# Response to Tsunamis in Apra Harbor, Guam: A User's Manual

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**Updated 9/22/2021 by Charles 'Chip' Guard**

**Tropical Weather Sciences**

**From a Tsunami Modeling Study by**

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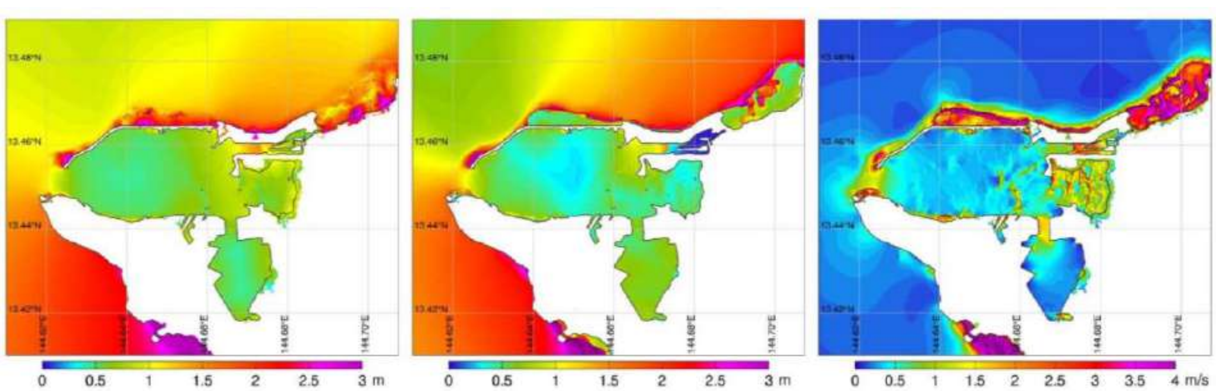

# Response to Tsunamis in Apra Harbor: A User's Manual

**The purpose of this document is to provide guidance to decision makers for the necessary responses to tsunamis that don't meet Warning criteria but that do meet Advisory criteria for strong *currents* and wave runup less than 3 feet. These tsunamis are generated by earthquakes that occur in subduction zones where two oceanic plates collide with one subducting beneath the other.**

**There are four important aspects of tsunamis inside harbors and marinas. These four aspects are *surge, drawdown*, *current* speed and *period*.**

***Surge* is the increase in water level as the wave enters the harbor. *Surge* can force ships against the peers and can cause minor flooding of coastal areas.**

***Drawdown* occurs when the water level decreases as water exits the mouth of the harbor. *Drawdown* can cause the bottom of a ship to hit the floor of the harbor that could be mud, sand, or coral.**

**The *period* determines how frequently the *surge* and the *drawdown* occur and how often the *currents* reverse direction.**

**In General, *currents* can be dangerous if they reach a certain speed and if the direction drastically changes. *Currents* of 3 knots or less are usually not damaging. *Currents* with speeds greater than 3 knots to 6 knots can cause moderate damage. *Currents* with speeds greater than 6 knots can cause more serious damages. Apra Harbor is complicated with an outer harbor and an inner harbor separated by a narrow channel. Thus, the *surges* and *drawdowns* can be out of phase with the *current* speed and direction changing at different times in the inner and outer harbors.**

***Eddies* are rather small circulations caused by the interaction between the *currents* and adjacent structures. When the *currents* change direction, the *eddies* change rotation. This can make it very difficult to navigate when these changes are occurring over *period* of a few minutes.**

**This study by Dr. Kwok Fai Cheung, through sensitivity analysis, identifies the four major tsunami genesis areas that can affect Apra Harbor with strong *currents*. Dr. Cheung used his NEOWAVE (Non-hydrostatic Evolution of Ocean Waves) model for the sensitivity analysis. The four areas include:**

**The Marianas Trench**

**The Nankai Trough (and nearby Ryukyu Trench)**

**The Mindanao (East Philippine) Trench**

**The New Guinea Trench (and nearby Manus Trench)**

Each of these areas can produce earthquakes of various moment magnitudes (Mw) that can generate tsunamis with unique characteristics that in turn can produce unique patterns of ***surge***, ***drawdown*** and ***current*** speed and direction in Apra Harbor. Although the source parameters only depend on the moment magnitude (Mw), the resulting tsunami is also influenced by the local tectonics and water depth. The source regions are shown in Figure 1.

