Tsunami Emergency Response Playbooks and FASTER Tsunami Height Calculation: Background Information and Guidance for Use

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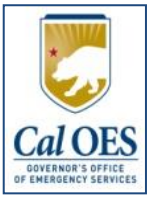

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Note: CGS and CalOES provide the following information on how elevation-based and scenario-based evacuation playbook maps were constructed, and guidance on how to use the playbooks during future tsunami events. Evacuation and emergency response planning for future tsunamis is the responsibility of each community, and these playbook products are intended as internal emergency response planning tools for community emergency managers.

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Overview

California's experience during 2010 Chile and 2011 Japan tsunamis has brought to light the desire by coastal emergency managers and decision makers to obtain more detailed information on the estimated impact and hazard of the tsunami well ahead of its arrival time. The main issue is that existing tsunami evacuation plans call for evacuation of the predetermined "worst-case" tsunami evacuation zone (typically at a 30- to 50-foot elevation) during a "Warning" level event; the alternative is to not call an evacuation at all. To provide more detailed information for secondary evacuation zones, tsunami evacuation "playbooks" have been developed to plan for tsunami scenarios of various sizes and source locations. NOAA-issued Tsunami Alert Bulletins received in advance of a distant event will contain a forecasted tsunami amplitude, or wave height, and arrival time for a number of locations along the coastline. Elevation "playbook" evacuation lines can be useful for partial tsunami evacuations when information about forecasted tsunami amplitudes and arrival times is available to coastal communities and there is sufficient time to implement a partial evacuation. Provision for multiple elevation evacuation lines and response plans for those lines enables planning for different evacuation scenarios based on the forecast tsunami amplitude, potentially alleviating the need for an "all or nothing" decision with regard to evacuation.

Scenario tsunami playbooks and guidance have been developed for maximum local and regional tsunamis, and for tsunamis generated by the Cascadia Subduction Zone that impact central and southern California. Scenario playbook information about the expected tsunami amplitude and travel time is available from the numerical modeling results for these sources. These are important scenarios for emergency managers to prepare for as there could only be ten to fifteen minutes to evacuate before a local tsunami arrives, or just a few hours to conduct response or evacuation activities before a regional tsunami arrives.

To assist in the decision making process of what level of evacuation should occur, an analytical tool called the "FASTER" approach has been developed that takes the forecast amplitude of the tsunamis and integrates other factors influencing tsunami inundation, including storm, tides, modeling errors, and location specific tsunami run-up potential. Both the evacuation playbooks and FASTER approach will help communities better evaluate the amount of expected flooding, and implement evacuations and response activities for minor to moderate (less than maximum) tsunami events (i.e. events where the worst-case scenario evacuation may be excessive).

A Work Group comprised of federal, state, and local governmental scientists, emergency managers, and community planners has evaluated the products and plans for use of the playbooks and FASTER calculation. The outcome of this review will be development of secondary tsunami evacuation plans for coastal communities which can be used for tsunami drills and exercises, and evacuation during an impending tsunami event. This report includes a summary of how these products were developed as well as guidance on how to develop playbook evacuation plans and how to implement them during an emergency.

Introduction

The California Geological Survey (CGS) and the California Governor's Office of Emergency Services (CalOES) have created maps identifying potential inundation areas for multiple tsunami scenarios based on either: 1) the forecasted amplitudes (tsunami wave heights above normal tide conditions) from the National Tsunami Warning Center (NTWC), or 2) tsunamis generated by sources in close proximity, and expected short travel time, to the California coast. These products supplement the existing state-wide inundation maps, which are available on the www.tsunami.ca.gov website, identifying inundation for multiple "worst-case" scenarios (Wilson et al., 2008; Barberopoulou et al., 2009).

During the typical tsunami alert, the NTWC provides information about the tsunami in "bulletins" to the state and local jurisdictions. These bulletins include information about the tsunami source, typically an earthquake (location, depth, magnitude), and forecasts about the impending tsunami itself (alert level, first arrival, maximum amplitudes or wave height). There are four levels of "alert" that can be sent by the NTWC (from least to greatest significance):

- **Tsunami Information Statement** - Issued to inform and update emergency managers and the public that an earthquake has occurred, or that a tsunami Watch, Advisory or Warning has been issued elsewhere in the ocean.
- **Tsunami Watch** - Issued to alert emergency managers and the public of an event which may later impact the Watch area. May be upgraded to an Advisory or Warning - or canceled - based on updated information and analysis.
- **Tsunami Advisory** - Issued due to the threat of a tsunami which may produce strong currents or waves dangerous to those in or near the water; typically called when forecasted tsunami amplitudes between 0.3m and 1m (1ft and 3ft) above existing tidal conditions are expected. Coastal communities are advised that beach and harbor areas could expect rapid, moderate tidal changes and strong currents.
- **Tsunami Warning** - Issued when a tsunami with significant widespread inundation is imminent or expected; typically called when forecasted tsunami amplitudes are equal to or greater than 1m (3ft). Coastal communities are advised to evacuate people from low-lying areas identified as vulnerable to tsunamis.

Tsunami Advisories and Warnings are situations where coastal emergency managers and harbor masters are recommended to take action, from limiting access to beaches or waterfront areas to full evacuation of the formal evacuation zone identified in their emergency response plans. These evacuation zones encompass the state "worst-case" inundation areas and are typically set at an elevation of 10m to 20m (30ft to 60ft) above sea level. However, when a relatively small-amplitude tsunami Warning is issued, emergency managers struggle with the decision to partially or fully evacuate or whether to evacuate at all (Wilson et al., 2012). An example of this occurred during the March 11, 2011 tsunami when forecasted amplitudes of only 1m to 2.5m (3ft to 8ft) were expected along the California coast north of Point Conception. To complicate local response decision-making and actions, the first five hours of tsunami activity in California coincided with low-tide conditions further reducing the potential for inundation of dry land. Improving the information about the potential for tsunami inundation will allow emergency managers to make more accurate decisions about response and evacuation activities. This, in turn, could reduce the potential for injury to people due to hastily over-evacuating, save businesses from having to close unnecessarily, and decrease the costs of emergency response coordination and personnel. Providing

a more accurate evacuation strategy will also improve public confidence in those response activities.

To help provide additional evacuation options for emergency managers, CGS and CalOES have developed several tsunami response products (Wilson et al., 2014):

- **Playbooks**
  - **Tsunami elevation "playbook" maps** - Secondary evacuation maps and guidance based on various land elevations (1m, 2m, 3m, and 4m) incorporating high tide conditions.
  - **Tsunami scenario "playbook" maps** – Secondary evacuation maps and guidance for the largest local and distant sources as well as the Cascadia Subduction Zone, located off the coast of Del Norte and Humboldt counties, which represents both a local and regional tsunami source for the state.
- **FASTER tsunami flood height calculation** – A simple analytical tool that incorporates storm and tidal conditions, potential forecast errors, and site-specific tsunami run-up potential with the forecasted tsunami amplitude to determine a more exact tsunami flood height along the coast.

This report summarizes the creation of these products and guidance on how these products can be used together. These playbooks and the FASTER approach provide more information and more options for coastal jurisdictions to implement response activities during future tsunamis. They can also be used for table-top and field exercises to help with response to various size tsunami events. Similar types of tsunami response playbooks are being generated for the over 100 maritime communities along California's coast (Lynett et al., 2014; Wilson et al., 2014).

Tsunami Playbook Work Group

To help develop and refine these products, CalOES and CGS formed a "Work Group" comprised of: emergency managers from five counties (Humboldt, Monterey, Ventura, Orange, and San Diego counties); four coastal NOAA Warning Forecast Office Warning Coordination Meteorologists (WCMs) in California (Eureka, Monterey, Oxnard, and San Diego); the National Tsunami Warning Center (NTWC) Director; and other tsunami experts. A number of teleconference meetings with the Work Group were held from March to August, 2013. Workshops were held in each of the five counties in 2013 and 2014 to get community-level feedback on the products, and improving the process for using the products. Follow up workshops and meetings were held to help communities integrate these products into their emergency response plans. The format and content of the final playbook products were vetted through the California Tsunami Steering Committee comprised of representatives from all 20 coastal counties. These products were also shared with members of the U.S. National Tsunami Hazard Mitigation Program to gather feedback and develop guidance for other states to develop and utilize evacuation playbook-type products.

Tsunami Evacuation Playbooks

There are two types of tsunami evacuation playbooks being produced. The first type of playbook is for scenarios where the tsunami travel time to California is greater than 4-5 hours, and there is

enough time for the Warning Center to process data and make accurate wave-height and arrival-time forecasts. This forecast information can allow coastal communities to initiate emergency response plans which might include partial or full evacuations for their communities. This 4-5 hour period is also the minimum amount of time it takes for emergency managers to implement secondary or less-than-maximum evacuations. Secondary evacuation plans can be implemented if an Advisory or small to moderate Warning level alert is issued, and evacuation of the "worst-case" inundation zones is not warranted, such as during the 2011 tsunami. These secondary evacuation plans are "elevation-based playbook" lines where forecasted tsunami amplitudes and tidal information can help guide what areas below a certain elevation might get inundated.

The second type of playbook is for when there is less than 5 hours tsunami travel time and forecast tsunami amplitude information might not be readily available for emergency managers. In this situation, coastal communities could use existing tsunami "scenario-based playbooks" to make swift decisions on response and/or evacuation. These scenario playbooks were developed based on the state tsunami modeling work, and include tsunamis generated from three types of tsunami sources based on where they originate:

- Distant-source earthquake events along the Alaska-Eastern Aleutian Islands Subduction Zones where there is only 4-6 hours travel time to California;
- The local/regional source Cascadia Subduction Zone earthquake where locally there may be only 10 minutes to evacuate in Del Norte and Humboldt counties, and one to two hours along the rest of the California coast; and
- Other various local submarine earthquake or landslide sources where there may only be 10 minutes until tsunami arrival.

