TSUNAMI MITIGATION IN HAWAI`I

George D. Curtis

University of Hawai`i, Department of Ocean and Resource Engineering, 2450 Dole St.,
Honolulu HI, 96822
gcurtis@hawaii.edu

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ABSTRACT

Hawai`i has a long, though sporadic history of deadly tsunami attacks. Since the 1946 tsunami disaster the State of Hawaii has developed increasingly sophisticated and effective mitigation strategies. The evolution and operation of these strategies is described in this paper. Tsunamis will no longer be Hawai`i's deadliest natural hazard.

INTRODUCTION

The tragic 1946 tsunami, striking Hawai`i from the Aleutians, and killing 159 people, illustrated the problem of the tsunami-susceptible coastline. There was no warning system at that time. Tsunamis are the most deadly natural hazard affecting Hawai`i and good mitigation is critical. This paper discusses the development of mitigation efforts in Hawai`i and the implementation of the present system.

THE PROBLEM

Table 1. Relative hazards, last century (lives lost)

(Sources: Cox, Furumoto, Schmidt, Curtis)

HAZARD (last century)	LIVES, TOTAL	LIVES, PER YEAR
Earthquake	0	0
Volcano	1	.01
Hurricanes	\<8	<1
Tsunami	**234**	**2.5**
Opihi gathering	?? Many	??
Auto	~4000+	~60+

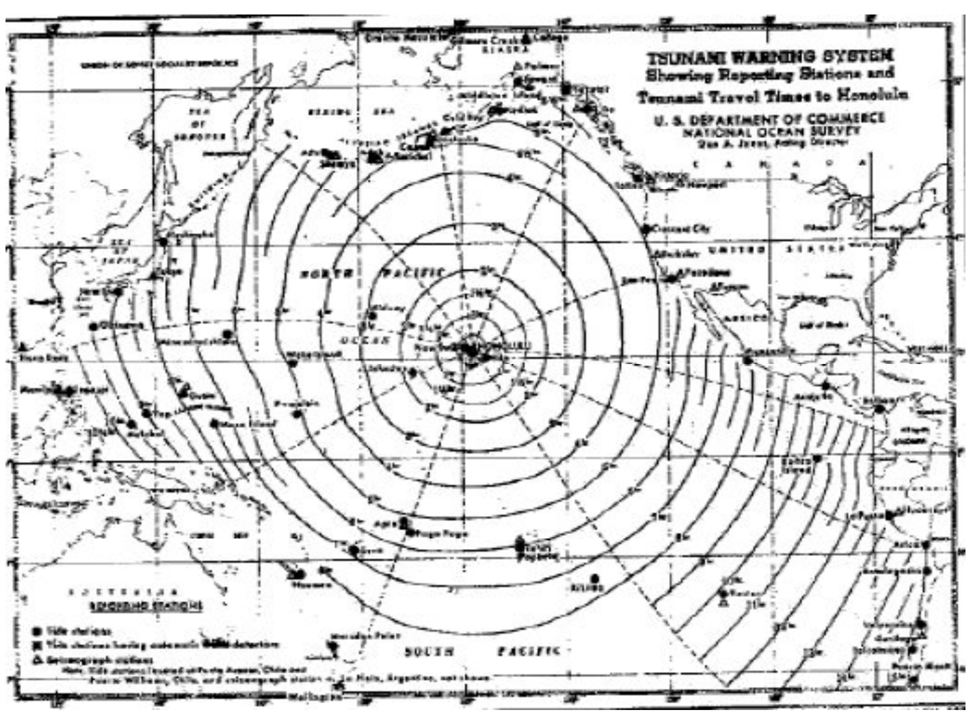

Fig. 1 Tsunami Travel Time Chart to Hawai`i

Although attempts to provide a tsunami warning based on seismographic data of the Hawaiian Volcano Observatory had been made (one was partly successful), the instruments were too slow and, furthermore, most of the large earthquakes do not necessarily generate tsunamis. Without timely confirmation of hazardous wave action, reliable tsunami warning was not feasible. Thus, coastal residents were vulnerable to this hazard.