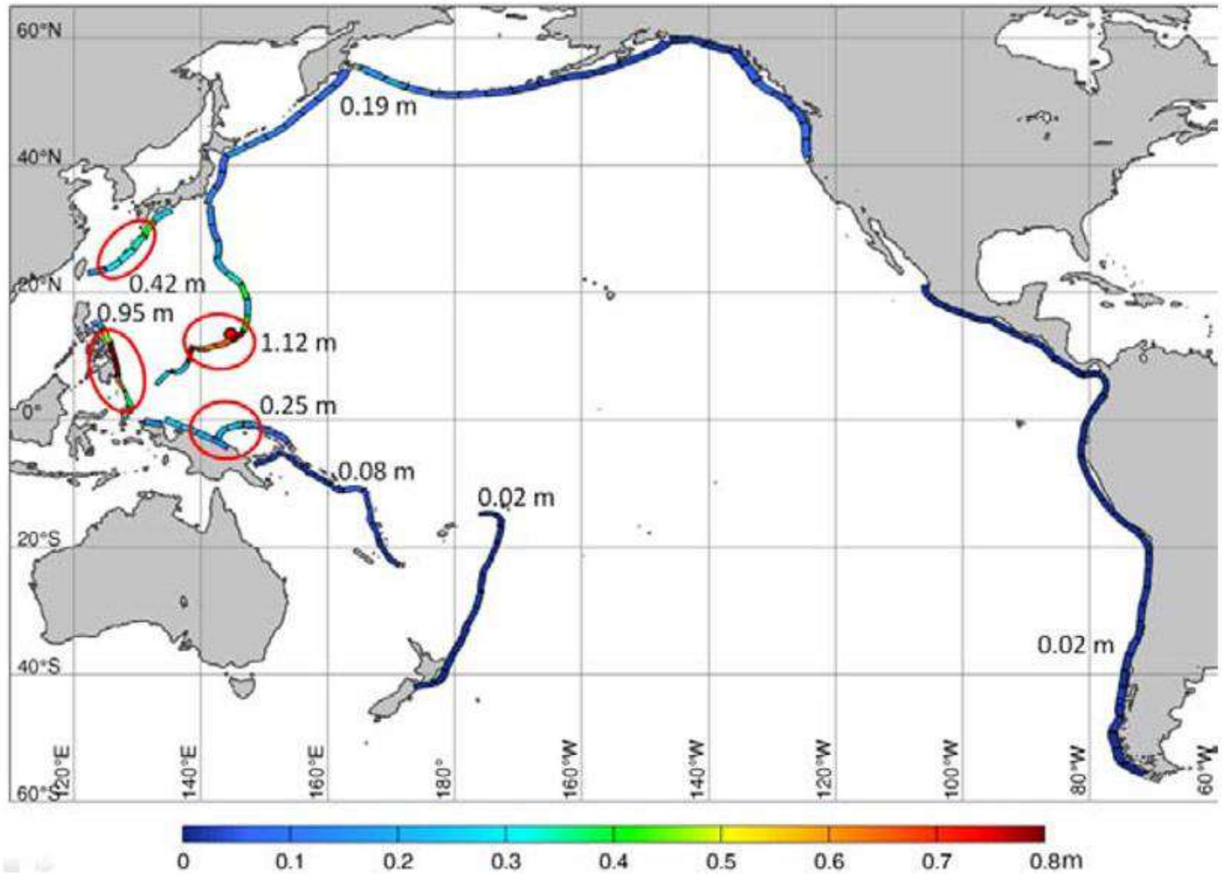


**Figure 1. Sensitivity analysis of tsunami wave amplitude outside Apra Harbor from hypothetical Mw 8.5 earthquakes at subduction zones in the Pacific Ocean.**

**When an earthquake occurs in one of the four subduction zones, it can produce a tsunami wave that propagates across the ocean. The Pacific Tsunami Warning Center (PTWC) monitors the earthquakes and determines whether or not a significant tsunami wave was generated. PTWC then either indicates that there is no threat or issues Tsunami Watches, Warnings, or Advisories.**

**If a Warning is warranted, then Apra Harbor decision makers have specific procedures for dealing with the necessary evacuations. However, if only Advisory criteria are met for Apra Harbor, how should the decision makers respond? The following procedures address the Advisories that deal with tsunamis from one of the four primary generation areas.**

**Port customers have identified four critical locations/areas important for decision makers. These are the opening of the outer harbor, Kilo Wharf, the commercial port pier area, and the channel between the inner and outer harbors. These locations/areas are shown in Figure 2.**


**Figure 2. Critical areas at Apra Harbor for compilation of summary tables.**

**For each of these critical areas, Dr. Cheung derived a set of tables from his NEOWAVE model that maps the tsunami from its source to Apra Harbor and shows the *surge*, *drawdown*, the *period* of each, and the *current* and *period of current* reversal in Apra Harbor. NEOWAVE has specialized features that enable it to model tsunamis in the shallow-reef environment of the Mariana Islands.**

**When PTWC issues a Tsunami Bulletin, the Watch Officer or responsible person should make the necessary notifications for required assessments and activations. Once the first tsunami wave is within 3 hours of arrival, PTWC will issue a Tsunami Warning, a Tsunami Advisory, or a cancellation. In the event that PTWC issues a Tsunami Warning or a Tsunami Advisory, perform the following procedures:**

**1. Determine the location of the threat and review the characteristics of tsunamis from that location.**

**2. Next, go to the associated Table and determine the location(s) of interest (e.g., Main Entrance, Port, Kilo Wharf, Inner Basin Entrance) and match them to the reported earthquake magnitude (Mw).**

**3. Determine the surge, drawdown, current speed, and the return time/period (or range of times/periods) of subsequent waves and currents for the locations of interest.**

**4. Based on the information, make the required operational decisions regarding the Port and Apra Harbor. Except for Marianas Trench events, there will be some time to evacuate ships, boats and people, if necessary. Strong Marianas Trench events may require an immediate evacuation of people in low elevations including the inner and outer harbors, Route 11, the Harbor Refuge, Piti Channel, Commercial Port facilities and the Navy Port facilities. However, if the earthquake magnitude is 7.7 to 8.3, while a coastal evacuation may be necessary, only strong *currents* can be expected inside Apra Harbor. Apra Harbor provides a very good shelter from local tsunami waves, but strong currents and eddies can present significant challenges within the Harbor.**

## Marianas Trench

**Figure 3 illustrates the maximum *surge*, maximum *drawdown*, maximum *currents* and *periods* at Mw 7.6, 7.8, and 8.0 earthquakes. Earthquake damage may be a greater concern than the tsunami threat, however, the tsunami threat should not be ignored.**