As noted in the beginning of the document, CGS and CalOES provide the following information on how these playbook maps were constructed, and guidance on how to use the playbooks during future tsunami events. These playbook products are intended as an internal planning tool for local emergency managers.

Elevation-Based Playbooks

Elevation playbook lines are useful for partial evacuations when sufficient information about forecast amplitude and arrival times is available for coastal communities. These lines were created using new 1m resolution LiDAR digital elevation models (DEMs) collected in 2009 to 2011 along the California coast. The DEM elevations were transformed into 1m, 2m, 3m, and 4m zones at Mean High Water conditions, to capture "worst-case" inundation potential similar to the numerical tsunami model runs by the state which also incorporate Mean High Water. Based on the feedback from local communities, evacuation zone lines were created for each of the individual elevation lines. These evacuation zone lines typically follow roads and recognizable landmarks to help with more efficient and practical evacuation planning. Figure 1 illustrates an example of how playbook "evacuation" lines were developed from "elevation" lines. These elevation-based evacuation playbook lines are numbered as "phased" evacuation lines in the playbook guidance documents to reduced confusion about what elevation they represent.

The digital playbook lines can be used by communities for secondary evacuation planning, exercises and drills, as well as integrated into the local telephone notification systems for use during an event. Table 1 demonstrates what elevations, or Phases these playbook evacuation lines represent and how they could be used in tsunami response, which is discussed in more detail below.

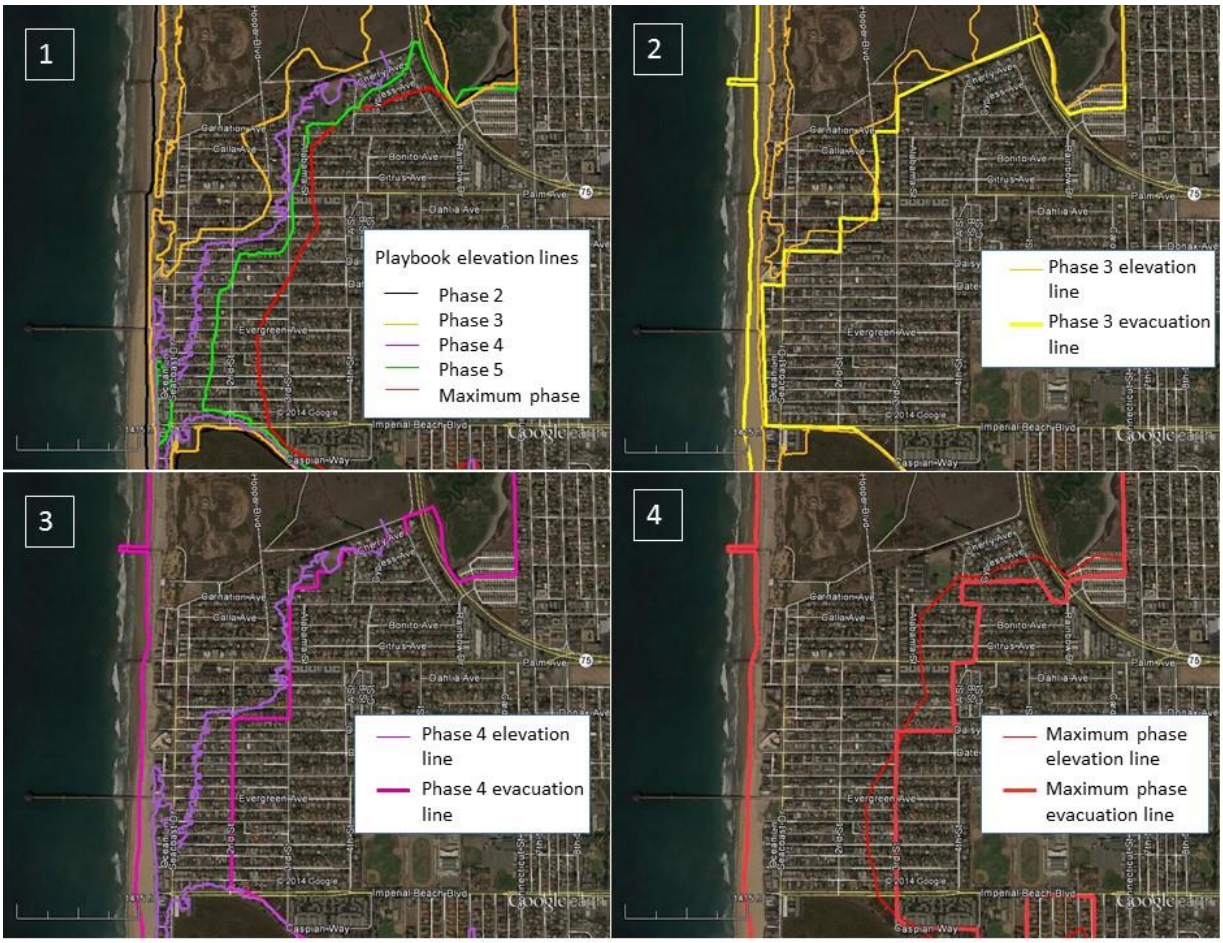

Figure 1. Illustration of how tsunami playbook evacuation lines are developed from elevation lines at Imperial Beach in San Diego County. Panel 1 shows all four phase elevation lines and the maximum state inundation line. Because these lines are not straight nor easy to use for evacuation planning, phase-specific "evacuation" lines were developed along streets and landmarks as shown in panels 2-4. A phase 5 evacuation line was not developed because it would have been too similar in location to the phase 4 evacuation line.

Community Playbook Evacuation Zone Name	Recommended FASTER Tsunami-Height Number (in METERS)	Recommended FASTER Tsunami-Height Number (in FEET)	Anticipated Associated NOAA Tsunami Alert Level	Community Recommended Areas to Evacuate (local decision)
Phase 1	less than 1.00m	less than 3.3ft	Advisory	beaches, docks, waterfront areas
Phase 2	1.00m to 1.50m	3.3ft to 5.0ft	Warning	Typically areas of normal flooding; areas mapped as Phase 2
Phase 3	1.50m to 2.50m	5.0ft to 8.2ft	Warning	Areas mapped as Phase 3
Phase 4	2.50m to 3.50m	8.2ft to 11.5ft	Warning	Areas mapped as Phase 4
Phase 5	3.50m to 4.50m	11.5ft to 14.8ft	Warning	Areas mapped as Phase 5
Maximum Phase	more than 4.50m	more than 14.8ft	Warning	Evacuate maximum evacuation zone

Table 1. Recommended guidance for use of evacuation playbooks. The FASTER elevation values are referenced to Mean Sea Level. The colors on the table correspond to the colors of the phase elevation and evacuation lines on Figure 1. The number of playbook evacuation phases for each community may vary depending on the elevation of the maximum phase evacuation line; for example, the lower the elevation of the maximum phase evacuation line, the fewer phase evacuation lines needed.

Scenario-Based Playbooks

The database of numerical modeling scenarios developed for the 2009 state-wide inundation mapping project is used to generate information for "scenario-based playbooks," specifically for local and regional tsunamis where the travel time is relatively short (less than 4-5 hours). The sources and source regions that fall into this category include: 1) the Cascadia Subduction Zone where travel time could be from 10 minutes in Del Norte and Humboldt counties, and 1-2 hours for the rest of the state; 2) the Alaska and Eastern Aleutian Islands Subduction Zones where travel times range from 4 to 6 hours; and 3) other local offshore tsunami sources where travel time could be only 10 minutes. Table 2 shows the expected maximum tsunami wave height from modeled scenarios from these sources at the significant coastal communities in California.

Magnitude 9.0+ Earthquake - Cascadia Subduction Zone Scenario

A tsunami created by this scenario will arrive on shore within about 10-30 minutes along the coasts of Del Norte, Humboldt, and the northern portion of Mendocino counties, and within two hours along the rest of the California coast. This scenario will not give coastal emergency managers enough time to wait for forecast information from the National Tsunami Warning Center (NTWC) to help them make a decision. For this reason, the state is providing guidance about what low-lying, populated areas to evacuate based on modeled inundation results for this scenario.

Magnitude 9.0+ Earthquake - Alaska-Eastern Aleutian Islands Subduction Zone Scenario

The eastern Aleutian Islands tsunami source region is considered one of the "worst-case" source regions for tsunamis along the California coast because of the large expected tsunami heights (see Table 2) and relatively short travel time. A tsunami created by a scenario magnitude 9.2 earthquake in this region, which results in the maximum considered distant event for most parts of the state, will arrive in California within four (Crescent City) to six (San Diego) hours after generation. This scenario may not provide enough time for emergency managers to wait for forecasted information from the NTWC to make a decision about evacuation. For this reason, evacuation of the maximum evacuation zone is recommended for all parts of the state.

Worst-Case Local Scenario

The state tsunami program has modeled potential local tsunami sources for most coastal locations in the state. These local sources, both submarine faults and landslides, may create tsunamis that arrive on shore within 10 minutes. Inundation information for these scenarios has been provided to each county so that coastal jurisdictions can educate and prepare their communities to evacuate immediately, especially if they feel strong shaking from an earthquake along the coast. Evacuation of the maximum evacuation zone is recommended for all parts of the state for these local tsunami events.