Figure 1 illustrates how tsunamis approach Hawai`i from many directions, as well as the time available to evaluate the event, warn, and evacuate those in inundation zones.

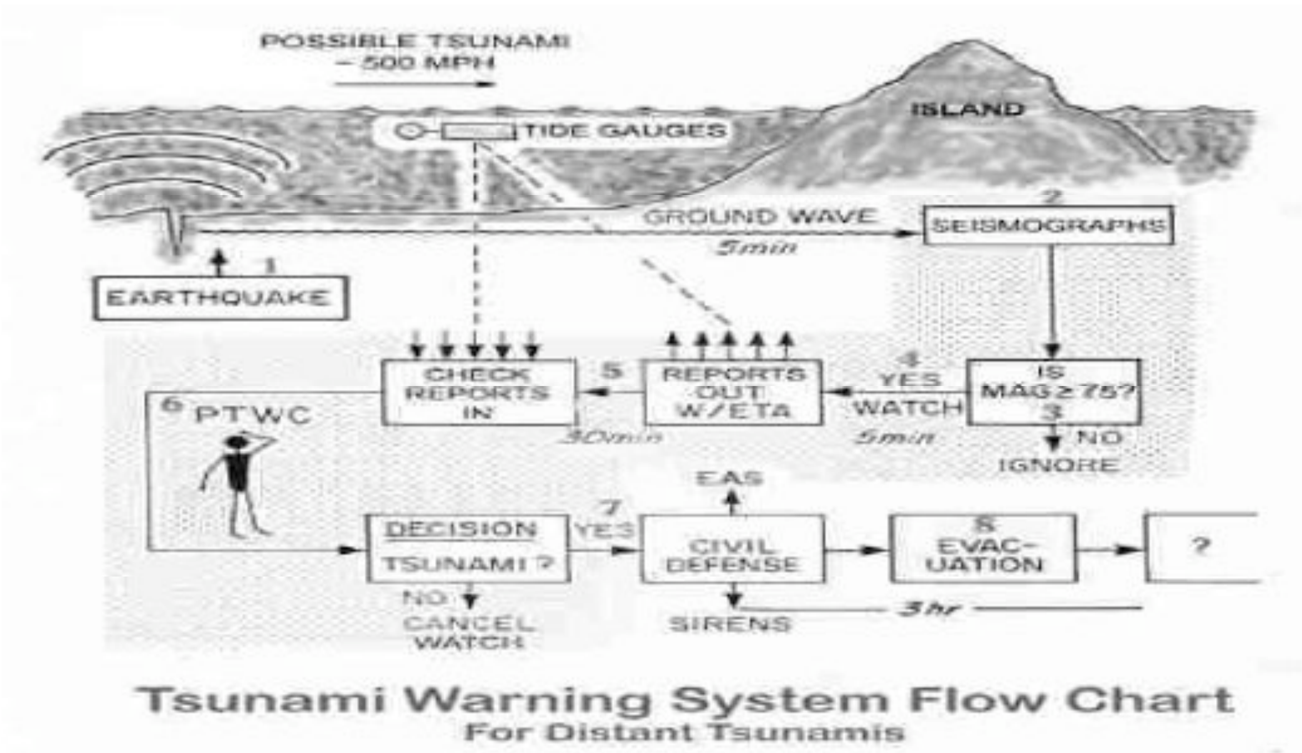

Fig. 2 Data and Action Flow in Tsunami Warning System

THE SOLUTIONS

Scientists began to take advantage of the World War II improvements in communications and instrumentation to help provide warning of distant tsunamis. By 1948, a basic tsunami warning system was in place at the U.S.G.S. Honolulu Observatory, using seismic information and verbal contact with tide gauge stations around the Pacific (Zetler, 1988). Over the years this capability has expanded to use more communications channels, observers, and seismic stations. Eventually this system became the Pacific Tsunami Warning Center (PTWC), which now encompasses 24 nation states.