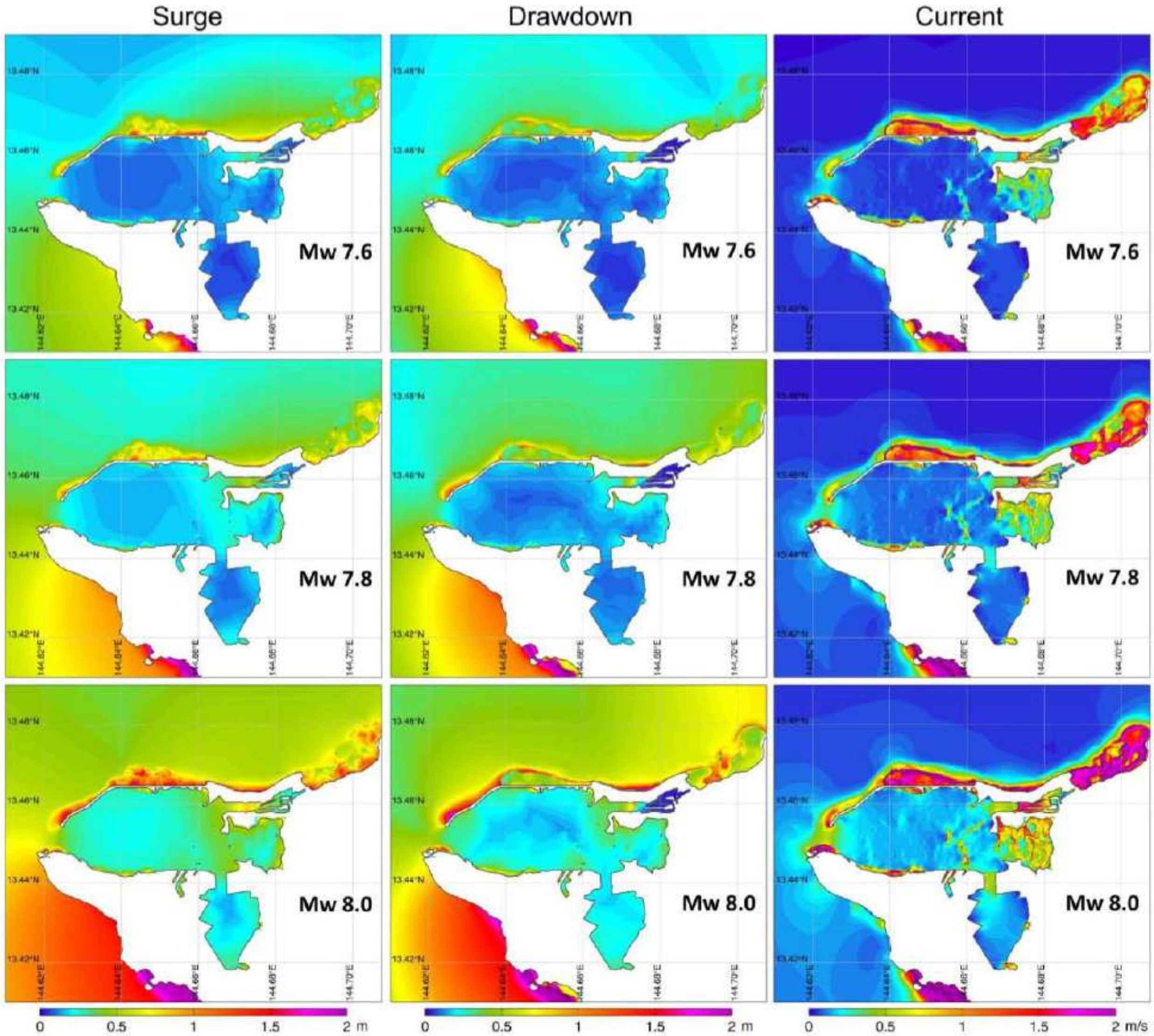


**Figure 3*. Surge*, *drawdown*, *and current* at Apra Harbor from the Mw 7.6, 7.8, and 8.0 Mariana Trench earthquake scenarios.**

**The Marianas Trench is a special case. It is so close to the island that there likely won't be time for a Warning or Advisory. If there is a strong earthquake in the Marianas Trench, people will feel it and should duck, cover, hold on and then move to higher ground. The first wave can arrive in as little as 6 minutes. Someone needs to monitor the location and magnitude of the earthquake and the arrival time of the wave from PTWC. It will take several minutes for the information to arrive from PTWC. If the magnitude is 7.7 to 8.3, a coastal evacuation may be necessary, but inside Apra Harbor, only strong *currents* can be expected. Apra Harbor provides a very good shelter from local tsunamis.**

**Go to Table 1 and determine the Mw of the earthquake, then go to the harbor location of interest (e.g., Harbor Entrance, Kilo Wharf, the Commercial Port, the**

**Inner Harbor Entrance) to determine the *surge, drawdown*, *current* speed and the wave and current return *periods*.**

**Table 1. Maximum *surge*, *drawdown*, and current at Apra Harbor from Mariana Trench source tsunamis**

| Mariana Mw | Main Entrance | | | | |
|---|---|---|---|---|---|
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 7.7 | 1.2 | 1.6 | 10, 15 | 1.3 | 19, 43 |
| 7.8 | 1.6 | 1.8 | 10, 12 | 1.5 | 43, 19 |
| 7.9 | 2.3 | 2.7 | 10, 12 | 1.8 | 43, 19 |
| 8.0 | 3.0 | 4.1 | 10, 12 | 2.1 | 43, 19 |
| 8.1 | 3.6 | 4.8 | 10, 12 | 2.2 | 43, 22 |
| 8.2 | 4.4 | 5.9 | 10, 12 | 3.9 | 43, 22 |
| 8.3 | 4.9 | 6.1 | 10, 12 | 4.5 | 43, 22 |
| | Kilo Wharf | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 7.7 | 0.5 | 0.5 | 8, 19 | 0.3 | 10, 19 |
| 7.8 | 0.6 | 0.5 | 8, 19 | 0.3 | 10, 43 |
| 7.9 | 0.8 | 0.7 | 8, 19 | 0.4 | 10, 43 |
| 8.0 | 1.0 | 1.0 | 8, 19 | 0.5 | 43, 10 |
| 8.1 | 1.2 | 1.1 | 8, 22 | 0.7 | 43, 10 |
| 8.2 | 1.5 | 1.4 | 8, 22 | 0.9 | 43, 22 |
| 8.3 | 1.8 | 2.0 | 8, 42 | 1.1 | 43, 22 |
| | Port of Guam | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 7.7 | 1.6 | 1.5 | 9, 19 | 0.8 | 8, 6 |
| 7.8 | 2.0 | 2.0 | 9, 19 | 0.9 | 8, 6 |
| 7.9 | 2.7 | 2.1 | 9, 19 | 1.1 | 8, 6 |
| 8.0 | 2.9 | 2.6 | 10, 43 | 1.2 | 8, 10 |
| 8.1 | 3.3 | 2.4 | 10, 43 | 1.4 | 8, 10 |
| 8.2 | 4.0 | 3.3 | 10, 43 | 1.7 | 10, 22 |
| 8.3 | 4.9 | 4.5 | 10, 43 | 2.4 | 10, 40 |
| | Inner Basin Entrance | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 7.7 | 0.8 | 0.6 | 9, 42 | 0.4 | 24, 42 |
| 7.8 | 1.0 | 0.8 | 9, 42 | 0.7 | 24, 43 |
| 7.9 | 1.2 | 1.0 | 10, 43 | 0.9 | 23, 43 |
| 8.0 | 1.5 | 1.0 | 10, 43 | 1.2 | 23, 43 |
| 8.1 | 1.8 | 1.2 | 43, 10 | 1.7 | 22, 43 |
| 8.2 | 2.3 | 1.5 | 43, 10 | 2.3 | 22, 43 |
| 8.3 | 3.0 | 2.2 | 43, 8 | 3.5 | 43, 22 |