FASTER Tsunami Height Calculation

Forecast tsunami amplitudes, or wave heights, from the NTWC typically represent the near-shore tsunami height without consideration of the existing tidal conditions and other factors which may influence inundation. To help communities understand the potential for flooding along the coast and in order to determine which elevation playbook line to use, a full understanding of the overall tsunami flood potential is required. An approach developed by the state tsunami program to calculate these flood conditions is known as the "FA-S-T-E-R" method (Wilson et al., 2014). FASTER is an acronym that includes the following variables for calculating the most conservative, yet accurate run-up and flood elevation that the tsunami could reach at a particular location:

- **FA = Forecasted Amplitude** (wave heights) calculated and provided by the National Tsunami Warning Center during the first hours after a tsunami is generated;
- **S = Storm** surge or existing ocean conditions, predicted by the regional NOAA Weather Forecast Offices;

- **T =** Maximum **Tidal** height first 5 hours of tsunami, obtained from NOAA tidal forecast data;
- **E** = Forecast modeling **Error** potential, which has been calculated to be 30% of the forecast amplitude based on analysis of past events (Wilson et al., 2012); and,
- **R =** Site-specific amplified **Run-up** potential, calculated from existing state tsunami modeling.

Tsunami Forecast Amplitudes

Tsunami forecast amplitudes, also known as "tsunami wave heights," are predicted and provided by the National Tsunami Warning Center (NTWC) for pre-selected locations along the California coast after it is clear that a significant tsunami has been generated (Figure 2). The NTWC develops forecasts through evaluation of observational data and are provided in the tsunami alert bulletins or on the NTWC website. These tsunami amplitudes represent the expected near-shore tsunami wave height above existing tidal and ocean conditions. This number is the starting point for incorporating all other variables influencing wave heights in the FASTER approach.

Storm and Other Existing Conditions

Storm surge and other existing ocean conditions are important to understand and incorporate into any potential inundation calculation during a tsunami. For example, a day after the February 27, 2010 tsunami hit California, a high spring tide and minor tsunami activity produced inundation in parts of Huntington Beach (Wilson et al., 2012). Information about storm or high surf conditions can be obtained from the four NOAA National Weather Service Warning Forecast Offices (WFOs) for all sections of coastline in California.

Existing Tidal Conditions

Incorporating existing tidal conditions into the evaluation of tsunami inundation is imperative. During the 2010 and 2011 tsunamis in California, the first five hours after the initial wave arrival were the most important for capturing the highest actual tsunami amplitude for most locations in California (Wilson et al., 2012). During both tsunamis, inundation of dry land was essentially non-existent in the state because this peak tsunami activity occurred in conjunction with low-tide conditions. During future tsunamis, while the projected tsunami arrival time is being forecasted by the NTWC, tidal conditions for the first five hours of the event can be obtained from the predicted tide level curves for tide gauges on the NOAA Tides and Currents website (tidesandcurrents.noaa.gov).

Potential Errors in the Forecast Amplitudes

To help ensure that tsunami height predictions are conservative, a forecast error factor has been incorporated into the FASTER calculation. Based on a comparison of forecasted amplitudes and measured and observed tsunami amplitudes during the 2010 and 2011 tsunamis, Wilson et al. (2012) calculated that the forecast amplitudes were within $\pm$30% accurate along the California coast; this 30% figure corresponds to calculations by Whitmore (2003) from other events. Therefore, a set error factor of +30% of the forecast amplitude will be applied to the calculation of the FASTER tsunami flood potential. The intent is to err on the side of caution to make sure the FASTER number used for evacuations are sufficiently conservative.

Site-Specific Tsunami Run-Up Potential

Tsunami run-up on land will be different for different sections of California's coast because of the directionality of the incoming tsunami and the bathymetric and topographic conditions at each

location. This effect was demonstrated during past inundating tsunami events in 1946, 1960, and 1964. For this reason, a factor must be incorporated into the FASTER total flood potential that addresses site-specific run-up conditions. This amplified run-up factor has been calculated for each location based on a suite of modeled tsunami results from the state tsunami inundation mapping project (Wilson et al., 2008; Barberopoulou et al., 2009). CGS has evaluated the existing numerical model database to determine the run-up potential for each location along the coast, an example of which is shown in Table 2. It should be noted that the tsunami run-up factor should be applied during Warning-level events where inundation may be expected; for smaller Advisory-level events, amplified run-up is not likely to be a factor in the total flood level because inundation is unlikely to occur.

Calculation of the FASTER Number

Each variable will be estimated when an Advisory- or Warning-level alert is called for sections of the California coast. These values will be calculated for the first 5 hours after the tsunami's projected arrival time; some communities may also want this information at the maximum tidal conditions in the first 24 hours following the tsunami's arrival. The number from the FASTER calculation is referred to as the "FASTER tsunami-height or flood number." Table 3 is an example spreadsheet of how the FASTER number is calculated, using the key input parameters discussed above.

To formalize the calculation of the FASTER tsunami-height number, the FASTER number will be produced by the four NOAA Weather Forecast Offices and the state, and the associated elevation-based playbook phase will be recommended and shared with communities via multiple, redundant on-line sources such as the CalWeb/WebEOC and through regional and county email chains. It is anticipated that while the NTWC is calculating the tsunami forecast amplitudes within the first couple of hours after the earthquake, the state and NOAA Weather Forecast Offices will be gathering information on the other FASTER variables. The FASTER number will then be calculated within fifteen minutes after the forecast amplitude is provided.

Location	County	Maximum Onshore Runup Elevation (feet)	High Near-Shore Tsunami Height - Distant Source from Aleutian Islands (feet)	High Near-Shore Tsunami Height - Local Source (feet)	Local Source with Maximum Tsunami Heights	High Near-Shore Tsunami Height - Regional Cascadia Source (feet)
Crescent City	Del Norte	45	17	37	***Cascadia (entire length)***	*
Humboldt - Inside Bay	Humboldt	17	10	17	***Cascadia (entire length)***	*
Humboldt - Outside Bay	Humboldt	28	16	24	***Cascadia (entire length)***	*
Arena Cove	Mendocino	22	12	11	Cascadia (entire length)	11
Bodega Bay	Sonoma	21	18	8	Cascadia (entire length)	8
Bolinas/Stinson Beach	Marin	25	20	8	Pt Reyes Thrust Fault	4
San Francisco	San Francisco	19	15	4	Pt Reyes Thrust Fault	4
Sausalito	Marin	12	10	6	Pt Reyes Thrust Fault	4
Mare Island	Solano	5	4	3	Pt Reyes Thrust Fault	3
Richmond	Contra Costa	11	10	4	Pt Reyes Thrust Fault	3
Alameda	Alameda	17	16	4	Pt Reyes Thrust Fault	4
Redwood City	San Mateo	7	5	4	Pt Reyes Thrust Fault	NA
Pacifica	San Mateo	24	18	7	Pt Reyes Thrust Fault	4
Half Moon Bay	San Mateo	32	27	10	Pt Reyes Thrust Fault	NA
Santa Cruz	Santa Cruz	30	19	19	Monterey Cyn Landslide	4
Monterey	Monterey	18	16	15	Monterey Cyn Landslide	3
Cayucos	San Luis Obispo	32	24	4	1927 Pt Arguello EQ	3
Port San Luis	San Luis Obispo	39	37	3	1927 Pt Arguello EQ	4
Pismo Beach	San Luis Obispo	31	27	NA		5
Santa Barbara	Santa Barbara	31	13	26	***Goleta Landslide #2***	NA
Ventura	Ventura	12	10	7	Channel Isl. Thrust Fault	4
Oxnard	Ventura	10	9	10	***Goleta Landslide #2***	3
Malibu	Los Angeles	8	5	8	***Anacapa-Dume Fault***	NA
Santa Monica	Los Angeles	12	11	6	Palos Verdes Landslide #1	3
San Pedro/LA Harbor	Los Angeles	16	13	8	Palos Verdes Landslide #2	3
Huntington Beach	Orange	16	8	16	***Palos Verdes Landslide #2***	3
Newport Beach	Orange	16	5	13	***Catalina Fault***	NA
Dana Point	Orange	20	7	13	***San Mateo Thrust Fault***	3
San Clemente	Orange	17	6	16	***San Mateo Thrust Fault***	3
Oceanside	San Diego	16	9	13	***Carlsbad Thrust Fault***	NA
La Jolla	San Diego	15	8	12	***Carlsbad Thrust Fault***	3
San Diego Bay	San Diego	7	6	3	Coronado Cyn Landslide	3
Coronado	San Diego	17	8	17	***Carlsbad Thrust Fault***	4
Imperial Beach	San Diego	17	7	16	***Coronado Cyn Landslide***	3

Table 2. Near-shore and onshore maximum tsunami heights from numerical tsunami modeling for various scenarios with short response times. Bolded, italicized sources indicate if local source is responsible for maximum onshore run-up elevation for that location; otherwise, Aleutian source is maximum. (*=Cascadia is a local source, not regional; NA=information not available)