In Hawai`i the State Civil Defense agency receives the watch and warning information from PTWC and coordinates the overall response; all islands proceed with warning simultaneously. The preparation and evacuation is carried out by the four County Civil Defense agencies using police, fire, public works, Red Cross, national and state parks, and other available personnel. The watch period (during which a tsunami might be en route) begins six hours before expected arrival of the first wave. If the tsunami is forecast to be hazardous, the actual warning and evacuation starts three hours before first wave arrival.

Warnings were successful for the 1952 and 1957 tsunamis with no lives lost, but the strong attack of the 1960 tsunami from Chile showed the inadequacy of the evacuation and response to the warning. The 1960 tsunami caused more than 60 deaths in Hilo, for example. The rather high "false alarm" rate from the warning system contributed to the response problem with the public. Actually, there have been no false alarms; those were non-hazardous tsunamis, but this was seldom the public perception.

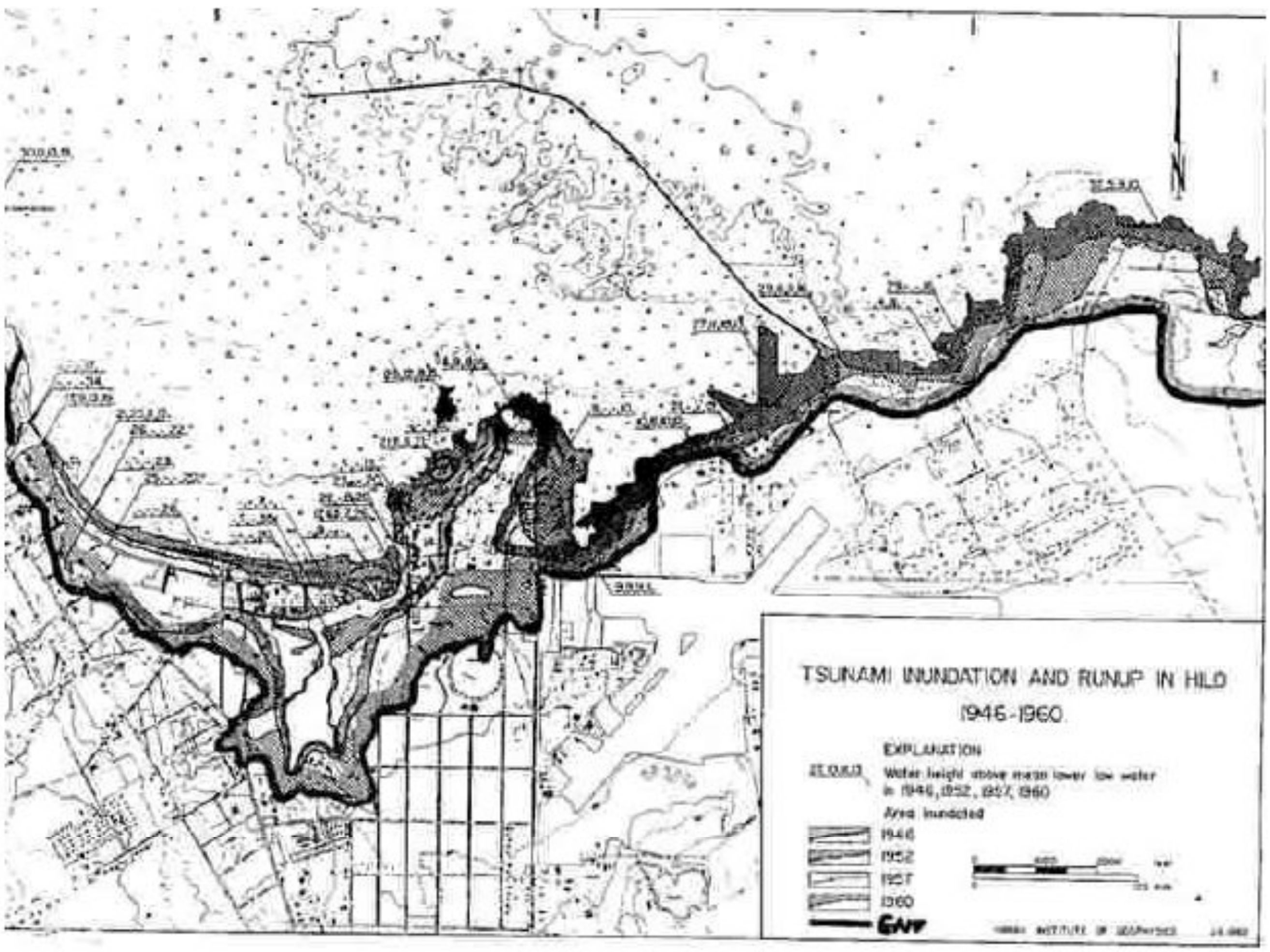

Fig. 3 Flooding in Hilo from Four Tsunamis

Because of the long, though sporadic history of tsunamis affecting the Hawaiian islands, both authorities and the public began additional steps to avoid further deaths and minimize damage to facilities. Using the historical run-up and wave action records gathered by tsunami researchers at the University of Hawai`i (UH) and published by Loomis (1976), Cox (1961) developed the initial, broad brush tsunami inundation maps for the Hawaiian islands. By 1963, these maps were published by Civil Defense and used for evacuation after they were placed in the phone books of each island. More coastal sirens were installed and both the State and County civil defense agencies made plans for better evacuation in the affected areas.

During this period, Vitousek (1961) proposed a deep sea tsunami wave detection system based on a sensor at the end of an unused undersea cable. Using a modified commercial pressure sensor, he successfully deployed the device on a cable offshore the island of Hawai`i. However, no funding was available at the time to deploy the actual deep ocean system. The Deep Ocean Assessment and Reporting of Tsunamis (DART) system has since successfully filled this need with deployment of a number of buoys in both the north and south Pacific.

