Tohoku-Oki Earthquake Tsunami Runup and Inundation Data for Sites Around the Island of Hawai‘i

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Cover: Vehicles swept inland by the tsunami at Napo'opo'o Point near Kealakekua Bay, Hawai‘i.
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Tohoku-Oki Earthquake Tsunami Runup and Inundation Data for Sites Around the Island Of Hawai‘i

By Frank A. Trusdell, Amy Chadderton, Graham Hinchliffe, Andrew Hara, Brent Patenge, and Tom Weber

Introduction

At 0546 U.t.c. March 11, 2011, a Mw 9.0 (“great”) earthquake occurred near the northeast coast of Honshu Island, Japan, generating a large tsunami that devastated the east coast of Japan and impacted many far-flung coastal sites around the Pacific Basin. After the earthquake, the Pacific Tsunami Warning Center issued a tsunami alert for the State of Hawaii, followed by a tsunami-warning notice from the local State Civil Defense on March 10, 2011 (Japan is 19 hours ahead of Hawaii). After the waves passed the islands, U.S. Geological Survey (USGS) scientists from the Hawaiian Volcano Observatory (HVO) measured inundation (maximum inland distance of flooding), runup (elevation at maximum extent of inundation) and took photographs in coastal areas around the Island of Hawai‘i. Although the damage in West Hawai‘i is well documented, HVO’s mapping revealed that East Hawai‘i’s coastlines were also impacted by the tsunami. The intent of this report is to provide runup and inundation data for sites around the Island of Hawai‘i.

Methods

We measured runup heights by using binoculars and a 4-m-long rod. The person using the binoculars (hereinafter referred to as the gunperson) the rodperson worked in tandem, whereby the gunperson stood at the high-water debrisline and the rodperson stood at the water's edge. Where the horizon (earth-sky interface) intersected the rod, we noted the elevation. All measurements were corrected for the sighting height of the gunperson; this sighting height was subtracted from the runup. In addition, we noted the date and time of day. All elevations were measured in meters, corrected to mean lower low water (MLLW); tidal corrections were based on National Oceanic and Atmospheric Administration (NOAA) high-resolution water-level gages (see http://co-ops.nos.noaa.gov/tsunami/), and tidal lag was inferred from NOAA tide charts (see http://co-ops.nos.noaa.gov/tide_predictions.shtml?gid=353).
A Global Positioning System (GPS) track file was created, when plausible, of the inundation (high-water inundation mark) zone in the backshore. Furthermore, GPS waypoints were collected at all survey points (using hand-held Garmin GPSMAP 60 CSx receivers), for example, at the location of the rodperson, at the shoreline, and at the location of the gunperson.
Data

The inundation and runup data measured at sites around the island are listed in table 1.

Economic Impact of the March 11, 2011, Tsunami on Hawai‘i

On March 11, 2011, a $M_w$ 9.0 earthquake occurred in eastern Japan. The tsunami that followed had far-reaching impacts, including damage along the west coast of Hawai‘i. Almost immediately after the tsunami struck, potential impacts on the State’s economy were being forecast. Thankfully, there was no loss of life on any of the Hawaiian Islands.

Initial damage reports revealed the worst-hit areas to be the on west coast of the Big Island, mostly at the Kona Village Resort, at the Four Seasons Resort at Hualālai (Star Advertiser staff, 2011), and on Kealakekua Bay (Jenson, 2011). Nonetheless, many small businesses—such as the Kona seafront shops that were forced to close in the immediate aftermath of the event—reopened within 3 days, thereby minimizing loss of revenue (Burnett, 2011c). Many businesses, including hotels, shops, and restaurants, conducted business as usual in the aftermath of the tsunami to discourage tourists from changing their travel plans and avoiding visits to the island (Burnett, 2011c).

