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

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Overview

Experience during recent tsunamis impacting the state, especially the March 11, 2011 tsunami from Japan, has brought to light the desire by California emergency managers and decision makers for even more detailed information ahead of future tsunamis. A solution to provide enhanced information has been development of “playbooks” to plan for a variety of expected tsunami scenarios. Elevation “playbook” lines can be useful for partial tsunami evacuations when enough information about forecast amplitude and arrival times is available to coastal communities and there is sufficient time to make more educated decisions about who to evacuate for a given scenario or actual event. NOAA-issued Tsunami Alert Bulletins received in advance of a distant event will contain an expected wave height (a number) for each given section of coast. Provision of four elevation lines for possible inundation enables planning for different evacuation scenarios based on the above number potentially alleviating the need for an “all or nothing” decision with regard to evacuation.

Scenario tsunami playbooks and guidance have also 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 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 between 10 minutes and five hours to conduct response or evacuation activities before the tsunami arrives.

Additionally an analytical tool called FASTER is being developed to integrate storm, tides, modeling errors, and local tsunami run-up potential with the forecasted tsunami amplitudes in real-time when a tsunami Alert is sent out. Both of these products will help communities better implement evacuations and response activities for minor to moderate (less than maximum/worst case) tsunami events.

A Work Group comprised of federal, state, and local governmental scientists, emergency managers, first responders, and community planners has explored details and delivery of the above tools for incorporation into emergency management protocols. The eventual outcome will be inclusion in plans, testing of protocols and methods via drills and exercises and application, as appropriate, during an impending tsunami event.

Introduction

The California Geological Survey (CGS) and the California Governor's Office of Emergency Services (CalOES) have created maps identifying expected inundation areas for a number of tsunami scenarios based on either: 1) forecasted amplitudes (tsunami wave heights above normal tide conditions) from the West Coast/Alaska Tsunami Warning Center (WCATWC), or 2) proximity of the source and expected short tsunami 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 WCATWC provides information about the tsunami in "bulletins" to the state and Local jurisdictions. This includes information about the earthquake (location, depth, magnitude) and forecasts about the impending tsunami (alert level, first arrival, maximum amplitudes or wave height). There are four levels of "alert" from the WCATWC (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 of 0.3m to 1m (1ft to 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 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 struggled 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 pre-planned response actions, the first five hours of tsunami activity in California coincided with low-tide conditions further reducing the potential for inundation of dry land. Improved anticipation of expected tsunami inundation will allow emergency managers to implement more accurate evacuations, which could save many thousands of dollars in over-evacuation costs to businesses and emergency response coordination personnel as well as improve public confidence in response activities.

To help provide additional evacuation options for emergency managers, CGS and CalOES have developed several tsunami response products:

1) Playbooks
    a. Tsunami **elevation** "playbook" maps - Secondary evacuation maps based on various land elevations, at 1m, 2m, 3m, and 4m incorporating high tide conditions.
    b. Tsunami **scenario** "playbook" maps – Secondary evacuation maps and guidance for the largest local and distant sources as well as the Cascadia subduction zone, which is a local and regional source for the state.
2) FASTER tsunami height calculation – An analytical tool that incorporates storm and tidal conditions, potential forecast errors, and site runup potential with the forecasted tsunami amplitude to determine true tsunami height along the coast.

These products and guidance on how these products can be used together are discussed in this report. These playbooks provide more information and options for coastal jurisdictions to help plan with and use during future tsunamis.

Tsunami Playbook Work Group

To help develop these products, CalOES and CGS formed a "Work Group" comprised of five county emergency managers (Humboldt, Monterey, Ventura, Orange, and San Diego counties), the four coastal NOAA Warning Forecast Office Warning Coordination Meteorologists (WCMs) in California (Eureka, Monterey, Oxnard, and San Diego), and the West Coast/Alasaka Tsunami Warning Center (WC/ATWC) Director. 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 to get community-level feedback on the products, and the process for using the products.

Tsunami Evacuation Playbooks

There are two types of tsunami evacuation playbooks being produced.

The first case is for when there is enough time (+5 hours) for the Warning Center to process all the data and make a forecast, this information can allow coastal communities time to initiate emergency response plans which might include partial or full evacuations for their communities. 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 may not be warranted such as during the 2011 tsunami. These secondary evacuation plans are be based on "elevation playbook" lines where forecasted tsunami amplitudes and tidal information can help guide what elevation is appropriate to evacuate to.

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, coastal communities could use existing "scenario playbooks" developed based on the state tsunami modeling work to make swift decisions on response and/or evacuation. These scenario playbooks include tsunamis generated from three categories of tsunami based on where they originate:

- Distance-source events along the Alaska-Aleutian Islands subduction zones where there is only 4-6 hours travel time to California;
- The local/regional Cascadia subduction zone where there may be only 10 minutes to 2 hours travel time along the California coast; and
- Other various local submarine fault or landslide sources where there may only be 10 minutes until tsunami arrival.

