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POTENTIAL DEFICIENCIES IN EDUCATION, INSTRUMENTATION, AND WARNINGS FOR LOCALLY GENERATED TSUNAMIS

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ABSTRACT

A review of historical data for Hawaii reveals that significant tsunamis have been reported for only four of twenty-six potentially tsunamigenic earthquakes from 1868 through 2009 with magnitudes of 6.0 or greater. During the same time period, three significant tsunamis have been reported for substantially smaller earthquakes. This historical perspective, the fact that the last significant local tsunami occurred in 1975, and an understandable preoccupation with tsunamis generated around the margins of the Pacific, all combine to suggest apparent deficiencies in: (1) personal awareness of what to do in the event of a possible local tsunami; (2) the distribution of instrumentation capable of providing rapid confirmation that a local tsunami has been generated; and (3) the subsequent issuance of timely warnings for local tsunamis. With these deficiencies, far more lives may be lost in Hawaii due to local tsunamis than will result from tsunamis that have originated along the margins of the Pacific. Similar deficiencies may exist in other areas of the world threatened by local tsunamis.

Key words: Tsunami preparedness; tsunami education; tsunami instrumentation; warning systems; local tsunamis, Hawaii tsunamis

1. INTRODUCTION

Public officials, educators, residents, and visitor industry personnel need to know that the greatest threat to loss of life from natural hazards in the Hawaiian Islands may be from locally generated tsunamis rather than from Pacific-wide tsunamis. Although the discussions that follow are based on Hawaii's history and current state of preparedness for future tsunamis, the resulting conclusions of this report may be applicable to agencies and individuals in other coastal areas of the world threatened by local tsunamis.

2. HISTORICAL DATA

Of the thirty-one earthquakes with magnitudes of 6.0 or greater reported in the Hawaiian Islands from 1868 through 2009 (U.S. Geological Survey on-line data), five of these were in the interior of the Big Island and the other twenty-six were in or near the Big Island's coastal areas. Most, for which depths are available, were shallow with the greatest reported value being 50 km. Of the twenty-six earthquakes, only four of these generated significant local tsunamis (Table 1; Figs. 1 through 3). The other reported local tsunamis were generated by much smaller earthquakes or by possible submarine landslides (Table 1; Fig. 2). In addition to these reported tsunamis, unexplained flooding with characteristics consistent with a tsunami generated by a submarine landslide was observed along the eastern shoreline in the Pohoiki and Opihikao area of the Big Island. The vertical height of flooding on land (i.e., run-up) was estimated to be about 27 feet and the inland extent of flooding (i.e., inundation) was estimated to be about 800 feet. No earthquake was felt prior to the flooding and no other shoreline areas reported flooding. Although the flooding was initially considered to possibly be the result of a storm (Cox and Morgan 1977), later unpublished investigations indicated that a storm could not have been the cause of this flooding (personal communication).

In summarizing the available historic data, we find that most earthquakes with magnitudes of 6.0 or greater have not generated significant local tsunamis, while much smaller earthquakes or submarine landslides that may not even be felt could generate highly localized but potentially deadly tsunamis. As will be revealed in discussions that follow, this fact poses a daunting challenge for our public officials, educators, and visitor industry in terms of education, instrumentation, and warnings.

3. EDUCATIONAL DEFICIENCIES

Some very simple, life saving concepts related to locally generated tsunamis are not well known in our State. This deficiency is, in part, a result of our understandable preoccupation with past tsunamis originating along the margins of the Pacific that have struck Hawaii. A common singular recommendation for people in inundation areas is: "If you feel the ground shake, move as quickly and safely as possible to higher elevations"**.** However, as the historical data indicates, this advice may not be sufficient to save some lives.

An additional recommendation should be the following. “If you feel the ground shake, do not assume that a siren or other warning will be given to you in time to save your life. Also, do not assume that the earthquake is far enough away so that you can take your time in getting to higher elevations.” The tsunami generating the earthquake that is felt may be very large and hundreds of miles away, or very small but very close. There may be a few minutes or a few tens of seconds to avoid death or injury.

Knowledge of the following could also save lives. “Tsunamis are a series of waves and the first wave is not necessarily the largest. You may not feel a small earthquake or submarine landslide that could send a highly localized but potentially deadly tsunami towards your coastal area. Even small tsunamis can flood far inland for several minutes. Subsequent tsunami waves can interact with earlier waves draining off the land back into the ocean producing even higher waves with powerful, debris-laden currents. Always pay attention to any early signs of a tsunami. These signs could include the unexplained exposure of reefs, inland flooding, unusual currents, or unusual changes in the locations of breaking waves.”

