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

Open-File Report 2012–1229

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U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2012

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Suggested citation:
Trusdell, F.A., Chadderton, A., Hinchliffe, G., Hara, A. Patenge, B., and Weber, T., 2012, Tohoku-Oki earthquake tsunami runup and inundation data for sites around the Island of Hawai‘i: U.S. Geological Survey Open-File Report 2012—1229, 36 p.

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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 Hawaiʻi

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Introduction

At 0546 U.t.c. March 11, 2011, a M_w 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 Hawaiʻi.

Although the damage in West Hawaiʻi is well documented, HVO’s mapping revealed that East Hawaiʻi'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 Hawaiʻi.

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*).

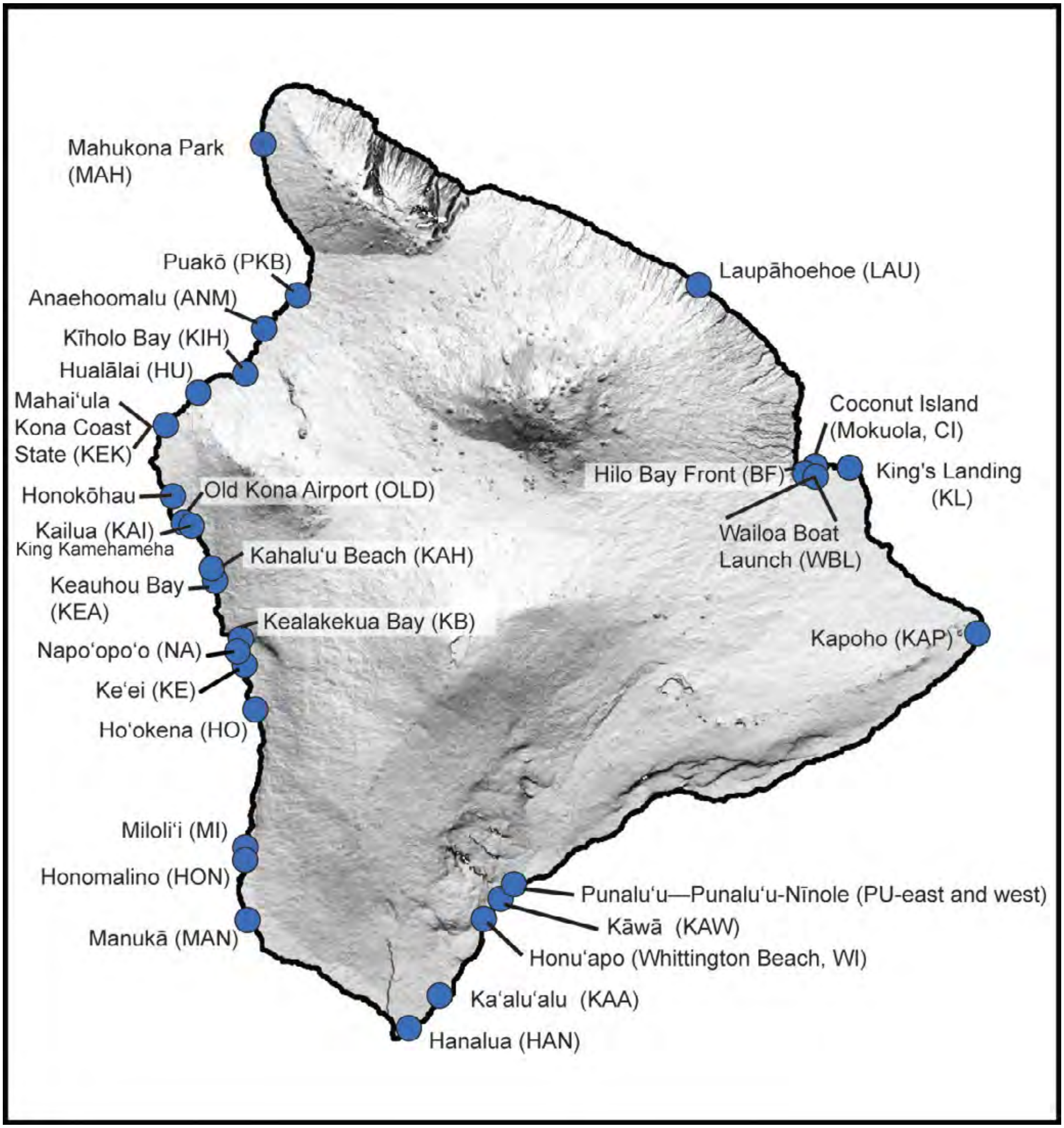

Figure 1. Island of Hawai‘i, showing location of sites where runup and inundation were measured after the 2011 Japanese tsunami.

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 Hawaiʻi

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 Hawaiʻi. 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 (*Hawaiʻi 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		
Hawaiʻi County	$2.3 million	
Maui County	$2.7 million	
City and County of Honolulu	$3.4 million	
Kauai County	$60,400	
Total Public Infrastructure Damages	$8.5 million	
Damage to Businesses and Residents		
West Hawaiʻi businesses	$13.5 million	
Hawaiʻi Island homes	$2.5 million	
Maui County homes	$600,000	
Private property (including boats)	$5.5 million	(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 Hawaiʻi 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.

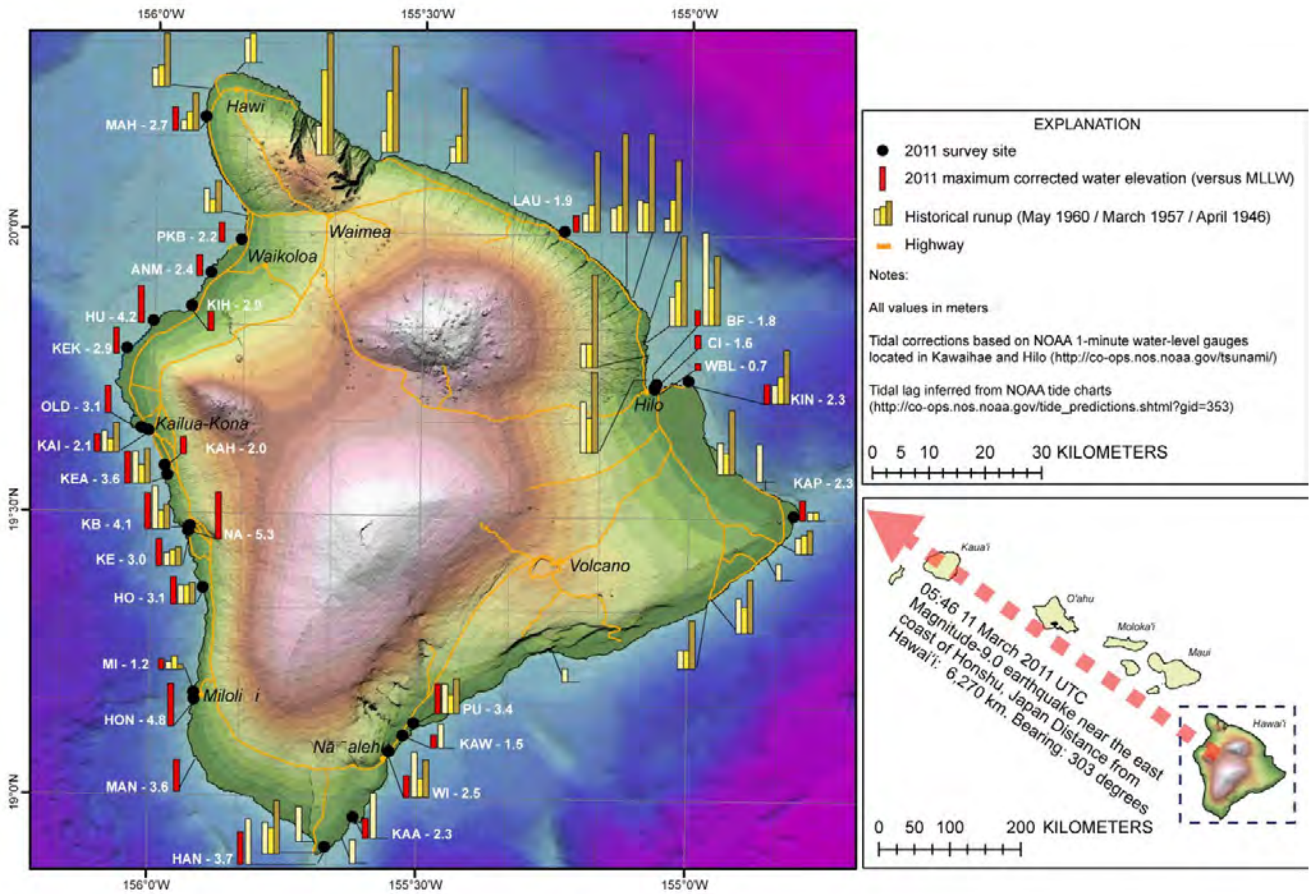

Figure 2. Island of Hawai‘i, showing runup data from 2011 Tohoku-Oki tsunami (red bars) in comparison with those from the 1960, 1957, and 1946 tsunamis. Earlier tsunamis arrived in Hawai‘i generally from the east, resulting in higher runups on east side of island.

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.

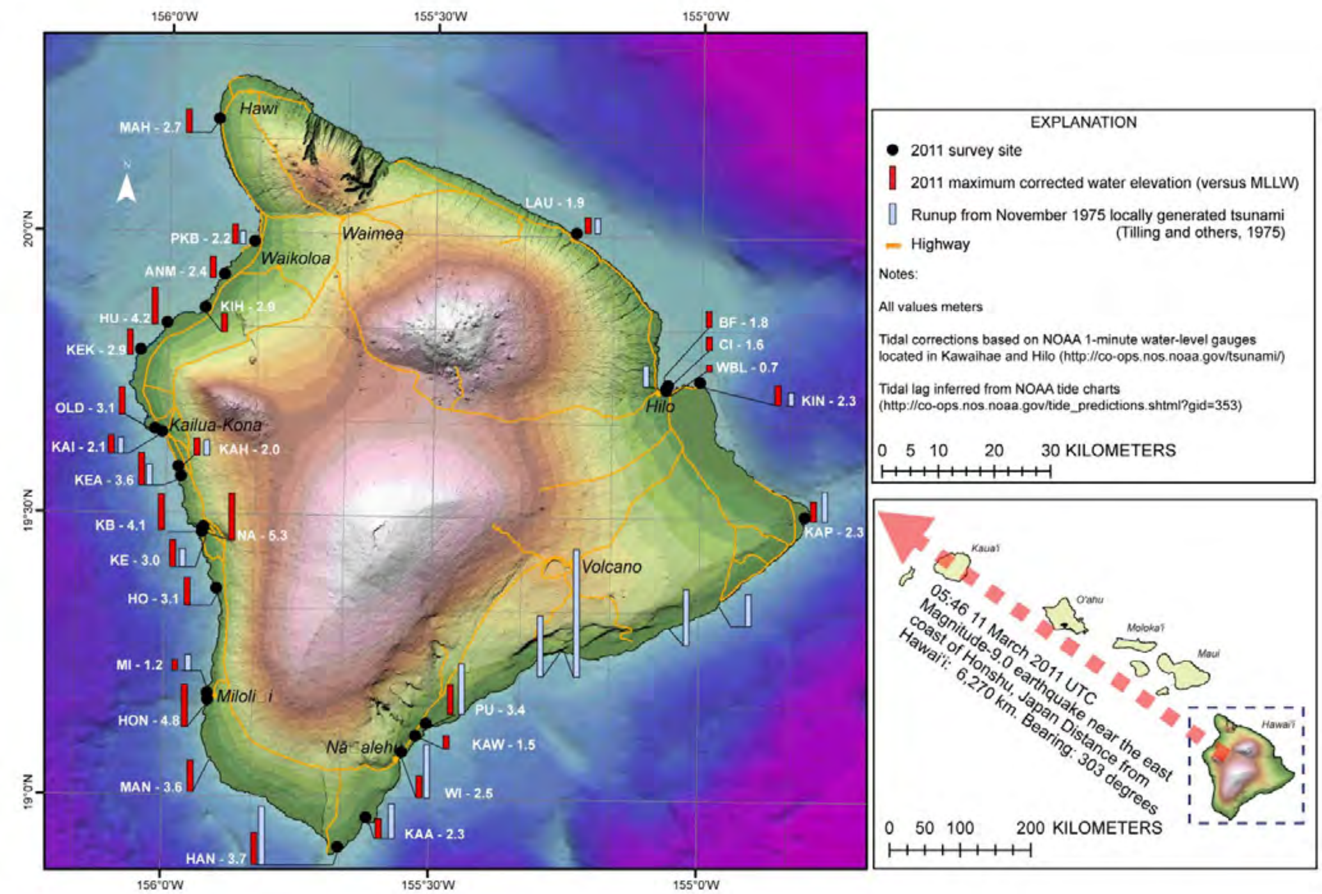

Figure 3. Island of Hawai'i, showing runup data from the 2011 Tohoku-Oki tsunami (red bars) in comparison with those from locally generated tsunami accompanying the 1975 M 7.2 Kalapana earthquake. As expected, runup from local tsunami was highest near the epicenter along the southeast coast.