Note: 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 and will not be released to the public by the state. Evacuation and emergency response planning for future tsunamis is the responsibility of each community and, therefore, should be a local decision when and how to release this type of information. Consideration must be made that if the maps were made public prior to a tsunami Alert, individuals may make their own decision on evacuation which may be at odds with the community emergency managers plan.

Elevation Playbooks

Elevation playbook lines are useful for partial evacuations when sufficient information about forecast amplitude and arrival times is available to 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 county workshops, evacuation zone lines, typically drawn using roads and recognizable landmarks, were created for each of the elevations 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 digital lines can be used by communities for secondary evacuation planning, exercises and drills, and reverse-911 use during an event. Table 1 demonstrates what these playbook evacuation lines represent and how they could be used in tsunami response planning. The 1m line could be useful to identify areas potentially impacted by borderline Advisory-/Warning-level forecasts, designated when maximum amplitudes close to 1m are expected. The 2m, 3m, and 4m lines can be used for small or moderate Warning-level forecasts (maximum amplitudes above 1m) and calling for full evacuations (typically to a 10m elevation) is not warranted.

Scenario Playbooks

The database of numerical modeling scenarios developed for the 2009 state-wide inundation mapping project is used to generate information for scenario playbooks, specifically for local and regional tsunamis where the travel time is relatively short (less than 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 to 2 hours in California, 2) the eastern Aleutian Islands subduction zone where travel times range from 4 to 6 hours, and 3) other local offshore tsunami sources where travel time could be 10 minutes. Table 2 shows the expected maximum tsunami wave height from modeled scenarios from these sources.

M9+ 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 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 Warning Center to help them make a decision. For this reason, the state is providing a modeled inundation results for this scenario and guidance for evacuation in low-lying, populated regions.

M9+ Eastern Aleutian Islands Subduction Zone Scenario

The eastern Aleutian Islands tsunami source region is considered one of the "worst-case" regions for tsunamis along the California coast because of the large expected tsunami heights (see Table 2) and short travel time. A tsunami created by this source scenario, which may produce the maximum credible distant event state-wide, 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 Warning Center to make a decision about evacuation. For this reason, the state is providing modeled inundation information and guidance for this scenario.

Worst-Case Local Scenario

The state tsunami program has modeled potential local tsunami sources for most of 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 will be provided to each county so that coastal jurisdictions can educate and prepare their communities to evacuate immediately, especially if they feel an earthquake along the coast.

FASTER Tsunami Height Calculation

Forecast amplitudes from the WC/ATWC typically represent the near-shore tsunami wave height without consideration of the existing tidal conditions. 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 to calculate these flood conditions is known as the "FA-S-T-E-R" method. FASTER includes the following variables for calculating the highest run-up elevation that the tsunami could reach at a particular location:

- **FA = Forecasted Amplitude** (wave heights)calculated by the Tsunami Warning Centers;
- **S = Storm** surge or existing ocean conditions;
- **T =** Maximum **tidal** height first 5 hours of tsunami;
- **E** = Forecast modeling **error** potential, which is 30% of the forecast amplitude based on analysis of the 2010 and 2011 tsunamis in California (Wilson et al., 2012); and,
- **R =** Site-specific amplified **run-up** potential from existing state tsunami modeling.

Each variable is estimated after an Advisory or Warning alert is called. These values can be calculated for the first 5 hours after the tsunami's projected arrival time, or at the maximum tidal conditions in the first 24 hours following the tsunami's arrival. Table 3 is an example spreadsheet of the FASTER approach has been developed for implementation by the WC/ATWC, the state, or the county, using the key input parameters discussed below.

Tsunami Forecast Amplitudes

Forecast amplitudes, also known as "tsunami wave heights," are provided by the WC/ATWC for pre-selected locations along the California coast after it is clear that a tsunami has been generated (Figure 2). These data are provided in the tsunami alert bulletins or on the WC/ATWC 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 applying all other variables influencing wave heights.

Storm and Other Existing Conditions

Storm surge and other existing ocean conditions are important to understand and incorporate to any potential inundation calculation during a tsunami. For example, a day after the February 27, 2010 tsunami, it was demonstrated that extreme storm surge 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 one of 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 recent 2010 and 2011 tsunamis, the first five hours after first wave arrival have been the most important for capturing the peak tsunami amplitude for most locations in California (Wilson et al., 2012). During both tsunamis, inundation was very limited because this peak tsunami activity occurred in conjunction with low-tide conditions. During future tsunamis, once the projected tsunami arrival time is forecasted by the WC/ATWC, 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 protect against underestimation of the forecast amplitudes from the WC/ATWC, incorporation of an error factor into the total flood potential is important. Based on a comparison of forecasted amplitudes and measured/observed tsunami amplitudes during the 2010 and 2011 tsunamis, Wilson et al. (2012) calculated that the forecast amplitudes were within ±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 tsunami flood potential. The intent is to err on the side of public safety.