## Nankai Trough

**If there is a strong earthquake in the Nankai Trough, the arrival time of the first tsunami wave is 3 hours over the 1242-nm (1429-statute mile) distance. PTWC may place Guam into an immediate Warning or Advisory. If the magnitude is 8.1 to 8.7, a coastal evacuation may likely be necessary, but only strong *currents* can be expected in Apra Harbor.**

**If the source of the earthquake is the Nankai Trough or the Ryukyu Trench, Go to Table 2 and determine the Mw of the earthquake, then go to the harbor location of interest to determine the *surge, drawdown*, *current* speed and *periods*.**

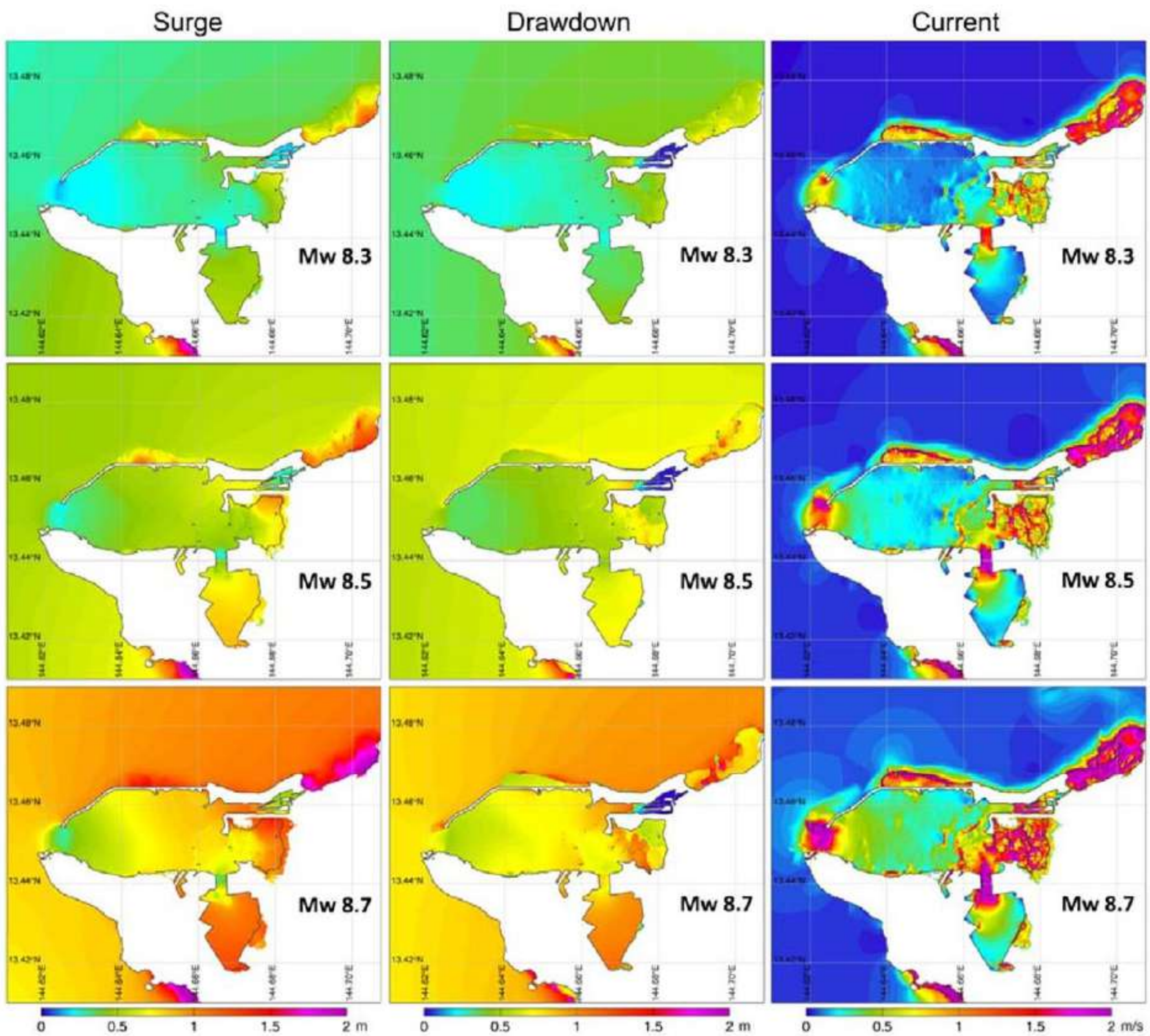


**Figure 4. *Surge*, *drawdown*, and current at Apra Harbor from the Mw 8.3, 8.5, and 8.7 Nankai Trough earthquake scenarios.**