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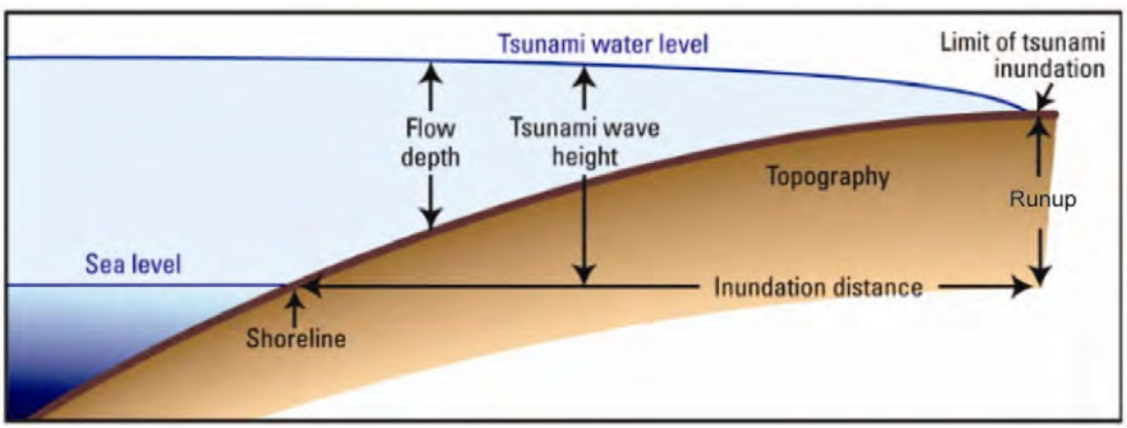
Glossary

inundation Inland flooding.
inundation distance Maximum inland distance of flooding.
runup Elevation at maximum extent of inundation.

Appendix A: Tsunami terminology and usage in this report.



English	Japanese English
Flow depth	Inundation depth
Tsunami wave height	Inundation height
Runup elevation	Runup height

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.

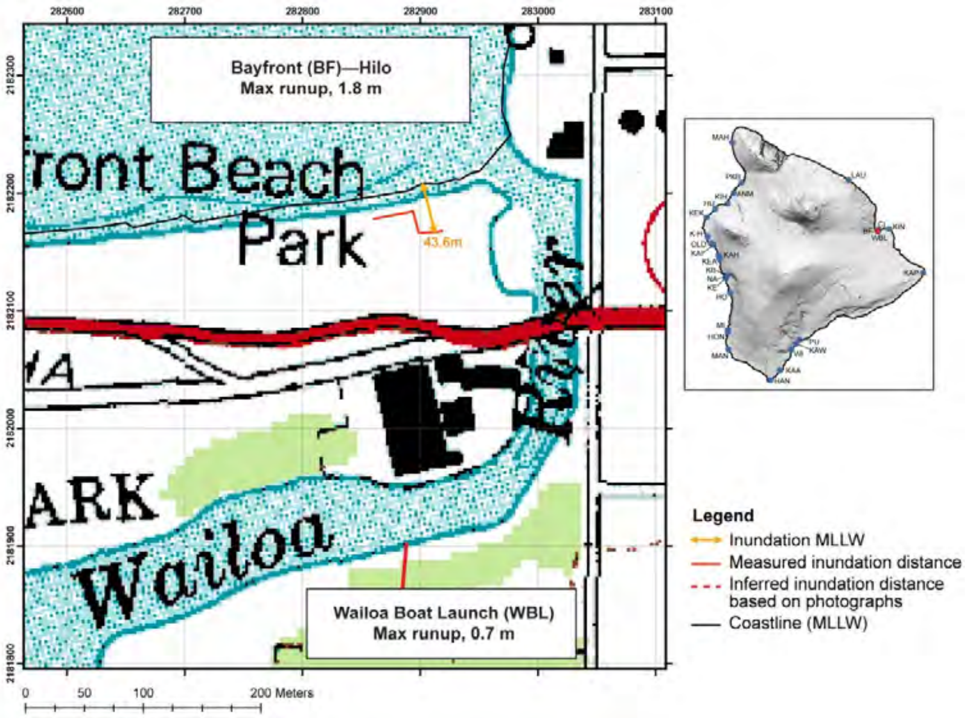


Figure B 1a. Wailoa River outlet. Area of study site near mouth of outlet; runup, 1.8 m.

Figure B1b. Debrisline near mouth of outlet near Suisan fish market in Hilo.

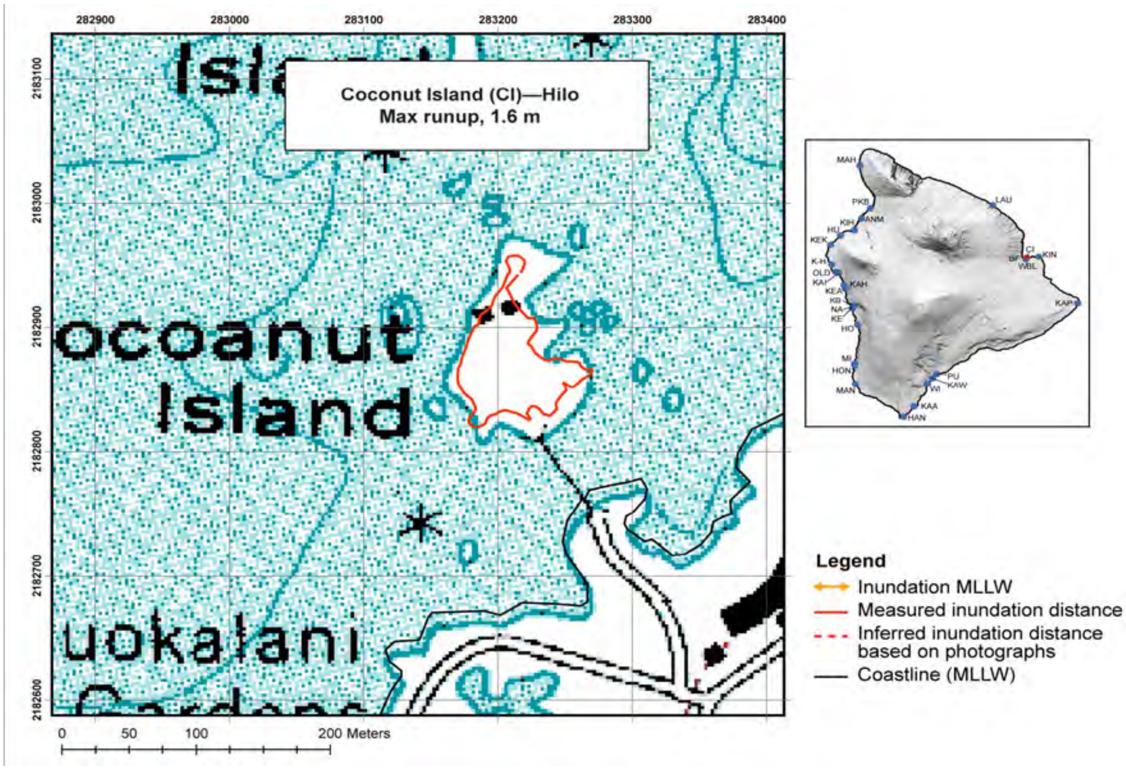


Figure B2a. Cocoanut Island (Mokuola). Area of study site near the Hilo Hawaiian Hotel in Hilo; runup, 1.6 m.

Figure B2b. Debrisline on Cocoanut (Coconut) Island (Mokuola) in Hilo.

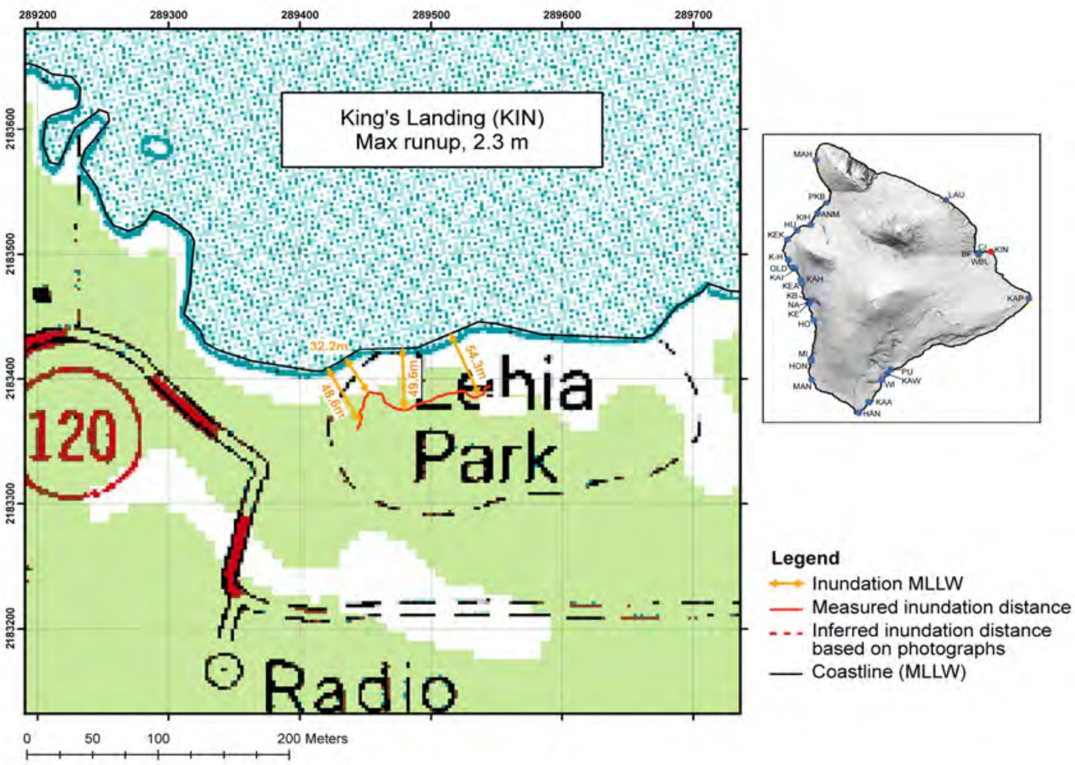


Figure B3. King's Landing, near Richardson Ocean Center, Hilo; runup, 2.3 m.