Site-Specific Tsunami Run-Up Potential

During past inundating tsunami events in 1946, 1960, and 1964, tsunami run-up is 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. For this reason, a factor must be incorporated into the total flood potential that addresses site-specific run-up conditions. This amplified run-up factor will be 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 data to determine the run-up potential for each location along the coast, and is provided in Table 1. 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.

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 between Crescent City and Point Conception was put into a tsunami "Warning" level of alert. Crescent City was forecasted to receive a tsunami amplitude of 2.5m (8ft) from the WC/ATWC. Real-time model results of potential inundation were produced and provided to the city. Because the tsunami was modeled using high-tide conditions, inundation at high tide was initially projected to be similar to that of the devastating 1964 tsunami and the community called for a full evacuation beyond their existing "worst-case" evacuation zone, which is located at about a 20m elevation. However, because the first five hours of tsunami activity occurred during low-tide conditions, only very minor inundation of waterfront areas in Crescent City occurred. Therefore, full evacuation was an appropriate action given the information that was available but if the low-tide condition would have been considered in the real-time modeling, a different tsunami flood level would have been expected and evacuations might have been different (significantly less), especially if a secondary 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. Figure 3 demonstrates that the potential FASTER total flood level would have been calculated to be 2.7m (9ft) for Crescent City incorporating the forecast amplitude and the other FASTER variables. Although the FASTER approach calculated a similar level to the original forecast amplitude at Crescent City, Table 1 shows that for a total flood potential of only 2.7m (9ft), the 3m tsunami elevation playbook line would have been appropriate to use for evacuation. This would have reduced the area of evacuation by two-thirds.

The tidal conditions have a very large impact on the relatively minor Warning level events like the 2011 tsunami. Tables 5 and 6 demonstrates 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 original tsunami forecast amplitudes and alert messages indicated that inundation of dry land may occur along this section of coast, the FASTER calculation shows that little or no inundation was likely to occur at most locations because of the low-tide conditions, and evacuated areas could have been smaller or, in most cases, evacuation was not needed. Conversely, 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 WC/ATWC. 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.

Guidance: 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 here must be approved, vetted, well understood, and then incorporated into local response and evacuation plans for testing in advance of application during an incoming tsunami. Misuse of these products could expose the emergency personnel and the public to life-threatening conditions by underestimating 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 cannot dictate if or how these products can be used. However, we provide the following as a step-by-step guide on how to use this information when a tsunami alert for a community is generated (NOTE: 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):

1) **Gather pertinent information on the potential tsunami event:** When the WC/ATWC 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) **Determine whether to use scenario playbook and/or 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.
    b. If the tsunami is generated by a large earthquake on a regional source or Alaska/Aleutian Islands source (>M8.5) where there is 5 hours or less before arrival, refer to the "scenario playbook" recommendations on the FASTER spreadsheet (like Table 3 for San Diego County).
    c. If a Warning is forecasted, evacuations of previously mapped zones should commence as soon as possible.
    d. If the travel time is more than 5 hours and there is sufficient time to utilize the FASTER approach and/or organize an appropriate and effective evacuation, steps #3 through #5 can be followed.

3) **Gather pertinent information on your coastal conditions:** The FASTER approach requires numerical forecast information about coastal conditions such as potential storm activity and tides. This information can be provided by the regional NWS Weather Forecast Office or obtained from online sources such as www.tidesandcurrents.noaa.gov. Once the tsunami arrival time is available, determine the storm and tidal conditions for the first five hours after the tsunami arrives, and the potential peak storm and tidal conditions over a 24 hour period.

4) **Calculate the FASTER tsunami flood elevation:** Enter the numerical information about forecast amplitude/wave height, storm conditions, and tidal conditions into the county/community spreadsheet (like Table 3 for San Diego County). Enter data for both the first 5 hours of tsunami activity and for the maximum values over a 24 hour period. Obtain the FASTER tsunami flood elevation for both periods from the spreadsheet for your community. If the FASTER elevation values are greater than 1m without runup included, then use the FASTER value where runup is part of the calculation.

5) **Determine whether to use one of the playbook lines or the maximum line for evacuation:** Once the correct FASTER flood elevation is calculated and there is sufficient time for organizing the appropriate evacuation (>5 hours), Table 1 can be referenced for determining what level of evacuation could be called. If a Warning alert is forecasted and there is uncertainty in the FASTER approach or what the emergency response action should be taken, we recommend that coastal communities evacuate to their maximum evacuation line. Communities can chose to utilize the FASTER value calculated for the first 5 hours or over the 24 hour period.