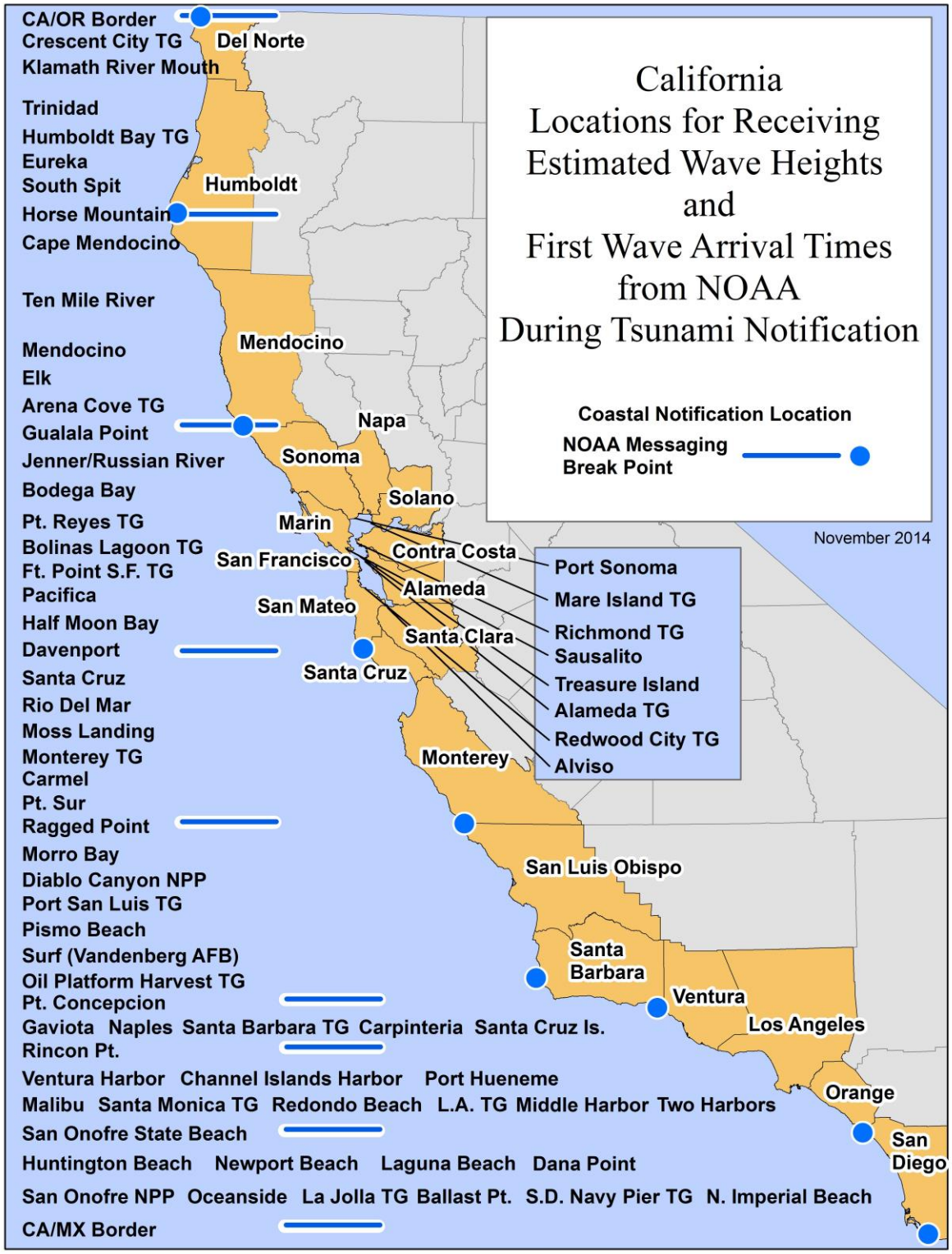

Figure 2. Set locations where tsunami forecast information will be provided by the National Tsunami Warning Center during a tsunami alert notification. Blue dots represent break points for tsunami alert level messaging.

FASTER calculations for ELEVATION PLAYBOOK use: San Diego County Communities	Set to Receive Forecast Amplitude from National Tsunami Warning Center	Forecast Amplitude given (red) and projected (black; meters)	Storm/ ambient conditions first 6 hours, w/ errors (meters)	Tide conditions first 6 hours, w/ errors (meters)	Error in forecast amplitudes (from Wilson et al., 2012; 30% of Amplitude, meters)	**Anticipated tsunami height first 6 hours (IN METERS)**	**Anticipated tsunami height first 6 hours (IN FEET)**	Runup potential factor per location, based on existing model results (applied if inudation expected)	Runup potential calculated per location (runup factor times forecast amplitude; meters)	**Anticipated tsunami height first 6 hours, if inundation expected (IN METERS)**	**Anticipated tsunami height first 6 hours, if inundation expected (IN FEET)**
San Onofre State Beach	Yes	0.5	0.0	0.0	0.2	**0.7**	**2.1**	0.2	0.1	**0.8**	**2.6**
Oceanside	Yes	0.6	0.0	0.0	0.2	**0.8**	**2.6**	0.2	0.2	**0.9**	**3.1**
Carlsbad		0.6	0.0	0.0	0.2	**0.8**	**2.6**	0.2	0.2	**0.9**	**3.1**
Encinitas		0.6	0.0	0.0	0.2	**0.8**	**2.6**	0.2	0.2	**0.9**	**3.1**
Del Mar		0.7	0.0	0.0	0.2	**0.9**	**3.0**	0.2	0.2	**1.1**	**3.6**
La Jolla	Yes	0.7	0.0	0.0	0.2	**0.9**	**3.0**	0.2	0.2	**1.1**	**3.6**
Mission Bay		0.7	0.0	0.0	0.2	**0.9**	**3.0**	0.2	0.2	**1.1**	**3.6**
Shelter Isl./Ballast Pt.	Yes	0.8	0.0	0.0	0.2	**1.0**	**3.4**	0.1	0.1	**1.1**	**3.8**
San Diego/National City	Yes	0.9	0.0	0.0	0.3	**1.2**	**3.8**	0.1	0.1	**1.3**	**4.2**
Coronado		1.0	0.0	0.0	0.3	**1.3**	**4.3**	0.2	0.3	**1.6**	**5.1**
Imperial Beach	Yes	1.0	0.0	0.0	0.3	**1.3**	**4.3**	0.2	0.3	**1.6**	**5.1**
Red numbers = manually real-time input Black numbers = set values											

Table 3. Example spreadsheet for calculating the FASTER tsunami height value. The table also includes guidance for the scenario playbook sources. These calculations will be performed for each county at risk to tsunamis.

Example of Use: Revisiting the 2011 Tohoku-oki Tsunami in California

Approximately 7 to 8 hours prior to the arrival the 2011 tsunami in California, the area north of Point Conception was forecasted as a tsunami "Warning" level of alert status, and the area south was placed into an "Advisory" alert level. Crescent City was forecasted to receive a tsunami amplitude of 2.5m (8ft) from the NTWC, which was ultimately close to observed amplitude of 2.47m. Because the potential for inundation existed, the city called for a full evacuation from their pre-established evacuation area at an approximate elevation of 20m (60ft). However, during the first five hours of tsunami activity, which is considered the largest and most dangerous time after tsunami first arrives, relatively low-tide conditions were present and only very minor inundation of waterfront areas in Crescent City occurred. Therefore, full evacuation was an appropriate action given the "Warning" alert level. However, if the low-tide condition would have been considered, a different tsunami flood level would have been expected and evacuations might have been significantly less, especially if a secondary and more appropriate evacuation zone was available.

As described in the previous section, the FASTER approach considers tides, storms, tsunami run-up, and potential forecast errors when calculating a more complete forecast tsunami height or flood elevation. Considering these variables, Figure 3 demonstrates that the potential FASTER total flood level during the 2011 tsunami would have been calculated to be 2.7m (9ft) for Crescent City. Although the FASTER approach calculated a similar level to the original forecast amplitude at Crescent City, Figure 1 shows that for a total flood potential of only 2.7m (9ft), the Phase 4 tsunami elevation-based playbook line would have been appropriate to use for a secondary evacuation. This would have reduced the area of evacuation in the city by at least two-thirds.

This also demonstrates that the tidal conditions have a very large impact on the relatively minor Warning level events like the 2011 tsunami. Tables 4 and 5 illustrate the impact of low and high tide conditions, respectively, on the FASTER calculations during the 2011 tsunami for areas within the Warning-level alert north of Point Conception. Although the generic recommendation in the Warning message indicated that inundation of dry land may occur along this section of coast, the FASTER calculation in Table 4 shows that little or no inundation was likely to occur at most locations because of the corresponding low-tide conditions. Therefore, evacuated areas could have been significantly less than the maximum evacuation zone, or, in most cases, evacuation was not needed. Conversely, Table 5 shows if high-tide conditions would have existed during the first five hours of the tsunami, inundation elevations (run-up) may have been double that of the forecast amplitudes provided by the NTWC for some locations. In summary, the FASTER calculations would have improved the overall understanding of total flood potential along California's coast, and the playbook evacuation zones would have provided alternative evacuation and response options for emergency managers.

