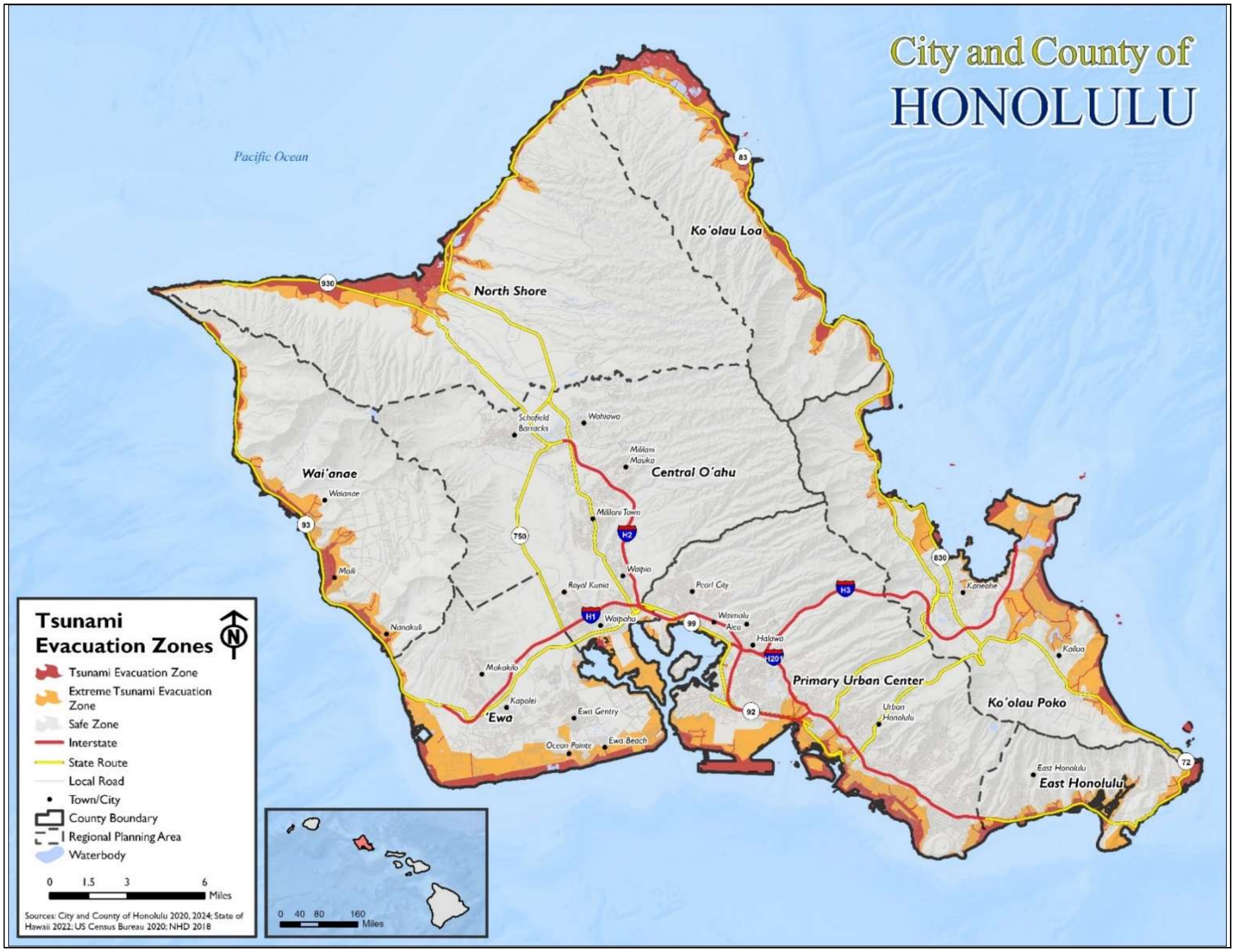


Figure 17-7. Standard and **Extreme Tsunami Evacuation Zones**



Location of Events Generating Tsunamis in O‘ahu

Distant tsunamis from all around the Pacific Ring of Fire have been observed on O‘ahu. Between 1819 and March 2025, 111 tsunamis were measured, with the greatest originating in South America, as summarized in Figure 17-8. Figure 17-9 shows the locations of earthquakes that have caused tsunami runups of more than 1 m (3.3 feet). Historically, the most frequent source locations of dangerous tsunamis to Hawai‘i are Japan, the Kuril Islands and Kamchatka, Aleutian Islands, and South America. Local tsunamis have been generated by earthquakes associated with the active volcanoes on Hawai'i island. Between 1819 and March 2025, there were nine confirmed local-source tsunamis. Four were measured on O‘ahu but none were dangerous; all had measurements less then 0.3 meter (1 foot).

Figure 17-8. Source Location of Tsunamis Observed on Oʻahu from 1819 to 2025

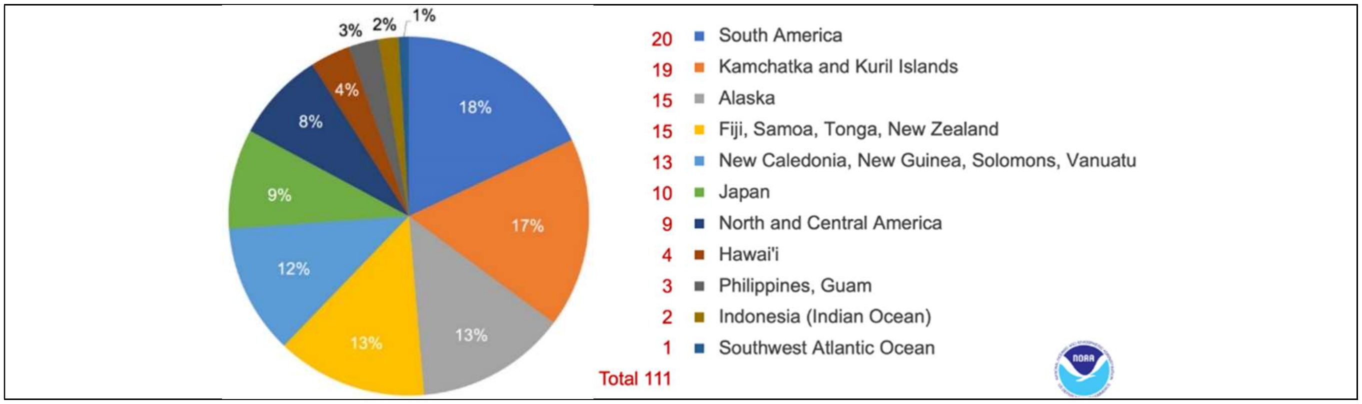
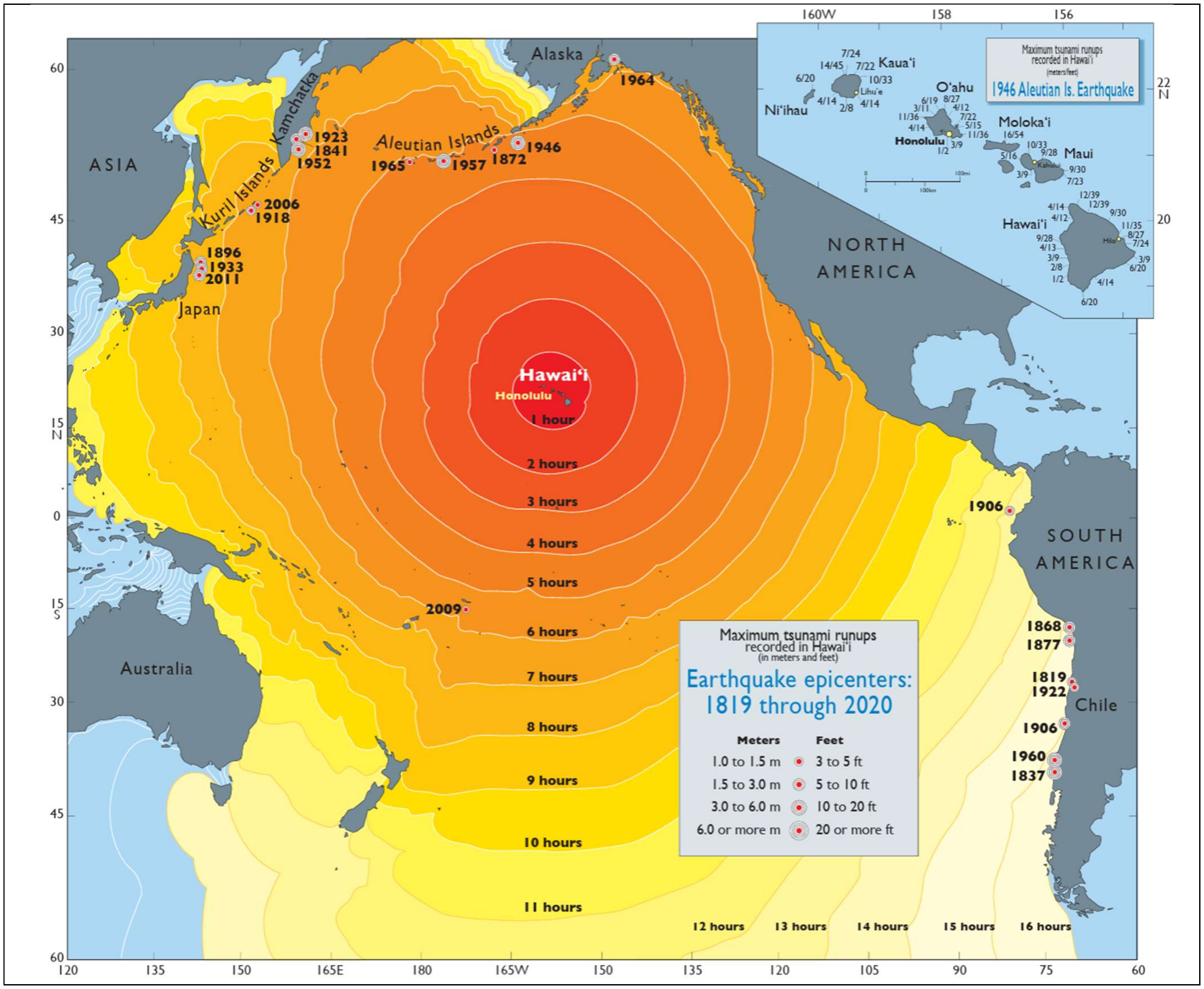