Again, we recommend that communities be conservative with their decision making with regard to tsunami evacuation. Hopefully 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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Table 1 Recommended guidance for use of evacuation playbooks.

County Evacuation Name (local decision)	Recommended FASTER Expected Flood Level Value (METERS)	Recommended FASTER Expected Flood Level Value (FEET)	Anticipated NOAA Tsunami Alert Level	County Tsunami Alert Level description (local decision)	County recommended areas to evacuate (local decision)		Elevation Line on "Playbook" Map (Evacuate up to this level, in feet)	Elevation Line on "Playbook" Map (Evacuate up to this level, in meters)
Level/Stage/Phase 1	less than 1.00m	less than 3.3ft	Advisory	Advisory	beaches, docks, waterfront areas		none	none
Level/Stage/Phase 2	1.00m to 1.50m	3.3ft to 5.0ft	Warning	large Advisory (Advisory at high tide)/minor Warning (Warning at low tide)	Stage1/Phase 1 and low-lying areas prone to normal flooding		3.28ft at Mean High Water = 5.25ft above Mean Sea Level	1m at Mean High Water = 1.6m above Mean Sea Level
Level/Stage/Phase 3	1.50m to 2.50m	5.0ft to 8.2ft	Warning	minor to moderate Warning (Warning at low tide to moderate tide)	Areas mapped as Stage 3 (if applicable)		6.6ft at Mean High Water = 8.5ft above Mean Sea Level	2m + Mean High Water = 2.6m above Mean Sea Level
Level/Stage/Phase 4	2.50m to 3.50m	8.2ft to 11.5ft	Warning	moderate to large Warning (Warning at moderate to high tide)	Areas mapped as Stage 4 (if applicable)		9.8ft at Mean High Water = 11.8ft above Mean Sea Level	3m + Mean High Water = 3.6m above Mean Sea Level
Level/Stage/Phase 5	3.50m to 4.50m	11.5ft to 14.8ft	Warning	large Warning (Warning at high tide)	Areas mapped as Stage 5 (if applicable)		13.1ft at Mean High Water = 15ft above Mean Sea Level	4m + Mean High Water = 4.6m above Mean Sea Level
Maximum Phase (as recommended by existing NOAA protocol)	more than 4.50m	more than 14.8ft	Warning	very large Warning	Evacuate to maximum evacuation zone		Use maximum evacuation line	Use maximum evacuation line

Table 2 Near-shore maximum tsunami heights from numerical tsunami modeling for various scenarios with short response times. Bolded and italicized sources are the maximum for that location. (*=no regional Cascadia source; NA=not available)

Location	County	Maximum Onshore Runup Elevation (feet)	High Incoming Wave Elevation - Distant Source (feet)	Max Source - Distant	High Incoming Wave Elevation - Local Source (feet)	Max Source - Local	High Incoming Wave Elevation - Regional Cascadia Source
Crescent City	Del Norte	45	17	Aleutians 3	30	***Cascadia (entire length)***	*
Humboldt - Inside Bay	Humboldt	17	10	1964 Alaska EQ	17	***Cascadia (entire length)***	*
Humboldt - Outside Bay	Humboldt	28	16	Aleutians 3	24	***Cascadia (entire length)***	*
Arena Cove	Mendocino	22	12	***Aleutians 3***	11	Cascadia (entire length)	11
Bodega Bay	Sonoma	21	15	***Aleutians 3***	8	Cascadia (entire length)	8
Point Reyes	Marin	23	19	***Aleutians 3***	10	Pt Reyes Thrust Fault	4
Bolinas/Stinson Beach	Marin	25	19	***Aleutians 3***	8	Pt Reyes Thrust Fault	4
San Francisco	San Francisco	19	13	***Aleutians 3***	4	Pt Reyes Thrust Fault	4
Saucilito	Marin	12	10	***Aleutians 3***	6	Pt Reyes Thrust Fault	4
Mare Island	Solano	5	4	***Aleutians 3***	3	Pt Reyes Thrust Fault	3
Richmond	Contra Costa	11	10	***Aleutians 3***	4	Pt Reyes Thrust Fault	3
Alameda	Alameda	17	16	***Aleutians 3***	4	Pt Reyes Thrust Fault	4
Redwood City	San Mateo	7	5	***Aleutians 3***	4	Pt Reyes Thrust Fault	NA
Pacifica	San Mateo	24	18	***Aleutians 3***	7	Pt Reyes Thrust Fault	4
Half Moon Bay	San Mateo	32	27	***Aleutians 3***	10	Pt Reyes Thrust Fault	NA
Santa Cruz	Santa Cruz	30	19	***Aleutians 3***	19	Monterey Cyn Landslide	4
Monterey	Monterey	18	16	***Aleutians 3***	15	Monterey Cyn Landslide	3
Cayucos	San Luis Obispo	32	24	***Aleutians 3***	4	1927 Pt Arguello EQ	3
Port San Luis	San Luis Obispo	39	37	***Aleutians 3***	3	1927 Pt Arguello EQ	4
Pismo Beach	San Luis Obispo	31	27	***Aleutians 3***	NA		5
Santa Barbara	Santa Barbara	31	13	Aleutians 3	26	***Goleta Landslide #2***	NA
Ventura	Ventura	12	10	***Aleutians 3***	7	Channel Isl. Thrust Fault	4
Oxnard	Ventura	10	9	Aleutians 3	10	***Goleta Landslide #2***	3
Malibu	Los Angeles	8	5	Aleutians 3	8	***Anacapa-Dume Fault***	NA
Santa Monica	Los Angeles	12	9	***Aleutians 3***	6	Palos Verdes Landslide #1	3
San Pedro/LA Harbor	Los Angeles	16	13	***Aleutians 3***	8	Palos Verdes Landslide #2	3
Huntington Beach	Orange	16	8	Aleutians 3	16	***Palos Verdes Landslide #2***	3
Newport Beach	Orange	16	5	Aleutians 3	13	***Catalina Fault***	NA
Dana Point	Orange	20	7	Aleutians 3	13	***San Mateo Thrust Fault***	3
San Clemente	Orange	17	6	Aleutians 3	16	***San Mateo Thrust Fault***	3
Oceanside	San Diego	16	9	Aleutians 3	13	***Carlsbad Thrust Fault***	NA
Del Mar	San Diego	19	8	Aleutians 3	17	***Carlsbad Thrust Fault***	NA
La Jolla	San Diego	15	8	Aleutians 3	9	***Carlsbad Thrust Fault***	3
San Diego Bay	San Diego	7	4	***Aleutians 3***	3	Coronado Cyn Landslide	3
Coronado	San Diego	17	8	Aleutians 3	17	***Carlsbad Thrust Fault***	4
Imperial Beach	San Diego	17	7	Aleutians 3	16	***Coronado Cyn Landslide***	3