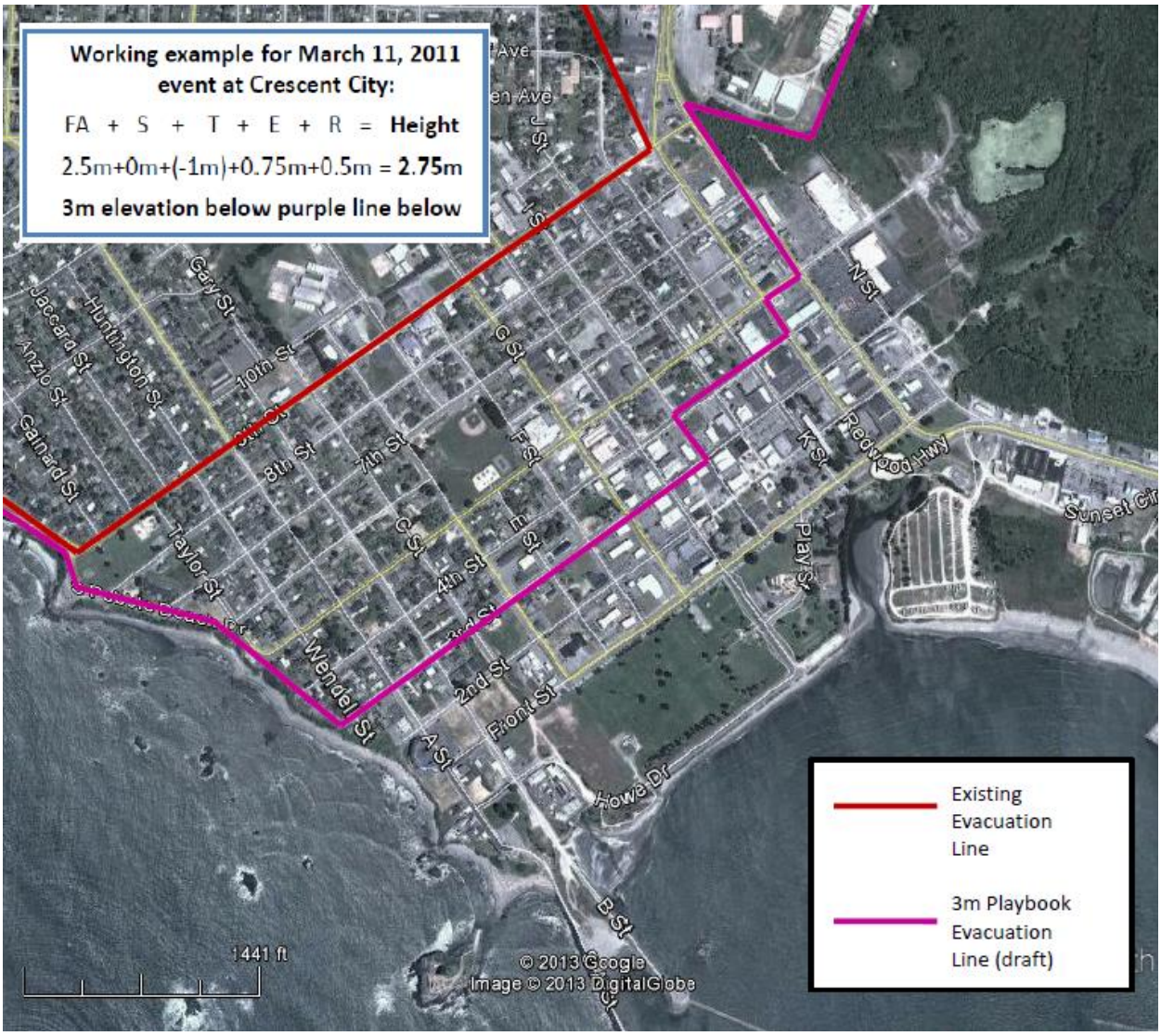

Figure 3. Example playbook map for Crescent City. The red line represents the existing evacuation line and the purple line is an example of the 3m playbook evacuation line.

March 11, 2011 Tsunami - "Warning" level locations in CA	**Forecast Amplitude (meters)**	**Storm/ other conditions**	**Tidal conditions first 5 hours**	**potential Error in forecast modeling (FAx0.3)**	**potential site-specific Run-up (FAx0.2)**	**Total tsunami elevation or run-up (FASTER)**	**Recommended Playbook Evacuation Level**
Crescent City	2.50	0.00	-1.00	0.75	0.50	**2.75**	**Phase 4**
Humboldt Bay	1.33	0.00	-1.00	0.40	0.27	**1.00**	**Phase 2**
Arena Cove	1.30	0.00	-1.00	0.39	0.26	**0.95**	**none or Phase 1**
Bodega Bay	0.92	0.00	-1.00	0.28	0.18	**0.38**	**none or Phase 1**
Point Reyes	0.63	0.00	-1.00	0.19	0.13	**-0.06**	**none or Phase 1**
Half Moon Bay	0.92	0.00	-1.00	0.28	0.18	**0.38**	**none or Phase 1**
San Francisco	0.73	0.00	-1.00	0.22	0.15	**0.10**	**none or Phase 1**
Santa Cruz	1.01	0.00	-1.00	0.30	0.20	**0.52**	**none or Phase 1**
Monterey	0.52	0.00	-1.00	0.16	0.10	**-0.22**	**none or Phase 1**
Morro Bay	1.18	0.00	-1.00	0.35	0.24	**0.77**	**none or Phase 1**
Port San Luis	2.14	0.00	-1.00	0.64	0.43	**2.21**	**Phase 3**

Table 4. Example calculated total tsunami height (FASTER) for areas in a Warning-Alert level during the March 11, 2011 tsunami. This area was at low-tide conditions for the first 5 hours.

March 11, 2011 Tsunami - "Warning" level locations in CA - AT HIGH TIDE	**Forecast Amplitude (meters)**	**Storm/ other conditions**	**Tidal conditions first 5 hours**	**potential Error in forecast modeling (FAx0.3)**	**potential site-specific Run-up (FAx0.2)**	**Total tsunami elevation or run-up (FASTER)**	**Recommended Playbook Evacuation Level**
Crescent City	2.50	0.00	1.00	0.75	0.50	**4.75**	**Maximum**
Humboldt Bay	1.33	0.00	1.00	0.40	0.27	**3.00**	**Phase 4**
Arena Cove	1.30	0.00	1.00	0.39	0.26	**2.95**	**Phase 4**
Bodega Bay	0.92	0.00	1.00	0.28	0.18	**2.38**	**Phase 3**
Point Reyes	0.63	0.00	1.00	0.19	0.13	**1.95**	**Phase 3**
Half Moon Bay	0.92	0.00	1.00	0.28	0.18	**2.38**	**Phase 3**
San Francisco	0.73	0.00	1.00	0.22	0.15	**2.10**	**Phase 3**
Santa Cruz	1.01	0.00	1.00	0.30	0.20	**2.52**	**Phase 4**
Monterey	0.52	0.00	1.00	0.16	0.10	**1.78**	**Phase 3**
Morro Bay	1.18	0.00	1.00	0.35	0.24	**2.77**	**Phase 4**
Port San Luis	2.14	0.00	1.00	0.64	0.43	**4.21**	**Phase 5**

Table 5. Example calculated total tsunami height (FASTER) for areas in a Warning-Alert level during the March 11, 2011 tsunami if it would have occurred at high tide; the column highlighted in yellow shows the change in tidal conditions.

Guidance for Use: Evacuation Playbooks with FASTER Approach

Similar to the example above, the FASTER approach can be used with the evacuation playbooks to provide emergency managers a number of options for evacuation. Before being used, communities should become familiar with the FASTER spreadsheets and the playbook maps and information. Certainly the tools described in this document must be approved, vetted, well understood, and then incorporated into local response and evacuation plans for testing in advance of application during a tsunami in real-time. Communities should fill out the needed response plans and activities for each of the individual "phase" playbook scenarios PRIOR to using the playbook guidance document in an emergency. Misuse of these products could expose the emergency personnel and the public to life-threatening conditions by misunderstanding and miscalculating the tsunami hazard. Simulations and exercises using these materials will improve the effectiveness of evacuation activities and help ensure that emergency response is done correctly and conservatively.

As previously mentioned, evacuation planning is the responsibility of the coastal communities and jurisdictions. The state does not prescribe if or how these products are used. However, the state has developed a separate tsunami playbook guidance document for each community for use in planning and during a real event. The appendix contains a draft example of one of these playbooks for the City of Oceanside (San Diego County). Local emergency managers who are responsible for tsunami evacuation planning and response should develop plans for each of the "phased" evacuation playbooks. This step is very important so that the playbook evacuation plans are tailored for each community.

The following is a step-by-step summary of the guide on how to use this information, especially the community-specific tsunami evacuation playbook guidance, when a tsunami alert for a community is generated. Please note that the steps discussed are simplified and directly related to the use of FASTER and the playbooks, and do not include many other response actions or activities for the community. There are "quick" and "expanded" reference pages for use during an emergency within the playbook guidance document depending on the experience of the user. For emergency managers sufficiently familiar with the evacuation playbooks and the FASTER approach, the user can follow the instructions on the "Expanded Reference" sheet; for those less familiar looking for a more simplified and direct approach, the user should follow the "Quick Reference" sheet:

1) **Gather pertinent information on the potential tsunami event:** When the NTWC alert message is generated, coastal communities should determine what the tsunami "forecast" is for their jurisdiction. If a "Watch," "Advisory," or "Warning" alert level is forecasted for your area, review the rest of the alert message for information on the event (time of the earthquake, epicenter location, earthquake magnitude, and depth) and potential forecast information for your coastal area (tsunami arrival time and amplitude/wave height).

2) **If the potential tsunami arrival time is less than 4 hours, determine whether to use a scenario-based playbook line or the maximum evacuation line:**
    a. If a large earthquake is felt along the coast, evacuation of coastal populations to high ground or inland should be immediate. The public should evacuate the maximum evacuation zone and should be rigorously educated as to where the boundaries of this zone are located.

b. If the tsunami is generated by a large earthquake on a regional source (Cascadia for central and southern California) or an Alaska/Aleutian Islands source (>M8.5) where there are 4 hours or less before arrival, refer to the "scenario-based playbook."

3) **If the forecasted tsunami arrival time is more than 4 hours, acquire information on the applicable elevation-based "phase" evacuation plan for your community:** The FASTER number will be calculated for each community by the state and the regional NOAA Weather Forecast Offices. The applicable "phase" evacuation plan number will be provided to county and city emergency managers during the event or available on multiple websites, such as CalEOC/WebEOC. If time permits, obtain the FASTER numbers for both the first 5 hours of tsunami activity and for the maximum values over a 24 hour period which could incorporate high tide; the 24-hour FASTER number will represent the highest potential tsunami run-up based on forecasts

4) **Determine what phase playbook line to use for evacuation:** The applicable playbook phase number will be provided to the community by the state and the regional NOAA Weather Forecast Offices. This recommendation will be based on what the projected FASTER tsunami flood elevation value is. The ultimate responsibility for what evacuation, if any, should be called will be up to the emergency manager for the community. If the community would like to use the playbook phase recommended by the state and NOAA, find and utilize the corresponding emergency response activities and map within the playbook guidance document.

During a real event, resources will be available for community emergency managers to consult with state and federal experts on how the FASTER number should be used to determine the appropriate evacuation plan. If a Warning alert is forecasted and there is uncertainty in using the phased evacuation plan or the FASTER approach, it is recommended that coastal communities evacuate to their maximum evacuation line. Communities can choose to utilize the FASTER value calculated for the first 5 hours or over a 24 hour period.

Again, it is recommended that communities be conservative with their decision making with regard to tsunami evacuation. The objective is that the playbook products and the FASTER analytical tool provide additional safe and consistent options for emergency managers during future tsunamis affecting their jurisdiction.