Figure 17-9. Earthquakes That Generated Tsunamis in Hawaiʻi with Runup of 1 Meter or More



Source: Tsunami Memorial Institute, NOAA ITIC

17.1.3 EXTENT

Hazard extent refers to the potential severity or magnitude of hazard events in a given area. This section describes measurements used to indicate the extent of this hazard and the systems in place for monitoring severity and providing warnings as necessary.

Tsunami Amplitude

Amplitude is the measurement of how much above or how much below normal sea level the water will rise and fall. The amplitude and inundation produced by a tsunami wave is influenced by several factors, including the depth of the ocean floor, the shape of the coastline, and the intensity of the event that generated the tsunami (e.g., earthquake, landslide). Inundation is the measurement of how far inland from the coastline the water will flood.

- Any tsunami amplitude over a meter (3.3 feet) has the potential to generate dangerous flooding that threatens lives and can destroy property. The greater the amplitude, the more extensive the damage. An Extreme Tsunami event is the worst case scenario for Oʻahu in terms of amplitude, but that type of event is less probable than a tsunami impacting the Standard Tsunami Evacuation Zone.
- Smaller tsunamis can create impacts in coastal areas that will not result in widespread inundation requiring evacuation but are strong enough to produce strong currents and dangerous ocean conditions. A tsunami that results in amplitudes between 0.3 meters (1 foot) but less than 1.0 meter (3.3 feet) falls into this category.

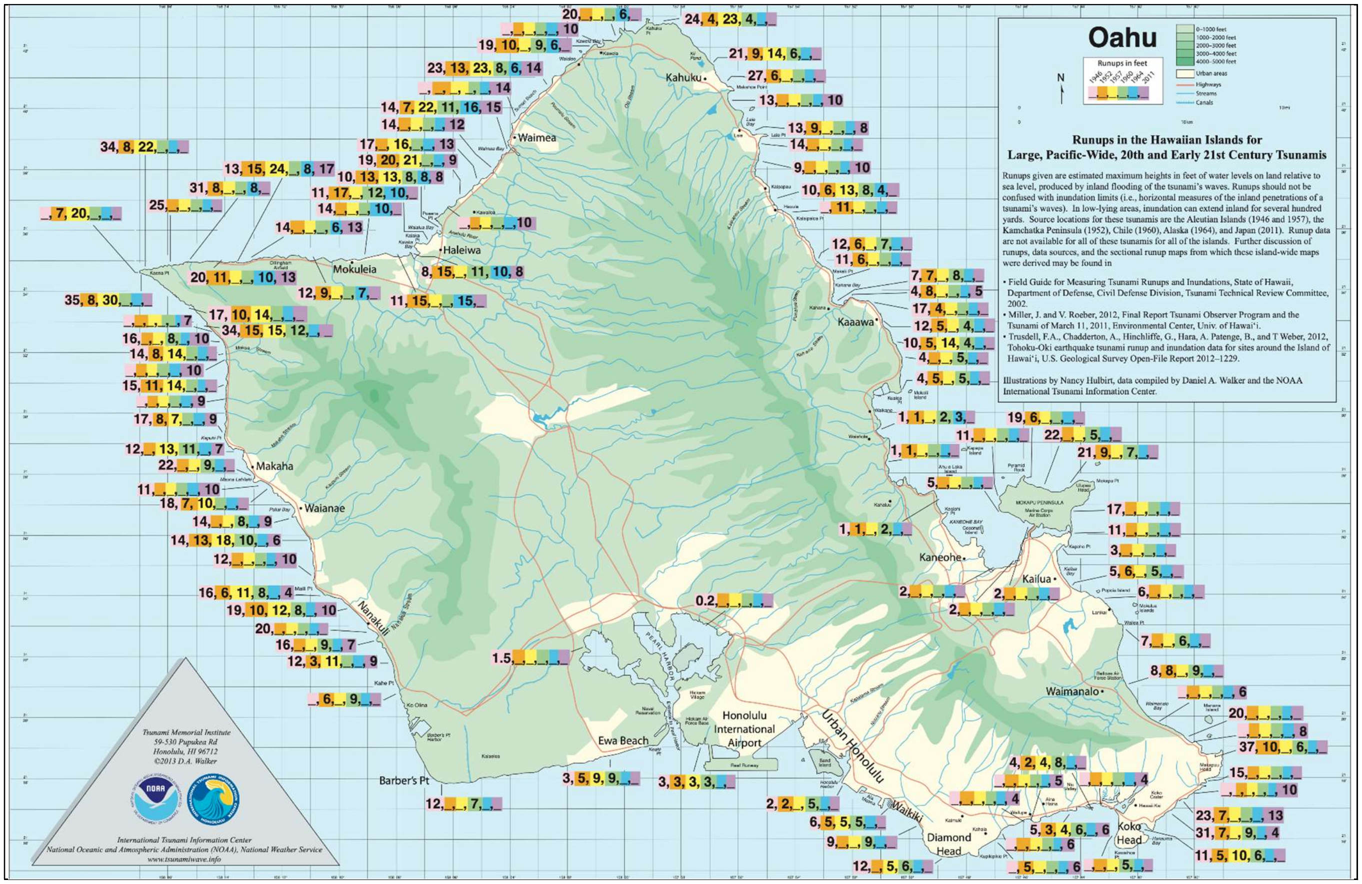
Tsunami Runup

Most tsunamis do not result in giant breaking waves, but instead come onto land like strong, fast-moving tides. Tsunamis will often travel much farther inland than normal waves. Tsunami runup occurs when a peak in the tsunami wave travels from the near-shore region onto shore. Runup is a measurement of the height of the water onshore observed above a reference sea level (USGS n.d.)