Table 3 Example spreadsheet for calculating the FASTER tsunami height value. Table also includes guidance for the scenario playb sources.

FASTER calculations for ELEVATION PLAYBOOK use: San Diego County Communities	Set to Receive Forecast Amplitude from WC/ATWC	Forecast Amplitude given (red) and projected (black; meters)	Storm/ ambient conditions first 5 hours, w/ errors	Tide conditions first 5 hours, w/ errors	Error in forecast amplitudes (from Wilson et al., 2012; 30%)	**Anticipated tsunami height first 5 hours (IN METERS)**	**Anticipated tsunami height first 5 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 5 hours, if inundation expected (IN METERS)**	**Anticipated tsunami height first 5 hours, if inundation expected (IN FEET)**		SCENARIO PLAYBOOKS: Recommended evacuation lines for local/regional tsunami sources with short time for evacuation =====>>	Local earthquake/ landslide source (10-20 minutes travel time)	M9+ Cascadia Source (2 hour travel time)	M9+ Alaska-Aleutians Source (5-6 hour travel time)
San Onofre State Beach	Yes	1.3	0.0	-0.7	0.4	**1.0**	**3.2**	0.2	0.2	**1.2**	**3.9**		San Onofre State Beach	Max evac	2m	Max evac
Oceanside	Yes	1.2	0.0	-0.7	0.4	**0.9**	**2.8**	0.2	0.2	**1.0**	**3.4**		Oceanside	Max evac	2m	Max evac
Carlsbad		1.2	0.0	-0.7	0.4	**0.9**	**2.8**	0.2	0.2	**1.0**	**3.4**		Carlsbad	Max evac	2m	Max evac
Encinitas		1.2	0.0	-0.7	0.4	**0.9**	**2.8**	0.2	0.2	**1.0**	**3.4**		Encinitas	Max evac	2m	Max evac
Del Mar		0.8	0.0	-0.7	0.2	**0.3**	**1.1**	0.2	0.1	**0.4**	**1.3**		Del Mar	Max evac	2m	Max evac
La Jolla	Yes	0.8	0.0	-0.7	0.2	**0.3**	**1.1**	0.2	0.1	**0.4**	**1.3**		La Jolla	Max evac	2m	Max evac
Mission Bay		0.8	0.0	-0.7	0.2	**0.3**	**1.1**	0.2	0.1	**0.4**	**1.3**		Mission Bay	Max evac	2m	Max evac
Shelter Isl/Ballast Pt	Yes	0.9	0.0	-0.7	0.3	**0.5**	**1.5**	0.1	0.0	**0.5**	**1.7**		Shelter Isl/Ballast Pt	Max evac	2m	Max evac
San Diego/Nat. City	Yes	0.6	0.0	-0.7	0.2	**0.1**	**0.3**	0.1	0.0	**0.1**	**0.3**		San Diego/Nat. City	Max evac	2m	Max evac
Coronado		1.4	0.0	-0.7	0.4	**1.1**	**3.7**	0.2	0.2	**1.3**	**4.4**		Coronado	Max evac	2m	Max evac
Imperial Beach	Yes	1.4	0.0	-0.7	0.4	**1.1**	**3.7**	0.2	0.2	**1.3**	**4.4**		Imperial Beach	Max evac	2m	Max evac