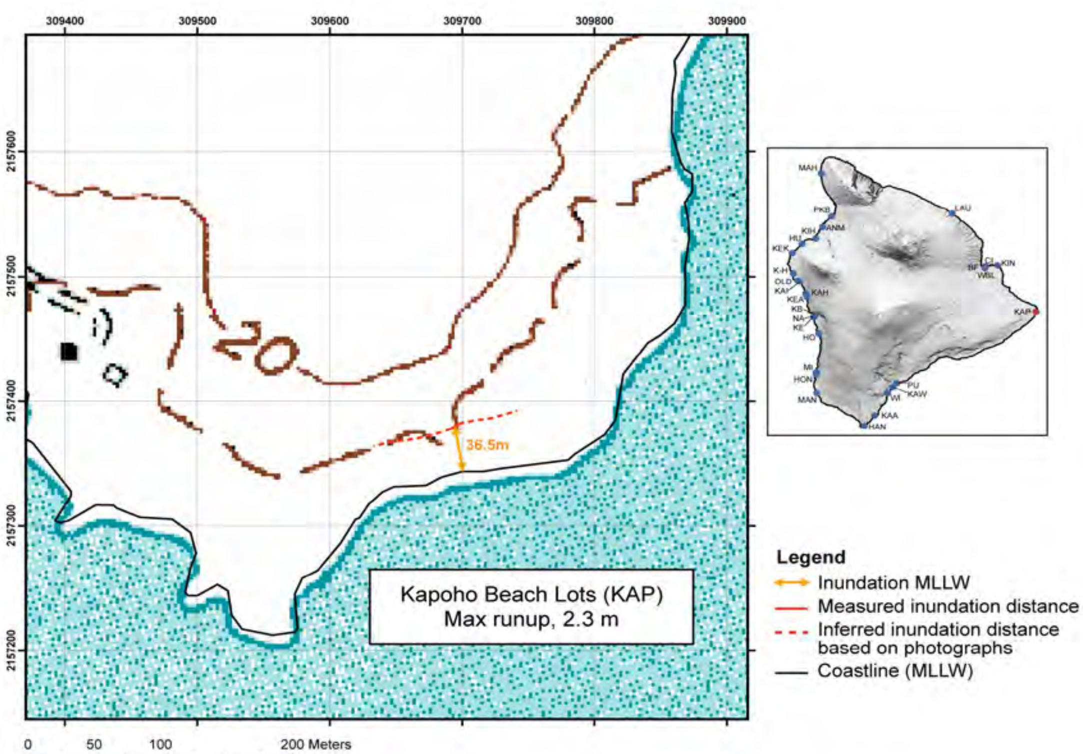


Figure B4. Kapoho Beach Lots near Cape Kumukahi, Puna; runup, 2.3 m.

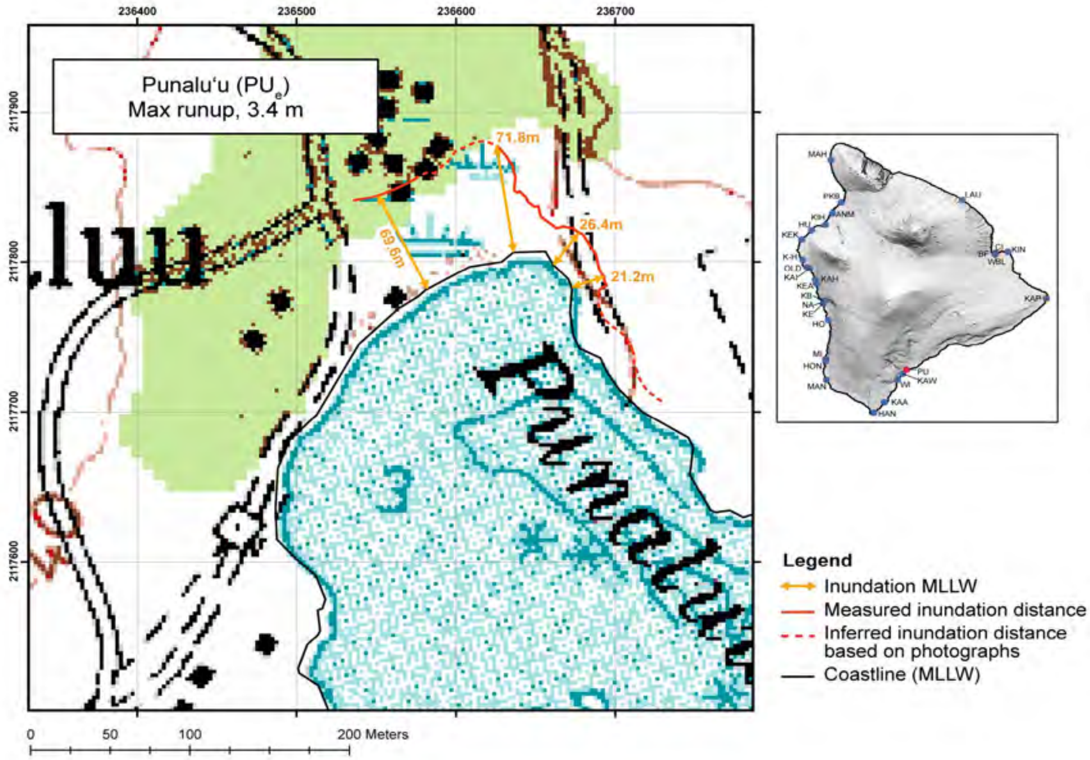


Figure B5a. Punaluʻu Beach. Area of study site in Punaluʻu, Kaʻū; runup, 3.4 m.

Figure B5b. Debrisline at base of coconut trees in backshore of Punaluʻu Bay, Kaʻū.

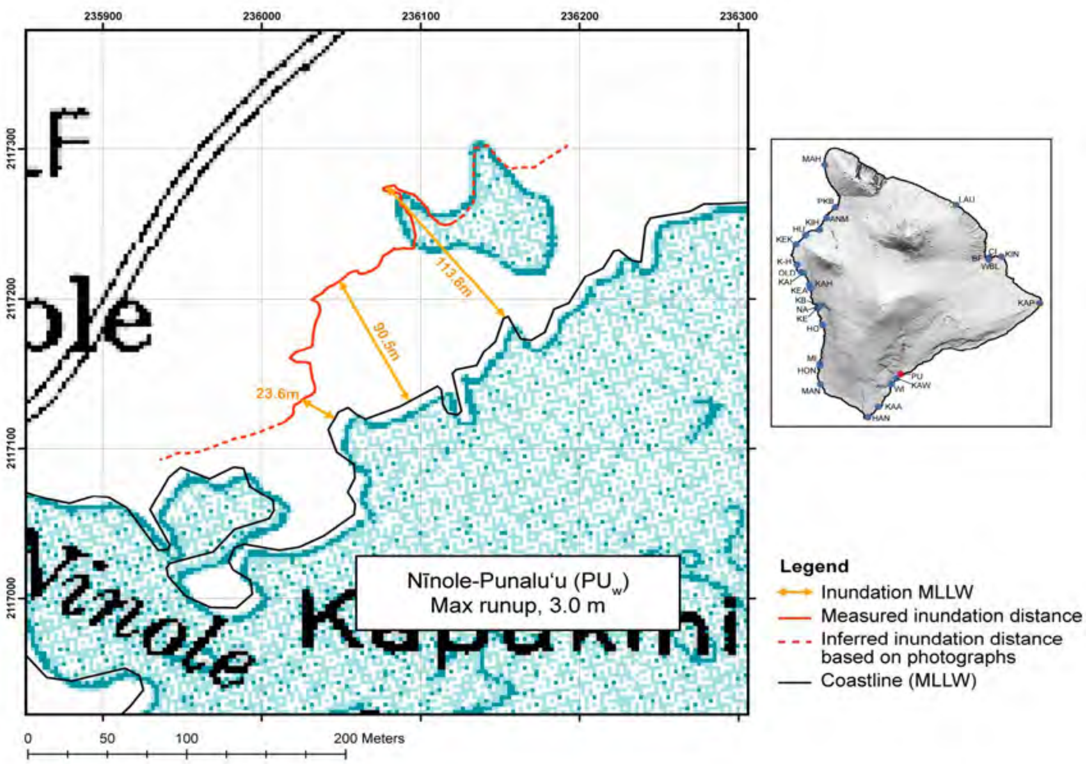


Figure B6a. Nīnole, west of Punaluʻu Beach Park. Area of study site in Punaluʻu, Kaʻū; runup, 3.0 m.

Figure B6b. Flowlines pressed onto grass the backshore of Nīnole, Kaʻū.

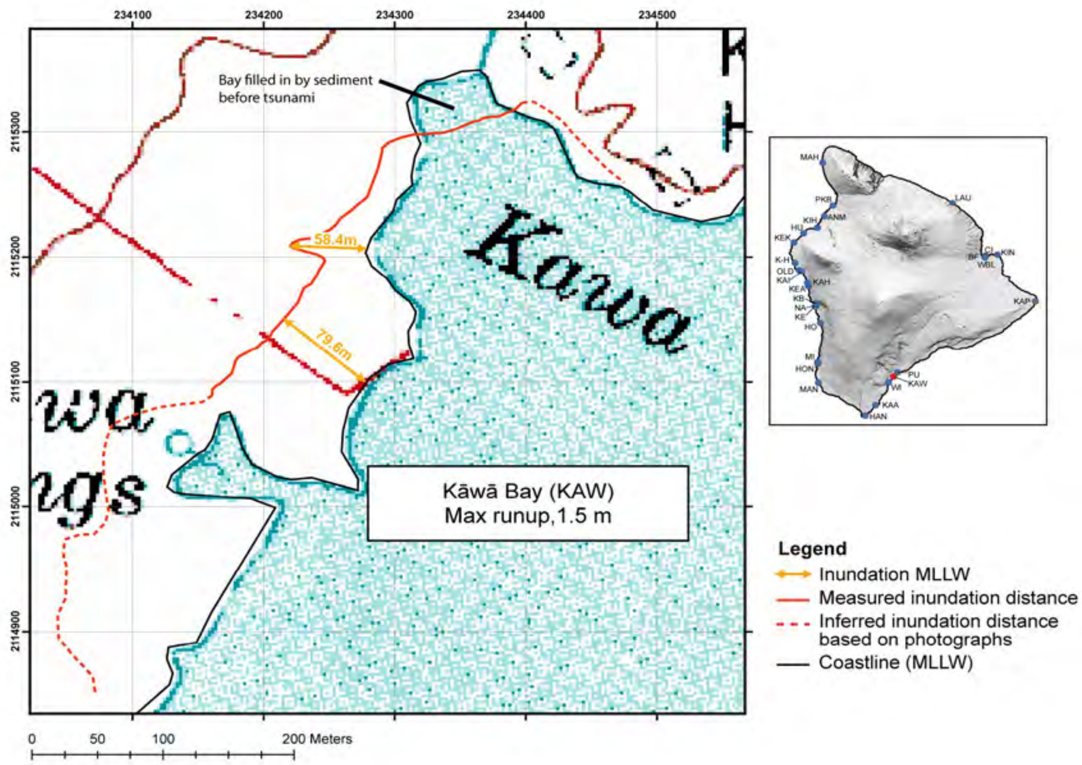


Figure B7. Kāwā, Ka‘ū, showing area of study site; runup, 1.5 m.