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APPENDIX – Example tsunami evacuation playbook

NOTE: This example playbook is only a draft and does not represent the final evacuation playbook for the City of Oceanside. The page numbers in the lower right corner (starting on the next page) and the discussion of page numbers in the playbook text correspond to the pages within the playbook, not the overall document.

DRAFT 06/19/2014

California Tsunami Evacuation Playbook

City of Oceanside – San Diego County

Playbook No. 2014-SD-03

DURING AN EMERGENCY, USE THE "QUICK REFERENCE" SHEET ON THE BACK PAGE (PAGE 20).

(For the expanded playbook analysis, use directions on Page 4)

California Tsunami Evacuation Playbook No. 2014-SD-03

California Geological Survey
California Governor's Office of Emergency Services
National Oceanic and Atmospheric Administration

Funded by the National Tsunami Hazard Mitigation Program

THE NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM (U.S.)

Table of Contents – Tsunami Response Plan Playbooks

DURING AN EMERGENCY, USE THE "QUICK REFERENCE" ON PAGE 20 FOR GATHERING INFORMATION FOR RESPONSE ACTIVITIES.

PURPOSE: NOTE: Emergency managers should become familiar with this Playbook plan prior to use. The local emergency manager has the ultimate responsibility for decisions on tsunami evacuation/response activities. A significant issue for emergency managers is that existing tsunami evacuation plans call for evacuation of the predetermined tsunami evacuation zone (typically at a 30- to 50-foot elevation) during a "Warning" level event; the alternative is to not call an evacuation at all. A solution to provide more detailed information has been the development of tsunami evacuation "Playbooks" to plan for tsunami scenarios of various sizes and source locations. NOAA-issued Tsunami Alert Bulletins received in advance of a distant event will contain a tsunami alert level, forecasted tsunami amplitude (or wave height) and arrival time for a number of locations along the coastline. Elevation-based "playbook" evacuation lines/zones can be useful for partial tsunami evacuations when information about forecasted tsunami amplitudes and arrival times is available to coastal communities and there is sufficient time to implement a partial evacuation. Provision for multiple elevation-based evacuation lines and response plans for those lines enables planning for different evacuation scenarios based on the forecast tsunami amplitude, potentially alleviating the need for an "all or nothing" decision with regard to evacuation.

USE: This playbook is designed to help the emergency managers with tsunami evacuation and response activities. First, it requires that the emergency manager become familiar with the information herein, especially the "Tsunami Response Decision Tree" (Page 5), the overall Playbook approach, and FASTER calculation (Page 3). When a distant-source tsunami is occurring, **fill out the information on Page 4 regarding the earthquake (magnitude, location) and tsunami (alert level, forecasted amplitude and arrival time).** Keep in mind that this information can change during the first hour or two after the earthquake occurs.

Use this information to determine which branch of the decision tree applies to the event. Refer to information on Pages 6 and 7 regarding the "Elevation-Based Evacuation Playbook," the "Scenario-Based Evacuation Playbook," and the FASTER calculation value. FASTER will be calculated and provided to each community by the state, county or regional NOAA Weather Forecast Office. The state or NOAA will also provide a recommendation on which tsunami "playbook" phase plan for each community to use. Each scenario-based Playbook will be accompanied by a digital file identifying the full evacuation zone for a community. This file should be referenced and used during an event. Communities may wish to use these maps to establish "reverse 911" calling areas.

Tsunami Alert Bulletins: During the typical tsunami alert, the Warning Center provides information about the tsunami in "bulletins" to the state and local jurisdictions. There are four levels of "alert" that can be sent by the NTWC (from least to greatest significance):

Tsunami Information Statement - Issued to inform and update emergency managers and the public that an earthquake has occurred, or that a tsunami Watch, Advisory or Warning has been issued elsewhere in the ocean.

Tsunami Watch - Issued to alert emergency managers and the public of an event which may later impact the Watch area. May be upgraded to an Advisory or Warning - or canceled - based on updated information and analysis.

Tsunami Advisory - Issued due to the threat of a tsunami which may produce strong currents or waves dangerous to those in or near the water; typically called when forecasted tsunami amplitudes are between 0.3m and 1m (1ft and 3ft) above existing tidal conditions are expected. Coastal communities are advised that beach and harbor areas could expect rapid, moderate tidal changes and strong currents.

Tsunami Warning - Issued when a tsunami with significant widespread inundation is imminent or expected; typically called when forecasted tsunami amplitudes are equal to or greater than 1m (3ft). Coastal communities are advised to evacuate people from low-lying areas identified as vulnerable to tsunamis.

FASTER Analytical Tool: To determine the full impact of the tsunami, other variables such as tidal and storm conditions must be considered. An analytical method has been created which incorporates important variables that will impact the ultimate tsunami flood level. The FASTER calculation will be made by the regional NOAA NWS Weather Forecast Office for each community during a tsunami event; it is used to help determine which "phase" evacuation/response playbook plan should be used. **NOAA and/or the state will recommend which particular phase evacuation plan should be used by each community, and transmit that information to the communities prior to the tsunami's arrival.** Communities themselves can also use the FASTER value to match which phase playbook plan to use. The simplified components of the calculation are shown to the right.

Working example: Formula for determining playbook evacuation line to use (FA-S-T-E-R):

FA: **Forecasted Amplitude (Wave Height)** from Warning Center

+

S: **Storm** surge or existing ocean conditions

+

T: Maximum **tidal** height (first 5 hours of tsunami)

+

E: Forecast **error** potential (30%; analysis of 2010-11 events)

+

R: Site amplified **run-up** potential (from existing modeling, unique to each location; applied if inundation expected)

= Maximum tsunami run-up height

= Playbook elevation line

Expanded and Enhanced Reference Information for Determining Real-Time Tsunami Response Activities

NOTE: Tsunami response activities are the responsibility of the coastal community. It is important to review all sections of this Playbook prior to using it during a tsunami emergency. When a tsunami alert is issued by the National Tsunami Warning Center, fill out the Expanded Reference page below under Step 1 and follow steps on the right side of the page to determine response activities. To help reduce confusion, the state/NOAA will provide information on recommended "Phase" evacuation and response plans to use based on the FASTER tsunami flood level value calculated for each community.

Step 1: Obtain information about earthquake and tsunami from National Tsunami Warning Center in Alaska, regional NOAA-Weather Forecast Office, and/or county emergency manager. The explanation of the FASTER calculation is provided on Page 3. **FASTER value will be calculated and provided to the emergency manager**; it is used to determine which Playbook scenario to use.

Earthquake location _____
Earthquake magnitude _____
Tsunami Alert level (circle one) WATCH ADVISORY WARNING
Forecasted tsunami amplitude/wave height _____
Forecasted tsunami arrival time _____
Calculate/obtain FASTER tsunami run-up value in first 5 hours: _____
Calculate/obtain FASTER tsunami run-up value at highest tide _____

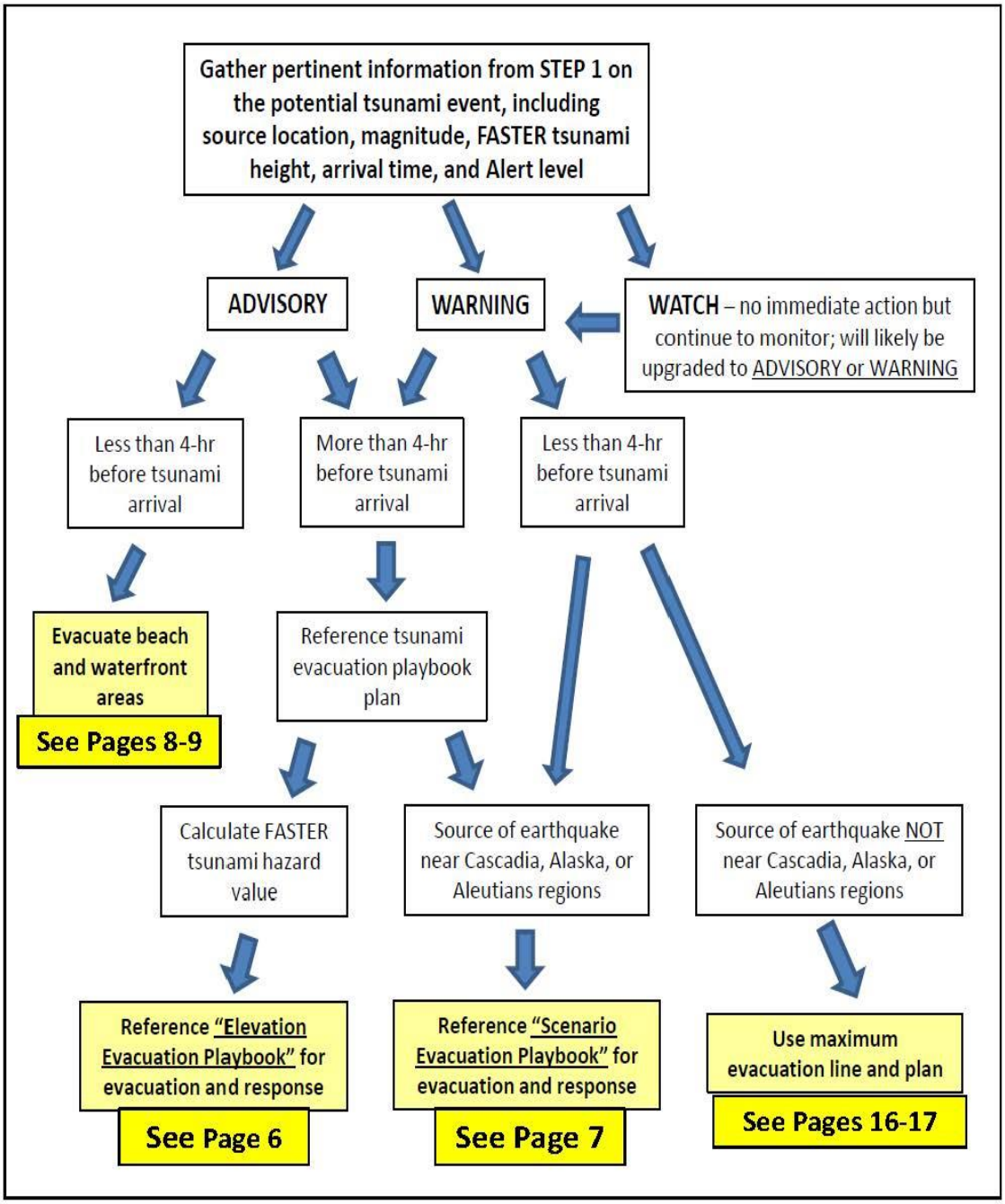
Other general information regarding tidal, storm, and other ambient conditions:_____

Step 2: Compare the information from Step 1 to the **Tsunami Response Decision Tree** on the right. Select the decision tree branch that best fits the forecast tsunami information.