Of the 111 distant-source tsunamis summarized in Figure 17-8, 10 had observed tsunami runups of at least 1 meter (3.3 feet), and 11 had tsunami runups between 0.3 meter (1 foot) and 1 meter (3.3 feet).

Figure 17-10 shows observed tsunami runups on Oʻahu for tsunamis in 1946, 1952, 1957, 1960, 1964, and 2011. Source locations for these tsunamis are the Aleutian Islands (1946 and 1957), the Kamchatka Peninsula (1952), Chile (1960), Alaska (1964), and Japan. The runups shown are the elevation (height in feet) where the wave inundated to its maximum distance inland.

Figure 17-10. Recorded Runup from Largest Tsunamis on O‘ahu



Concurrent Conditions

Tsunami impacts can increase in severity based on other conditions. If the tsunami waves arrive at high tide, or if there are concurrent storm waves in the area, the effects will be cumulative and the inundation and destruction even greater.

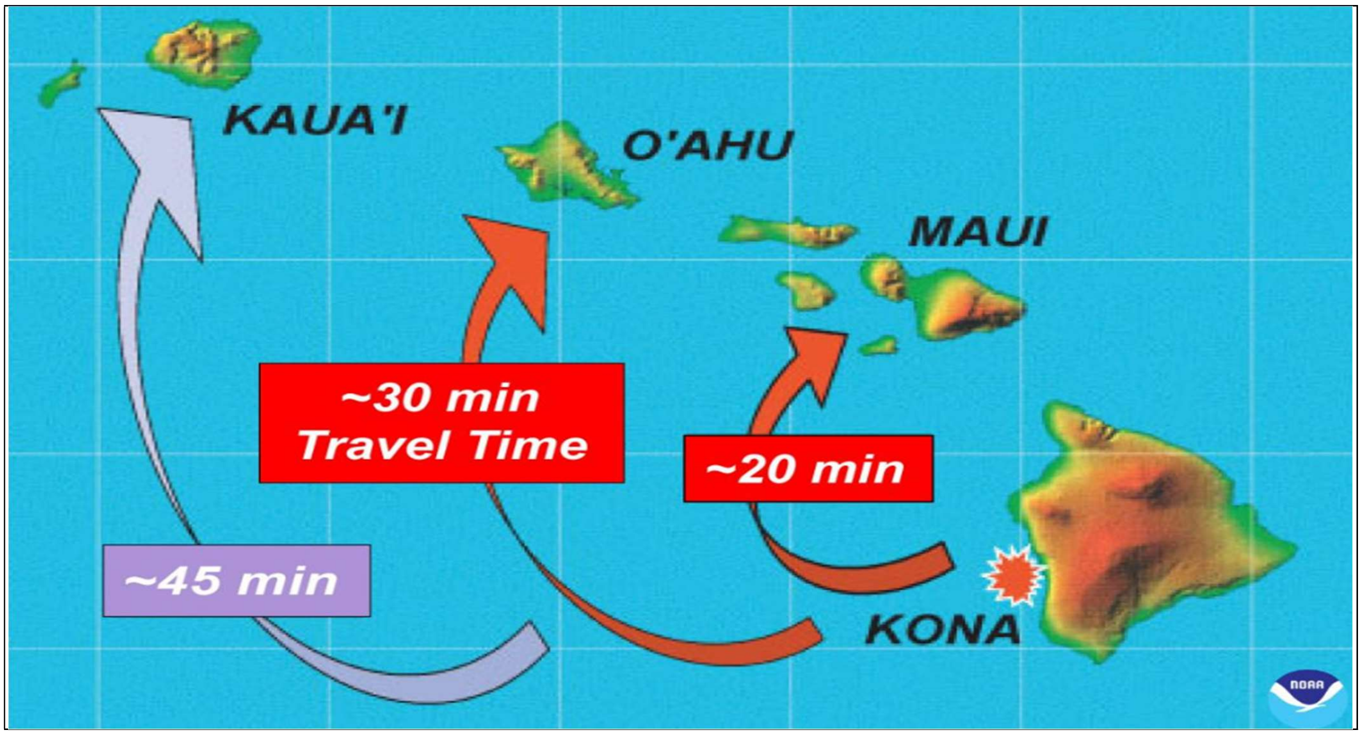
Warning Time

The severity of a tsunami's impacts depends not only on size of the wave and extent of tsunami inundation it causes, but also whether there was sufficient warning time to act to protect people and property. Events with a limited warning period are more severe threats to the population as there is limited time to evacuate, particularly from coastal areas that have limited roadways. Longer lead time for wave arrival allows for more effective evacuations and time relocate some critical assets out of evacuation zones.

Warning time varies with the location of the tsunami-generating source event:

- Distant tsunamis provide anywhere from 4.5 hours up to 15 hours of warning time before wave arrival. Figure 17-9 illustrates the time it takes for a tsunami to travel from the Pacific Ring of Fire to Hawaiʻi. The following are example tsunami travel times to Hawaiʻi from specific locations:
    - Alaska—4.5 hours
    - U.S. West Coast—5 hours
    - Russia or Japan—6 – 8 hours
    - South Pacific—7 hours
    - Chile—14 – 15 hours
- A tsunami from a locally generated source will impact Oʻahu within 30 minutes to an hour (see Figure 17-11, allowing very limited time to warn the population and for people to evacuate. Few, if any, critical assets can be relocated out of the evacuation zone.

Figure 17-11. Local Tsunami Travel Time from a Generating Event off Kona



Source: (NWS 2025)