Table 1
Locally Generated Tsunamis in the Hawaiian Islands *

Year	Month	Day	Ms	Run-ups on Tide Gauge Readings in Feet
1868	04	03	7.5	45
1901	08	09	---	4
1908	09	21	6.8	4
1919	10	02	---	14
1951	08	21	6.9	4
1952	03	17	4.5	10
1975	11	29	7.2	47

** Data are taken from Lander and Lockridge (1989). Run-ups are maximum vertical measures of a tsunami’s wave height on land relative to mean sea level. The run-ups or tide gauge readings given here are the largest reported for the Big Island. Significant run-ups (i.e., 3 feet or more) were not reported on any island other than the Big Island. Additional run-up values for the Big Island are given in Figures 1 through 3. See Walker (2000) for a discussion of the 1901 event. Newspaper articles were examined for indications of felt earthquakes possibly associated with the 1901 and 1919 events (Cox and Morgan, 1977; and Walker, 2000). None were found. Also, in searching Hawaiian Volcano Observatory (HVO) earthquake reports based on seismic data, no events could be found that might be responsible for the 1919 tsunami. There is no evidence to suggest that the HVO seismic network was not operational on 2 October 1919.*

Public officials, educators, and visitor industry personnel should be responsible for ensuring that residents and visitors respect and understand the unique characteristics of locally generated tsunamis, requiring quick evacuations and the avoidance of false assumptions. Many of these educational deficiencies were apparent during the 6.7 Kiholo earthquake of 15 October 2006 off the west coast of the Island of Hawaii as hundreds of visitors and residents stood along the shorelines immediately after the earthquake wondering what to do. People in inundation zones on other islands also felt the shaking but did not move quickly to higher elevations. Fortunately, in this instance, no significant local tsunami was generated. Should such educational deficiencies persist in the event of an 1868 or 1975 type tsunami along the west coast of the Big Island rather than along the east coast of the Big Island, fatalities would be especially large on the Big Island and Maui, with additional fatalities possible on Oahu and Kauai

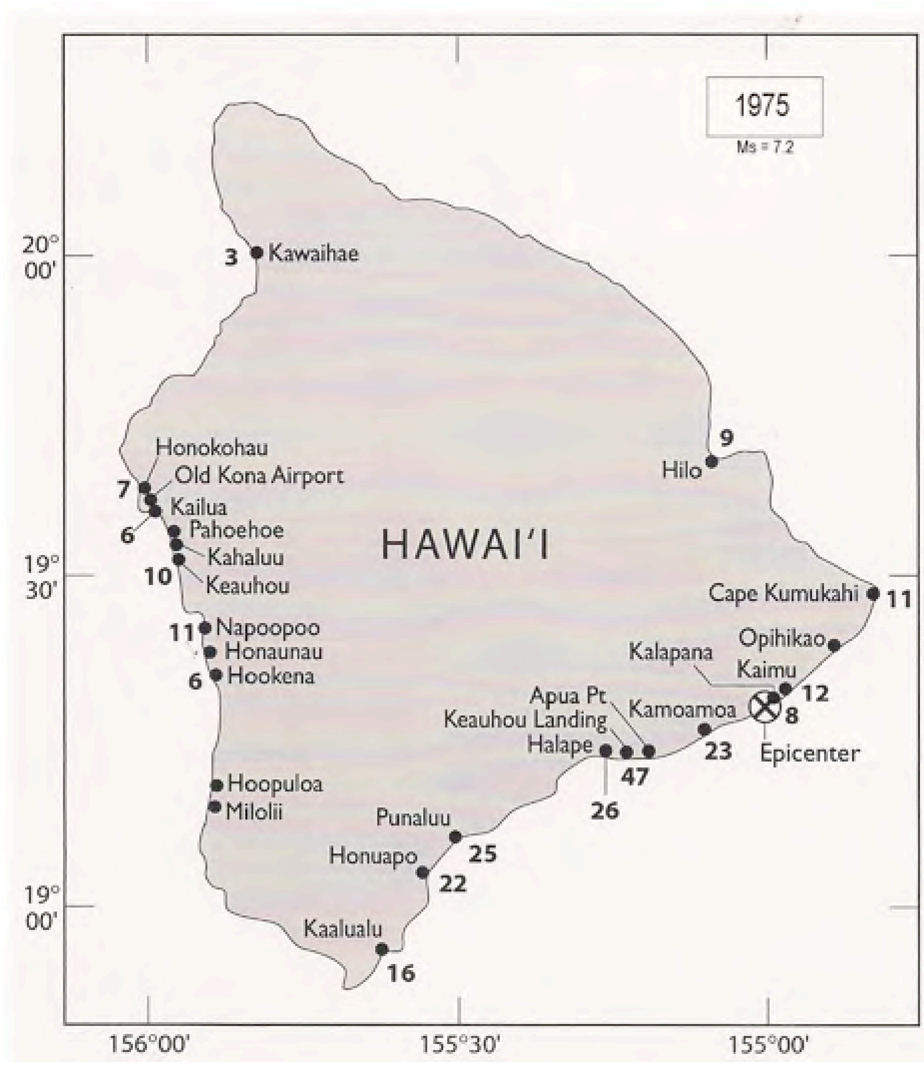

Figure 1. Earthquake epicenter, magnitude, and run-up values in feet for the 1975 tsunami (Lander and Lockridge, 1989).