Red numbers = manually real-time input

Black numbers = set values

Table 4 Calculated total tsunami height 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	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	Recommended Playbook Evacuation Level
Crescent City	2.50	0.00	-1.00	0.75	0.50	**2.75**	**3m**
Humboldt Bay	1.33	0.00	-1.00	0.40	0.27	**1.00**	**2m**
Arena Cove	1.30	0.00	-1.00	0.39	0.26	**0.95**	**none or 1m**
Bodega Bay	0.92	0.00	-1.00	0.28	0.18	**0.38**	**none or 1m**
Point Reyes	0.63	0.00	-1.00	0.19	0.13	**-0.06**	**none or 1m**
Half Moon Bay	0.92	0.00	-1.00	0.28	0.18	**0.38**	**none or 1m**
San Francisco	0.73	0.00	-1.00	0.22	0.15	**0.10**	**none or 1m**
Santa Cruz	1.01	0.00	-1.00	0.30	0.20	**0.52**	**none or 1m**
Monterey	0.52	0.00	-1.00	0.16	0.10	**-0.22**	**none or 1m**
Morro Bay	1.18	0.00	-1.00	0.35	0.24	**0.77**	**none or 1m**
Port San Luis	2.14	0.00	-1.00	0.64	0.43	**2.21**	**3m**

Table 5 Calculated total tsunami height for areas in a Warning-Alert level during the March 11, 2011 tsunami if it would have occurred at high tide.

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**	**Recommended Playbook Evacuation Level**
Crescent City	2.50	0.00	1.00	0.75	0.50	**4.75**	**All**
Humboldt Bay	1.33	0.00	1.00	0.40	0.27	**3.00**	**4m**
Arena Cove	1.30	0.00	1.00	0.39	0.26	**2.95**	**3m**
Bodega Bay	0.92	0.00	1.00	0.28	0.18	**2.38**	**3m**
Point Reyes	0.63	0.00	1.00	0.19	0.13	**1.95**	**2m**
Half Moon Bay	0.92	0.00	1.00	0.28	0.18	**2.38**	**3m**
San Francisco	0.73	0.00	1.00	0.22	0.15	**2.10**	**3m**
Santa Cruz	1.01	0.00	1.00	0.30	0.20	**2.52**	**3m**
Monterey	0.52	0.00	1.00	0.16	0.10	**1.78**	**2m**
Morro Bay	1.18	0.00	1.00	0.35	0.24	**2.77**	**3m**
Port San Luis	2.14	0.00	1.00	0.64	0.43	**4.21**	**All**