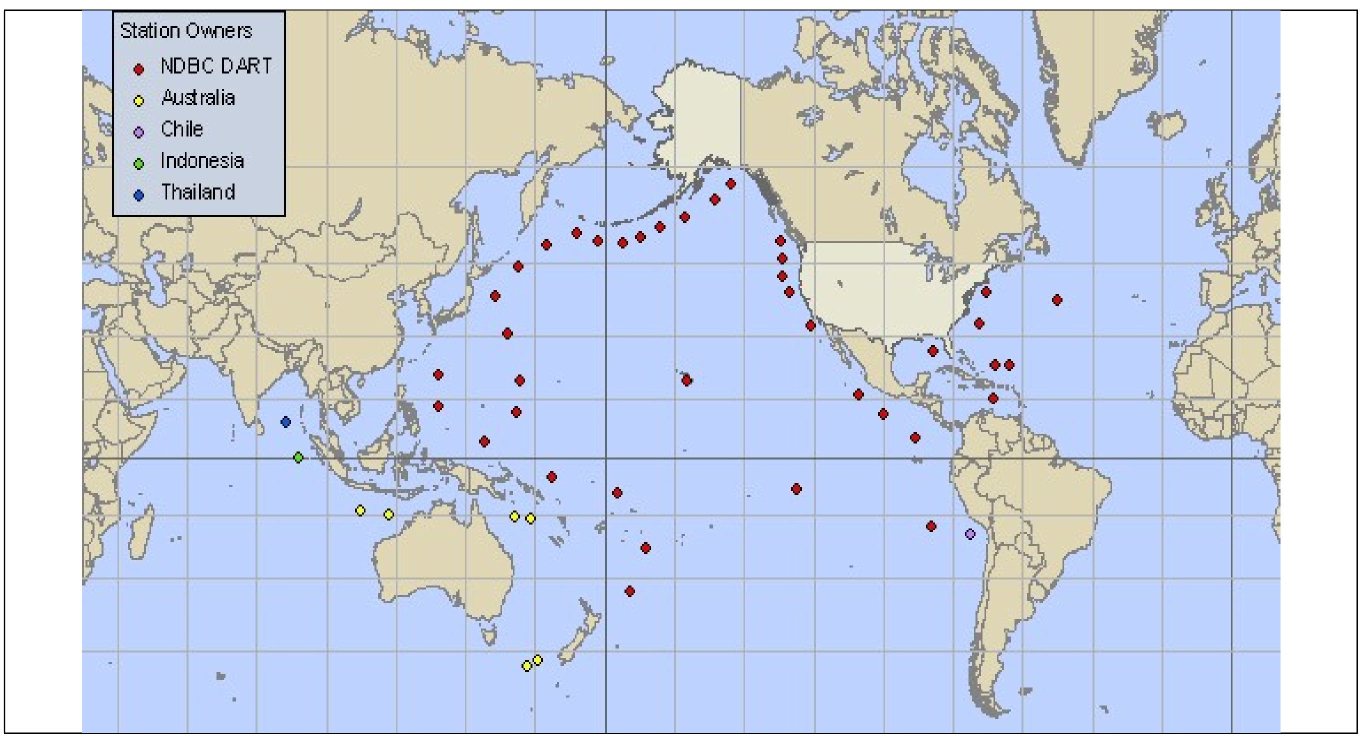
Monitoring

NOAA has two tsunami warning centers that monitor for earthquakes and tsunamis in the Pacific and Atlantic Oceans and issue early warning of a tsunami threat. The Pacific Tsunami Warning Center (PTWC), located on Ford Island on Oʻahu, is the regional warning center for the State of Hawaiʻi. The National Tsunami Warning Center in Palmer Alaska serves as Hawaiʻi's back-up warning center (NOAA 2025).

PTWC provides around-the-clock monitoring through a tsunami detection system consisting of the following:

- **Seismic Networks**—Seismometers positioned around the world are the initial detection tool used to evaluate earthquake occurrences, locations and magnitudes and identify potential tsunami threats.
- **Coastal Sea-Level Networks**—Nine sea-level gauges around the state measure the ocean height, allowing PTWC to both detect a tsunami and estimate its impact at the coast. Hundreds of other sea level gauges around the Pacific are used by PTWC to detect and measure tsunami waves coming towards Hawaiʻi from distant sources.
- **Deep Ocean Assessment and Report of Tsunami (DART) Networks**—DART stations, which consist of a pressure sensor on the sea floor and a data transmission buoy on the sea surface, are positioned at strategic locations throughout the Pacific Ocean (see Figure 17-12). As a tsunami wave passes over a DART station, the buoy transmits water level changes, which are used by PTWC to determine whether a tsunami was generated and help forecast wave amplitudes at the coast.
- **Runup Detectors**—The state's sea-level gauges only provide some of the data needed to rapidly detect and evaluate a local tsunami generated from a source other than an earthquake, such as a landslide. To complement these data and fill gaps, a runup detector system is installed on the southwest and southeast shorelines of Hawai`i Island. Six (6) sensor devices located on land within 50 yards of the ocean will sound an alarm at PTWC if they detect flooding. This can help provide positive confirmation of coastal flooding from any type of tsunami.
- **Natural Signs**—Public outreach efforts focus on educating the public to recognize the natural signs a tsunami may be imminent, including feeling an earthquake or observing the ocean receding unusually rapidly. These natural signs may be the public's first or only alert for locally generated tsunamis.

Figure 17-12. Deep-Ocean Assessment and Reporting of Tsunami (DART) Buoy Locations



Warning

Once an earthquake or tsunami is detected, PTWC issues one of the forecast products described in Table 17-2 and Figure 17-13 to convey the anticipated wave action and recommended actions to emergency officials. To provide the earliest possible alert, initial messages are issued based solely on seismic information—earthquake magnitude, location and depth. Products are updated, adjusted geographically, downgraded or canceled as additional information from sea level gauges and DARTs is received. During an active tsunami threat, PTWC forecasts are generally updated hourly and may include wave height, arrival time and inundation estimates.

Table 17-2. PTWC Tsunami Alert Types

<table>
<tr><th>Alert Type</th><th>Description</th><th>Example</th></tr>
<tr><td>Tsunami Information Statement</td><td>Issued to inform emergency management officials and the public that an earthquake has occurred, but there is no threat of a destructive tsunami in Hawaiʻi. Information Statements indicating no threat to Hawaiʻi may also be issued for larger distant earthquakes greater than magnitude 7.8 if they are located too deep inside the earth, are too far inland, or are too far away and not oriented to send a dangerous tsunami towards Hawaiʻi.
A Tsunami Information Statement indicating a potential tsunami threat still under evaluation may be issued for very distant earthquakes, such as those generated in Chile that will take 14 or more hours to reach Hawaiʻi.
For earthquakes within the state, information statements are issued to prevent unnecessary evacuations as the earthquake may have been felt. Information statements may be re-issued with additional information, though normally these messages are not updated.</td><td><table><tr><th colspan="3">INFORMATION STATEMENTS</th></tr><tr><th></th><th>Magnitude</th><th>PTWC Message Type</th></tr><tr><td>Local Event</td><td>4.0-6.8</td><td>Local Tsunami Information</td></tr><tr><td>Distant Event</td><td>6.5-7.8</td><td>Tsunami Information</td></tr></table></td></tr>
<tr><td>Tsunami Watch</td><td>Issued when a potentially dangerous, distant seismic event has occurred which may have generated a tsunami that may later impact Hawaiʻi with hazardous waves. A watch is an alert to management officials and the public to monitor the situation and prepare to act.
A tsunami watch is issued when an earthquake of 7.9 magnitude or greater has occurred that likely presents a flooding threat to Hawaiʻi and the potential tsunami is more than three (3) hours away. Watches are not issued for local source events.</td><td><table><tr><th colspan="3">TSUNAMI WATCH</th></tr><tr><th></th><th>Magnitude</th><th>PTWC Message Type</th></tr><tr><td>Distant Event</td><td>≥ 7.9 and ETA 3-6 hr</td><td>Tsunami Watch
Tsunami Watch Supplement
Tsunami Watch Cancellation</td></tr></table></td></tr>
</table>