On March 15, 4 days after the tsunami struck Hawaii, an initial estimate of the damage incurred was “tens of millions of dollars” (Burnett, 2011b). This preliminary projection included damage to homes, businesses, hotels, boats, piers, and government infrastructure but not total loss in terms of damage to the economy. Predictions for the local economy of Hawaii that were made in conjunction with this damage estimate were centered on the anticipated decline in Japanese tourists visiting the State in the aftermath of the tsunami (Sur, 2011). Economists predicted that even potential Japanese visitors not directly impacted by the earthquake would refocus their spending priorities from international travel to helping fellow countrymen. Many Japanese consumers adopted the new attitude of *jishuku*, or “voluntary self-restraint,” to limit their spending on luxury vacations in the near future (University of Hawaii Economic Research Organization, 2011). The number of Japanese tourists visiting Hawaii in the months after the earthquake was predicted to decline significantly. Because Japanese tourists compose a sizable proportion of the total number of visitors to Hawaii and outspend American tourists nearly 2 to 1 on a per-person, per-day average (Song, 2011), a prolonged reduction in their numbers would significantly affect the tourism industry in Hawaii (Sur, 2011).

In light of these predictions, on March 16, Hawaii Governor Neil Abercrombie announced that the recently determined State budget would be reviewed and adjusted by the Council on Revenues (COR) to take into account the economic effects of the Japanese earthquake on the State of Hawaii (Abercrombie, 2011b). Evidence suggesting the validity of predictions of a decline in the number of Japanese tourists came on March 16, when it was reported that a group of 2,000 Japanese tourists scheduled to arrive in Hawaii 2 weeks later had canceled their bookings (Associated Press, 2011). The travel agency H.I.S. Hawaii also reported that new bookings were reduced by half and cancellations tripled in the first 3 days after the earthquake (Song, 2011). A further blow to Hawaiian tourism came on March 19, when Japanese Airlines announced the suspension of nearly two dozen flights to Hawaii, China, and South Korea through April (Hawai‘i Tribune-Herald staff and wire services, 2011).

On March 23, more detailed damage estimates for the Big Island were released, based on assessments by Civil Defense. The price tag for tsunami damage was estimated at $14.2 million (structural and utility damage only) (Burnett, 2011a). Commercial properties constituted $11.1 million of this figure, and residential properties $2.5 million. North Kona hotels sustained the most damage, with the King Kamehameha Kona Beach Hotel reporting $3.58 million in damage, the Kona Village Resort $3.53 million, and the Four Seasons Resort at Hualālai $257,000 (Burnett, 2011a).
On March 24, Governor Abercrombie released State-wide damage estimates totaling $30.6 million, broken down as follows:

**Government Damage Estimates**

<table>
<thead>
<tr>
<th>County</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawai‘i County</td>
<td>$2.3 million</td>
</tr>
<tr>
<td>Maui County</td>
<td>$2.7 million</td>
</tr>
<tr>
<td>City and County of Honolulu</td>
<td>$3.4 million</td>
</tr>
<tr>
<td>Kauai County</td>
<td>$60,400</td>
</tr>
<tr>
<td><strong>Total Public Infrastructure Damages</strong></td>
<td><strong>$8.5 million</strong></td>
</tr>
</tbody>
</table>

**Damage to Businesses and Residents**

<table>
<thead>
<tr>
<th>Location</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Hawai‘i businesses</td>
<td>$13.5 million</td>
</tr>
<tr>
<td>Hawai‘i Island homes</td>
<td>$2.5 million</td>
</tr>
<tr>
<td>Maui County homes</td>
<td>$600,000</td>
</tr>
<tr>
<td>Private property (including boats)</td>
<td>$5.5 million</td>
</tr>
</tbody>
</table>

(Abercrombie, 2011b)

The Governor also formally requested an Administrative Disaster Declaration from the U.S. Small Business Administration (SBA) and a Disaster Declaration from President Obama to aid with the financial burden of damage repair (Abercrombie, 2011a). In addition, the Hawaii Tourism Authority released $3 million in reserve funds on March 24 to offset the tourism shortfall due to the decline in the number of Japanese tourists after the tsunami (Tang, 2011).