**Table 2. Maximum *surge*, *drawdown*, and current at Apra Harbor from Nankai Trough tsunamis.**

| Nankai Mw | Main Entrance | | | | |
|---|---|---|---|---|---|
| | Surge (m) | Drawdown (m) | Period (min) | Current (m/s) | Period (min) |
| 8.1 | 0.2 | 0.3 | 24, 15 | 1.3 | 18, 24 |
| 8.2 | 0.2 | 0.4 | 24, 15 | 1.6 | 18, 24 |
| 8.3 | 0.3 | 0.5 | 24, 17 | 2.2 | 18, 24 |
| 8.4 | 0.3 | 0.7 | 24, 17 | 2.6 | 17, 24 |
| 8.5 | 0.4 | 0.9 | 24, 17 | 2.8 | 17, 24 |
| 8.6 | 0.6 | 1.1 | 24, 17 | 3.4 | 17, 24 |
| 8.7 | 0.7 | 1.3 | 24, 17 | 4.1 | 17, 46 |
| | Kilo Wharf | | | | |
| | Surge (m) | Drawdown (m) | Period (min) | Current (m/s) | Period (min) |
| 8.1 | 0.1 | 0.1 | 24, 18 | 0.1 | 18, 24 |
| 8.2 | 0.2 | 0.2 | 24, 18 | 0.2 | 18, 24 |
| 8.3 | 0.2 | 0.2 | 24, 18 | 0.2 | 17, 24 |
| 8.4 | 0.3 | 0.3 | 24, 18 | 0.3 | 17, 24 |
| 8.5 | 0.4 | 0.4 | 24, 50 | 0.4 | 17, 40 |
| 8.6 | 0.5 | 0.5 | 24, 50 | 0.6 | 17, 51 |
| 8.7 | 0.5 | 0.6 | 23, 51 | 0.7 | 17, 51 |
| | Port of Guam | | | | |
| | Surge (m) | Drawdown (m) | Period (min) | Current (m/s) | Period (min) |
| 8.1 | 0.3 | 0.5 | 18, 24 | 0.3 | 18, 24 |
| 8.2 | 0.4 | 0.5 | 24, 17 | 0.3 | 18, 24 |
| 8.3 | 0.5 | 0.6 | 24, 17 | 0.4 | 17, 24 |
| 8.4 | 0.6 | 0.7 | 24, 17 | 0.4 | 17, 24 |
| 8.5 | 0.8 | 0.9 | 24, 17 | 0.5 | 17, 23 |
| 8.6 | 1.0 | 1.2 | 24, 17 | 0.6 | 17, 23 |
| 8.7 | 1.2 | 1.4 | 23, 19 | 1.0 | 17, 27 |
| | Inner Basin Entrance | | | | |
| | Surge (m) | Drawdown (m) | Period (min) | Current (m/s) | Period (min) |
| 8.1 | 0.3 | 0.2 | 24, 40 | 1.2 | 24, 28 |
| 8.2 | 0.4 | 0.3 | 24, 40 | 1.7 | 24, 28 |
| 8.3 | 0.5 | 0.4 | 24, 40 | 2.1 | 24, 28 |
| 8.4 | 0.6 | 0.5 | 24, 40 | 2.7 | 24, 28 |
| 8.5 | 0.8 | 0.7 | 24, 40 | 3.5 | 24, 28 |
| 8.6 | 0.9 | 1.0 | 24, 40 | 3.7 | 24, 40 |
| 8.7 | 1.1 | 1.5 | 23, 46 | 3.8 | 23, 40 |

## Philippine (Mindanao) Trench

**Tsunamis from the Philippine source have the most direct approach to Apra Harbor. This is shown in Figure 5. The travel time of 2.5 hr is shorter compared to Nankai trough events due to the slightly shorter distance of 1080 nm (1243 statute miles) and deeper water in the East Philippine Sea. If the Mw is between 7.9 and 8.5, Apra Harbor can expect strong *currents* (Advisory impacts), while coastal parts of Guam may reach Warning criteria and a coastal evacuation is needed.**

**If the source of the earthquake is the Philippine (Mindanao) Trench, Go to Table 3 and determine the Mw of the earthquake, then go to the harbor location of interest to determine the *surge, drawdown*, *current* speed and *periods*.**

