# Maritime Guidance for Distant and Local Source Tsunami Events

## Kodiak, Alaska


Kodiak Harbor.
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ALASKA EARTHQUAKE CENTER

Maritime response guidance in this document follows the draft guidance developed by the National Tsunami Hazard Mitigation Program (NTHMP) and is based on anticipated effects of **maximum-considered tsunami events, both distant and locally-generated**. Although smaller tsunamis occur more frequently, they are unlikely to cause significant damage compared to that of the maximum-considered scenarios. Check with local authorities for more specific guidance that may be appropriate for smaller distant tsunamis.

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# INTRODUCTION

Tsunamis are typically triggered by earthquakes and will cause sudden water level and current changes for many hours after their first arrival. The location of the earthquake plays an important role in determining the tsunami travel time to the coastal community. Distant earthquakes far away from the Southcentral Alaska coast may produce tsunami that strike *approximately* 4 hours or more after the earthquake, whereas locally occurring earthquakes near Kodiak Island may generate waves that hit the shore within minutes. 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. The first part of this document outlines the guidance for **DISTANT TSUNAMI**, whereas the second part is devoted to **LOCAL TSUNAMIS**.

Tsunami wave impacts are greatest in and around ocean beaches, low-lying coastal areas, and bounded water bodies such as harbors and estuaries. These areas should always be avoided during tsunamis. Any tsunami event can threaten harbors, facilities, and vessels.

**TSUNAMI HAZARDS** that can directly affect boats include:

- Sudden water-level fluctuations
    - Docks could overtop piles as water level rises
    - Grounding of vessels as water level suddenly drops
- Capsizing from incoming surges (bores), complex coastal waves, and surges hitting grounded boats
- Strong and unpredictable currents that can change direction quickly
- Eddies/whirlpools causing boats to lose control
- Drag on large-keeled boats
- Collision with other boats, docks, and debris

## Do Your Homework

The Alaska Tsunami Preparedness and Hazard Mitigation Program encourages maritime communities to utilize the following information to help mitigate damages and loss of life from future tsunamis. This information could be used to identify real-time response mitigation measures, determine where infrastructure enhancements should be initiated, and provide a mechanism for pre-disaster hazard mitigation funding through additions to their Local Hazard Mitigation Plans. Although these products, plans, and related mitigation efforts will not eliminate all casualties and damages from future tsunamis, they will provide a basis for reducing future impacts on life-safety, infrastructure, and recovery in Alaska maritime communities. For general information on tsunami maritime hazards consult http://www.tsunami.noaa.gov and the information below.

## Know real-time and permanent mitigation measures appropriate for your area

| Real-time response mitigation measures may include: | Permanent mitigation measures may include: |
|---|---|
| Moving boats and ships out of harbors | Fortify and armor breakwaters |
| Repositioning ships within harbor | Increase size and stability of dock piles |
| Move large, deep keeled ships from harbor entrances | Strengthen cleats and single-point moorings |
| Remove small boats/assets from water | Improve floatation portions of docks |
| Shut down infrastructure before tsunami arrives | Increase flexibility of interconnected docks |
| Evacuate public/vehicles from water-front areas | Improve movement along dock/pile connections |
| Restrict boats from moving during tsunami | Increase height of piles to prevent overtopping |
| Prevent boats from entering harbor during event | Deepen/dredge channels near high hazard zones |
| Secure boat/ship moorings | Move docks/assets away from high hazard zones |
| Personal flotation devices/vests for harbor staff | Widen size of harbor entrance to prevent jetting |
| Remove hazardous materials away from water | Reduce exposure of petroleum/chemical facilities |
| Remove buoyant assets away from water | Strengthen boat/ship moorings |
| Stage emergency equipment outside affected area | Construct floodgates |
| Activate Mutual Aid System as necessary | Prevent uplift of wharfs by stabilizing platform |
| Activate Incident Command at evacuation sites | Debris deflection booms to protect docks |
| Alert key first responders at local level | Make harbor control structures tsunami resistant |
| Restrict traffic entering harbor; aid traffic evacuating | Construct breakwaters farther away from harbor |
| Personnel to assist rescue, survey and salvage | Install Tsunami Warning Signs |
| Identify boat owners/live-aboards; establish phone tree, or other notification process | Equipment/assets (patrol/tug/fireboats, cranes, etc.) to assist response activities |

# PART 1: DISTANT SOURCE TSUNAMIS

Large underwater earthquakes are the most frequent cause of tsunamis, which can produce significant damage at distant shores. Earthquake-caused tsunamis occur when the seafloor abruptly deforms 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 along coastlines. Tsunami wave impacts are greatest in and around ocean beaches, low-lying coastal areas, and bounded water bodies such as harbors and estuaries. These areas should be avoided during tsunami events. The source of the distant tsunami greatly affects the ability of local governments to respond and the public to mitigate expected impacts. A tsunami originating in Chile (15-18 hours away) or Japan (6-8 hours away), provides more time for local response activity than will a tsunami originating in the closest distant sources along the West Coast of U.S. (4-5 hours away) or Russia Far East (5-7 hours away).

Maritime response guidance in this section is based on anticipated effects of a **maximum-considered distant tsunami event**, scenario describing a rupture of the Cascadia zone including the entire megathrust between British Columbia and northern California (see tsunami inundation modeling and mapping reports at http://dggs.alaska.gov/ for more information on this scenario). Smaller distant source tsunamis will occur more commonly and are likely to cause less damage than this maximum considered scenario[1] along the Western coast of U.S.

A distant source tsunami event does allow some time for local agencies and citizens to take steps to mitigate or reduce the expected impacts of tsunami surges. One of the steps is to evacuate from the ***Tsunami Evacuation Zone*** prior to the projected arrival time of the first tsunami surge. However, there may not be enough time to accomplish all needed response actions before the first wave arrives. Local response activities will be extensive and 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.

## Notable Historical Distant Source Tsunamis

The table below provides basic information about historical distant-source tsunamis (Lander, 1996); very minor tsunamis are not included. The largest historical, most damaging distant-source tsunamis in the Kodiak area occurred during the 1868 M8.5-9.0 earthquake in the Northern Chile region. The latest trans-Pacific tsunami generated by an earthquake along the Cascadia Subduction Zone, the West Coast of U.S., occurred in January 1700. Although, its impact on the Kodiak Islands remains unknown, numerical modeling of this event provide important information about the likely size of the tsunami in the Kodiak Islands. This information is referenced later in this document. The most recent distant tsunami event occurred on March 11, 2011 and originated in Japan. The peak amplitude and damage information presented in the table may help provide port authorities background information for comparing future Advisory and Warning level tsunamis in the area and is discussed in more detail below.