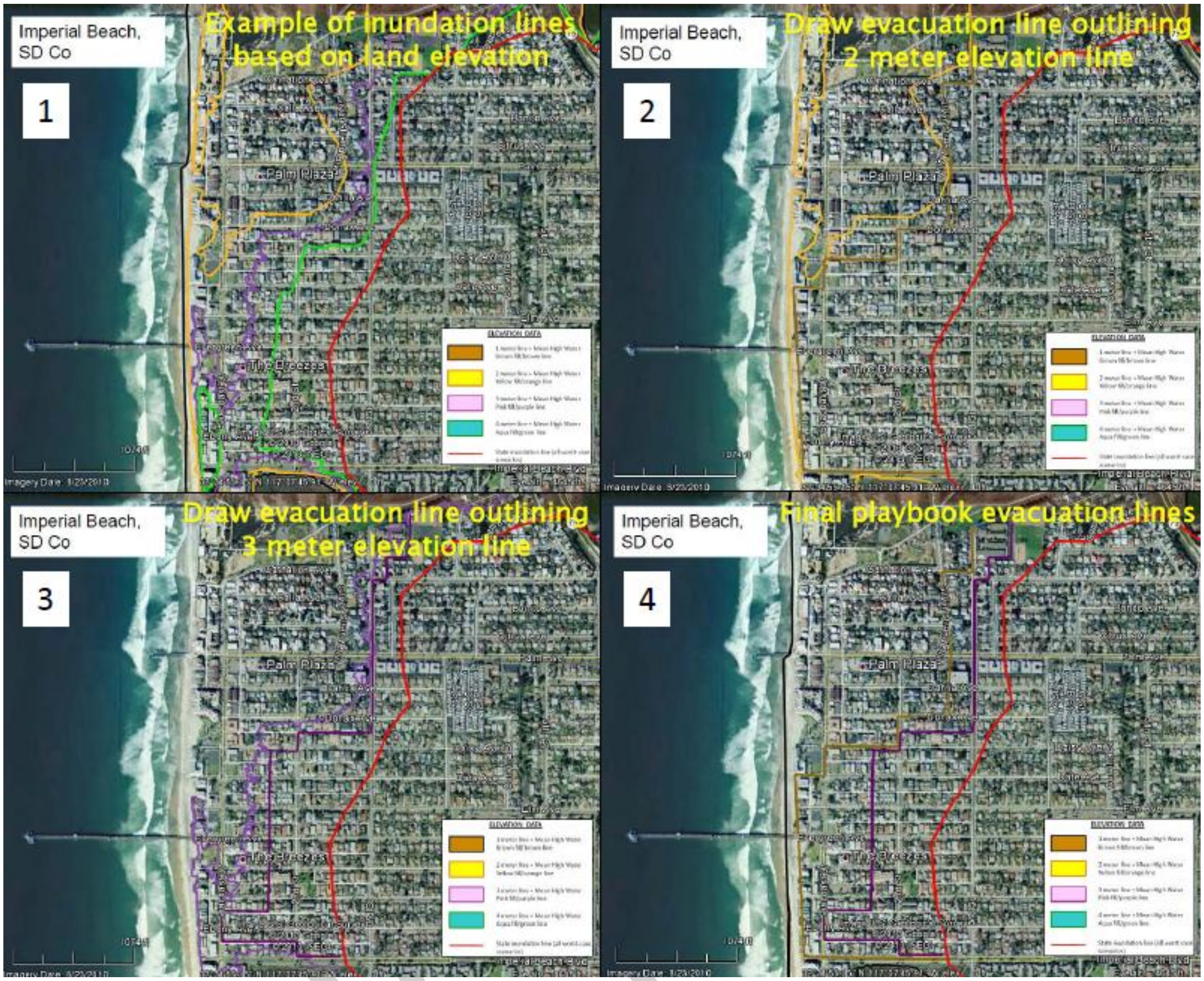

Figure 1 Illustration of how tsunami playbook evacuation lines are developed from elevation lines in Imperial Beach.