Alert Type	Description	Example
Tsunami Advisory	Issued when the tsunami will be too small to require evacuation but is expected to be large enough to produce strong currents or minor flooding that make beaches and near shore waters dangerous. The threat may continue for several hours after the arrival of the initial wave, but significant widespread inundation is not expected for areas under an advisory. Generally, this means that tsunami amplitudes are expected to exceed 0.3 meters (1 foot) somewhere in the state but will not exceed 1.0 meters (3.3 feet) anywhere. 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	**TSUNAMI ADVISORY MESSAGES** Magnitude / PTWC Message Type Distant Event: ≥ 7.9 and ETA > 6 hr — Tsunami Advisory; Tsunami Advisory Supplement; Final Tsunami Advisory
Tsunami Warning	Issued when a potential tsunami with significant widespread inundation is imminent or expected. Generally, this means that the tsunami is expected to have a maximum amplitude of more than one (1) meter (3.3 feet) above sea level somewhere in the state. Warnings alert the public that widespread, dangerous coastal flooding accompanied by powerful currents is possible and may continue for several hours after arrival of the initial wave. Warnings also alert emergency management officials to take action for the entire tsunami hazard area. 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 if there is time to safely do so. Warnings will be issued as Urgent Local Tsunami Warnings to indicate a local tsunami threat when life-saving action is required right away due to the short lead times before wave arrival A distant Tsunami Warning will be upgraded with an Extreme Tsunami Warning tag for extreme tsunami events.	**TSUNAMI WARNING** Magnitude / PTWC Message Type Local Event: ≥ 7.6 — Statewide Urgent Local TSUNAMI WARN; Statewide Urgent Local TSUNAMI WARN; Statewide Urgent Local TSUNAMI WARN Local Event: 6.9-7.5 — Urgent Local TSUNAMI WARNING; Urgent Local TSUNAMI WARNING Suppl; Urgent Local TSUNAMI WARNING Cance Distant Event: ≥ 7.9 and ETA < 3 hr — TSUNAMI WARNING; TSUNAMI WARNING Supplement; TSUNAMI WARNING Cancellation

Figure 17-13. Understanding Tsunami Alerts

ALERT TYPE	DEFINITION	ACTION	ALERT METHOD
TSUNAMI INFORMATION STATEMENT	NO TSUNAMI IMPACT IS EXPECTED AT THIS TIME. ALERT TYPE MAY CHANGE ONCE MORE INFO IS KNOWN.	NO ACTION IS NECESSARY AT THIS TIME. BE AWARE SINCE ALERT TYPE MAY CHANGE.	ALERTS MAY BE ISSUED VIA HNL.INFO UNDER CERTAIN CIRCUMSTANCES
TSUNAMI WATCH	TSUNAMI IS POSSIBLE. ALERT TYPE MAY CHANGE ONCE MORE INFO IS KNOWN.	BE PREPARED TO ACT. KNOW YOUR EVACUATION ZONES & STAY TUNED TO RADIO/TV.	HNL.INFO & SOCIAL MEDIA
TSUNAMI ADVISORY	WIDESPREAD FLOODING NOT EXPECTED, BUT WAVES WILL CREATE DANGEROUS CONDITIONS IN AND NEAR THE WATER.	STAY OUT OF BEACH AREAS & AWAY FROM WATERWAYS.	HNL.INFO & SOCIAL MEDIA
URGENT TSUNAMI WARNING (LOCAL)	DESTRUCTIVE TSUNAMI WAVES EXPECTED TO IMPACT LOW-LYING COASTAL AREAS WITHIN MINUTES.	IMMEDIATELY MOVE TO HIGH GROUND, INLAND, OR 4TH FLOOR OR ABOVE IN BUILDING WITH 10+ STORIES. EVACUATE MAP AREAS IN RED WITH SOLID LINE.	OUTDOOR SIRENS, MOBILE PHONE ALERTS, NOAA WEATHER RADIO, & TV/RADIO TAKE ACTION IF YOU SEE NATURAL WARNING SIGNS, LIKE STRANGE OCEAN BEHAVIOR
TSUNAMI WARNING	DESTRUCTIVE TSUNAMI WAVES EXPECTED TO IMPACT LOW-LYING COASTAL AREAS.	MOVE TO HIGH GROUND, INLAND, OR 4TH FLOOR OR ABOVE IN BUILDING WITH 10+ STORIES. EVACUATE MAP AREAS IN RED WITH SOLID LINE.	OUTDOOR SIRENS, MOBILE PHONE ALERTS, NOAA WEATHER RADIO, TV/RADIO, HNL.INFO, & SOCIAL MEDIA
EXTREME TSUNAMI WARNING	UNLIKELY, BUT PLAUSIBLE WORST CASE SCENARIO. DESTRUCTIVE TSUNAMI WAVES EXPECTED TO IMPACT FURTHER INLAND.	MOVE TO HIGH GROUND, INLAND, OR 4TH FLOOR OR ABOVE IN BUILDING WITH 10+ STORIES. EVACUATE MAP AREAS IN RED WITH SOLID LINE AND YELLOW WITH DOTTED LINE.	OUTDOOR SIRENS, MOBILE PHONE ALERTS, NOAA WEATHER RADIO, TV/RADIO, HNL.INFO, & SOCIAL MEDIA

Source: (DEM n.d.)

17.1.4 PREVIOUS OCCURRENCES

This section provides an overview of hazard occurrences since the publication of the previous LHMP, covering the period between January 2020 and February 2025. It identifies events that resulted in federal disaster declarations and/or state or local emergency proclamations. For events prior to 2020, refer to the 2020 LHMP.

Recent Events

Table 17-3 shows tsunami runup events for Oʻahu.

Table 17-3. **Wave Runup Events in the City and County of Honolulu (2020 to 2024)**

Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
March 25, 2020	N/A	N/A	N/A	The source of the tsunami was in the North Kuril Islands, Russia. The maximum runup near the source was 0.5 meters. Haleʻiwa had a maximum water height of 0.05 meters
October 19, 2020	N/A	N/A	N/A	The source of the tsunami was in the Shumagin Islands, Alaska. The maximum runup near the source was 0.76 meters. Haleʻiwa had a maximum water height of 0.19 meters. Mokuoloʻe-Coconut Island had a maximum water height of 0.02 meters.
March 4, 2021	N/A	N/A	N/A	The source of the tsunami was in the Kermadec Islands, New Zealand. The maximum runup near the source was not recorded due to power outages. Honolulu had a maximum water height of 0.08 meters. Waimānalo had a maximum water height of 0.1 meters. Barbers Point had a maximum water height of 0.01 meters. Haleʻiwa had a maximum water height of 0.05 meters.
August 12, 2021	N/A	N/A	N/A	The source of the tsunami was in the Southern Atlantic Ocean. Honolulu had a maximum water height of 0.04 meters. Haleʻiwa had a maximum water height of 0.04 meters.
January 15, 2022	N/A	N/A	N/A	The source of the tsunami was the eruption of the Hunga Tonga-Hunga Haʻapai Volcano in Tonga. The maximum runup near the source was 22.0 meters. Honolulu County sustained $3.32 million in damages. Haleʻiwa had a maximum water height of 0.69 meters. D51407 BPR, which is an offshore measurement, had a maximum water height of 0.05 meters. Makapuʻu Point had a maximum water height of 0.86 meters. Honolulu had a maximum water height of 0.12 meters. Barbers Point had a maximum water height of 0.19 meters. Waimānalo had a maximum water height of 0.28 meters.

Source: (HI-EMA 2022) (NOAA n.d.)

Historic Events

NOAA keeps records of tsunami events that occurred on O'ahu over the past 200 years. Since 1819, there have been 111 tsunamis observed on the island. Of these, four were local-sourced and 107 were distant-sourced. The distant-source locations include South America, the Kamchatka and Kuril Islands, Alaska, Fiji, Samoa, Tonga, New Zealand, and other Ring of Fire locations.

Of the 111 tsunamis, eight resulted in deaths or economic damage on Oʻahu. Tsunami waves with the highest runup are the source of the most damage. Larger tsunami waves have also led to the most deaths, but the amount of warning time to evacuate and adequacy of warning systems are important factors.