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[1] See the sensitivity study of water level fluctuations in the Kodiak Harbor with respect to the hypothetical rupture location (Wei and Arcas, 2010).

| Tsunami Event | Peak Amplitude Observed (m) | (ft) | Tsunami Alert Level Assigned | Tide During First Hours | Damage Summary |
|---|---|---|---|---|---|
| **1868 M8.5-9.0 Chile** | 2.2[2] | 7.2 | None | Mean | "A good deal of excitement upon the vessels" |
| **1952 M9.0 Russia** | 0.3 | 1.0 | Unknown[3] | High | Unknown |
| **1960 M9.5 Chile** | 0.7 | 2.3 | Unknown | Low | Unknown |
| **2010 M8.8 Chile** | 0.35 | 1.1 | Advisory | Low | no damage reported |
| **2011 M9.0 Japan** | 0.36 | 1.2 | Advisory | High | no damage reported |

## 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, many commercial fishing boats headed to sea. Once the tsunami hit and they realized they were unable to return to Crescent City Harbor, 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 Crescent City captains had never been to Humboldt Bay and some were running single handed as they did not have enough time to round up crewmen. As with the captains who chose to go to Brookings, all of the captains heading to Humboldt Bay 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 a captain plans to take his/her 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 within harbors and damage within harbors might prevent reentry.**

[2] Based on visual estimates of the ebbing tide and runup

[3] At Dutch Harbor/Unalaska, the schools were closed, and the people evacuated to higher ground (Lander, 1996).

## Actionable Tsunami Alert Levels

Tsunami Advisories and Warnings are the two **actionable** alert levels for maritime communities. For both Advisory and Warning level events, 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: http://wcatwc.arh.noaa.gov. The Center issues two types of bulletins that require action by Alaska boaters:

| ⚠ Tsunami Advisories | ⚠ Tsunami Warnings |
|---|---|
| **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.** | **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.** |
| **SIGNIFICANT** tsunami currents or damage are possible near harbor entrances or narrow constrictions. | **SIGNIFICANT** tsunami currents or damage are possible.<br><br>Depending on the tidal conditions, **docks may overtop the pilings.** |

## General Guidance on Response to NOAA Advisories and Warnings

| ⚠ Tsunami Advisories | |
|---|---|
| | • **During the event** (before the tsunami arrives):<br>o Evacuate from all structures and vessels in the water.<br>o Access of public along waterfront areas will be limited by local authorities.<br>o All personnel working on or near the water should wear personal flotation devices.<br>o Port authorities will shut off fuel to fuel docks, and all electrical and water services to all docks.<br>o Secure and strengthen all mooring lines throughout harbor, specifically areas near the entrance or narrow constrictions. |

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| | • **After the event**: Port authorities will not allow public to re-enter structures and vessels in the water until Advisory is cancelled and conditions are safe. |
| **Tsunami Warnings** | • **During the event:**<br>o Access of public along waterfront areas will be limited by local authorities.<br>o Port authorities will shut off fuel to fuel docks, and all electrical and water services to all docks.<br>o If you are on the water,<br>▪ 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.<br>▪ 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.<br>▪ 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.<br>▪ If conditions do not permit, dock your boat and get out of the ***Tsunami Evacuation Zone***.<br><br>o **VESSELS considering leaving** the harbor and heading to sea, please consider the following:<br>▪ Make sure your family is safe first.<br>▪ Check tide, bar, and ocean conditions.<br>▪ Check the weather forecast for the next couple of days.<br>▪ Ensure you have enough fuel, food and water to last a couple of days.<br>▪ Have someone drive you to the marina so your vehicle is not in the Tsunami Evacuation Zone.<br>▪ 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.<br>▪ If you do not have time to accomplish your goal, you should not make the attempt.<br><br>o **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 distant tsunami event; then go outside the Tsunami Evacuation Zone.<br><br>• **After the tsunami:**<br>o The "CAUTIONARY RE-ENTRY" DOES NOT MEAN THAT THE HARBOR IS OPEN. The "CAUTIONARY RE-ENTRY" message is for land entry only.<br>o Mariners at sea should monitor VHF Channel 16 for possible US Coast Guard Safety Marine Information Broadcasts regarding the conditions and/or potential restrictions placed on navigation channels and the entrances to harbors.<br>o 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 to 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.<br>o If in an onshore assembly or evacuation area, check with local authorities for guidance before returning to the inundation zone. |

## Mapping Current Velocities and Relationship to Damage

Much of the tsunami damage that occurs inside harbors can be directly attributed to strong currents. Lynett *et al.,* (2013) determined that damage in harbors might vary based on the age and location of docks and boats yet noted some generalities about the relationship between tsunami currents and damage.

One such generality, as shown in Figure 1, is a general trend of increasing damage with increasing current speed. In these data, there is a noticeable threshold for damage initiation at ~3 knots [1.5 m/s]. When 3 knots is exceeded, the predicted damage level switches from a no-damage to minor-to-moderate damage category. Thus, in the simulated data, 3 knots represents the first important current velocity boundary. The second threshold is at 6 knots [3 m/s], where damage transitions from moderate to the major category. A third current speed threshold is less clear, but is logically around 9 knots [4.5 m/s], where damage levels move to the extreme damage category.

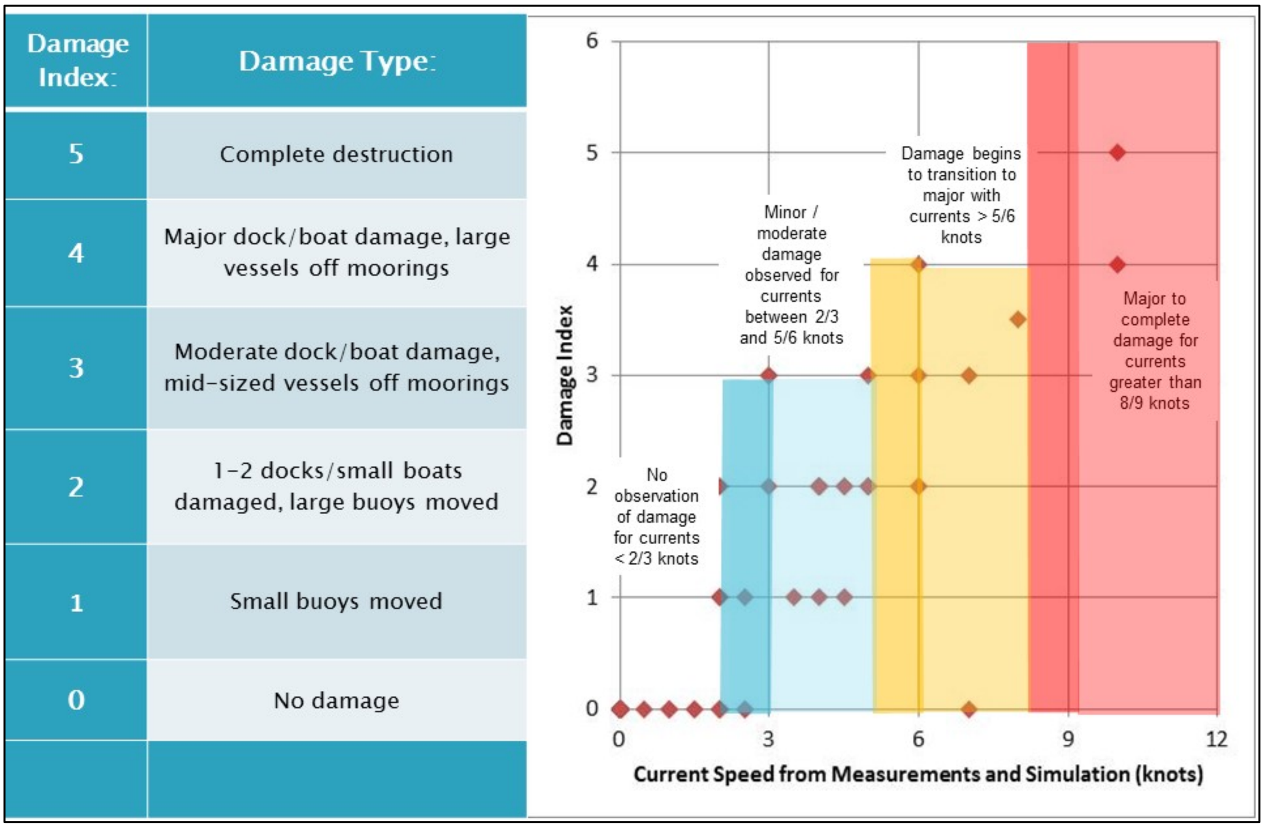


**FIGURE 1. GRAPHIC SHOWING THE RELATIONSHIP BETWEEN STRONG TSUNAMI CURRENTS AND DAMAGE** *in a number of harbors and real events. The red points represent damage-current data from past events and tsunami modeling (NOAA NTHMP, 2015).*