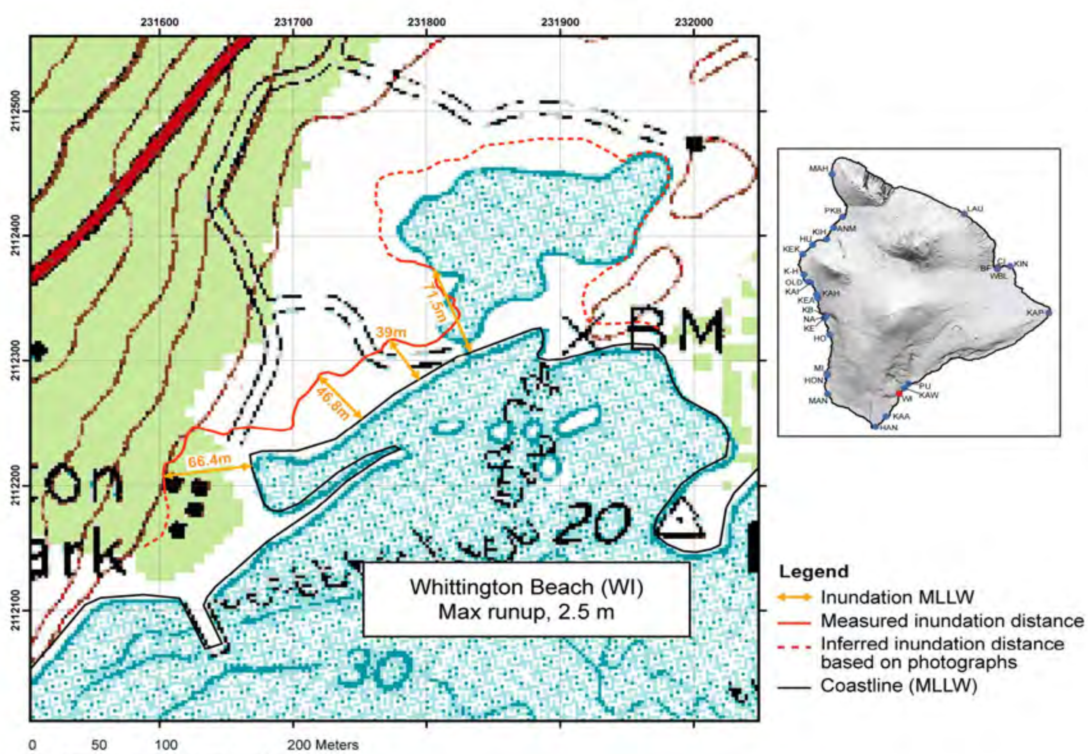


Figure B8. Whittington Beach Park, Ka‘ū, showing area of study site; runup 2.5 m.

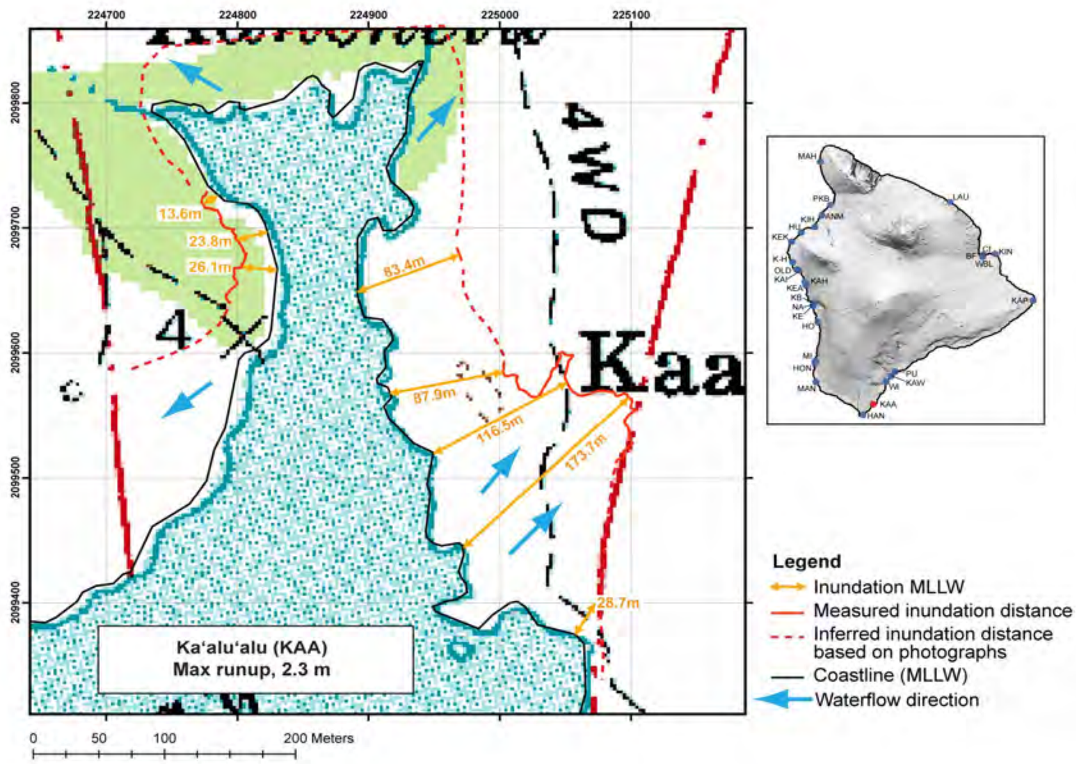


Figure B9a. Ka'alu'alu Bay, Ka'ū. Area of study site; runup, 2.3 m.

Figure B9b. Debrisline in backshore of Ka'alu'alu Bay, Ka'ū. Note shoreline nearly 200 m away, near coconut trees, in background.

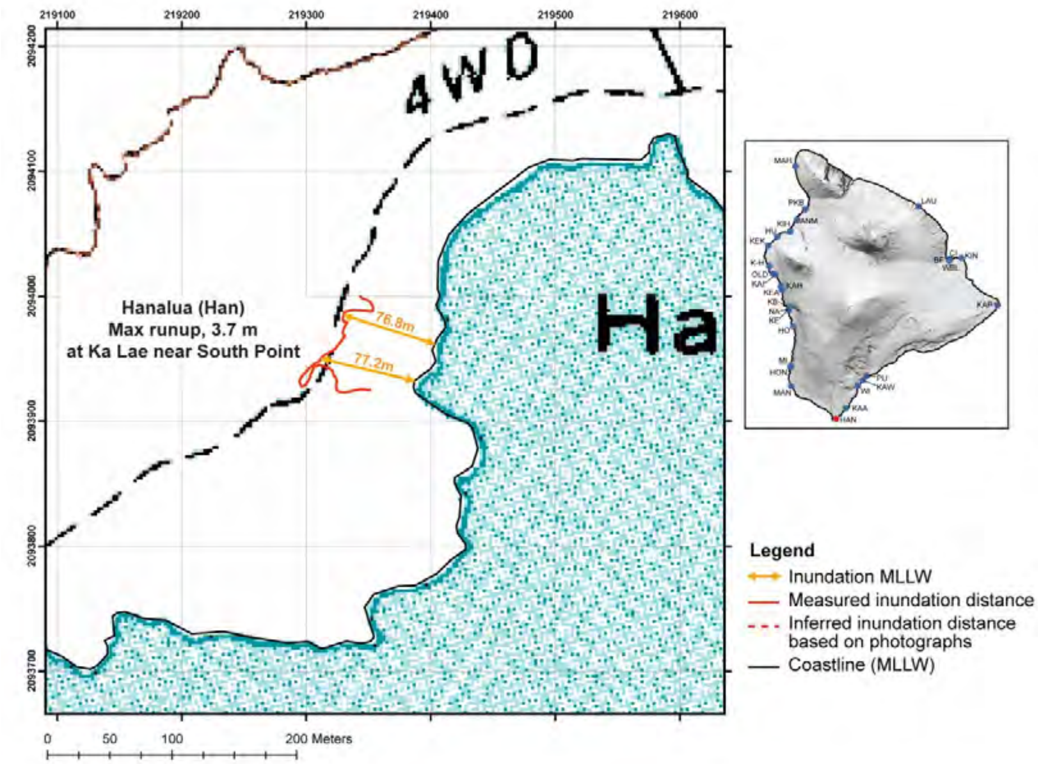


Figure B10. Hanalua Bay, showing area of study site east of South Point, Ka‘ū; runup, 3.7 m.

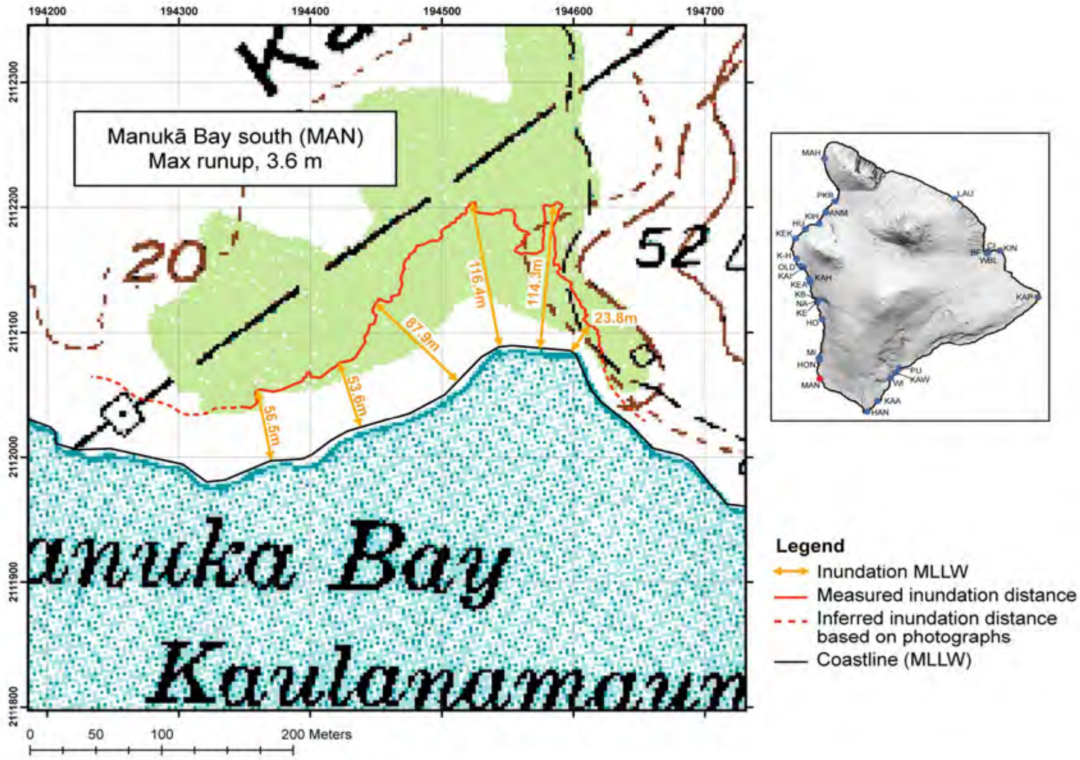


Figure B11a. Manukā Bay east, Ka'ū. Area of study site; runup, 3.6 m.

Figure B11b. Western part of Manukā Bay east, Ka'ū; runup, 3.6 m.