- The 1946 tsunami that originated in Alaska was the deadliest, resulting in 159 deaths statewide, six of which occurred on Oʻahu. Homes and structures were destroyed in coastal areas of the state, with North Shore, Punalu'u, and Kailua experiencing the most significant damage on Oʻahu. The 1946 tsunami resulted in measured runups of 11.3 meters at Makapuʻu and 10.9 meters at Kaena Point.
- The 1957 tsunami that originated in Alaska damaged the most homes; 50 homes were flooded and 30 homes were moved off their foundation. The 1957 tsunami resulted in runups of 9.1 meters at Kaena Point and 7.3 meters on the North Shore. The 2011 tsunami resulted in runups of 5.2 meters at Camp Erdman and 4.6 meters at Waimea Bay.
- The costliest tsunami occurred in 2011, when the Tohoku Earthquake in Japan triggered a tsunami that caused $3.4 million in damage to the City and County of Honolulu. In addition, Small boat harbors operated by the state also experienced significant damage to both public and private property at these sites. Public infrastructure damage was estimated at $300,0000 at Haleiwa Small Boat Harbor and $1M at Keehi Small Boat Harbor. Private property damage to vessels at these locations was estimated in the millions.
- Tsunamis in 1878, 1952, 1960, 2011, and 2022 also resulted in property damage.

Federal Disaster Declarations

Under the Stafford Act, the President of the United States may issue an Emergency Declaration (EM) or Major Disaster Declaration (DR) for health related events and activate certain federal assistance programs based on factors related to the magnitude of the hazard threat or impacts. No Stafford Act declarations for this hazard type that included the City occurred during this period.

State and Local Emergency Proclamations

State law authorizes the Governor to issue emergency proclamations if an emergency or disaster has occurred, or there is imminent danger or threat of an emergency or disaster in any portion of the state. County Mayors have the authority to issue local emergency proclamations when such conditions exist within any part of their respective jurisdictions. No state or local emergency proclamations related to this hazard were issued for the City during this period.

17.1.5 PROBABILITY OF FUTURE OCCURRENCES

Information on previous tsunami occurrences in the City was used to calculate the probability of future occurrence of such events. Table 17-4 lists the number of tsunami events from the NOAA Global Historical Tsunami Database over the 74-year period from 1950 to 2024, which is the most complete period of record for all sources reviewed. Based on these records, the probability of occurrence of tsunami in the City is considered "occasional."

Table 17-4. Probability of Future Tsunami Events in Honolulu County

Hazard Type	Number of Occurrences Between 1950 and 2024	% Chance of Occurring in Any Given Year
Tsunami	72	97.3%

Source: (NCEI n.d.)

Note: The time period presented in this table is the most complete period of record for the various data sources reviewed.

17.2 VULNERABILITY AND IMPACT ASSESSMENT

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. The following text evaluates people and assets vulnerable to the tsunami hazard and the potential impact of a tsunami on the City. Most of the results are for the inundation area mapping shown in Figure 17-6. For the evaluation of vulnerable population, results are also presented for the evacuation zones shown in Figure 17-7.

17.2.1 LIFE, HEALTH, AND SAFETY

Overall Population

It is assumed that the entire City's coastal population, property, critical facilities, and environment are exposed to tsunamis to some degree. The populations that would be most exposed to the tsunami hazard are those along beaches, low-lying coastal areas, tidal flats, and stream deltas that empty into ocean-going waters. People recreating in these areas would also be exposed.

Table 17-5 summarizes the estimated population located in the City's tsunami inundation areas. Table 17-6 summarizes the estimated population located in the City's tsunami evacuation zones. In both cases, the extreme area includes the standard area plus additional inland area. The population estimates are for residential populations only, and do not include visitors, many of whom gather around Oʻahu's coastal areas. The estimates also exclude residents who live outside the affected area but work in a location inside the area. Many parts of the urban core, particularly the business district and the Waikiki area, are large employment centers and are vulnerable to tsunamis. Depending on the time of day a tsunami occurs, these areas may have substantially more people at risk.

Table 17-5. Population in Tsunami Inundation Areas

Regional Planning Area	Total Population (2022 ACS)	Population in the Standard Tsunami Inundation Area		Population in the Extreme Tsunami Inundation Area	
		Number of Persons	% of Regional Planning Area Total	Number of Persons	% of Regional Planning Area Total
Central Oʻahu	175,966	0	0.0%	0	0.0%
East Honolulu	49,947	4,172	8.4%	12,014	24.1%
ʻEwa	128,498	4,401	3.4%	15,992	12.4%
Koʻolau Loa	14,512	7,587	52.3%	10,222	70.4%
Koʻolau Poko	120,704	4,541	3.8%	37,945	31.4%
North Shore	18,176	7,689	42.3%	13,794	75.9%
Primary Urban Center	451,030	5,318	1.2%	29,209	6.5%
Waiʻanae	51,266	6,318	12.3%	30,760	60.0%
City and County of Honolulu (Total)	**1,010,100**	**40,026**	**4.0%**	**149,936**	**14.8%**

Source: U.S. Census Bureau ACS 2022; City and County of Honolulu 2024

Table 17-6. Population in Tsunami Evacuation Zones

Regional Planning Area	Total Population (2022 ACS)	Population in the Standard Evacuation Zone		Population in the Extreme Evacuation Zone	
		Number of Persons	% of Regional Planning Area Total	Number of Persons	% of Regional Planning Area Total
Central Oʻahu	175,966	0	0.0%	234	0.1%
East Honolulu	49,947	5,822	11.7%	10,360	20.7%
ʻEwa	128,498	7,791	6.1%	14,303	11.1%
Koʻolau Loa	14,512	9,752	67.2%	2,369	16.3%
Koʻolau Poko	120,704	10,540	8.7%	39,465	32.7%
North Shore	18,176	9,366	51.5%	5,006	27.5%
Primary Urban Center	451,030	9,660	2.1%	29,934	6.6%
Waiʻanae	51,266	16,552	32.3%	19,988	39.0%
City and County of Honolulu (Total)	**1,010,100**	**69,483**	**6.9%**	**121,659**	**12.0%**

Source: U.S. Census Bureau ACS 2022; City and County of Honolulu 2024

Socially Vulnerable Population

As mentioned above, there are geographic locations on the island that are more likely to be impacted by a tsunami and face challenges during an evacuation. Populations that fall into one or more categories of social vulnerability may face compounding challenges during a disaster with evacuating, finding shelter, and communicating their needs. Table 17-7 and Table 17-8 summarize the socially vulnerable populations living the inundation area for the standard tsunami and extreme tsunami, respectively.

Table 17-7. Socially Vulnerable Population in Standard Tsunami Inundation Area

Regional Planning Area	Vulnerable Persons Living in the Standard Tsunami Inundation Area									
	Persons Over 65		Persons Under 5		Non-English Speaking Persons		Persons with a Disability		Persons in Poverty	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total	Numb er	% of Total
Central Oʻahu	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
East Honolulu	1,149	8.4%	180	8.3%	129	8.3%	404	8.3%	174	8.3%
ʻEwa	500	3.4%	334	3.4%	91	3.4%	440	3.4%	309	3.4%
Koʻolau Loa	818	52.3%	509	52.2%	127	52.2%	667	52.2%	651	52.3%
Koʻolau Poko	889	3.8%	280	3.8%	52	3.7%	455	3.8%	257	3.8%
North Shore	1,464	42.3%	586	42.3%	184	42.1%	929	42.3%	782	42.3%
Primary Urban Center	1,110	1.2%	266	1.2%	571	1.2%	612	1.2%	510	1.2%
Waiʻanae	821	12.3%	546	12.3%	105	12.3%	853	12.3%	1,153	12.3%
City and County of Honolulu (Total)	**6,751**	**3.6%**	**2,701**	**4.5%**	**1,259**	**2.0%**	**4,360**	**3.9%**	**3,836**	**4.4%**