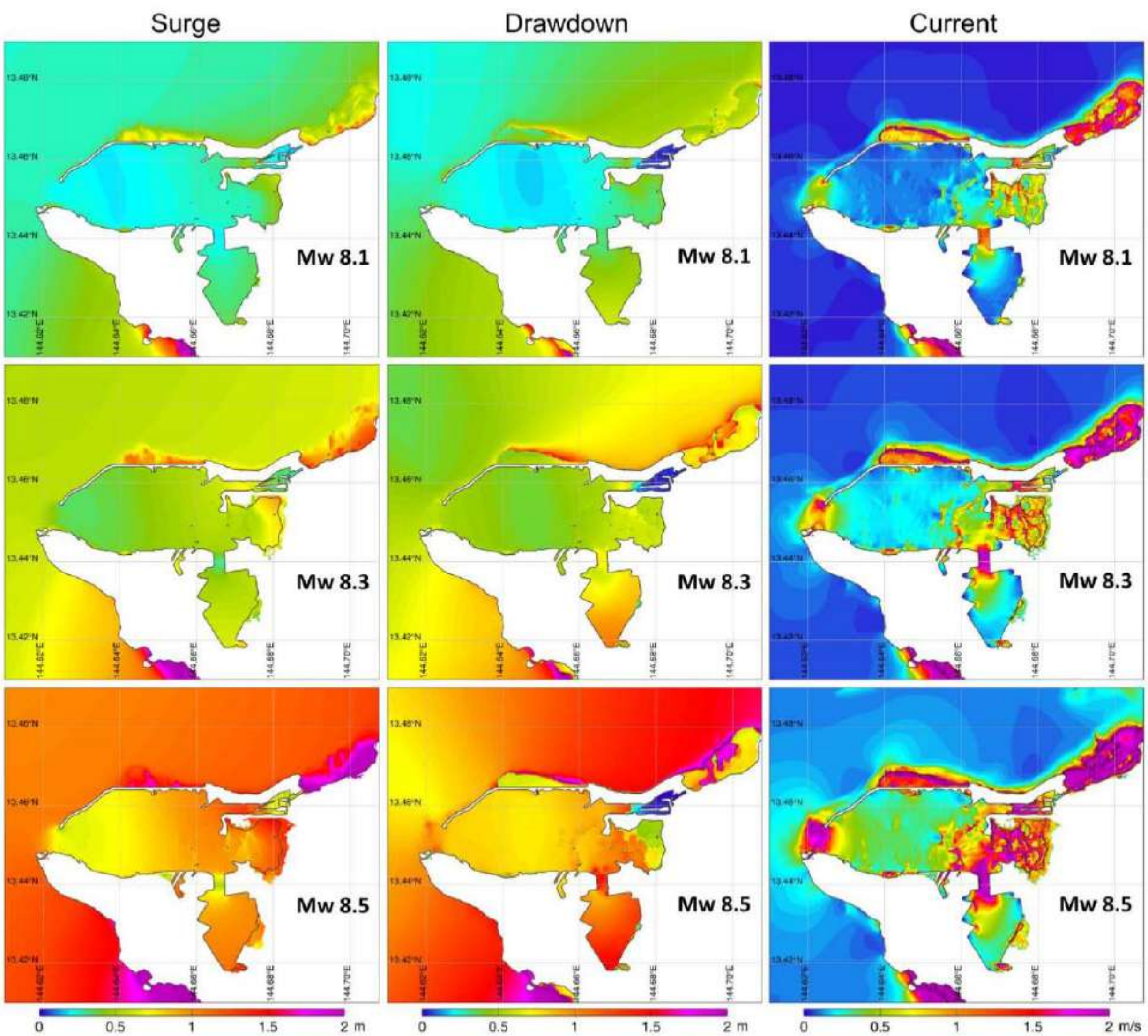


**Figure 5. *Surge*, *drawdown*, and current at Apra Harbor from the Mw 8.1, 8.3, and 8.5 Philippine Trench earthquake scenarios.**

**Table 3. Maximum *surge*, *drawdown*, and current Apra Harbor from Philippine Trench tsunamis.**

| Philippine Mw | Main Entrance | | | | |
|---|---|---|---|---|---|
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (Knots) | Period (min) |
| 7.9 | 0.7 | 0.6 | 9, 20 | 1.0 | 43, 23 |
| 8.0 | 0.8 | 0.8 | 9, 23 | 1.4 | 43, 23 |
| 8.1 | 1.0 | 1.1 | 9, 32 | 2.0 | 43, 23 |
| 8.2 | 1.3 | 1.6 | 9, 32 | 3.8 | 43, 23 |
| 8.3 | 1.7 | 2.0 | 9, 32 | 4.5 | 43, 23 |
| 8.4 | 2.4 | 2.8 | 9, 32 | 6.5 | 43, 22 |
| 8.5 | 3.2 | 3.7 | 9, 32 | 7.3 | 43, 22 |
| | Kilo Wharf | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 7.9 | 0.5 | 0.4 | 23, 43 | 0.2 | 43, 23 |
| 8.0 | 0.6 | 0.6 | 23, 43 | 0.3 | 43, 23 |
| 8.1 | 0.8 | 0.8 | 23, 43 | 0.4 | 43, 23 |
| 8.2 | 1.0 | 1.1 | 23, 43 | 0.5 | 43, 22 |
| 8.3 | 1.3 | 1.5 | 23, 43 | 0.6 | 43, 22 |
| 8.4 | 1.6 | 2.1 | 23, 43 | 0.9 | 43, 22 |
| 8.5 | 2.2 | 2.8 | 47, 23 | 1.2 | 43, 22 |
| | Port of Guam | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Speed (knots) | Period (min) |
| 7.9 | 0.7 | 0.7 | 43, 23 | 0.3 | 9, 23 |
| 8.0 | 1.0 | 1.0 | 43, 23 | 0.5 | 9, 22 |
| 8.1 | 1.5 | 1.4 | 43, 23 | 0.7 | 9, 23 |
| 8.2 | 1.8 | 1.9 | 22, 43 | 0.9 | 9, 22 |
| 8.3 | 2.5 | 2.5 | 43, 23 | 1.3 | 9, 22 |
| 8.4 | 3.2 | 3.1 | 43, 22 | 1.7 | 9, 22 |
| 8.5 | 4.3 | 4.1 | 43, 22 | 2.2 | 9, 22 |
| | Inner Basin Entrance | | | | |
| | Surge (m) | Drawdown (m) | Period (min) | Speed (m/s) | Period (min) |
| 7.9 | 0.6 | 0.7 | 43, 23 | 1.3 | 23, 43 |
| 8.0 | 0.9 | 1.0 | 43, 21 | 1.9 | 23, 43 |
| 8.1 | 1.0 | 1.4 | 43, 23 | 2.6 | 23, 43 |
| 8.2 | 1.5 | 1.9 | 43, 22 | 3.5 | 23, 43 |
| 8.3 | 1.8 | 2.6 | 43, 22 | 4.9 | 23, 43 |
| 8.4 | 2.4 | 3.3 | 43, 22 | 6.0 | 22, 32 |
| 8.5 | 3.2 | 5.3 | 43, 22 | 8.2 | 22, 32 |

## New Guinea Trench

**The New Guinea subduction zone is 972 nm (1118 statute miles) from Guam with a travel time of 2.4 hr. The fault plane characteristics make it inefficient at producing upward displacement of water. Also, its amplitude is somewhat diminished by its path across the Yap and Mariana Trenches. Thus, a strong earthquake is necessary to effect Guam. Figure 6 illustrates the coastal and Apra Harbor *surge*, *drawdown*, and current speeds for Mw 8.4, 8.6, and 8.8 earthquakes.**