Step 3: Go to Page 6 or 7 "Playbook" reference pages and utilize the appropriate Playbook or strategy for evacuation and response. Refer to the table on Page 6 to see which pages to related to a particular tsunami "phase" evacuation and response. The particular "phase" plan will be provided as a recommendation by the state/NOAA when a tsunami Advisory or Warning is issued.

A set of digital evacuation maps and response instructions will accompany each of the Elevation-based Evacuation Playbook plans. These files can be used to develop "reverse 911" calling areas prior to the event.

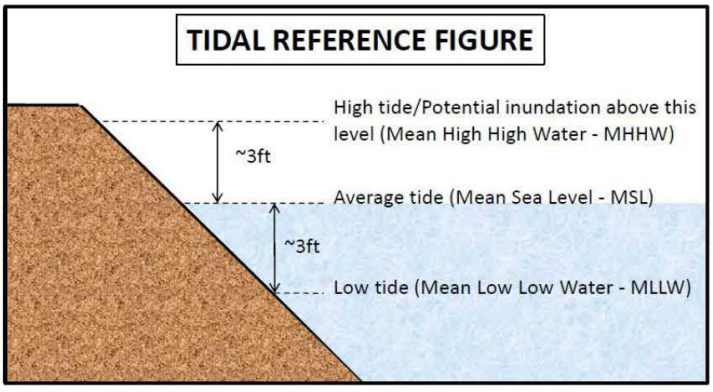
Tsunami Response Decision Tree



Elevation-Based Evacuation Playbook

NOTE: The local emergency manager has the ultimate responsibility for decisions on tsunami evacuation/response activities. The table below shows the appropriate tsunami elevation-based evacuation playbook response plan for the resulting FASTER tsunami flood level number. **Once the FASTER value is calculated for each community, it will be used by the state and NOAA to recommend a specific playbook phase plan to use.** For example, if the FASTER number is 1.3m, the state/NOAA will recommend as an option that the community could use the Phase 2 Evacuation Plan provided on pages 10-11.

Evacuation Playbook Reference Pages	Recommended Community Action	Associated FASTER Tsunami Flood Level Number (in METERS above Mean Sea Level)	Associated FASTER Tsunami Flood Level Number (in FEET above Mean Sea Level)	Anticipated Associated NOAA Tsunami Alert Level	Tsunami height compared to other tidal reference points (see TIDAL REFERENCE FIGURE)	
					Tsunami flood level above high tide line - MHHW (flow depth above low-lying dry land)	Tsunami flood level above low tide conditions (Mean Low Low Water - MLLW)
Pages 8-9	Phase 1 Evacuation	less than 1.00m	less than 3.3ft	Advisory	none (less than 0 ft)	0 ft to 6ft
Pages 10-11	Phase 2 Evacuation	1.00m to 1.50m	3.3ft to 5.0ft	Advisory or Warning	0 ft to 1.7ft	6ft to 7.7ft
Pages 12-13	Phase 3 Evacuation	1.50m to 2.50m	5.0ft to 8.2ft	Warning	1.7ft to 5.0ft	7.7ft to 11.0ft
Pages 14-15	Phase 4 Evacuation	2.50m to 3.50m	8.2ft to 11.5ft	Warning	5.0ft to 8.2ft	11.0ft to 14.2ft
Pages 16-17	Maximum Evacuation Phase	more than 3.50m	more than 11.5ft	Warning	more than 8.2ft	more than 14.2ft



NOTE FOR TABLE ABOVE: Use only locally enhanced FASTER numbers coming from the state or your regional NWS office to implement actions on this page. The NTWC forecast amplitude/wave height should not be referenced here as it does not include tides, storms, or other factors contributing to flood potential.

Scenario-Based Evacuation Playbook

NOTE: The local emergency manager has the ultimate responsibility for decisions on tsunami evacuation/response activities. Scenario-based tsunami playbooks and guidance have been developed for maximum local and distant tsunamis, and for tsunamis coming from the Cascadia subduction zone toward central and southern California. Scenario playbook information about the expected tsunami amplitude, tsunami travel time, and map of source regions is available from the numerical modeling results for these sources (Page 19). These are important scenarios for emergency managers to prepare for as there could only be tens of minutes to evacuate or just a few hours to conduct response or evacuation activities before the tsunami arrives. Because of the short time for making response decisions, the following evacuation and response plans are recommended for all of San Diego County:

Scenarios with short tsunami arrival times	Shortest tsunami travel time to San Diego County after earthquake	Suggested Scenerio Playbook Response Plan
Local coastal earthquake >M6.5 or landslide	10-15 minutes	Maximum evacuation zone
Cascadia subuduction zone >M8.5	2 hour	Level/State/ Phase 3 Elevation Playbook
Alaska or Aleutians subduction zone >M8.5	6 hours	Maximum evacuation zone

Phase 1 Evacuation Plan

Background Information:
Alert level = Advisory
FASTER tsunami value = less than 1.0m (3.3 ft)

Specific Instructions:

- Follow general guidance for Advisory-level tsunamis (Page 3)
- Evacuate beaches, piers, and harbor docks and boats. Strong currents and potential scour may be expected in harbors.
- A digital file showing evacuation maps and response instructions is available for use.
- Specific evacuation and response instructions…… (completed with community input)


Phase 1 Tsunami Evacuation
Recommend evacuating beaches, harbor docks, and piers
DRAFT
Mesa Dr
Downs St
Crouch St
Hunsaker St
Vista Way
Marron Rd
Jeffer son St
78
5
S21
Oceanside Blvd
Cassidy St
S Pacific St
Grant St
Mission Ave
N Coast Hwy
San Luis Rey Mission
5618 ft
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2014 Google
Data CSUMB SFML, CA OPC
Google earth

Phase 2 Evacuation Plan

Background Information:
Alert level = Warning
FASTER tsunami value = between 1.0m (3.3 ft) and 1.5m (5.0ft)

Specific Instructions:

- Follow general guidance for Warning-level tsunamis (Page 3)
- Evacuate areas are shown in red, including beaches, piers, and harbor docks and boats. Strong currents and potential scour may be expected in harbors.
- A digital file showing evacuation maps and response instructions is available for use.
- Specific evacuation and response instructions..... (completed with community input)


Phase 2 Tsunami Evacuation Zone
Vista Way
Marron Rd
Jefferson St
Downs St
Crouch St
Hunsaker St
Oceanside Blvd
Grant St
S Pacific St
Mission Ave
N Coast Hwy
San Luis Rey Mission
78
5
S21
DRAFT
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2014 Google
Data CSUMB SFML, CA OPC
5618 ft

Phase 3 Evacuation Plan

Background Information:
Alert level = Warning
FASTER tsunami value = between 1.5m (5.0ft) and 2.5m (8.2ft)

Specific Instructions:

- Follow general guidance for Warning-level tsunamis (Page 3)
- Evacuate areas are shown in red, including beaches, piers, and harbor docks and boats. Strong currents and potential scour may be expected in harbors.
- A digital file showing evacuation maps and response instructions is available for use.
- Specific evacuation and response instructions…… (completed with community input)


Phase 3 Tsunami Evacuation Zone
Mesa Dr
Downs St
Crouch St
Hunsaker St
Vista Way
Marron Rd
Jefferson St
78
5
S21
Cassidy St
Oceanside Blvd
S Pacific St
Grant St
Mission Ave
N Coast Hwy
San Luis Rey Mission
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2014 Google
Data CSUMB SFML, CA OPC
5618 ft
DRAFT

Phase 4 Evacuation Plan

Background Information:
Alert level = Warning
FASTER tsunami value = between 2.5m (8.2ft) and 3.5m (11.5ft)

Specific Instructions:

- Follow general guidance for Warning-level tsunamis (Page 3)
- Evacuate areas are shown in red, including beaches, piers, and harbor docks and boats. Strong currents and potential scour may be expected in harbors.
- A digital file showing evacuation maps and response instructions is available for use.
- Specific evacuation and response instructions..... (completed with community input)


Phase 4 Tsunami Evacuation Zone
Vista Way
Marron Rd
Jefferson St
Mesa Dr
Downs St
Crouch St
Hunsaker St
78
5
S21
Cassidy St
Oceanside Blvd
S Pacific St
Grant St
Mission Ave
N Coast Hwy
San Luis Rey Mission Exp
Google Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2014 Google
Data CSUMB SFML, CA OPC
5618 ft
DRAFT

Maximum Phase Evacuation

Background Information:
Alert level = Warning
FASTER tsunami value = greater than 3.5m (11.5ft)

Specific Instructions:

- Follow general guidance for Warning-level tsunamis (Page 3)
- Evacuate areas are shown in red (the maximum tsunami evacuation zone), including beaches, piers, and harbor docks and boats. Strong currents and potential scour may be expected in harbors.
- A digital file showing evacuation maps and response instructions is available for use.
- Specific evacuation and response instructions..... (completed with community input)


Maximum Phase Tsunami Evacuation Zone
Mesa Dr
Downs St
Crouch St
Vista Way
Marron Rd
Jefferson St
78
5
Hunsaker St
S21
Oceanside Blvd
Cassidy St
S Pacific St
Grant St
Mission Ave
San Luis Rey Mission Expy
N Coast Hwy
DRAFT
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2014 Google
Data CSUMB SFML, CA OPC
5618 ft
Google earth

Notable Historical Tsunamis: The following table provides very basic information about historical tsunami events; not all tsunamis are represented, especially minor or small tsunamis. Note that the largest, most damaging tsunamis in San Diego County history have come from large earthquakes in the Alaska-Aleutian Islands and Chile regions as distant tsunami sources and potential offshore faults or submarine landslide as local sources. Although the potential for local tsunamis exists, they are much less frequent than distant source tsunamis.