Maps in Figures 2a and 2b identify areas, where strong tsunami currents near the City of Kodiak due to the maximum-considered DISTANT scenario are likely to exist. The duration of strong, damaging tsunami currents may be of great importance to harbor masters and emergency managers for tsunami planning and response activities to enhance public safety for mariners. Figures 3 and 4 provides the duration of damaging currents in “time-threshold” maps. For a specified current velocity level, these maps show the time duration during which the velocity is exceeded based on numerical modeling results. There are potential limitations to models regarding accuracy as well as adequately capturing areas where eddies form and subsequently move away from the generating area. The “time-threshold” maps could be very useful for harbor personnel to estimate the duration of dangerous conditions; however, the estimates will be highly source dependent and scenario specific.

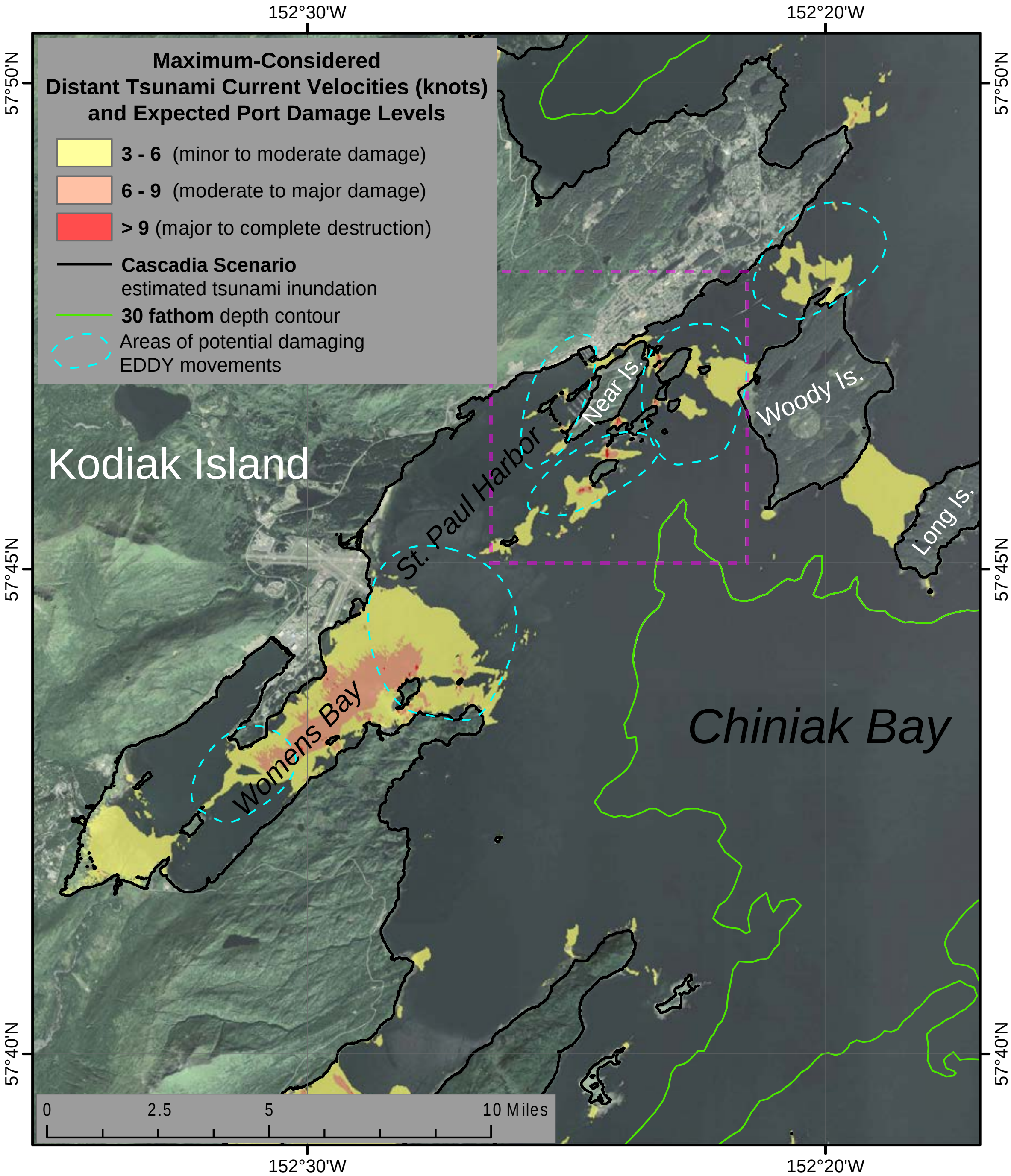


**FIGURE 2A. MAXIMUM CURRENTS, DISTANT SOURCE TSUNAMI.** *Map of maximum tsunami current velocities and expected port damage*[4] *resulting from a maximum-considered DISTANT tsunami. Dangerous eddies and whirlpools can be expected in Womens Bay, and along narrow channel constrictions such as between Kodiak and Near Islands. Areas of potentially damaging EDDY movements are indicated by dashed cyan line. Be aware that tsunamis surges could last for several hours. Withdrawing tsunami waves will rapidly drain the estuary and could ground your vessel, making it vulnerable to being sunk by the next incoming tsunami surge.*

[4] Based on scientific studies (e.g., Lynett *et al.*, 2013).