After the Council on Revenue’s revisions to the pretsunami budget, the decline in Japanese tourists, in combination with declining tax collections since February 2011, has increased Hawaii’s budget shortfall from approximately $1 billion to $1.3 billion over the next 2 years (Niesse, 2011b). Preliminary suggestions to combat this economic loss are being considered, including raising taxes and reducing government services, although tax increases will be avoided if at all possible (Niesse, 2011b).

On April 8, 2011, President Obama signed a Disaster Declaration for Hawaii, and Federal aid available to the State was outlined. The Government will contribute 75 percent of the cost of repairs to Government property, and the State/county governments will be responsible for the remaining 25 percent (Niesse, 2011a). Low-interest disaster loans from the SBA are available to private individuals, businesses, and nonprofits to aid with necessary repairs (Civil Defense Public Information Office, 2011). Just 3 days before the deadline for applications passed, however, only nine applications for SBA loans had been filed (Lucas-Zenk, 2011).

Despite the decline in the number of Japanese tourists by nearly 17.9 percent in March 2011—in contrast to arrivals in March 2010—the Hawaii Tourism Authority announced a 9-percent increase in the total number of visitors for the first quarter of 2011 (Kelleher, 2011). Business from other markets, such as an increase in arrivals from the U.S. mainland and Canada, helped make up for the loss due to the decline in the number of Japanese tourists (Kelleher, 2011). The State forecast update from the University of Hawaii’s Economic Research Organization (2011), released May 6, supported this observation and predicted a significant slowdown for the year in the growth of overall arrivals, but not an outright decline. Predictions for the Hawaiian economy in the coming months remain optimistic. Despite the decline in the number Japanese tourists due to the fairly persistent damage to the Japanese traveler’s psyche, the March 11 tsunami will not derail Hawaii’s economic recovery.

**Comparison with Previous Tsunamis**

The 2011 Tohoku-Oki tsunami is unique in that it provided data for a tsunami generated from the western Pacific. Overall, the west coast of Hawai‘i Island had the highest runups (fig. 2). In places,
offshore bathymetry and (or) seaward projection(s) of the coastline appeared to funnel wave energy, creating higher runups.

Figure 2. Island of Hawai‘i, showing runup data from 2011 Tohoku-Oki tsunami (red bars) in comparison with those from the 1960, 1957, and 1946 tsunamis. Earlier tsunamis arrived in Hawai‘i generally from the east, resulting in higher runups on east side of island.

Runup data for the 2011 Japanese tsunami are compared with those from a locally derived tsunami generated by the November 1975 M 7.2 Kalapana earthquake in figure 3.
Figure 3. Island of Hawai‘i, showing runup data from the 2011 Tohoku-Oki tsunami (red bars) in comparison with those from locally generated tsunami accompanying the 1975 M 7.2 Kalapana earthquake. As expected, runup from local tsunami was highest near the epicenter along the southeast coast.

References Cited


Glossary

inundation  Inland flooding.
inundation distance  Maximum inland distance of flooding.
r璞up  Elevation at maximum extent of inundation.

Appendix A: Tsunami terminology and usage in this report.

<table>
<thead>
<tr>
<th>English</th>
<th>Japanese English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow depth</td>
<td>Inundation depth</td>
</tr>
<tr>
<td>Tsunami wave height</td>
<td>Inundation height</td>
</tr>
<tr>
<td>Runup elevation</td>
<td>Runup height</td>
</tr>
</tbody>
</table>

From Jaffe and others (2006).
Appendix B: Maps and photographs of Study Sites Around the Island of Hawai‘i

In the following figures the red line on topographic maps represents the landward extent of inundation, and orange arrows and numerals indicate the inundation distance from mean sea level to the farthest landward extent of the tsunami. Solid lines were created with a GPS track file; dashed lines represent inundation distance inferred, derived, and (or) extrapolated from photographs.

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Figure B17b. Vehicles swept inland at Napo’opo’o Point, Kealakekua Bay.
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