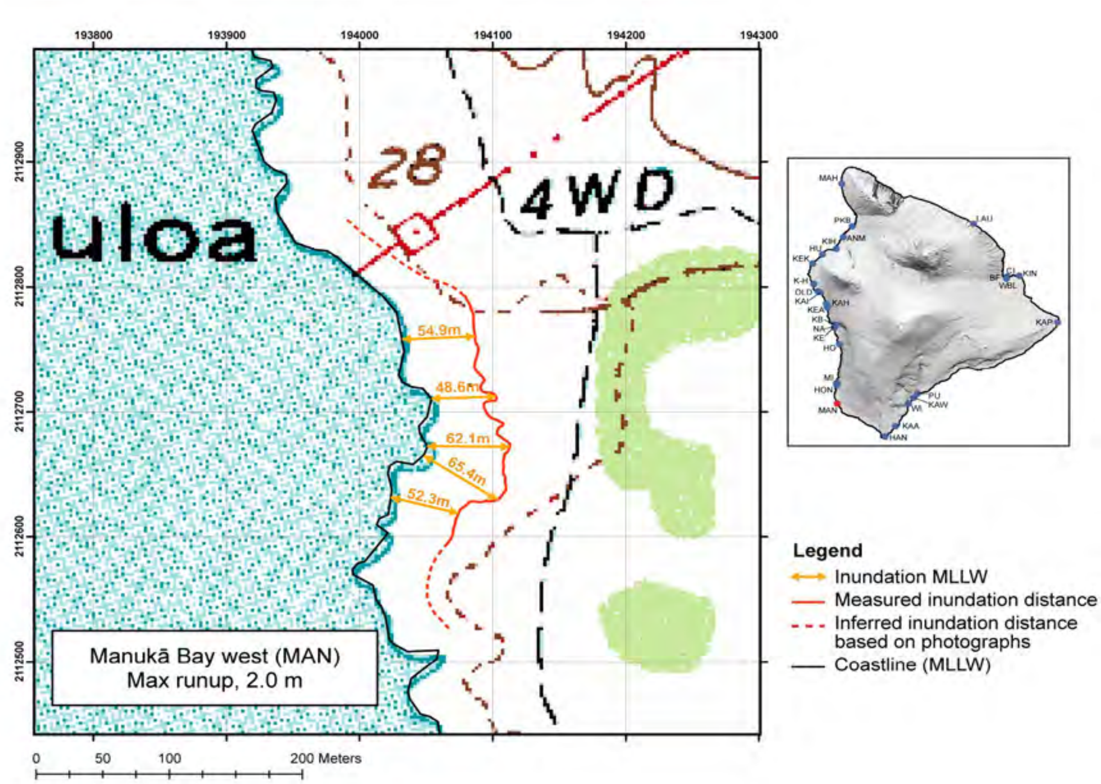


Figure B12a. Manukā Bay west, Kaʻū. Area of study site; runup, 2 m.

Figure B12b. Debrisline at Manukā Bay west, Kaʻū; runup, 2.0 m.

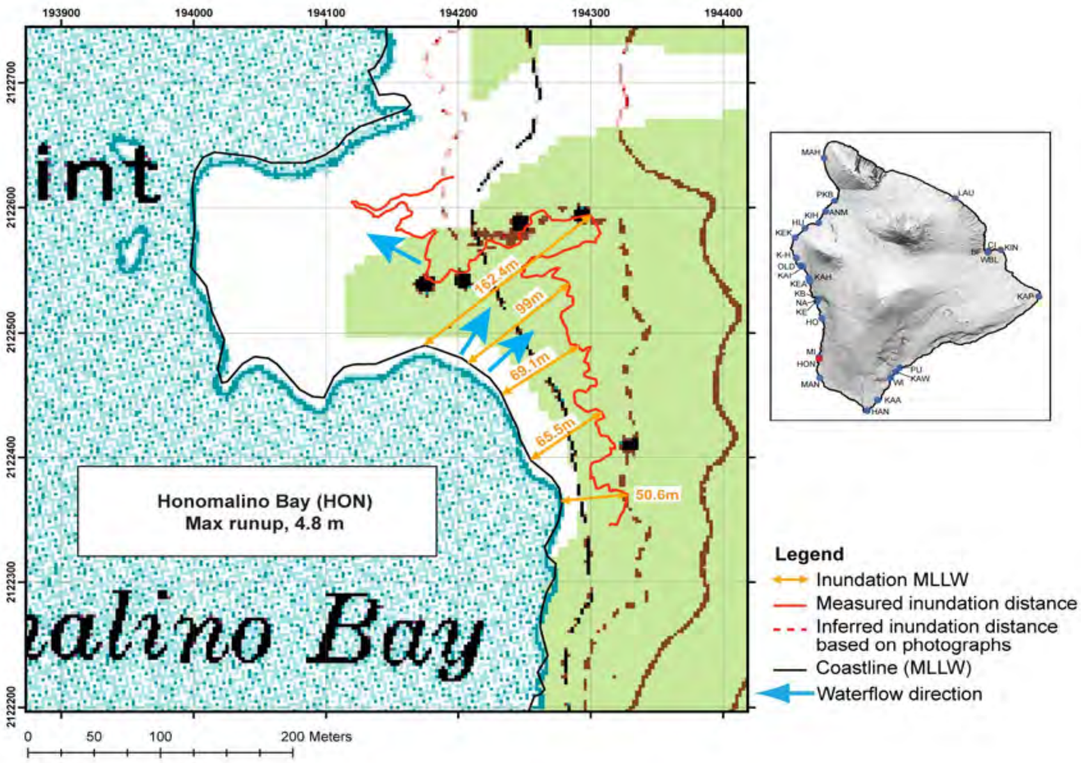


Figure B13a. Honomalino Bay, Ka‘ū. Area of study site; runup, 4.8 m.

Figure B13b. Home located on northern point of Honomalino Bay, Ka‘ū.

Figure B13c. Debris washed inland approximately 160 m at Honomalino Bay, Ka‘ū.

Figure B13d. Signage bent by force of tsunami at Honomalino Bay, Ka‘ū.

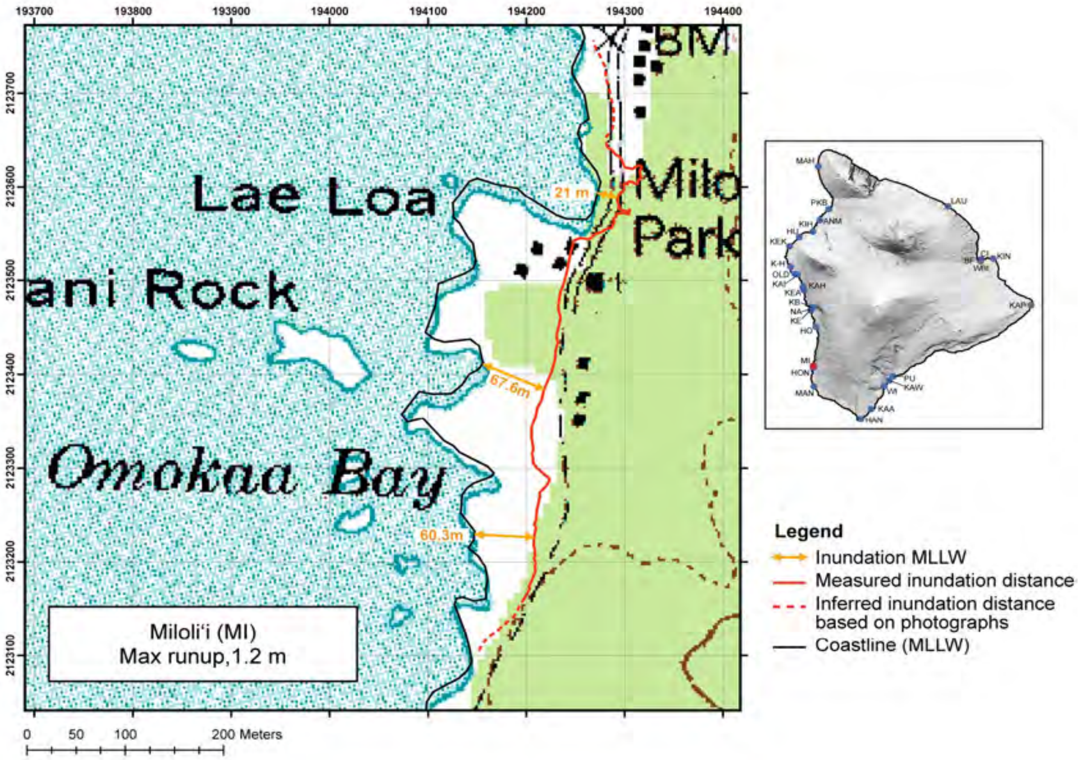


Figure B14a. Miloli'i Beach Park, Ka'ū. Area of study site; runup, 1.2 m.

Figure B14b. Debris from tsunami along road near Miloli'i Beach Park, Ka'ū.

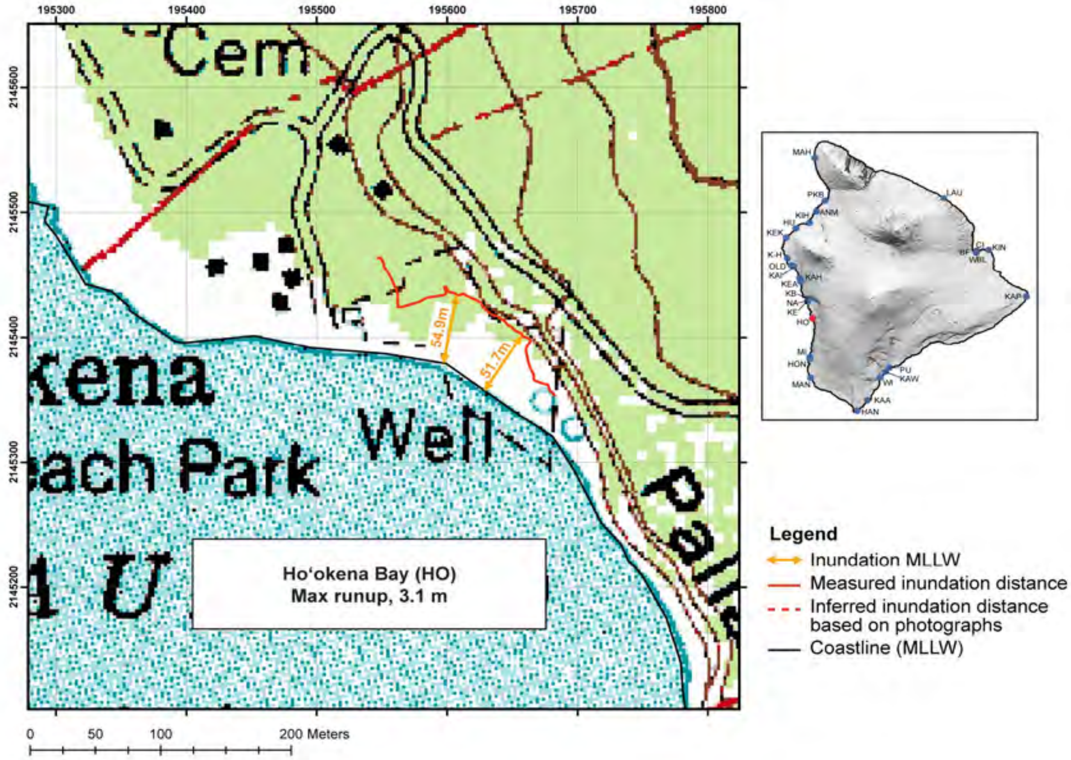


Figure B15. Ho'okena Bay Park, Ka'ū, showing area of study site; runup 3.1 m.

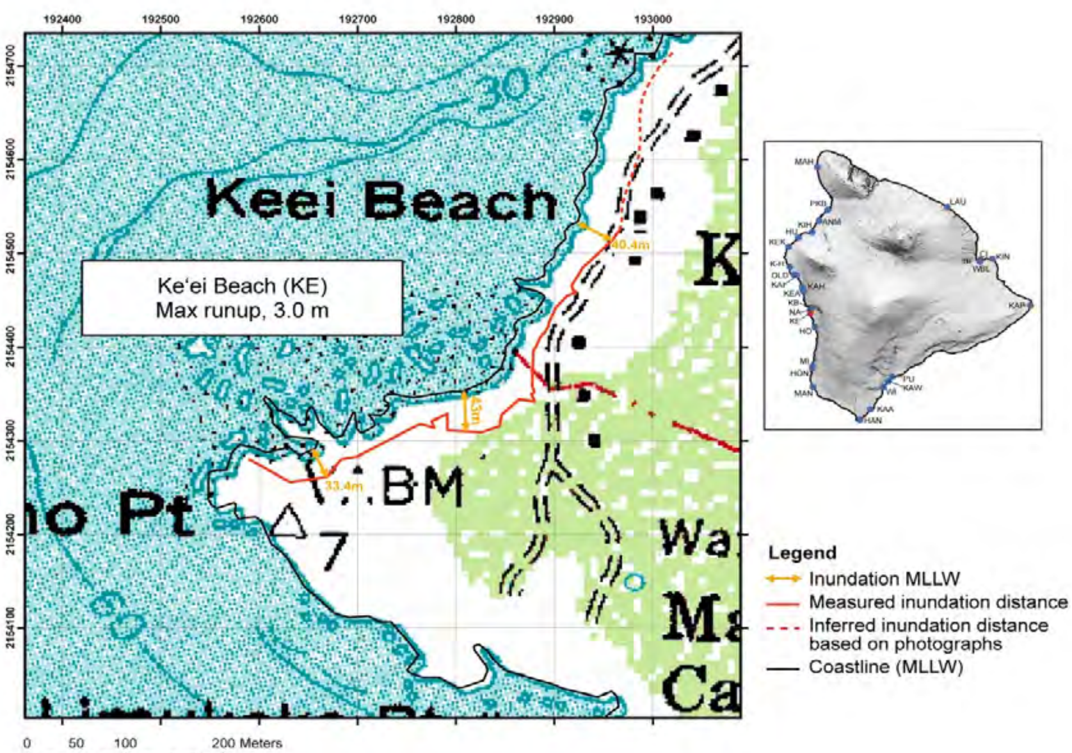


Figure B16. Ke'ei Beach, Ka'ū, showing area of study site; runup, 3 m.