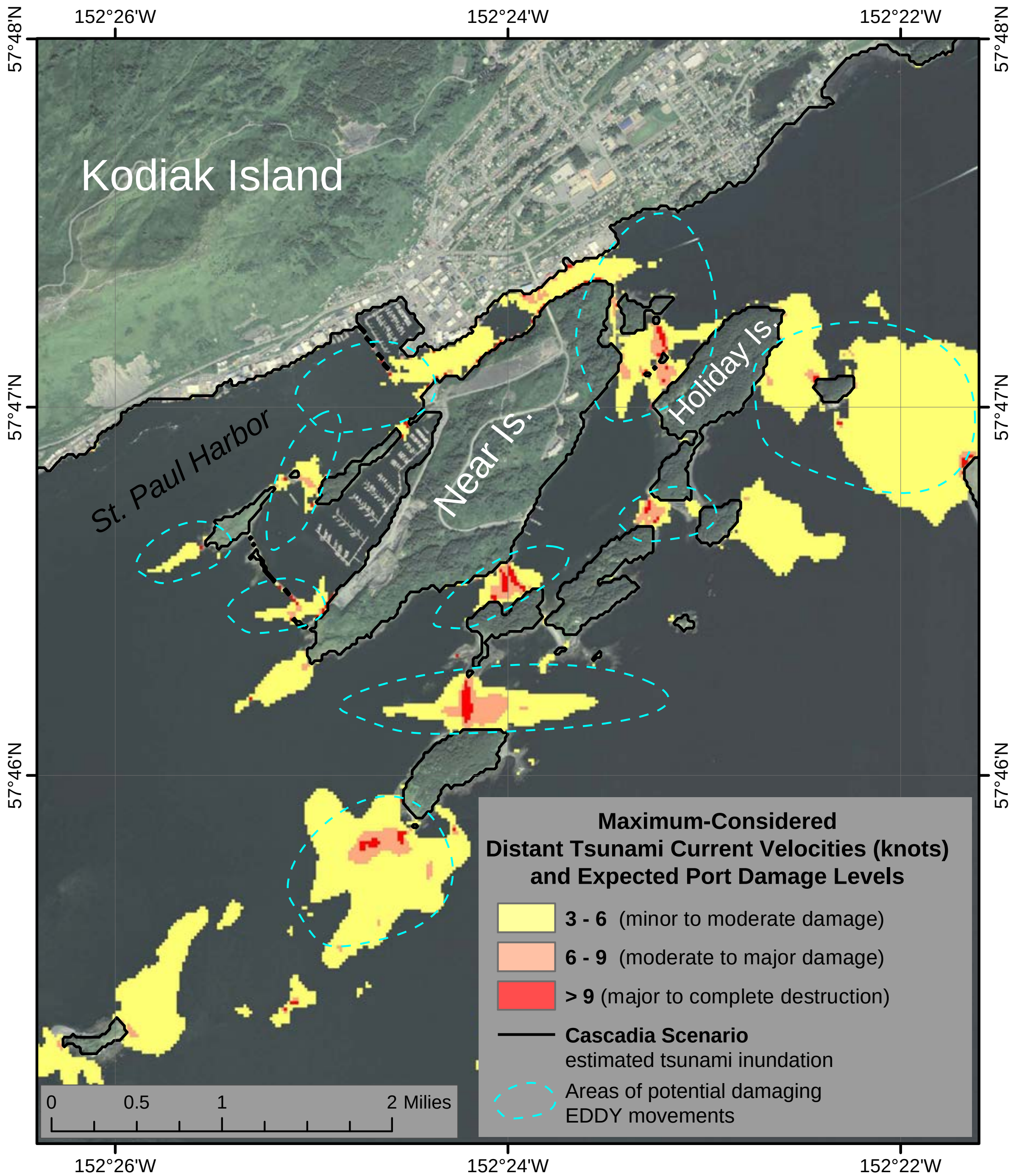


**FIGURE 2B. MAXIMUM CURRENTS AROUND NEAR ISLAND, DISTANT SOURCE TSUNAMI.** *Enlarged map of maximum tsunami current velocities and expected port damage in St. Paul Harbor and around Near Island. The spatial extent of this map is shown in Figure 2A by the dashed magenta rectangle.*

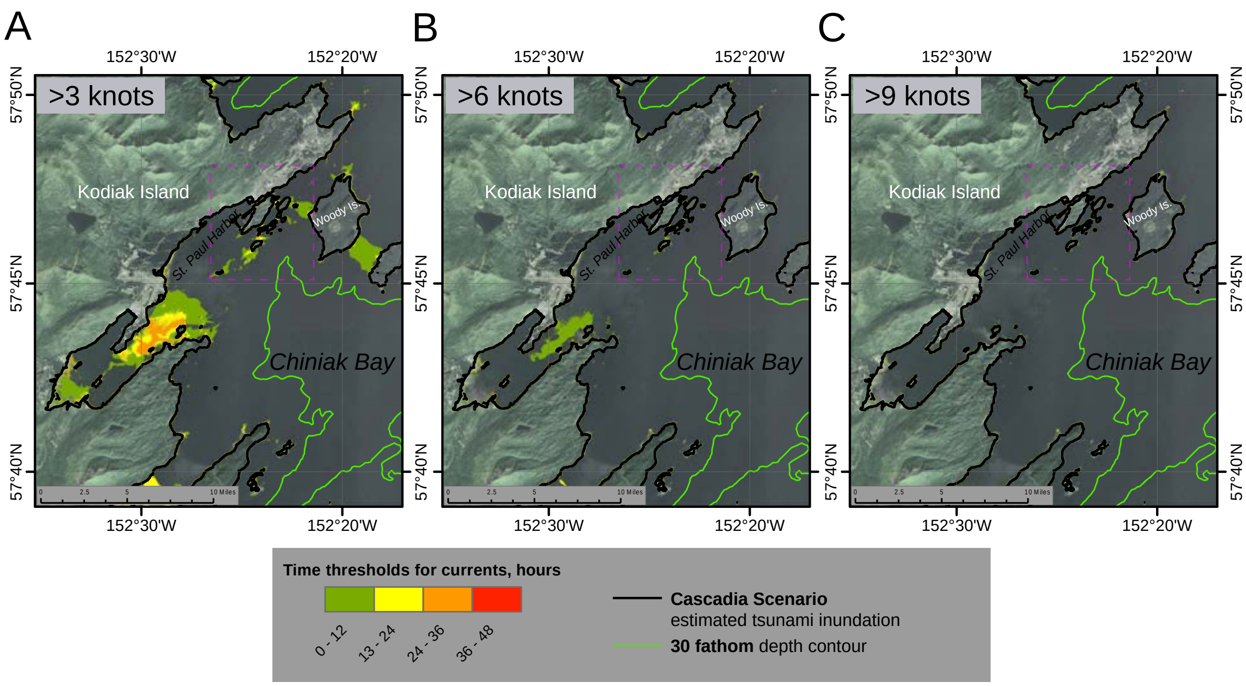


**FIGURE 3. THRESHOLD TIME FOR 3, 6, AND 9 KNOTS, DISTANT SOURCE TSUNAMI.** *Modeled estimates of duration of strong, damaging tsunami currents near the City of Kodiak. The maps for currents faster than 3 knots (A), 6 knots (B) and 9 knots (C) are shown.*