Source: U.S. Census Bureau ACS 2022; City and County of Honolulu 2024

Table 17-8. Socially Vulnerable Population in Extreme Tsunami Inundation Area

Regional Planning Area	Vulnerable Persons Living in the Extreme Tsunami Inundation Area									
	Persons Over 65		Persons Under 5		Non-English Speaking Persons		Persons with a Disability		Persons in Poverty	
	Number	% of Total	Number	% of Total	Number	% of Total	Number	% of Total	Numb er	% of Total
Central Oʻahu	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
East Honolulu	3,308	24.1%	520	24.0%	372	24.1%	1,165	24.0%	501	24.0%
ʻEwa	1,817	12.4%	1,216	12.4%	334	12.4%	1,598	12.4%	1,125	12.4%
Koʻolau Loa	1,102	70.4%	686	70.4%	171	70.3%	899	70.4%	877	70.4%
Koʻolau Poko	7,430	31.4%	2,346	31.4%	440	31.4%	3,804	31.4%	2,149	31.4%
North Shore	2,627	75.9%	1,052	75.9%	331	75.8%	1,666	75.9%	1,403	75.9%
Primary Urban Center	6,098	6.5%	1,464	6.5%	3,140	6.5%	3,363	6.5%	2,803	6.5%
Waiʻanae	3,998	60.0%	2,658	60.0%	514	60.0%	4,153	60.0%	5,614	60.0%
City and County of Honolulu (Total)	**26,380**	**14.1%**	**9,942**	**16.5%**	**5,302**	**8.5%**	**16,648**	**14.9%**	**14,472**	**16.7%**

Source: U.S. Census Bureau ACS 2022; City and County of Honolulu 2024

17.2.2 GENERAL BUILDING STOCK

Table 17-9 and Table 17-10 show the number and value of buildings that are located in the inundation areas for the standard and extreme tsunamis, respectively. For both events, the Primary Urban Center accounts for more than half of the total building value exposed to the tsunami hazard.

Table 17-11 and Table 17-12 show the distribution by occupancy class of buildings in the inundation areas for the standard and extreme tsunamis, respectively.

Table 17-13 estimates the debris that could be generated by a standard or extreme tsunami. For the standard tsunami, East Honolulu would be the planning area with the greatest amount of total debris. For the extremes tsunami, the Koʻolau Loa planning area would have the greatest amount.

Table 17-9. Building Stock in Standard Tsunami Inundation Area

Regional Planning Area	Regional Planning Area Total Buildings		Buildings in the Standard Tsunami Inundation Area			
			Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Regional Planning Area Total	Value	% of Regional Planning Area Total
Central Oʻahu	32,090	$31,358,898,963	0	0.0%	$0	0.0%
East Honolulu	14,670	$12,765,314,977	1,335	9.1%	$1,796,640,360	14.1%
ʻEwa	23,477	$23,523,097,571	790	3.4%	$508,320,557	2.2%
Koʻolau Loa	3,131	$3,703,783,129	1,608	51.4%	$1,395,893,340	37.7%
Koʻolau Poko	28,843	$24,614,804,769	1,052	3.6%	$1,117,673,336	4.5%
North Shore	4,723	$3,819,600,126	1,964	41.6%	$1,357,947,642	35.6%
Primary Urban Center	71,191	$137,698,243,063	2,118	3.0%	$13,064,270,793	9.5%
Waiʻanae	10,213	$7,730,241,840	1,319	12.9%	$1,197,498,245	15.5%
City and County of Honolulu (Total)	**188,338**	**$245,213,984,438**	**10,186**	**5.4%**	**$20,438,244,273**	**8.3%**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; City and County of Honolulu 2024; RS Means 2024

Table 17-10. Building Stock in Extreme Tsunami Inundation Area

Regional Planning Area	Regional Planning Area Total Buildings		Buildings in the Extreme Tsunami Inundation Area			
			Number of Buildings		Replacement Cost Value	
	Count	Replacement Cost Value	Count	% of Regional Planning Area Total	Value	% of Regional Planning Area Total
Central Oʻahu	32,090	$31,358,898,963	0	0.0%	$0	0.0%
East Honolulu	14,670	$12,765,314,977	3,730	25.4%	$4,803,354,542	37.6%
ʻEwa	23,477	$23,523,097,571	3,165	13.5%	$5,664,788,341	24.1%
Koʻolau Loa	3,131	$3,703,783,129	2,260	72.2%	$3,198,875,253	86.4%
Koʻolau Poko	28,843	$24,614,804,769	9,293	32.2%	$8,410,544,619	34.2%
North Shore	4,723	$3,819,600,126	3,604	76.3%	$2,645,230,809	69.3%
Primary Urban Center	71,191	$137,698,243,063	8,751	12.3%	$42,837,235,320	31.1%
Waiʻanae	10,213	$7,730,241,840	6,164	60.4%	$4,645,599,452	60.1%
City and County of Honolulu (Total)	**188,338**	**$245,213,984,438**	**36,967**	**19.6%**	**$72,205,628,336**	**29.4%**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; City and County of Honolulu 2024; RS Means 2024

Table 17-11. Buildings by Class in Standard Tsunami Inundation Area

Regional Planning Area	Buildings in the Standard Tsunami Inundation Area by General Occupancy Class			
	Residential	Commercial	Industrial	Other[a]
Central Oʻahu	0	0	0	0
East Honolulu	1,166	134	16	19
ʻEwa	761	18	7	4
Koʻolau Loa	1,486	93	13	16
Koʻolau Poko	1,010	34	4	4
North Shore	1,820	104	27	13
Primary Urban Center	697	1,147	164	110
Waiʻanae	1,199	94	9	17
City and County of Honolulu (Total)	**8,139**	**1,624**	**240**	**183**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; City and County of Honolulu 2024

a. Other = Government, Religion, Agricultural, and Education

Table 17-12. Buildings by Class in Extreme Tsunami Inundation Area

Regional Planning Area	Buildings in the Extreme Tsunami Inundation Area by General Occupancy Class			
	Residential	Commercial	Industrial	Other[a]
Central Oʻahu	0	0	0	0
East Honolulu	3,357	286	46	41
ʻEwa	2,765	217	162	21
Koʻolau Loa	2,002	155	69	34
Koʻolau Poko	8,438	650	115	90
North Shore	3,265	258	48	33
Primary Urban Center	3,828	3,777	761	385
Waiʻanae	5,837	259	26	42
City and County of Honolulu (Total)	**29,492**	**5,602**	**1,227**	**646**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; City and County of Honolulu 2024

a. Other = Government, Religion, Agricultural, and Education

Table 17-13. Debris Generated by Standard and Extreme Tsunami

Regional Planning Area	Estimated Debris Created by Standard Tsunami				Estimated Debris Created by Extreme Tsunami			
	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)
Central Oʻahu	0	0	0	0	0	0	0	0
East Honolulu	5,581	2,902	1,508	1,171	57,149	18,954	18,855	19,340
ʻEwa	0	0	0	0	1,027	628	275	124
Koʻolau Loa	1,585	1,191	237	158	90,950	29,235	42,414	19,301
Koʻolau Poko	728	547	111	70	69,384	26,702	21,561	21,121
North Shore	134	134	0	0	26,983	10,619	9,664	6,699
Primary Urban Center	93	93	0	0	2,665	2,643	13	9
Waiʻanae	353	335	11	7	52,472	25,786	15,218	11,468
City and County of Honolulu (Total)	**8,474**	**5,201**	**1,866**	**1,406**	**300,630**	**114,567**	**108,002**	**78,061**

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; City and County of Honolulu 2024; Hazus v6.1