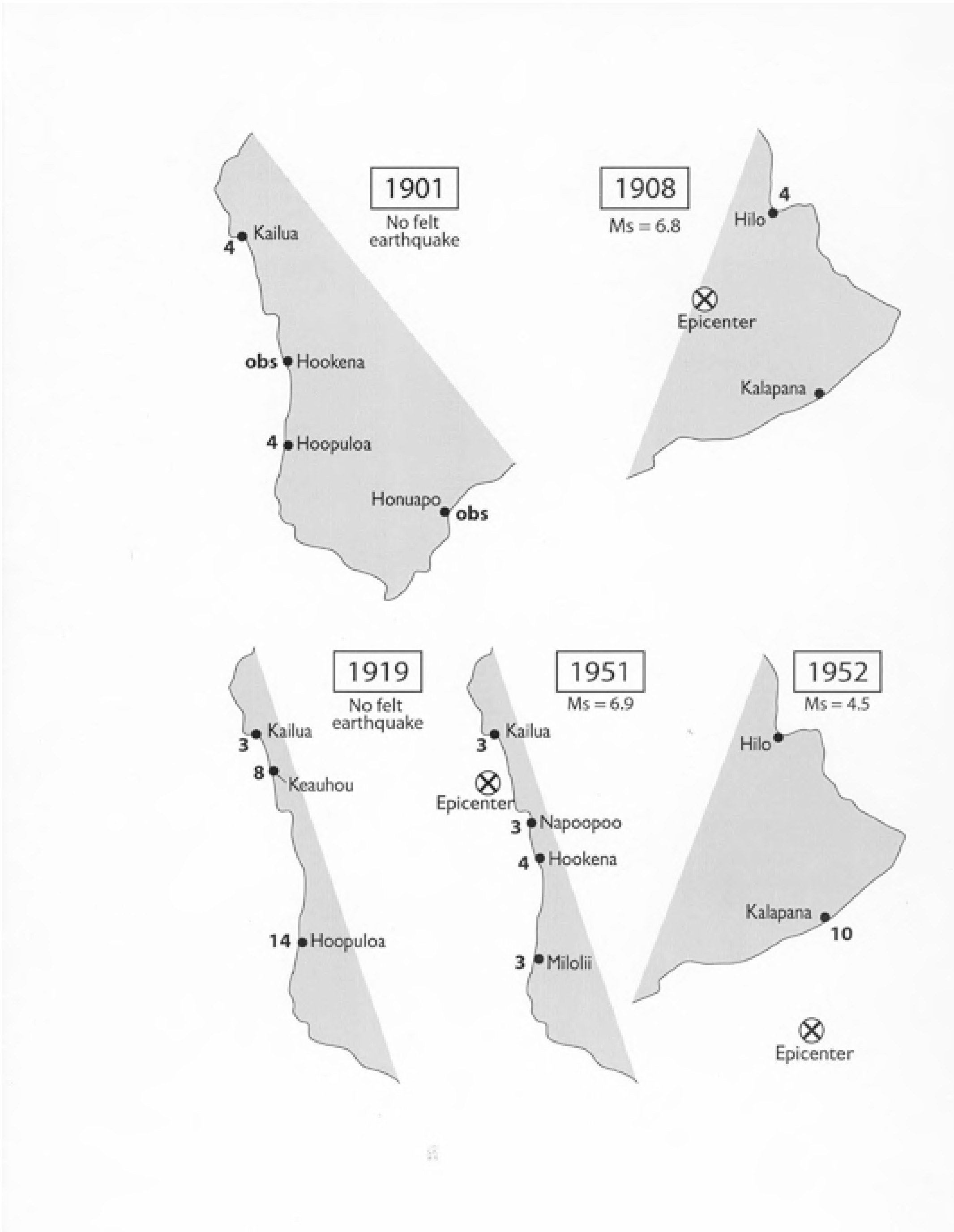

Figure 2. Earthquake epicenters, magnitudes, and run-up values in feet for other significant local tsunamis in the 20th century (Lander and Lockridge, 1989).