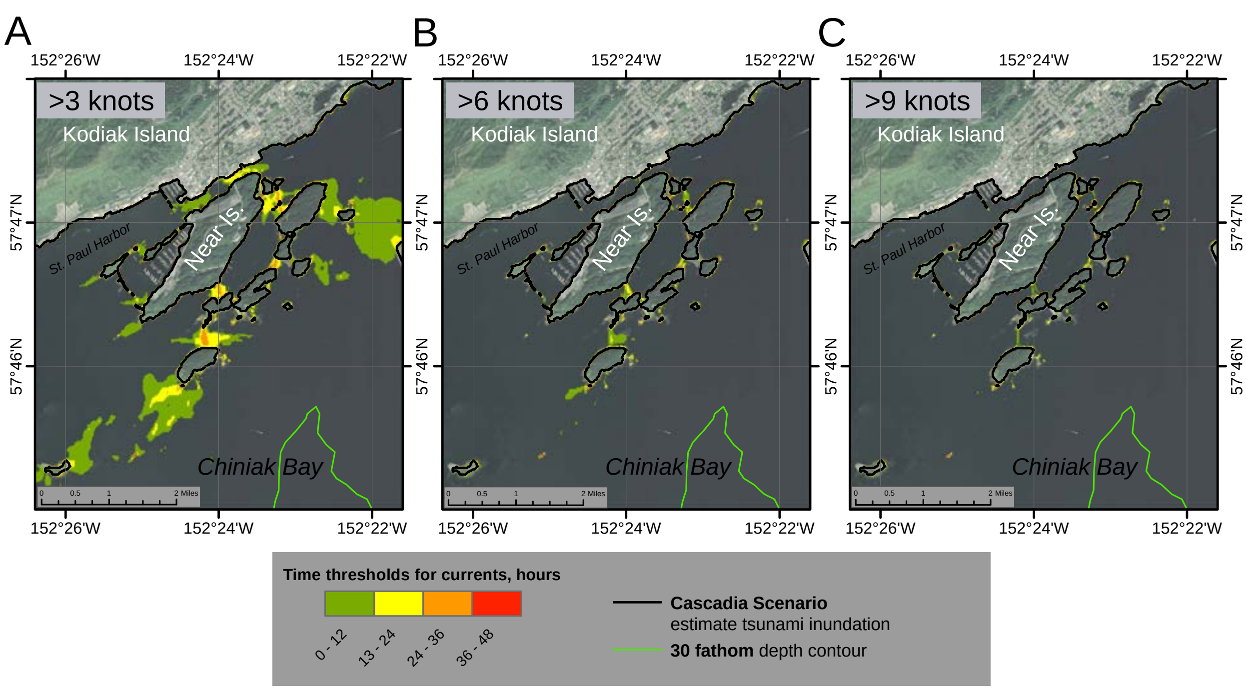


**FIGURE 4. THRESHOLD TIME FOR 3, 6, AND 9 KNOTS AROUND NEAR ISLAND, DISTANT SOURCE TSUNAMI.** *Enlarged maps of duration of strong, damaging tsunami currents in St. Paul Harbor and around Near Island. The maps for currents faster than 3 knots (A), 6 knots (B) and 9 knots (C) are shown. The spatial extent of each map is shown in Figure 3 by the dashed magenta rectangle.*

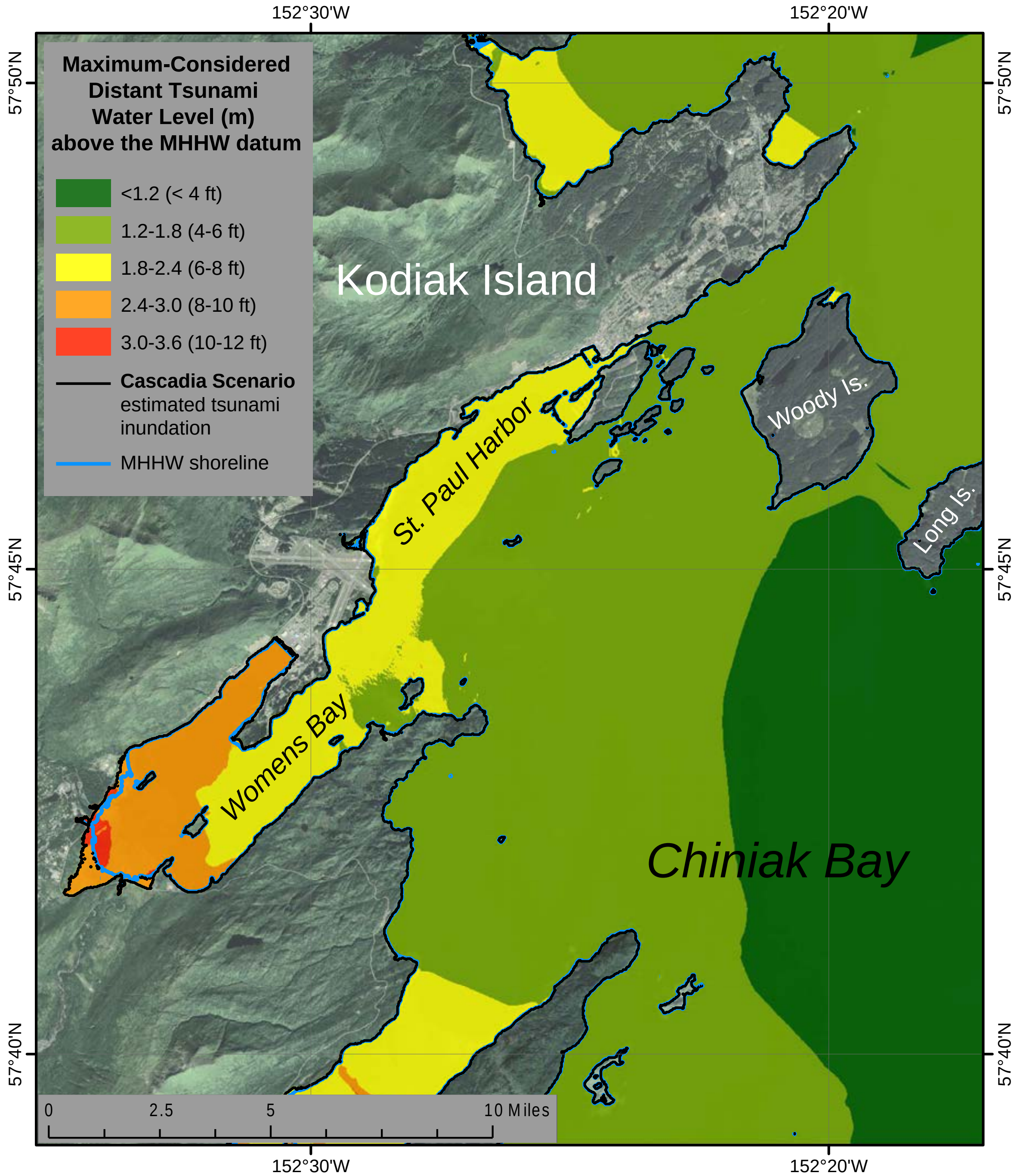


**FIGURE 5. MAXIMUM WATER LEVEL, DISTANT SOURCE TSUNAMI.** *Maximum rise of water from modeling results above prevailing tide is expected to be 2.4-3.0 m (8-10 ft) in Womens Bay at the US Coast Guard Air Station docks and 1.8-2.4 m (6-8 ft) in St. Paul Harbor. Where piles are shorter than the expected rise in water level, floating docks could overtop the piles. Harbors should consider extending piles to handle these changes in water level plus an appropriate tide such as mean higher high water (MHHW). Note: MHHW is 4.3 ft above the mean sea level in this area ([https://tidesandcurrents.noaa.gov](https://tidesandcurrents.noaa.gov)).*

# PART 2: LOCAL SOURCE TSUNAMIS

Large underwater earthquakes and landslide are the most likely cause of local source tsunamis, which can produce significant damage in Womens Bay, St. Paul and Kodiak Harbors. Landslide-generated tsunamis occur when the submarine or subaerial landslide propagates and displaces the water column. The local tsunami may strike in less than 30 minutes, which significantly affects the ability of local governments to respond and the public to evacuate. For the local tsunami sources, it is impossible to predict how soon the wave might strike. It may even occur while the ground is still shaking from an earthquake.

Maritime response guidance in this section is based on effects of three hypothetical **maximum-considered local tsunamis**, that may occur as a result of a rupture of the Alaska-Aleutian zone near the Island of Kodiak. Smaller local source tsunamis may also occur and are likely to cause significantly less damage than the maximum-considered scenarios. Check with local authorities for more specific guidance that may be appropriate for smaller local tsunami events.