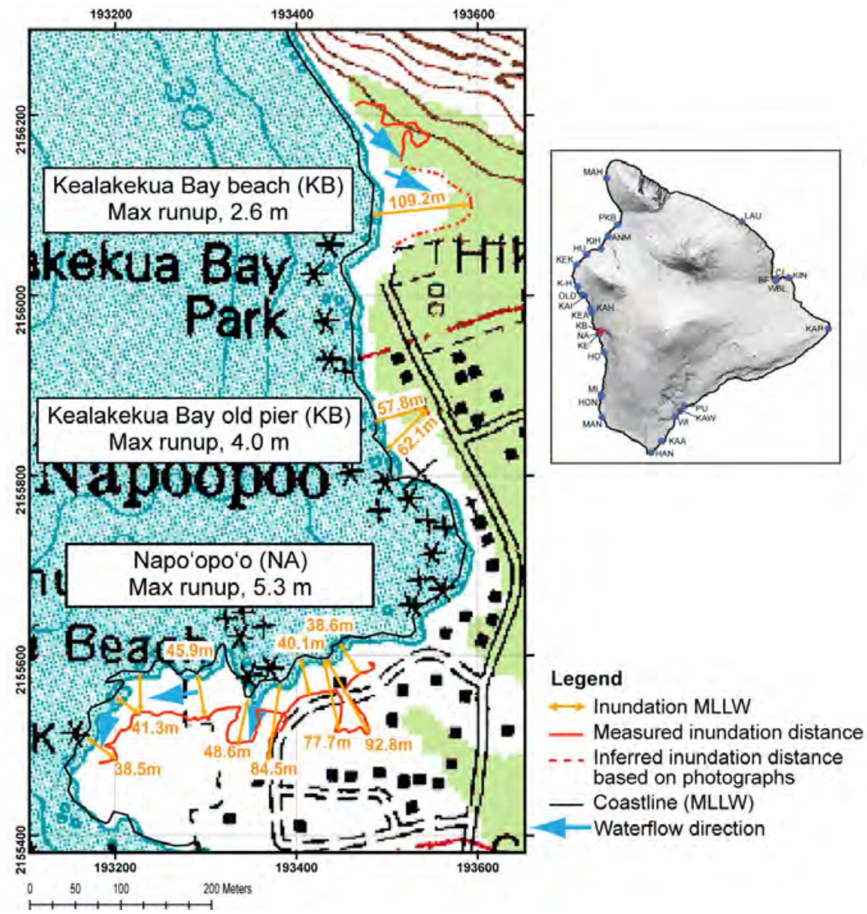


Figure B17a. Napo‘opo‘o Point and old pier and beach at Kealakekua Bay. Area of study site; runup, 5.3, 4, and 2.6 m.

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

Figure B17c. Vehicles swept inland at Napo‘opo‘o Point, Kealakekua Bay.

Figure B17d. Debris swept inland at Napo‘opo‘o Point, Kealakekua Bay. Note debris pile at base of tree to left of center in photograph.

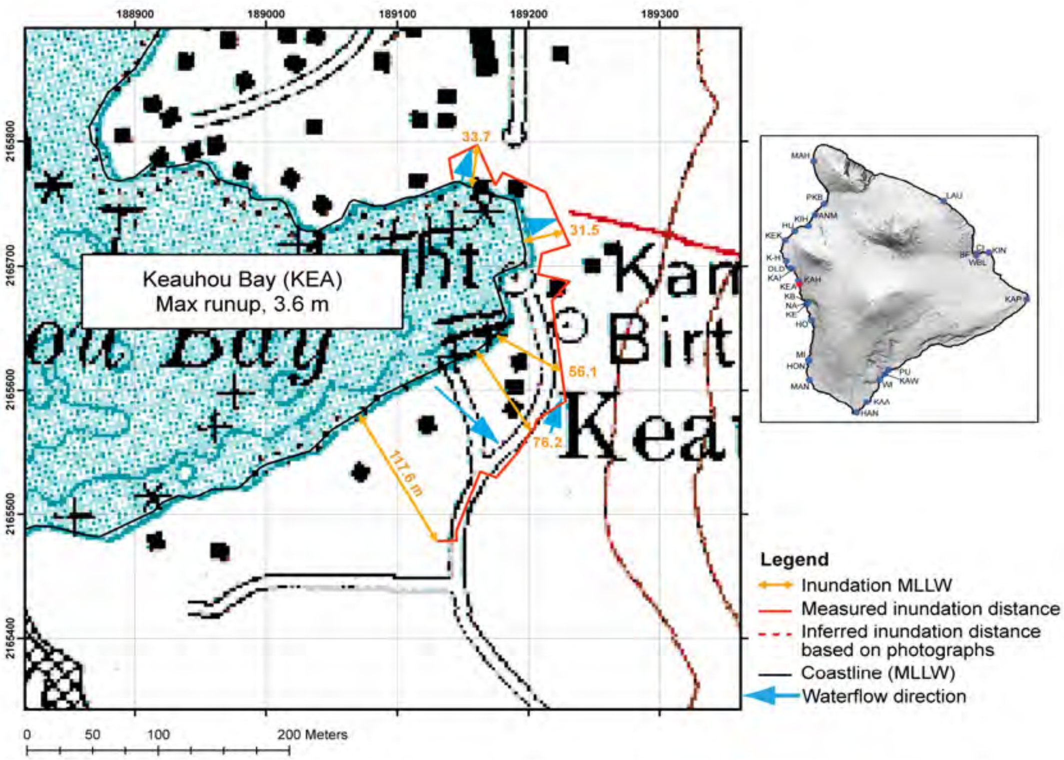


Figure B18a. Keauhou Bay, Kailua-Kona. Area of study site; runup, 3.6 m.

Figure B18b. View of Keauhou Bay outward from store. Wave reached top of vertical 2 by 4s (to right).

Figure B18c. Store-front walls breached by tsunami at Keauhou Bay. Wave reached top of vertical 2 by4s.

Figure B18d. North side of Keauhou Bay, where tsunami flooded park and washed onto roadway.

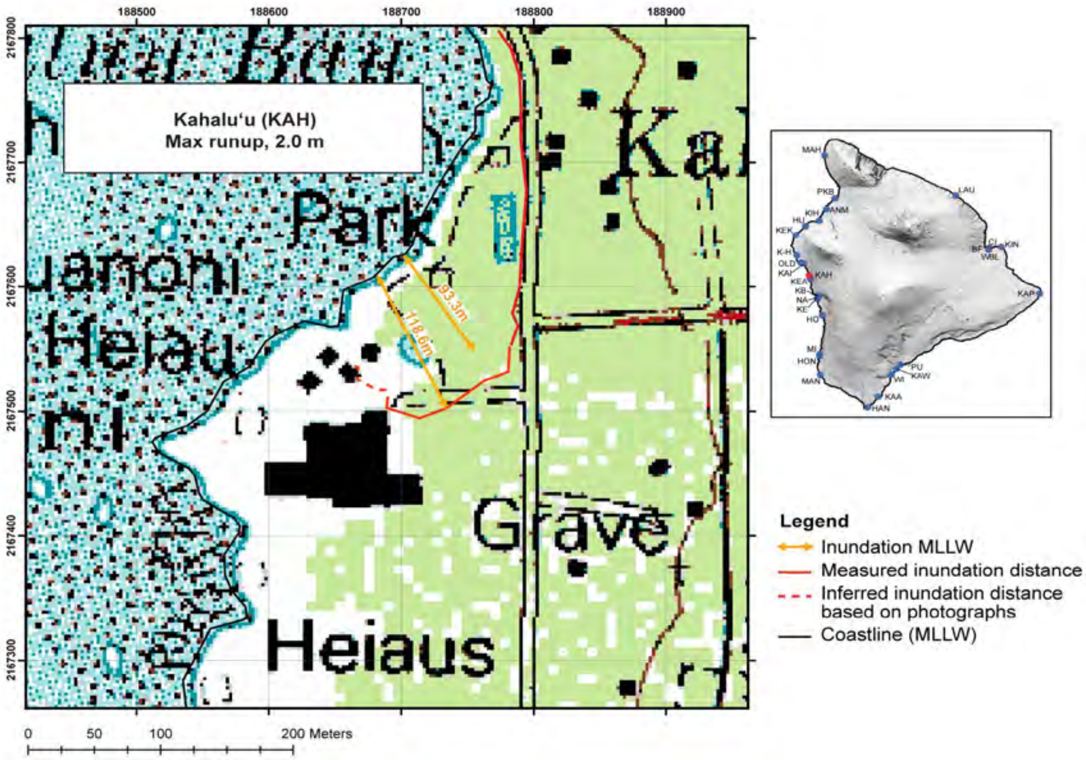


Figure B19. Kahalu‘u Bay, Kailua-Kona, showing area of study site; runup, 2 m.

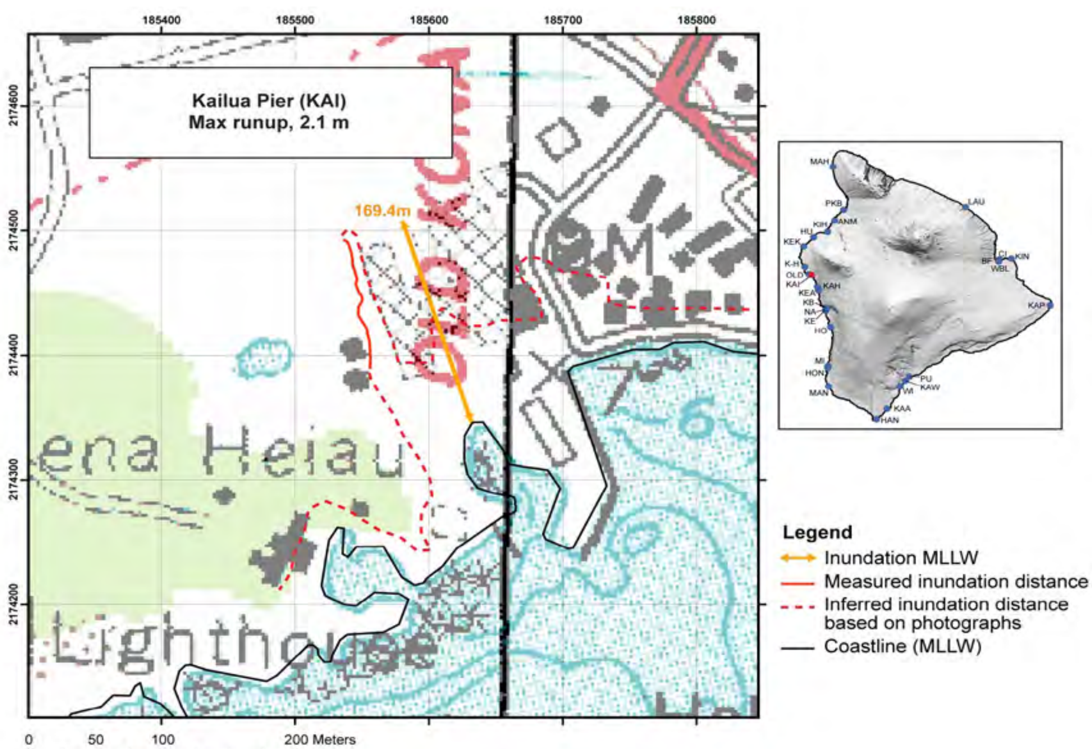


Figure B20a. Kailua Bay near the King Kamehameha Hotel, Kailua-Kona. Area of study site; runup, 2.1 m.