Figure 3. Earthquake epicenter, magnitude, and run-up values in feet for the 1868 tsunami (Lander and Lockridge, 1989).

In addition, there are reports of the tsunami being observed at other Big Island location. A value of 7 feet indicated for Apua may not be consistent with reports that all of the houses in the area were washed away. It should be noted that the waves could have been much larger as they swept across this extensive low-lying point of land. There may have been no topographic features in the area capable of providing reliable evidence of higher run-ups.

4. INSTRUMENTAL DEFICIENCIES

Deep ocean instrumentation can provide the data necessary for warnings of ocean-wide tsunamis. However, by the time signals are recorded on these instruments, destruction in the near field of the tsunami source area will already have occurred. As the historical data indicates, warnings for local earthquakes cannot be based only on earthquake magnitudes. Water level data is also required. In this regard Cellular Run-up Detectors (CRD's) were installed at various locations on the Big Island (Figure 4) to complement existing sea level gauges (Walker 2002). Mounted in inundation areas at elevations of about 10 feet above sea level on Civil Defense siren poles, these solar powered water sensors send cell phone transmitted signals of flooding to the Pacific Tsunami Warning Center (PTWC) in about 30 seconds. Signals received from these sensors subsequent to a nearby earthquake would confirm that a tsunami has in fact been generated. Although official warnings may not be possible for shorelines first struck by the tsunami, nearby and more distant coastal areas may receive timely official warnings. These land-based low cost instruments are relatively easy to install and maintain. In areas with little or poor cell phone coverage, sensors using satellite transmitters (SRD's) have been developed, tested, and installed (Walker 2010). These units are hidden in artificial rocks and are powered by eight primary lithium ion D-cells. Thus far these units have operated in development testing and in the field without maintenance for more than one year along the seismically active eastern shoreline of the Big Island (Figure 4). Support is needed to maintain these instruments and to install some additional units to provide warnings for beach parks and campsites along the Big Island's eastern shore and to provide for more advanced warnings for other coastal areas of the State – especially for other areas of the Big Island (e.g., Kona and Hilo) and for Maui. Also, siren systems triggered by satellite transmissions are needed for remote campgrounds in Hawaii Volcanoes National Park and possibly for other remote campsites throughout the State.

5. WARNING DEFICIENCIES

At present there is no difference between the siren tones for local tsunamis and distant tsunamis. People are advised to turn on their radios or televisions for further information when they hear a warning siren. Question: "Should people in inundation zones who hear a siren take time to find a radio or television to determine what they should do, or should they evacuate first and then find a radio or television?" Answer: "They should first get out of the danger zone." Without a difference in siren tones, they have no way of knowing whether the siren is for a local tsunami or for an ocean-wide tsunami. Evacuating first is the safest assumption.

Another potential deficiency in warning procedures may be unnecessary and timely human interventions. The recording of a local earthquake followed by the detection of flooding transmitted by ocean or land based instrumentation should be sufficient to automatically trigger tsunami warnings that automatically expand or terminate as more sensors are monitored. The speed of warnings is critically important for local tsunamis – especially for the Big Island and Maui. Again, a repeat of the 1868 and 1975 tsunamis (powerful 45 and 47 foot high water levels on land, respectively) occurring on the Kona (west) Coast rather than on the Puna and Kau (east) coasts, would be devastating along the western shores of the Big Island, the western and southern shores of Maui, and the southern coastlines of Oahu, and possibly Kauai. Even highly localized tsunamis for which no warning is given can undermine confidence in warning agencies. This loss of credibility could result in substantial additional fatalities even if a warning is issued for a subsequent larger tsunami.

Figure 4. Site locations for Cellular Run-up Detectors (CRD's), Satellite Run-up Detectors (SRD's), and nearby Pacific Tsunami Warning Center sea level gauges.

6. CONCLUSIONS

Because of existing potential deficiencies in education, instrumentation, and warnings, locally generated tsunamis may be a far greater risk to loss of life in the Hawaiian Islands than Pacific-wide tsunamis. These deficiencies should be addressed and corrected by public officials, educators, residents, and visitor industry personnel prior to, rather than after, the next locally generated tsunami.

Acknowledgements

The Cellular Run-up Detectors were developed, tested, and installed several years ago with funding given to the State of Hawaii's Civil Defense Agency by the National Tsunami Hazards Mitigation Program. The Pacific Tsunami Warning Center (PTWC) as part of their monitoring network now maintains these instruments. The development, testing, and installation of the Satellite Run-up Detectors were similarly funded. However, at present, support is unavailable for the maintenance of these critical units and for their integration into PTWC's monitoring network. Hawaii Volcanoes National Park and the Hawaiian Volcano Observatory provided assistance with the installation of these units on the Big Island.

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