Notable Historical Tsunamis in San Diego County

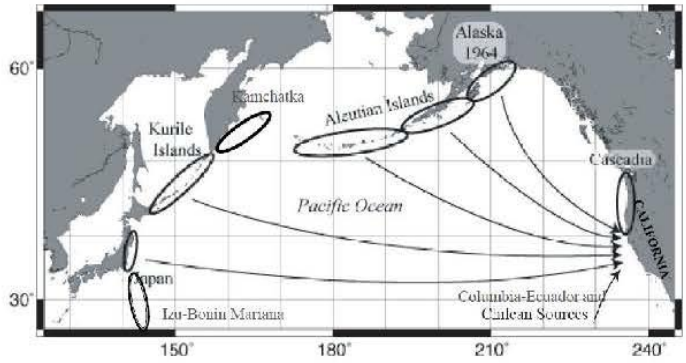
Run-up amplitude, in feet, above normal tide conditions

OBS = observed tsunami activity
NR = No damage or severe conditions reported

- Distant Source - Tsunamis without felt earthquakes

- Local Source - Earthquake and tsunami together

Date	Magnitude-Source area	Tsunami location	Run-Up/Amp	Remarks (NDR = no damage reported)
5/27/1862	M5.9 - local EQ	San Diego	4 ft	Possibly caused by cliff failure near Pt Loma
8/13/1868	M8.5 - Chile	San Diego	1 ft	NDR
11/11/1922	M8.5 - Chile	San Diego	1 ft	NDR
4/1/1946	M8.8 – Aleutian Islands	La Jolla	1 ft	NDR
		San Diego	1 ft	NDR
11/4/1952	M9.0 - Kamchatka	La Jolla	1 ft	NDR
		San Diego	1 ft	NDR
3/9/1957	M8.6 - Aleutian Islands	La Jolla	1 ft	NDR
		Shelter Isl	2 ft	North island: $5k in damage to docks/boats
		San Diego	1 ft	NDR
5/22/1960	M9.5 - Chile	Mission Bay	-	100-ton barge damaged bridge; month repair
		Shelter Isl	-	South island: Significant damage to docks and boats
		San Diego	4 ft	$22k in damage; ferry moved 1 mile off course
3/28/1964	M9.2 – Alaska	La Jolla	2 ft	NDR
		Shelter Isl	4 ft	North island: strong currents, broken moorings
2/27/2010	M8.8 – Chile	Oceanside	2 ft	Minor dock damage
		La Jolla	2 ft	NDR
		Mission Bay	-	Sail boat swamped
		Shelter Isl	3-4 ft	North island; moderate damage to docks, boats
		San Diego	1 ft	NDR
3/11/2011	M9.0 - Japan	Oceanside	2 ft	NDR
		La Jolla	3 ft	NDR
		Mission Bay	3 ft	$136k in damage to bait dock, 13 boats, 26 piles
		Shelter Isl	3 ft	South island: $110k damage to docks, boat sunk
		San Diego	2 ft	damage to docks

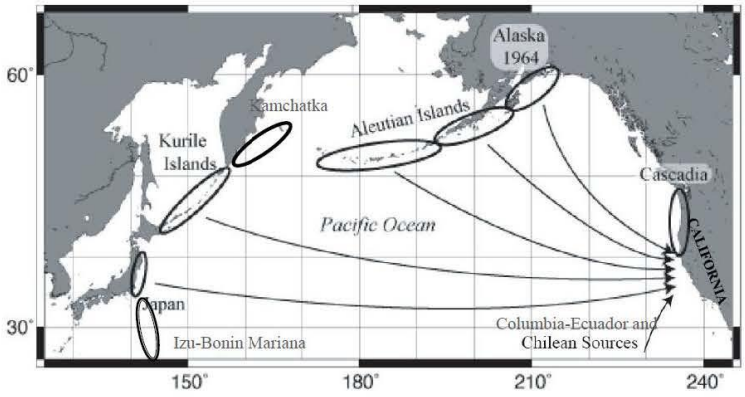


Modeled Tsunami Scenarios: Because very large tsunamis are infrequent and the likelihood that the largest potential tsunamis have not yet occurred in San Diego County, the state tsunami program developed a suite of maximum credible tsunami scenarios as part of their tsunami inundation mapping project for local evacuation planning. The general tsunami wave height for key locations from these scenarios are provided below. As identified in the historical tsunami table, the largest tsunamis could occur from large earthquakes in the Alaska-Aleutian Islands or Chile regions, or from a large offshore fault or submarine landslide in the Coronado Canyon.

Tsunami Source Scenario Model Results for San Diego County

Near shore tsunami heights (flow depths) for both local and distant source scenarios, in FEET above Mean Sea Level. NOTE: The projections do not include any adjustments for ambient conditions, such as storm surge and tidal fluctuations, and model error (it is very important to note this difference, as those numbers can increase the projected water height during an event).

	TSUNAMI SOURCES	Approximate Travel Time	San Onofre State Beach	Oceanside	Carlsbad	Encinitas	Del Mar	La Jolla	Mission Bay	Shelter Island (north San Diego Bay)	San Diego/ National City	Coronado	Imperial Beach
Local Sources	M7 Lausen Knoll Fault	10-15min	4					4	4	3	3	4	3
	M7.1 San Mateo Thrust Fault	10-15min	16	12	7	7	6						
	M7.1 Carlsbad Thrust Fault	15-20min		7	12	16	16	14	8	5	3	5	7
	M7 San Clemente Island Fault	15-20min						3	3	3	2	3	3
	M7.5 San Clemente Fault Bend	15-20min						5	4	4	2	6	4
	M7.3 Coronado Bank Fault	15-20min						6	10	6	7	7	12
	Coronado Canyon Landslide	15-20min						13	10	5	4	10	16
	M7.7 Catalina Fault	20-30min	8	7	7	7	7	5	7	4	3	9	9
Distant Sources	M9 Cascadia-full rupture	2hr	4					4	3	3	6	3	3
	M9.2 Alaska 1964 EQ	6hr	5	8	6	6	5	4	4	4	4	4	5
	M8.9 Central Aleutians I	6hr	4	6	4	4	4	4	5	4	7	4	4
	M8.9 Central Aleutians II	6hr	3					3	3	3	7	3	3
	M9.2 Central Aleutians III	6hr	8	13	7	8	8	8	7	5	8	9	7
	M9 Kamchatka 1952 EQ	9hr	3										
	M8.8 Kuril Islands II	10hr	2					3	3	3	3	3	3
	M8.8 Kuril Islands III	10hr	2					3	3	3	3	3	3
	M8.8 Kuril Islands IV	10hr	2					3	3	3	3	3	3
	M8.8 Japan II	11hr	2					3	3	3	3	3	3
	M9.5 Chile 1960 EQ	13hr	4					3	3	4	7	3	3
	M9.4 Chile North	13hr	4					4	4	4	8	4	3
	Maximum Runup - Local Source		**18**	**14**	**14**	**21**	**19**	**17**	**13**	**8**	**8**	**14**	**18**
	Maximum Runup - Distant Source		**10**	**15**	**9**	**10**	**10**	**10**	**9**	**6**	**8**	**10**	**9**



APPENDIX
Quick Reference Page for Determining Real-Time Tsunami Response Activities

Step 1: Obtain basic information about the earthquake and tsunami from National Tsunami Warning Center in Alaska, regional National Weather Service office, and/or county emergency manager. **NOTE: Tsunami Alert Level may change in first 2 to 3 hours after the earthquake; WATCH may be upgraded to ADVISORY or WARNING.**

Earthquake location _____

Earthquake magnitude _____

Tsunami Alert level (circle one) WATCH ADVISORY WARNING

Closest forecasted tsunami amplitude/wave height _____

Forecasted tsunami arrival time _____

Recommended community playbook evacuation zone phase plan _____

Calculated FASTER tsunami flood level number (if needed) _____

Step 2: Tsunami evacuation and response will depend on the amount of time before the tsunami arrival. Four (4) hours is considered the threshold time needed for evacuation. As a quick reference, we offer the following guidance:

1) **<u>If less than four hours</u> before tsunami arrival, we recommend the following:**
   - ADVISORY – evacuate beaches, harbor docks, and piers
   - WARNING – evacuate entire maximum evacuation zone

2) **<u>If greater than four hours</u> before tsunami arrival**, and your community has fully developed its tsunami playbooks plans, communities can utilize the tsunami elevation-based evacuation playbook "phase" plan recommended by the state and/or NOAA. Use the table on the right to identify the page numbers for the appropriate phase plan.

Evacuation Playbook Reference Pages	Recommended Community Action
Pages 8-9	Phase 1 Evacuation
Pages 10-11	Phase 2 Evacuation
Pages 12-13	Phase 3 Evacuation
Pages 14-15	Phase 4 Evacuation
Pages 16-17	Maximum Evacuation Phase