Figure B20b. Bar door with water-level line. Bar walls in background were breached by tsunami.

Figure B20c. Lūʻau grounds at the King Kamehemeha Hotel swept by tsunami. The Kailua pier in background was flooded by tsunami.

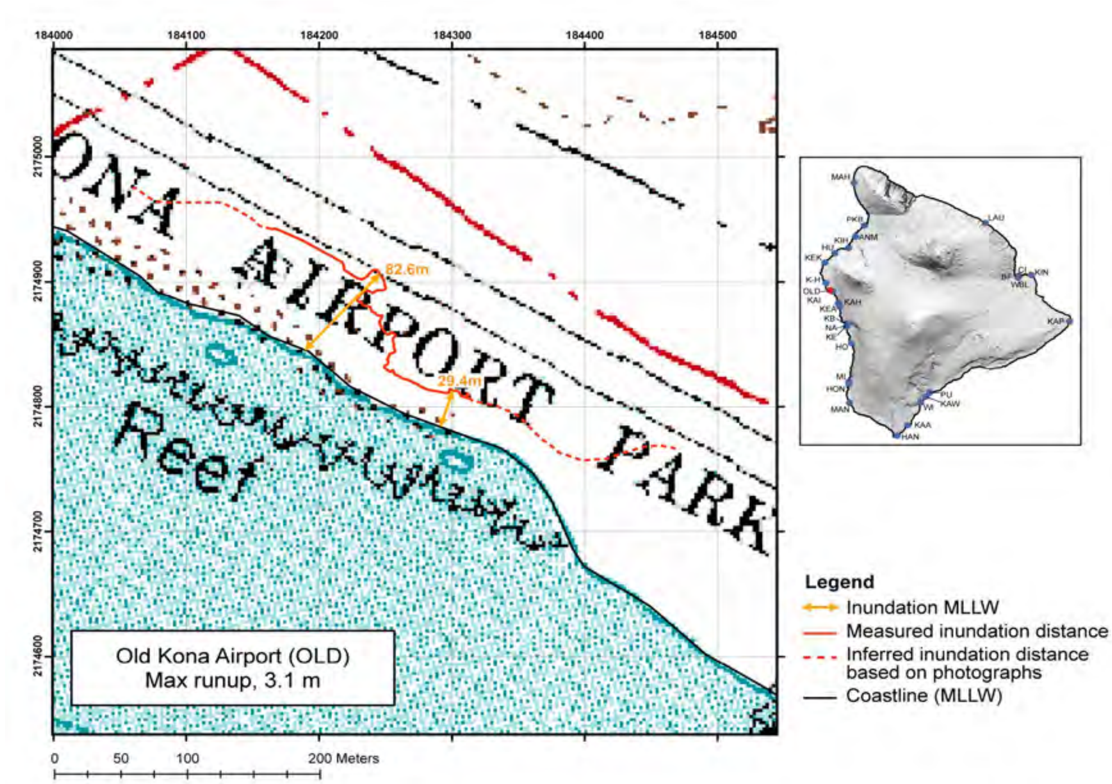


Figure B21a. Old Kona Airport Park, north of Kailua-Kona. Area of study site; runup, 3.1 m.

Figure B21b. Debrisline at the Old Kona Airport Park, north of Kailua-Kona.

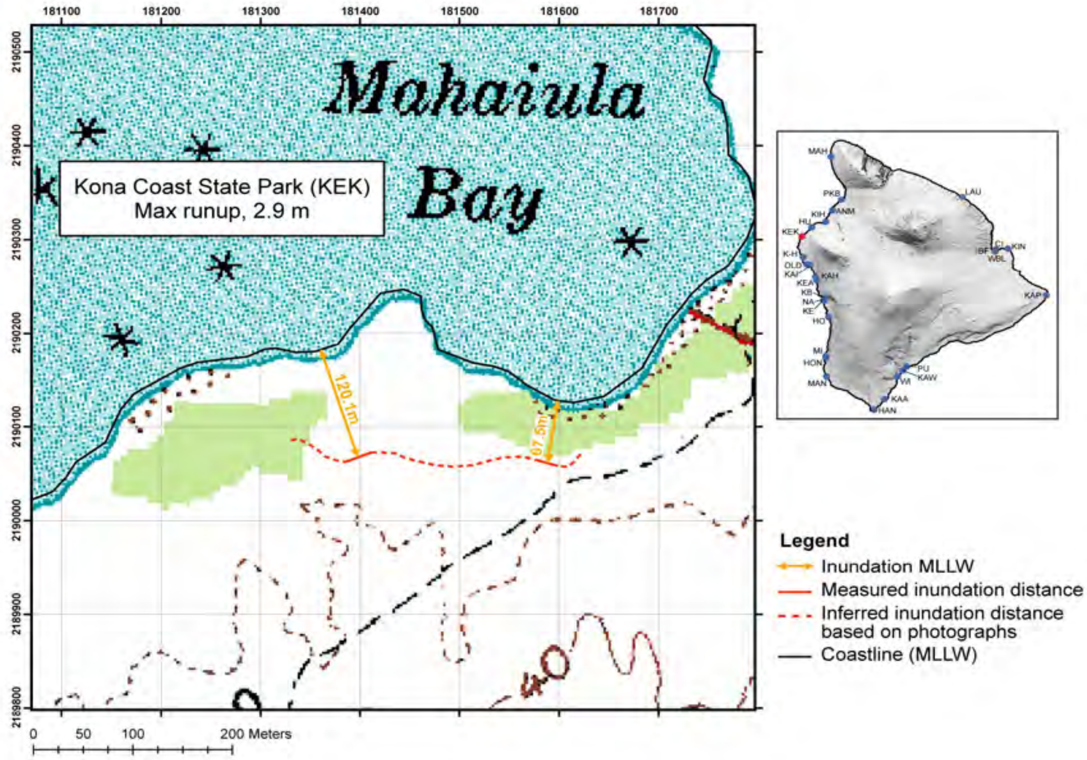


Figure B22a. Mahai‘ula Bay or Kona Coast State Park, north of the Kona Airport. Area of study site; runup, 2.9 m.

Figure B22b. Debris swept 120 m inland at Mahai‘ula Bay.

Figure B22c. Strandline at Mahai‘ula Bay.

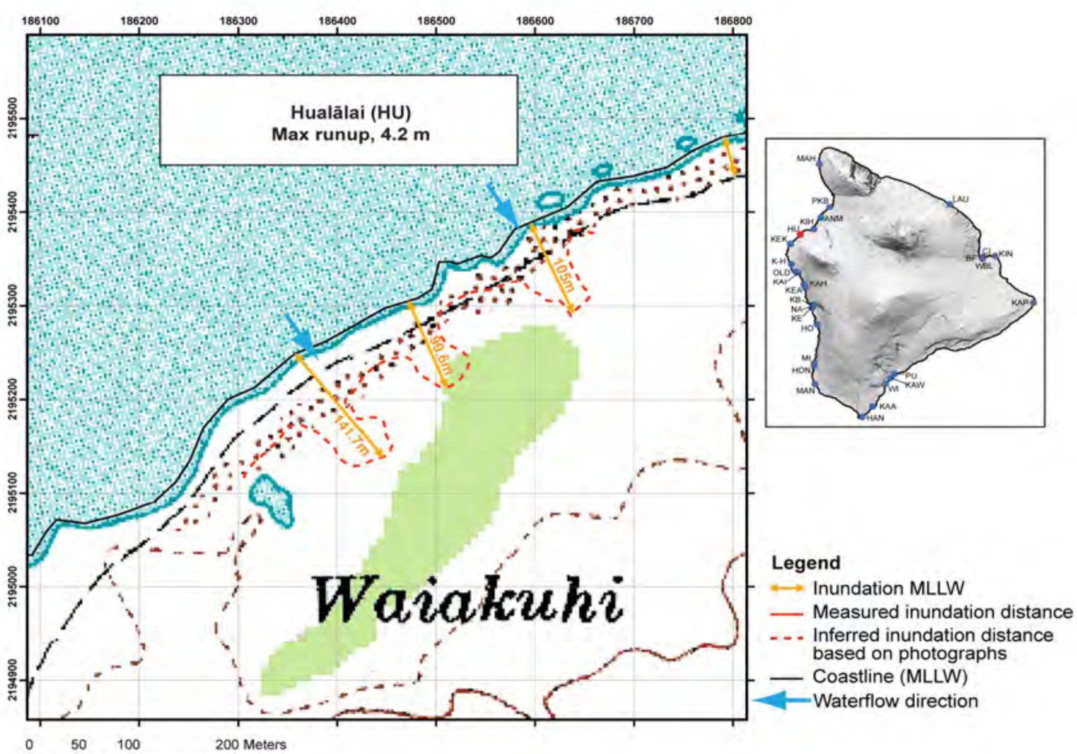


Figure B23. Hualālai resort beach at the Four Seasons Hotel, showing area of study site; runup, 4.2 m.

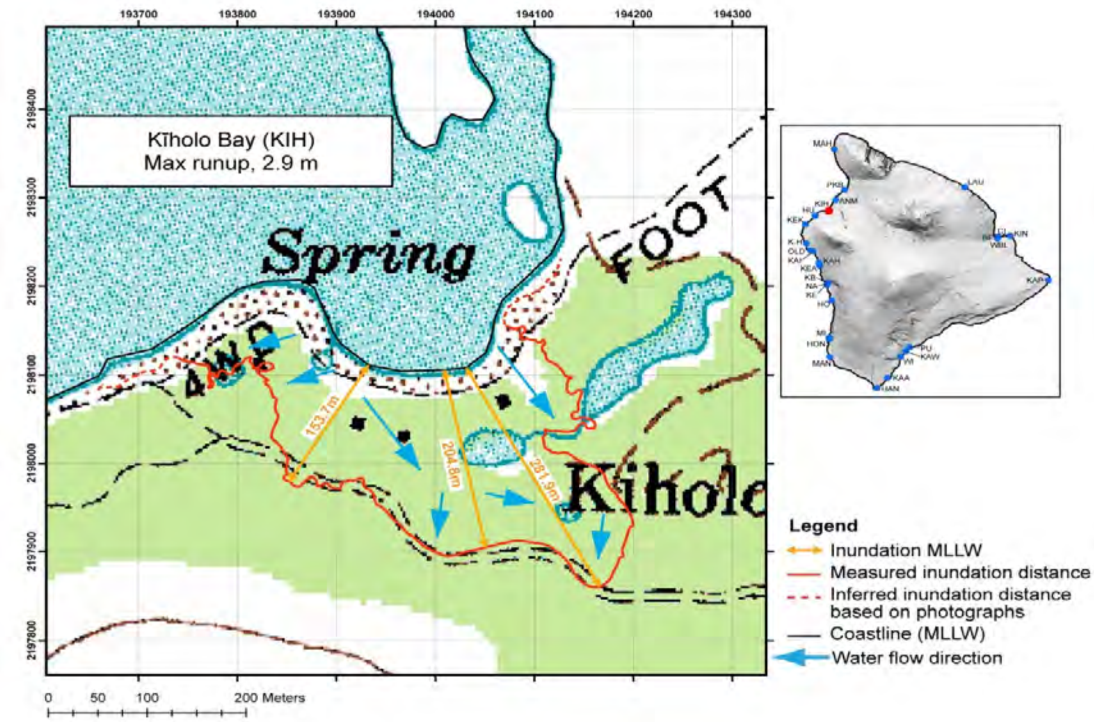


Figure B24a. Kīholo Bay, north side. Area of study site; runup, 2.9 m.