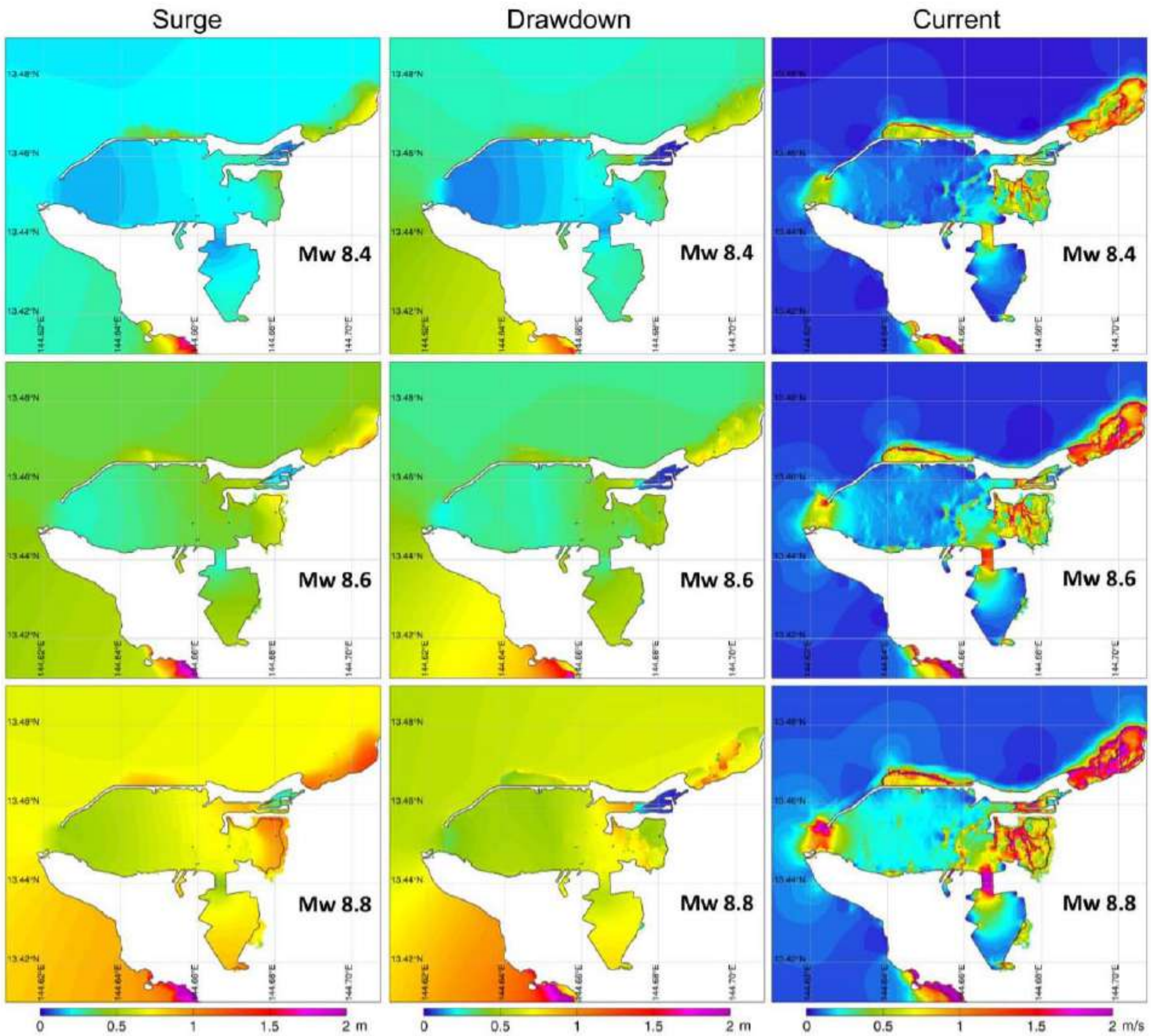


**Figure 6. *Surge*, *drawdown*, and current at Apra Harbor from the Mw 8.4, 8.6, and 8.8 New Guinea earthquake scenarios.**

**When a strong earthquake of Mw 8.2 to 8.8 occurs in the New Guinea Trench, PTWC will issue a Warning or Advisory for Guam. While coastal areas may be in a Warning, Apra Harbor will only experience Advisory-level strong *currents*.**

**If the source of the earthquake is the New Guinea Trench or the Manus Trench, Go to Table 4, and match the earthquake magnitude to the location(s) of interest.**