A local source tsunami event WILL not allow time for local agencies and citizens to take steps to help mitigate the expected impacts of tsunami surges. **It is necessary to evacuate the Tsunami Evacuation Zone as soon as possible.** There will not be enough time to accomplish all needed mitigation actions before the first wave arrives. The actions to be taken must be based on life-safety preservation. Only the most essential life-safety actions should be attempted, and only if they have a high likelihood of success.

## Notable Historical Local Source Tsunamis

The table below describes basic information about historical local-source tsunamis; minor tsunamis are not included. The largest historical, most damaging local-source tsunamis in the Kodiak area occurred during the 1964 M9.2 earthquake in Southcentral Alaska. The peak amplitude and damage information may help provide port authorities background for comparing future Advisory and Warning level tsunamis in the area.

| Tsunami Event | Peak Amplitude Observed | | Tide During First Hours | Damage Summary |
|---|---|---|---|---|
| | (m) | (ft) | | |
| **1788 M8.0 Alaska Peninsula** | Unknown | Unknown | Unknown | Ship cast on shore; several huts destroyed at some location in Kodiak |
| **1854 Kodiak**[5] | Unknown | Unknown | Unknown | The water in St. Paul harbor advanced and receded uncommonly at 2- and 3-minute intervals and there was a strong eddy |
| **1866 Kodiak** | Unknown | Unknown | Unknown | The earth settled by 0.71 m (2.3 ft) |
| **1964 M9.2 Gulf of Alaska** | 7.6 | 24.9 | Low | 9 deaths, more than $40 million[6] damage including five blocks of the business district destroyed, total destruction of cargo dock and heavy damage to roads and bridges. |

[5] Probably a local landslide
[6] $1.00 in 1964 had about the same buying power as $7.66 in 2015.

### Lessons learned from the March 28, 1964 Alaska tsunami

The first wave is not usually the largest for tectonic tsunamis. At Kodiak 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 prepare and harden the harbor or remove vessels offshore prior to the arrival of the tsunami. Evacuation inland and to high ground out of the tsunami evacuation zone is the recommended action.

## Actionable Natural Warning Signs

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

- **Onshore**
  - Strong ground shaking lasting for 20 seconds
  - Loud ocean roar
  - Water receding unusually far, exposing the sea floor
  - Water surging onshore faster than any tide
- **Offshore**
  - You may feel the earthquake through the hull of your boat
  - You could see a rapid and extreme shift in currents and simultaneous changes in wind wave heights

## General Guidance on Response to Natural Signs and NOAA Warnings

*You have only minutes to take action, so have a plan ahead of time that includes a quick way to release commercial fishing gear so your boat is not dragged down by currents; have at least 3 days of food, fuel and water.*

| | |
|---|---|
| **Tsunami Warnings**<br>**or**<br>**Natural Warning Signs** | • **During the event:**<br>o **<u>If you are on land or tied up at the dock:</u>** Leave your boat and go to high ground on foot as soon as possible. You do not have time to save your boat in this situation and could die if you try to do so.<br>o **<u>If you are on the water but near shore:</u>** Use your best judgment to decide between the two options: safely beach/dock the vessel and evacuate to high grounds or get to minimum offshore safe depth. Attempting to beach the vessel could be challenging and dangerous, being dependent on wave conditions, water levels, presence of bars. It is easy for a boat to run aground or capsize before reaching the shore only after that being swept by the coming tsunami. However, if you can safely beach or dock your boat and get to high ground before the tsunami, then this is your best chance. If that is not possible, head to deep water as quickly as possible. |

| | |
|---|---|
| | <ul><li>**<u>If you are on the water and not near shore:</u>**<ul><li>At **less than 100 fathoms (600 ft)**: (1) Stop fishing operations immediately, (2) free the vessel from any bottom attachment (cut lines if necessary), and (3) if you can beach or dock your boat and evacuate on foot within 10 minutes of a natural warning, then this is your best chance. If that is not possible, head to greater than 100 fathoms, keeping in mind the following:<ul><li>Proceed as perpendicular to shore as possible.</li><li>Sail directly into wind waves, keeping in mind that wind waves opposed by tsunami currents will be greatly amplified.</li><li>Maintain as much separation as possible from other vessels.</li><li>Synchronize movements with other vessels to avoid collisions.</li></ul></li><li>At **greater than 100 fathoms**: If you are in deep water but not quite 100 fathoms, head to deeper water. If you are already at greater than 100 fathoms, then you are relatively safe from tsunamis, but deeper water is safer from tsunami currents and the amplification of wind waves by those currents.</li></ul></li></ul><ul><li>**After the tsunami:**<ul><li>If in an offshore staging area, check with the USCG for guidance before leaving the staging area; conserve fuel by drifting until you know what actions you need to take.</li><li>If in an onshore assembly area, check with local authorities for guidance before returning to the inundation zone.</li><li>Do not return to local ports until you have firm guidance from USCG and local authorities.</li><li>Local ports will sustain heavy damage from a local tsunami and may not be safe for days, weeks or months.</li><li>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.</li><li>If at sea, consider checking with USCG about your role in response and recovery.</li></ul></li></ul> |