Figure B24b. Private home with breakaway walls. Structure sustained minimal damage.

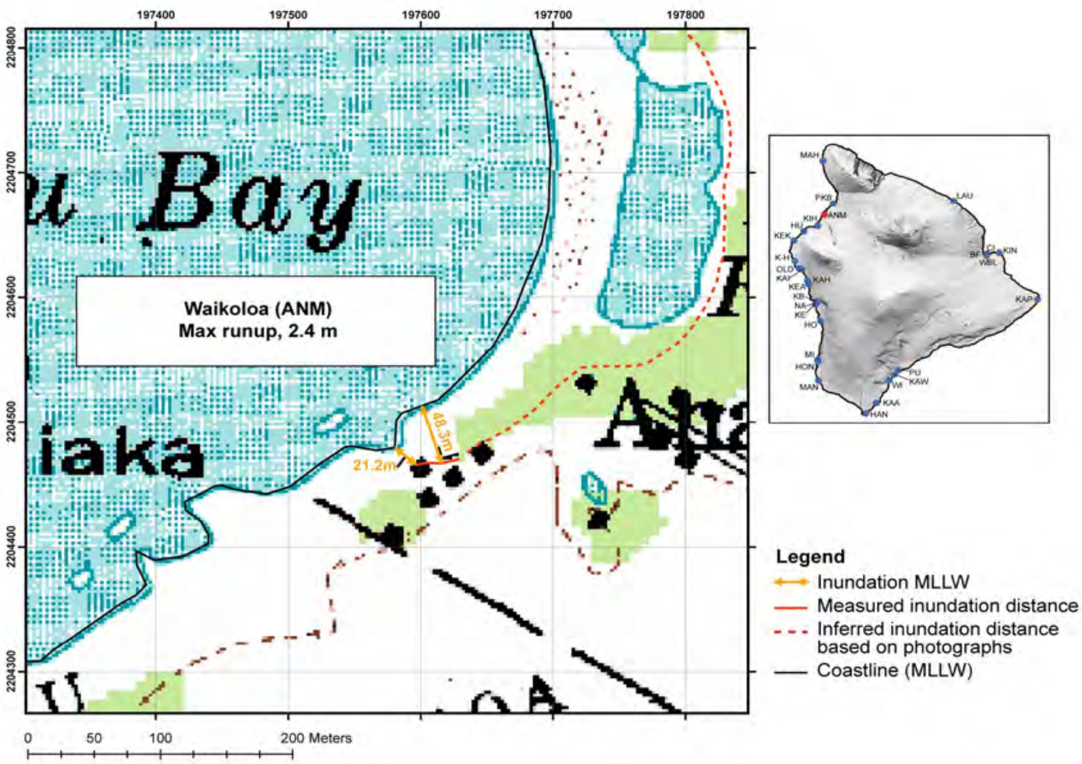


Figure B25a. Anaehoʻomalu Bay, Waikoloa. Area of study site; runup, 2.4 m.

Figure B25b. Fishpond breached by tsunami. View northward.

Figure B25c. Fishpond breached by tsunami. View northwestward.

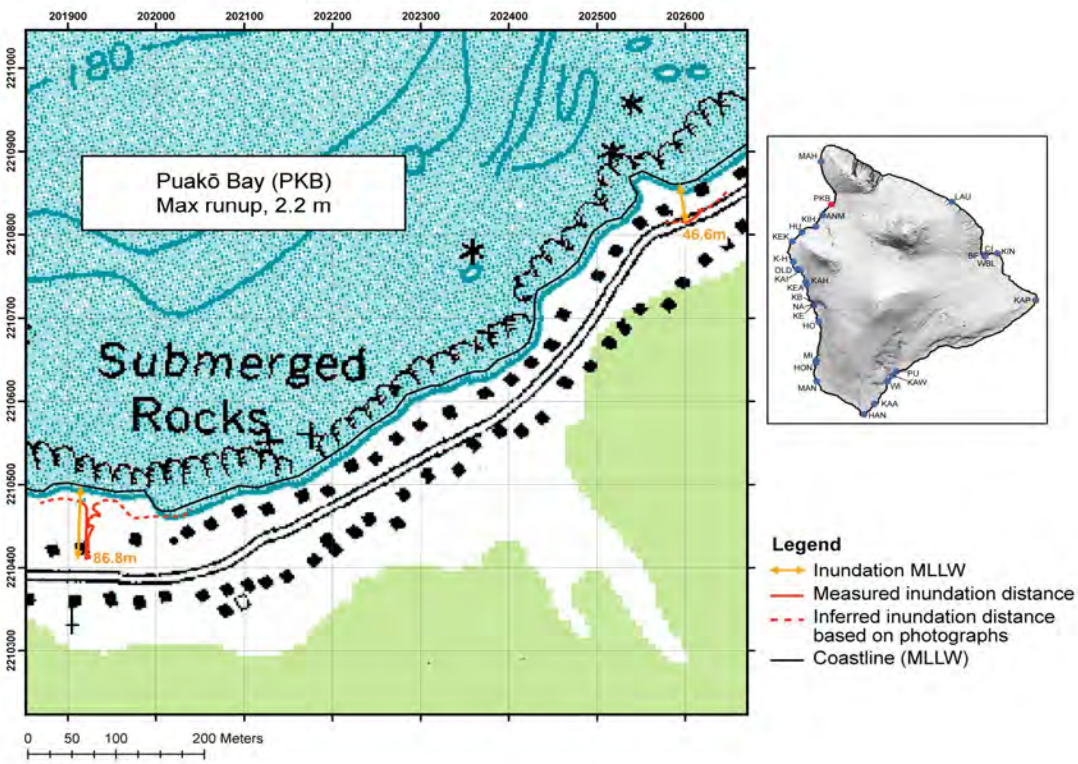


Figure B26a. Puakō Bay, North Kona. Area of study site; runup, 2.2 m.

Figure B26b. Debris swept inland on beach right-of-way at Puakō.

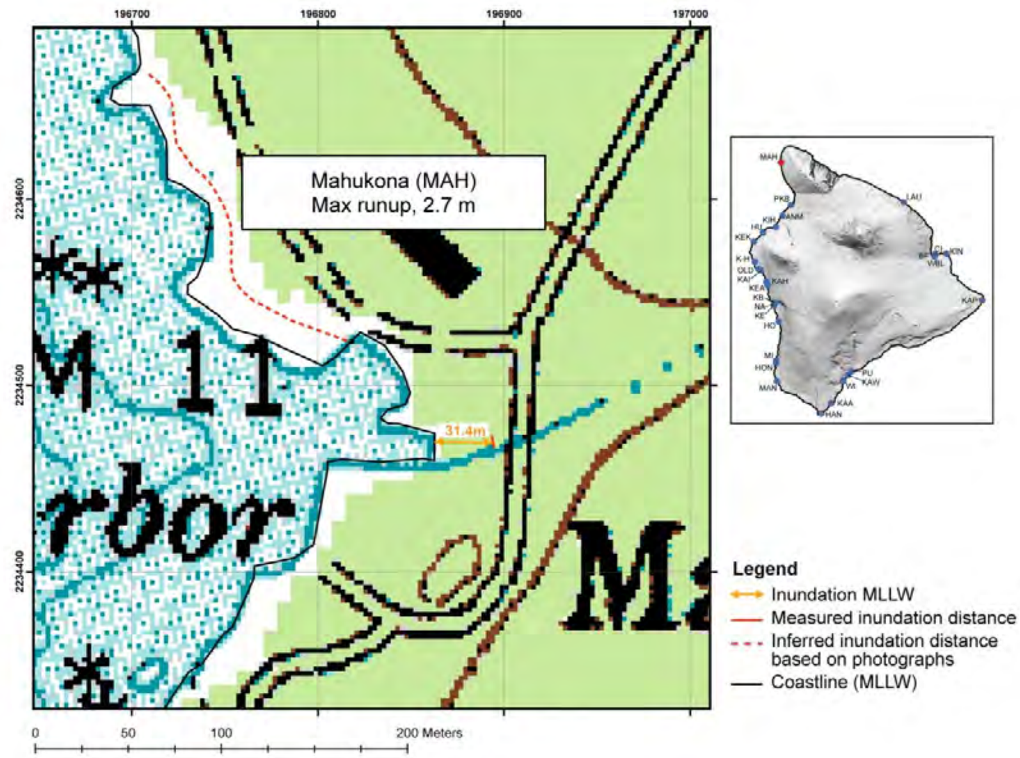


Figure B27a. Mahukona Harbor, Kohala. Area of study site; runup, 2.7 m.

Figure B27b. Debris swept inland up drainage ditch near old wharf at Mahukona Beach Park.

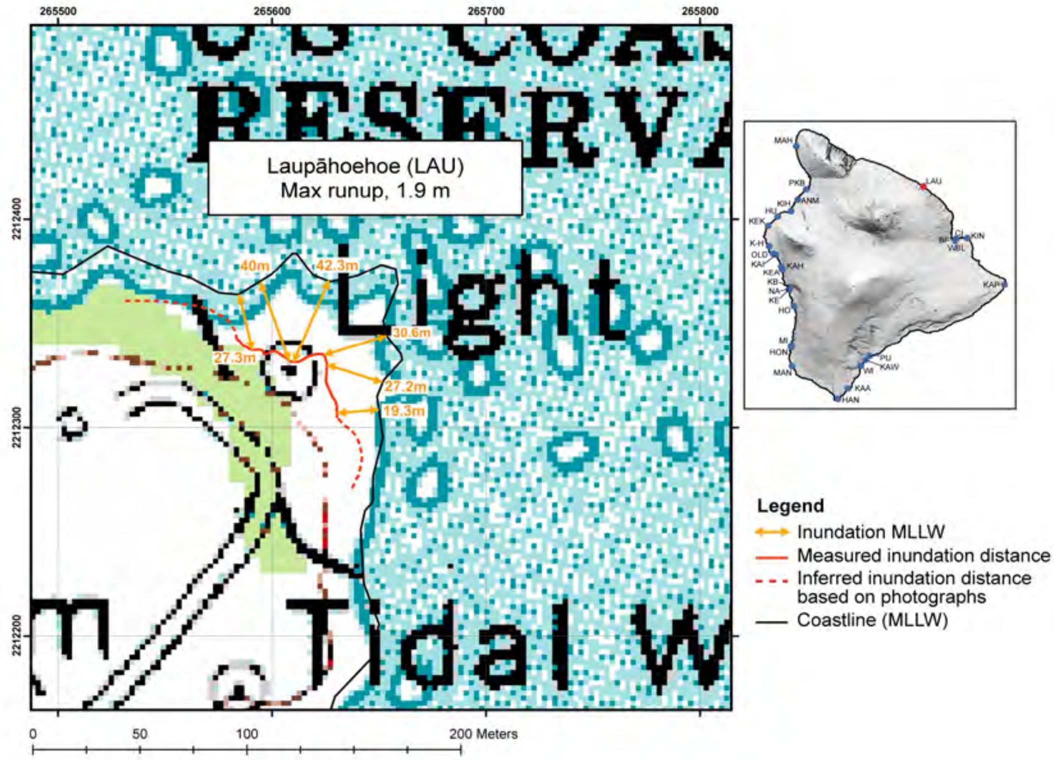


Figure B28a. Laupāhoehoe Point, at Laupāhoehoe Beach Park, north Hilo. Area of study site; runup, 1.9 m.

Figure B28b. Debris swept inland at Laupāhoehoe Point.