17.2.3 COMMUNITY LIFELINES AND OTHER CRITICAL FACILITIES

An analysis was conducted to understand the potential impact of tsunamis on the island's community lifeline facilities. Table 17-14 displays the number of community lifelines and other critical facilities in the standard tsunami inundation area. Table 17-15 shows the vulnerability within the extreme tsunami hazard area. The Primary Urban Center has the greatest number of vulnerable critical facilities for both tsunami scenarios

Table 17-14. Community Lifeline Facilities in the Standard Tsunami Inundation Area

Regional Planning Area	Number of Facilities in the Standard Tsunami Inundation Area, by Lifeline Category									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Regional Planning Area Total
Central O‘ahu	0	0	0	0	0	0	0	0	0	0	0.0%
East Honolulu	0	1	6	2	2	5	8	7	1	32	32.7%
‘Ewa	0	0	0	5	1	0	2	1	0	9	3.7%
Ko‘olau Loa	1	4	11	3	0	7	18	2	0	46	47.4%
Ko‘olau Poko	0	0	10	0	0	0	1	2	0	13	4.3%
North Shore	1	1	17	0	1	3	15	1	0	39	44.8%
Primary Urban Center	1	7	99	18	1	3	13	5	1	148	12.7%
Wai‘anae	2	4	1	2	2	4	16	2	1	34	26.8%
City and County of Honolulu (Total)	**5**	**17**	**144**	**30**	**7**	**22**	**73**	**20**	**3**	**321**	**13.3%**

Source: City and County of Honolulu 2023, 2024; State of Hawai‘i 2017, 2021, 2022, 2023, 2024; US Energy Atlas 2024

Table 17-15. Community Lifeline Facilities in the Extreme Tsunami Inundation Area

Regional Planning Area	Number of Facilities in the Extreme Tsunami Inundation Hazard Area, by Lifeline Category[a]									Total Facilities in Hazard Area	
	Communications	Energy	Food, Hydration, Shelter	Hazardous Materials	Health & Medical	Safety & Security	Transportation	Water Systems	Other Critical Facilities	Count	% of Regional Planning Area Total
Central O'ahu	0	0	0	0	0	0	0	1	0	1	0.4%
East Honolulu	1	2	9	5	5	10	12	8	1	53	54.1%
ʻEwa	3	19	7	57	2	5	4	3	1	101	41.2%
Koʻolau Loa	1	6	15	11	3	15	27	3	1	82	84.5%
Koʻolau Poko	4	4	33	9	4	18	16	19	1	108	35.5%
North Shore	2	2	25	2	2	9	21	2	1	66	75.9%
Primary Urban Center	5	12	177	76	8	53	33	13	4	381	32.7%
Waiʻanae	6	12	7	9	7	15	31	2	2	91	71.7%
City and County of Honolulu (Total)	**22**	**57**	**273**	**169**	**31**	**125**	**144**	**51**	**11**	**883**	**36.7%**

Source: City and County of Honolulu 2023, 2024; State of Hawaiʻi 2017, 2021, 2022, 2023, 2024; US Energy Atlas 2024

17.2.4 NATURAL, HISTORIC, AND CULTURAL RESOURCES

Natural

Tsunami inundation can result in erosion and scouring, debris movement and impact, water contamination, and the spread of disease due to standing water. Loss of wetlands from erosion and wetland migration due to tsunami inundation can reduce the natural filtration provided by wetland plants, increasing the likelihood of water quality issues.

Coral reefs provide protection from tsunamis and have experienced bleaching events since 1996 as ocean temperatures rise. Coasts with offshore reefs receive less wave energy than unprotected coastlines lying in the path of an approaching tsunami.

Septic tanks, cesspools, and other on-site sewage disposal systems are located along the coast. A tsunami may lead to the failure of these systems, releasing wastewater and hazardous materials and waste into nearshore waters and coastal habitats and diminishing water quality, impacting natural aquatic systems, and leading to human health exposure to these hazardous wastes.

Cultural and Historic

Many Native Hawaiian cultural resources are located near the shore and are threatened by a tsunami event, including fish ponds and burial sites along coastal areas (NHLC 2024).

An analysis was conducted to understand the impact that tsunamis may have on historic resources on Oʻahu. Table 17-16 displays the number of sites on the National and State Register of Historic Places that are within the inundation area for a standard or extreme tsunami. These sites include historic hotels, religious sites, public buildings, and homes of notable figures from history.

Table 17-16. Historic Sites in Standard and Extreme Tsunami Inundation Area

Regional Planning Area	Number of Historic Sites in the Inundation Area			
	Standard Tsunami		Extreme Tsunami	
	Count	% of Regional Planning Area Total	Count	% of Regional Planning Area Total
Central Oʻahu	0	0.0%	0	0.0%
East Honolulu	7	87.5%	7	87.5%
ʻEwa	0	0.0%	1	50.0%
Koʻolau Loa	1	50.0%	1	50.0%
Koʻolau Poko	14	51.9%	21	77.8%
North Shore	7	87.5%	7	87.5%
Primary Urban Center	37	8.2%	71	15.8%
Waiʻanae	0	0.0%	3	100.0%
City and County of Honolulu (Total)	**66**	**13.0%**	**111**	**21.9%**

Source: City and County of Honolulu 2024

17.2.5 FUTURE CHANGES THAT MAY AFFECT RISK

Understanding future changes that affect vulnerability can assist in planning for future development and ensure the establishment of appropriate mitigation, planning, and preparedness measures. The following sections examine potential conditions that may affect hazard vulnerability.

Potential or Planned Development

Non-urban zoned lands throughout Hawaiʻi are rapidly urbanizing. Projections indicate that from 2000 to 2030, housing density will substantially increase on approximately 8% (65,000 acres) of Hawaiʻi's private forest land (USDA 2014). On Oʻahu specifically, the City and County of Honolulu's directed growth policy encourages expansion beyond the primary urban center (Honolulu 2021). This policy has significant implications for Oʻahu's landscape, potentially leading to increased development in previously undeveloped areas and putting pressure on the island's limited land resources.

Table 17-17 identifies development since 2020 located in the standard and extreme tsunami hazard areas. The planning areas at most risk from an extreme tsunami are Koʻolau Loa, North Shore, and Waiʻanae.

Table 17-17. New Development in Tsunami Hazard Areas

Regional Planning Area	Number of New Developments in the Inundation Hazard Area			
	Standard Tsunami		Extreme Tsunami	
	Count	% of Regional Planning Area Total	Count	% of Regional Planning Area Total
Central Oʻahu	0	0.0%	0	0.0%
East Honolulu	21	17.6%	46	38.7%
ʻEwa	9	0.9%	27	2.6%
Koʻolau Loa	38	59.4%	48	75.0%
Koʻolau Poko	24	8.6%	109	38.9%
North Shore	21	35.6%	43	72.9%
Primary Urban Center	17	2.2%	70	9.0%
Waiʻanae	16	13.7%	63	53.8%
City and County of Honolulu (Total)	**146**	**5.7%**	**406**	**15.9%**

Source: City and County of Honolulu 2024

Projected Changes in Population

Honolulu's population is expected to moderately increase over the coming decades, as shown in Table 17-18. While population increases are unlikely to have an impact on the incidence of tsunamis, analysis throughout this chapter demonstrated that there are planning areas where the population is at higher risk from tsunamis.

Table 17-18. Population Projections for the City and County of Honolulu

	2020	2030	2040	2050
Population	1,012,305	1,033,600	1,054,670	1,060,110

Source: (DBEDT 2023)

Hazard Frequency, Severity, and Location

It is unlikely that climate change will directly impact tsunamis. However, landslides, which is one of the sources of tsunamis, could be impacted by climate change. Heavy rainfall could cause soil instability that may increase the likelihood of landslides into bodies of water, which can generate tsunamis. Rising seas could increase wave runup when tsunamis occur.