**Table 4. Maximum *surge*, *drawdown*, and current at Apra Harbor from New Guinea Trench tsunamis.**

| New Guinea Mw | Main Entrance | | | | |
|---|---|---|---|---|---|
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 8.2 | 0.4 | 0.7 | 11, 20 | 1.9 | 22, 43 |
| 8.3 | 0.5 | 0.9 | 11, 20 | 2.4 | 22, 46 |
| 8.4 | 0.7 | 1.0 | 11, 28 | 2.8 | 24, 46 |
| 8.5 | 0.9 | 1.2 | 11, 28 | 3.3 | 46, 22 |
| 8.6 | 1.2 | 1.3 | 17, 28 | 3.8 | 46, 24 |
| 8.7 | 1.6 | 1.9 | 17, 27 | 4.8 | 46, 23 |
| 8.8 | 2.1 | 2.1 | 17, 27 | 5.4 | 46, 23 |
| | Kilo Wharf | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 8.2 | 0.3 | 0.2 | 24, 20 | 0.2 | 43, 23 |
| 8.3 | 0.4 | 0.3 | 22, 20 | 0.3 | 43, 23 |
| 8.4 | 0.5 | 0.4 | 24, 43 | 0.3 | 43, 23 |
| 8.5 | 0.7 | 0.7 | 22, 43 | 0.4 | 43, 22 |
| 8.6 | 0.9 | 1.0 | 43, 24 | 0.5 | 43, 17 |
| 8.7 | 1.2 | 1.3 | 43, 22 | 0.7 | 43, 17 |
| 8.8 | 1.6 | 1.6 | 43, 26 | 0.8 | 43, 17 |
| | Port of Guam | | | | |
| | Surge (ft) | Drawdown (ft) | Period (min) | Current (knots) | Period (min) |
| 8.2 | 0.5 | 0.9 | 23, 43 | 0.2 | 11, 23 |
| 8.3 | 0.7 | 1.2 | 22, 46 | 0.3 | 11, 23 |
| 8.4 | 1.0 | 1.4 | 24, 43 | 0.4 | 24, 11 |
| 8.5 | 1.3 | 1.5 | 43, 22 | 0.5 | 22, 46 |
| 8.6 | 1.7 | 1.8 | 43, 23 | 0.5 | 17, 43 |
| 8.7 | 2.3 | 2.3 | 43, 23 | 0.6 | 17, 43 |
| 8.8 | 3.0 | 3.1 | 43, 23 | 0.8 | 17, 43 |
| | Inner Basin Entrance | | | | |
| | Surge (m) | Drawdown (m) | Period (min) | Current (m/s) | Period (min) |
| 8.2 | 0.4 | 0.5 | 24, 43 | 1.0 | 22, 30 |
| 8.3 | 0.5 | 0.7 | 24, 43 | 1.5 | 22, 30 |
| 8.4 | 0.7 | 1.0 | 24, 43 | 2.0 | 24, 43 |
| 8.5 | 1.0 | 1.1 | 43, 22 | 2.3 | 24, 43 |
| 8.6 | 1.3 | 1.6 | 43, 23 | 3.3 | 24, 43 |
| 8.7 | 1.8 | 2.1 | 43, 23 | 3.8 | 24, 43 |
| 8.8 | 2.4 | 2.6 | 43, 26 | 4.9 | 26, 43 |

## Piti Power Plant

The power plant's location between Piti Channel and Agana Bay make it vulnerable to tsunami impacts.

The results indicate notable *surge* buildup at the west end of Agana Bay and overtopping of Highway 11 into Piti Channel. The power plant facilities are flooded to an elevation of 8.53 feet above MSL. The power plant's location between Piti Channel and Agana Bay make it vulnerable to tsunami impacts.

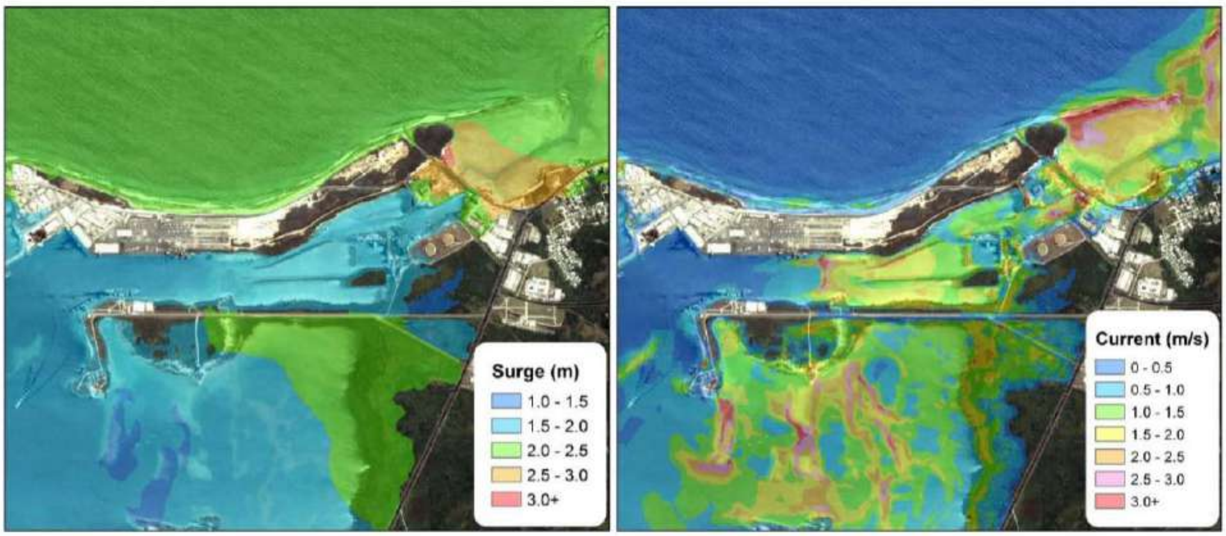


**Figure 7. *Surge* and current at the Port of Guam from the Mw 8.7 Nankai tsunami scenario at high tides.**

## Notes:

**The tabular values are in meters and meters/second. To convert to feet and knots and miles/hour, use the following formulas:**

**1 meter (m) = 3.281 feet**

**1 meter/second (m/s) = 1.944 knots = 2.237 miles/hour = 3.281 feet/second**

**The modeling work is based on the mean-sea level so that the *surge* and *drawdown* can be tabulated. These values need to be adjusted for the tide level during an actual event. This would mean adding 1-2 feet to the surge and**

**subtracting 1-2 feet from the drawdown at high tide. For low tide, both the surge and drawdown would be slightly lower. During El Nino events, high tides and low tides could be up to a foot lower than normal. During La Nina events, high tides and low tides could be up to a foot higher than normal.**

**Moment magnitude (Mw)** measures events in terms of how much energy is released. Mw was introduced in 1979 by Hanks and Kanamori to circumvent shortfalls in the Richter Scale. It is a more accurate scale for describing the size of earthquake events.

**Groin**, in coastal **engineering**, a long, narrow structure built out into the water from a beach in order to prevent beach erosion or to trap and accumulate sand that would otherwise drift along the beach face and nearshore zone under the influence of waves approaching the beach at an angle.