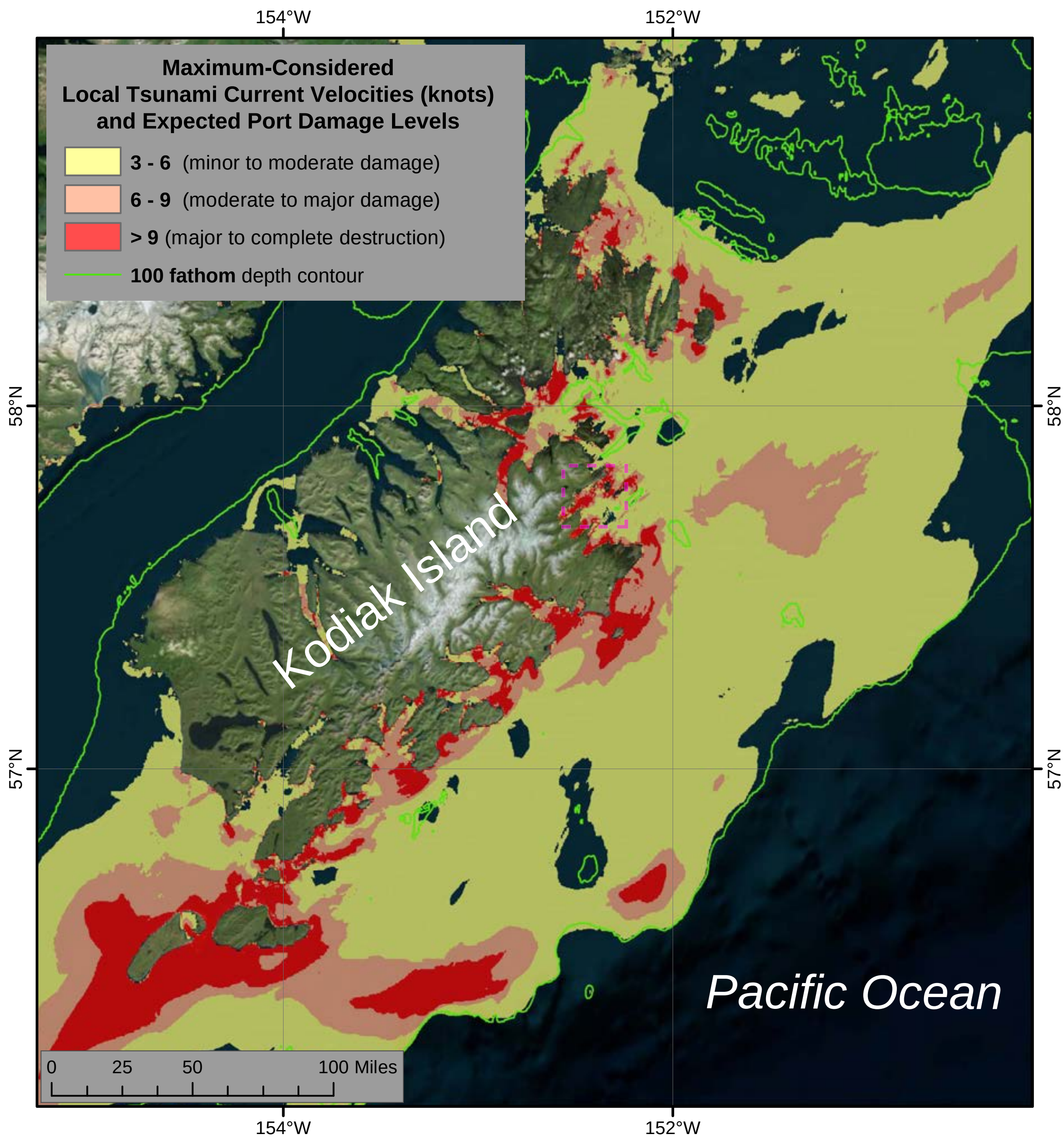


**FIGURE 6A: MAXIMUM CURRENTS, LOCAL SOURCE TSUNAMI.** *Map of maximum tsunami current velocities and expected port damage resulting from a composite[7] of three maximum-considered LOCAL tsunamis. Dangerous eddies and whirlpools are expected in narrow channel constrictions.*

[7] The composite map shows the maximum current across the three considered scenarios.

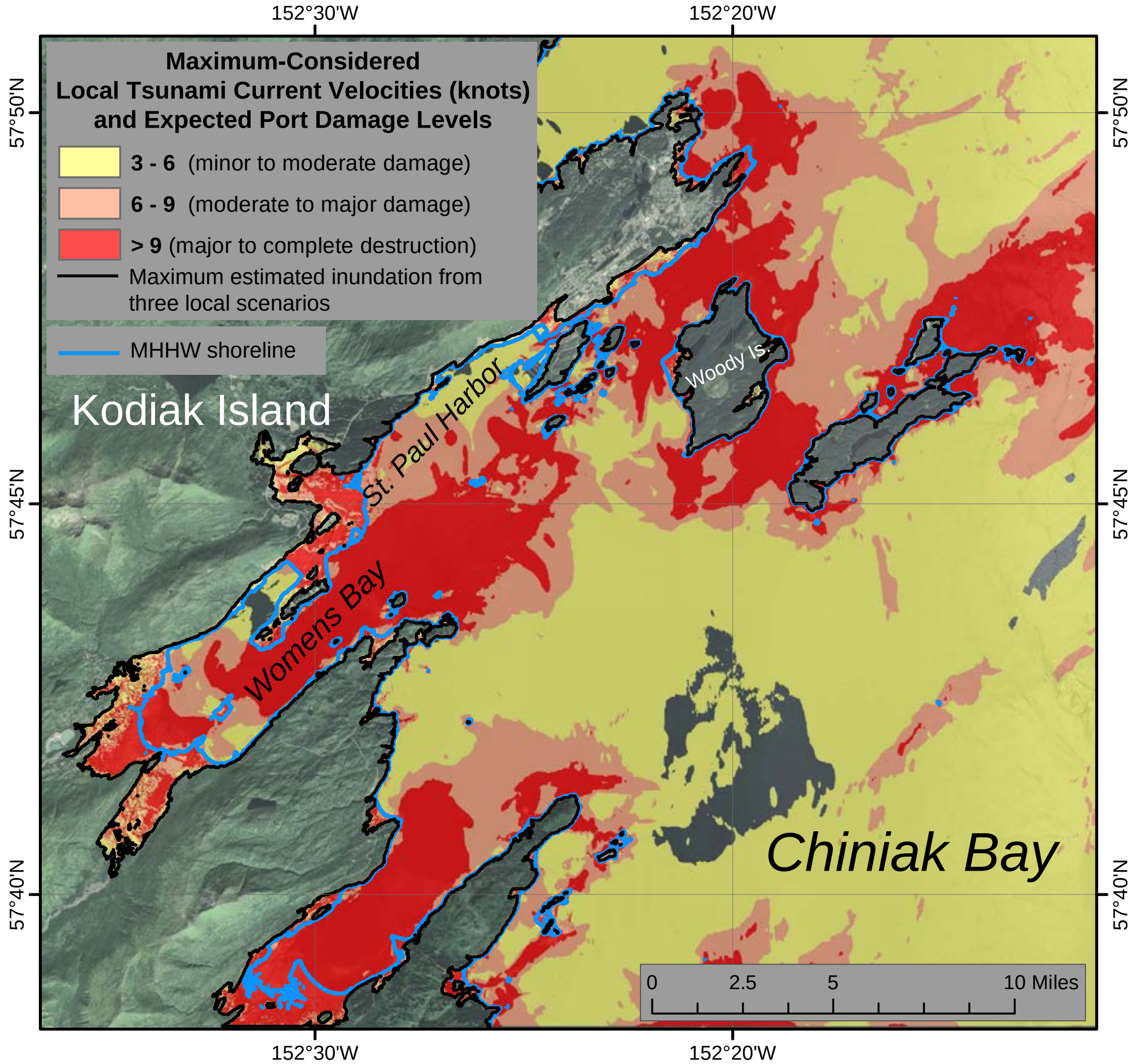


**FIGURE 6B: MAX CURRENTS IN CHINIAK BAY, LOCAL SOURCE TSUNAMI.** *Enlarged map of maximum tsunami current velocities and expected port damage in St. Paul Harbor and around Near Island. The maximum wave may reach as high as 8-12 m (26-39 ft) and overtop breakwater, pilings and cause a wide-spread inundation of the coastal areas. The spatial extent of this map is shown in Figure 6A by the dashed magenta rectangle.*