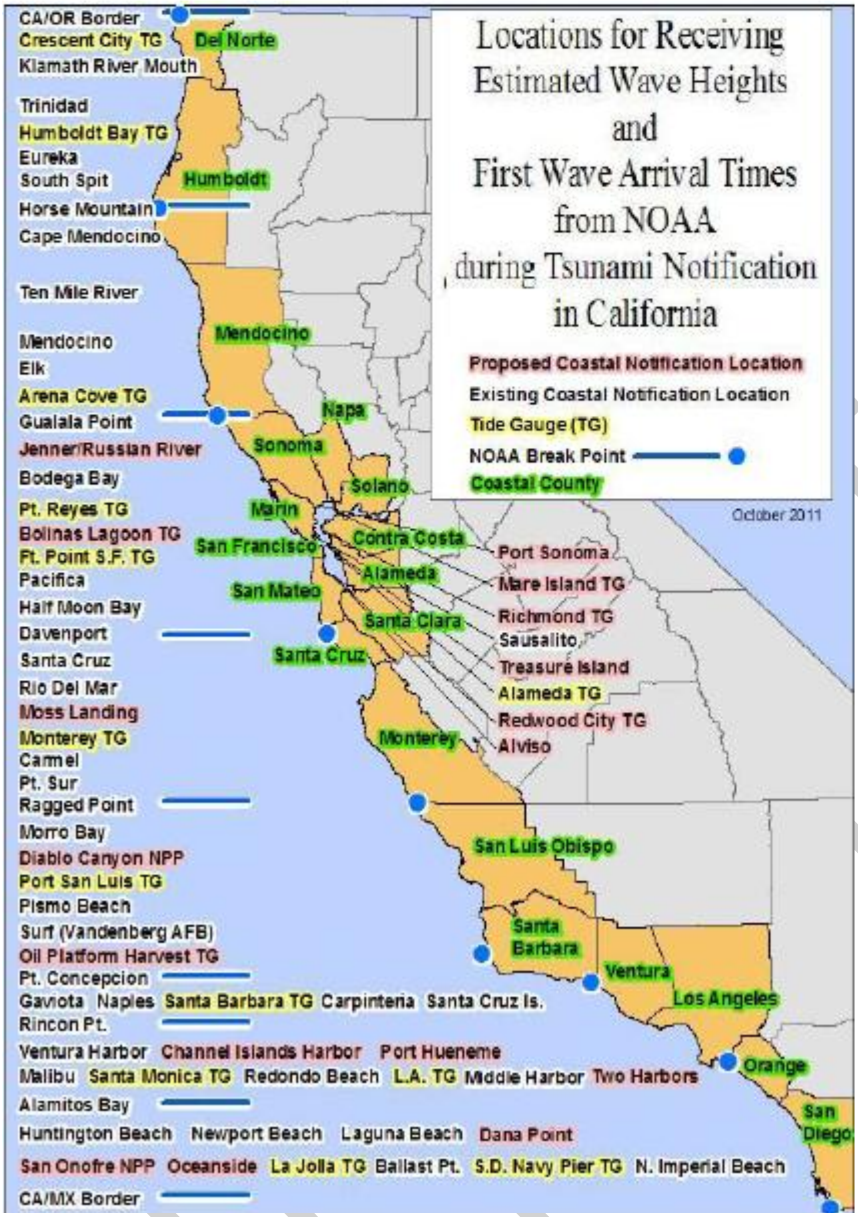

Figure 2 Set locations where tsunami forecast information will be provided by the West Coast/Alaska Tsunami Warning Center

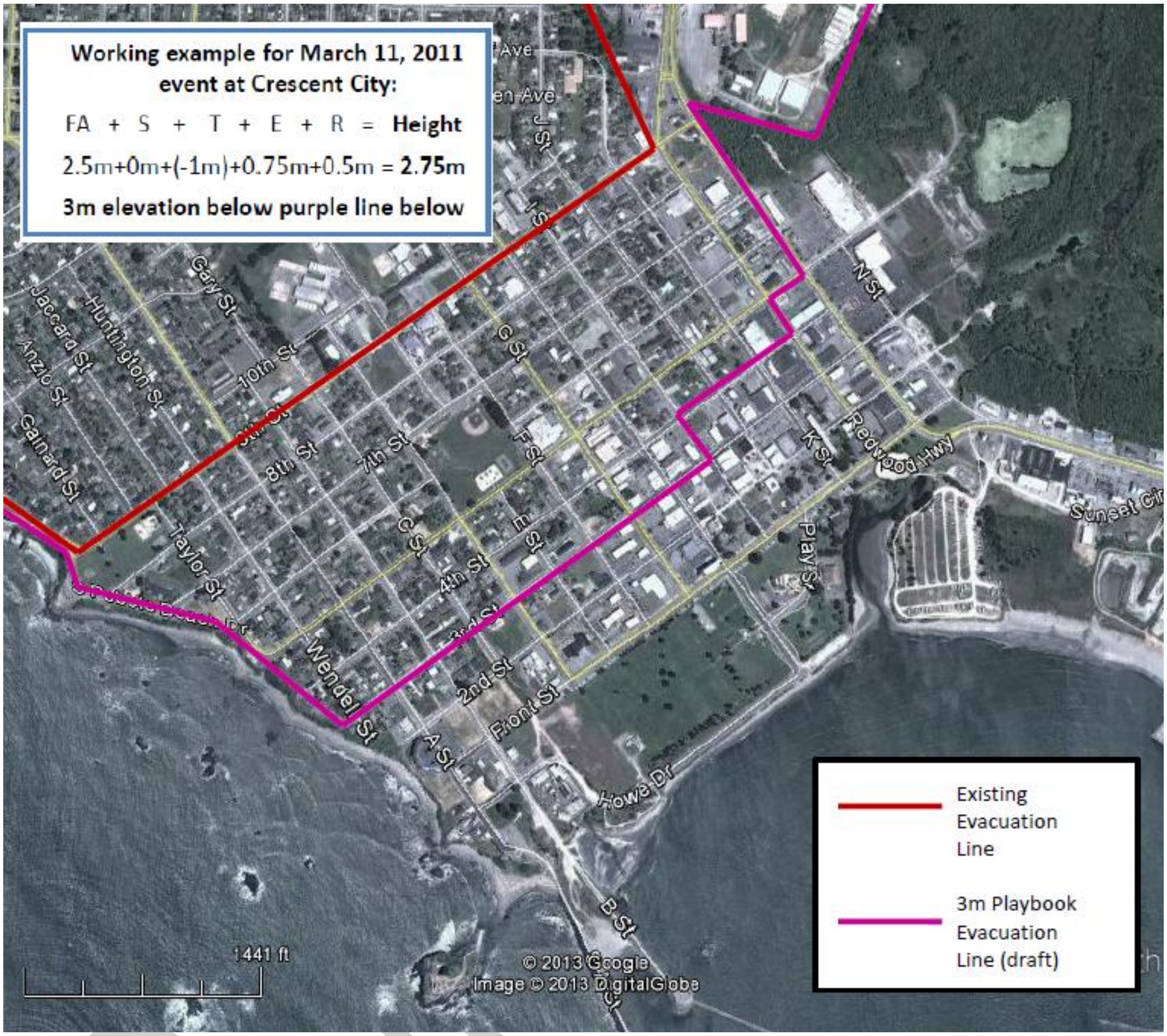

Figure 3 Example playbook map for Crescent City. The red line represents the existing evacuation line and the purple line is an example of the 3m playbook evacuation line.