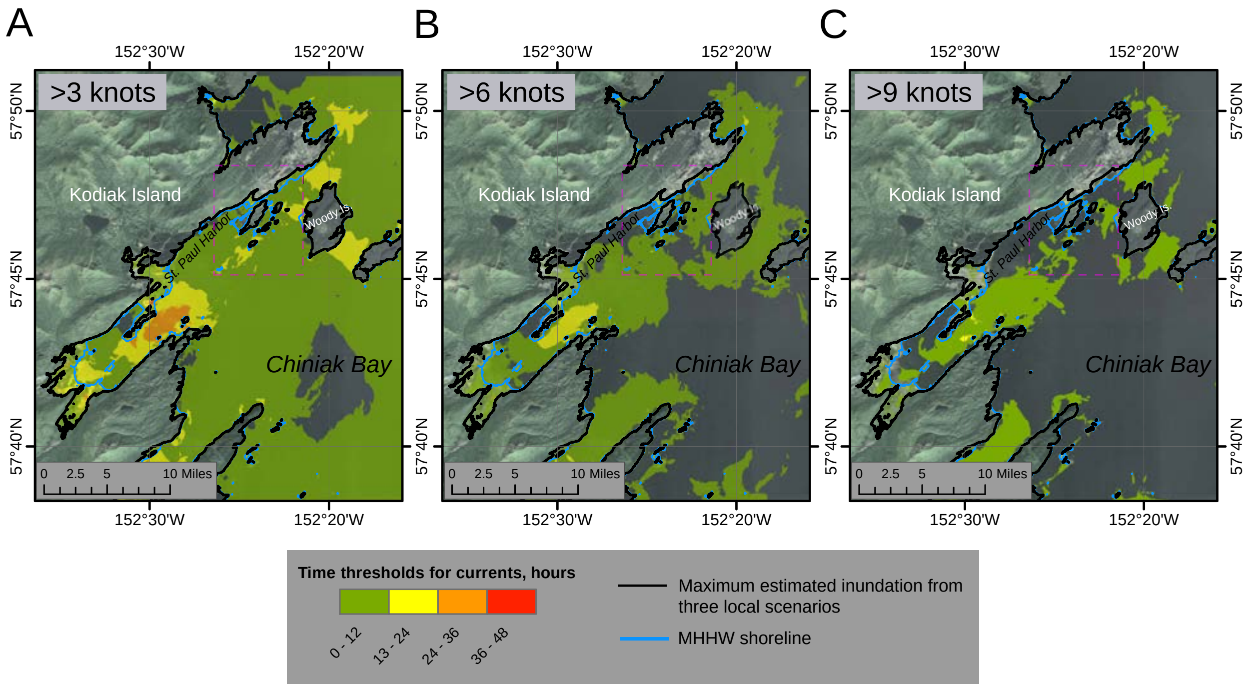


**FIGURE 7: THRESHOLD TIME FOR 3, 6, AND 9 KNOTS, LOCAL SOURCE TSUNAMI.** *Duration of strong, damaging tsunami currents near the City of Kodiak. The maps for currents faster than 3 knots (A), 6 knots (B) and 9 knots (C) are shown.*

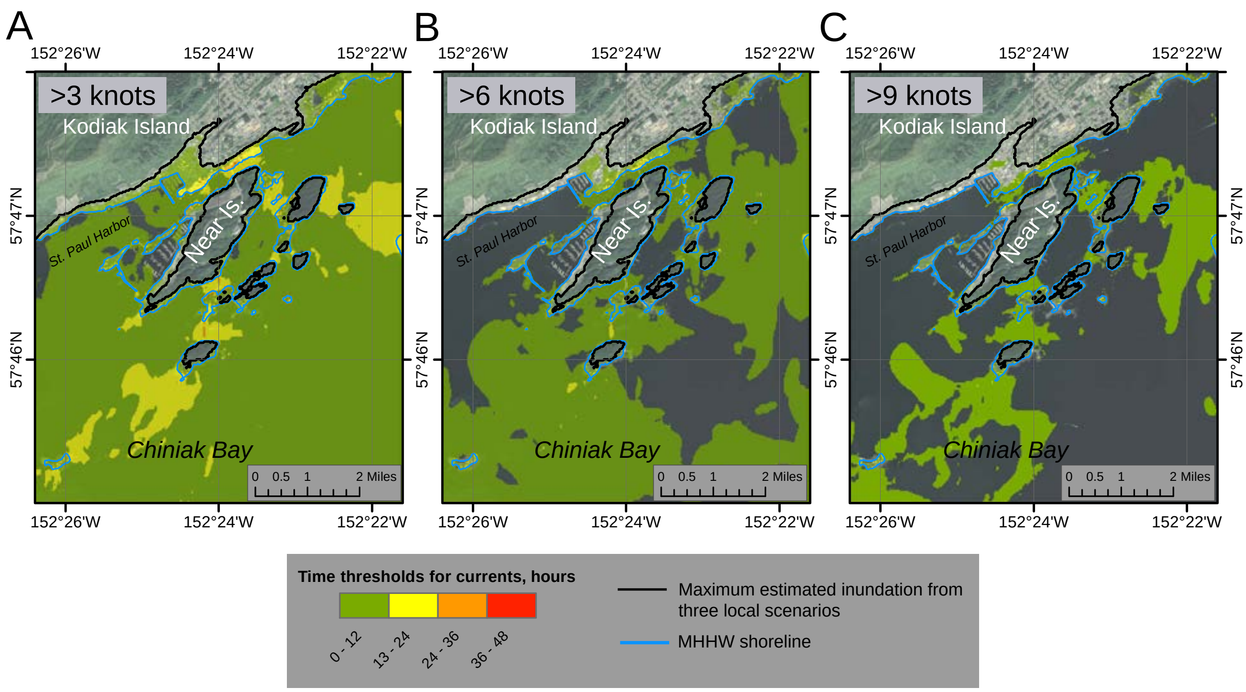


**FIGURE 8: THRESHOLD TIME FOR 3, 6, AND 9 KNOTS AROUND NEAR ISLAND, LOCAL SOURCE TSUNAMI.** *Enlarged maps of duration of strong, damaging tsunami currents in St. Paul Harbor and around Near Island. The maps for currents faster than 3 knots (A), 6 knots (B) and 9 knots (C) are shown. The spatial extent of each map is shown in Figure 7 by the dashed magenta rectangle.*

# REFERENCES

Humboldt Bay Tsunami Maritime Actions website: http://humboldtharborsafety.org/sites/humboldtharborsafety.org/files/BMP%20Tsunami%20Maritime%20Actions%20Small%20Craft%20Final.pdf.

Lander, J.F. (1996), Tsunamis affecting Alaska, 1737–1996: Boulder, Colorado, National Geophysical Data Center (NGDC), NOAA, Key to Geophysical Research Documentation, v. 31, 195 p.

Lynett, P., J. Borrero, S. Son, R. Wilson, and K. Miller (2013), Assessment of the tsunami-induced current hazards: Geophysical Research Letters, v. 41, no. 6, 2048-2055.

NOAA National Tsunami Hazard Mitigation Program (2015), Guidelines and best practices for tsunami hazard analysis, planning, and preparedness for maritime communities: draft 12/2015, 33 p.

Wilson, R., P. Lynett, K. Miller, A. Admire, A. Ayca, E. Curtis, L. Dengler, M. Hornick, T. Nicolini, and D. Peterson (2016), Maritime Tsunami Response Playbooks: Background Information and Guidance for Response and Hazard Mitigation Use, California Geological Survey, Special Report 241, p. 48.

Wei, Y., and D. Arcas (2010), A Tsunami Forecast Model for Kodiak, Alaska, PMEL Tsunami Forecast Series: Vol. 4, http://nctr.pmel.noaa.gov/forecast_reports, Contribution No. 3343 from NOAA/Pacific Marine Environmental Laboratory, Contribution No. 1763 from Joint Institute for the Study of the Atmosphere and Ocean (JISAO).

**TSUNAMI HAZARDS that can directly affect boats include:**

Sudden water-level fluctuations

Capsizing from incoming surges (bores), complex coastal waves, and surges hitting grounded boats

Strong and unpredictable currents that can change direction quickly

Eddies/whirlpools causing boats to lose control

Drag on large-keeled boats

Collision with other boats, docks, and debris