An evacuation for the non-hazardous tsunami of 1986 showed major problems on O`ahu and the need for more improvements. An evacuation rehearsal is not feasible as it could be a hazard itself and costs presently more than $50 million overall for the Hawaiian islands. The fortuitous warning served a valuable purpose, no one was injured during the evacuation – and it cost $30 million.

Thereafter, updated, more detailed maps with smaller, more usable zones were developed using all historical runup and inundation records (Houston, 1977; Loomis, 1976) applied in a 1-D model developed earlier at the UH (Curtis, 1991). In addition, evacuation procedures were overhauled and the combination was found to work much better in the next evacuation, which occurred in 1994. (Fig. 4)

These precepts, the historical records, and the tsunami data developed under these programs are used presently for evaluation and validation of new and better numerical models (Wei, et al, 2006). They are being applied by the Ocean and Resource Engineering to upgrading Hawai`i inundation zones and to contribute to warning (Yamazaki, et al, 2006) and modeling methodology in other coastal areas under sponsorship of NOAA.

CONCLUSION

The tsunami warning system, which became the Pacific tsunami warning system, has never missed an event and has benefitted from numerous improvements, which have greatly reduced the perceived false alarm rate as well as providing faster analyses of the threat. A greatly improved urgent local warning system, involving real-time wave sensors in addition to seismic data, has been put in place. The rare tsunami originating in Hawai`i, allows very little time for evacuation.

Further improvements now under way include application of real-time models to DART and other data, (Curtis and Mader, 1987) refined and updated zones being developed with 2-D models, more public education, and trained observers available to provide vital data from the next event (Curtis, 1990). Generally good response procedures are in place. With these improvements, tsunami deaths can be kept to an absolute minimum.

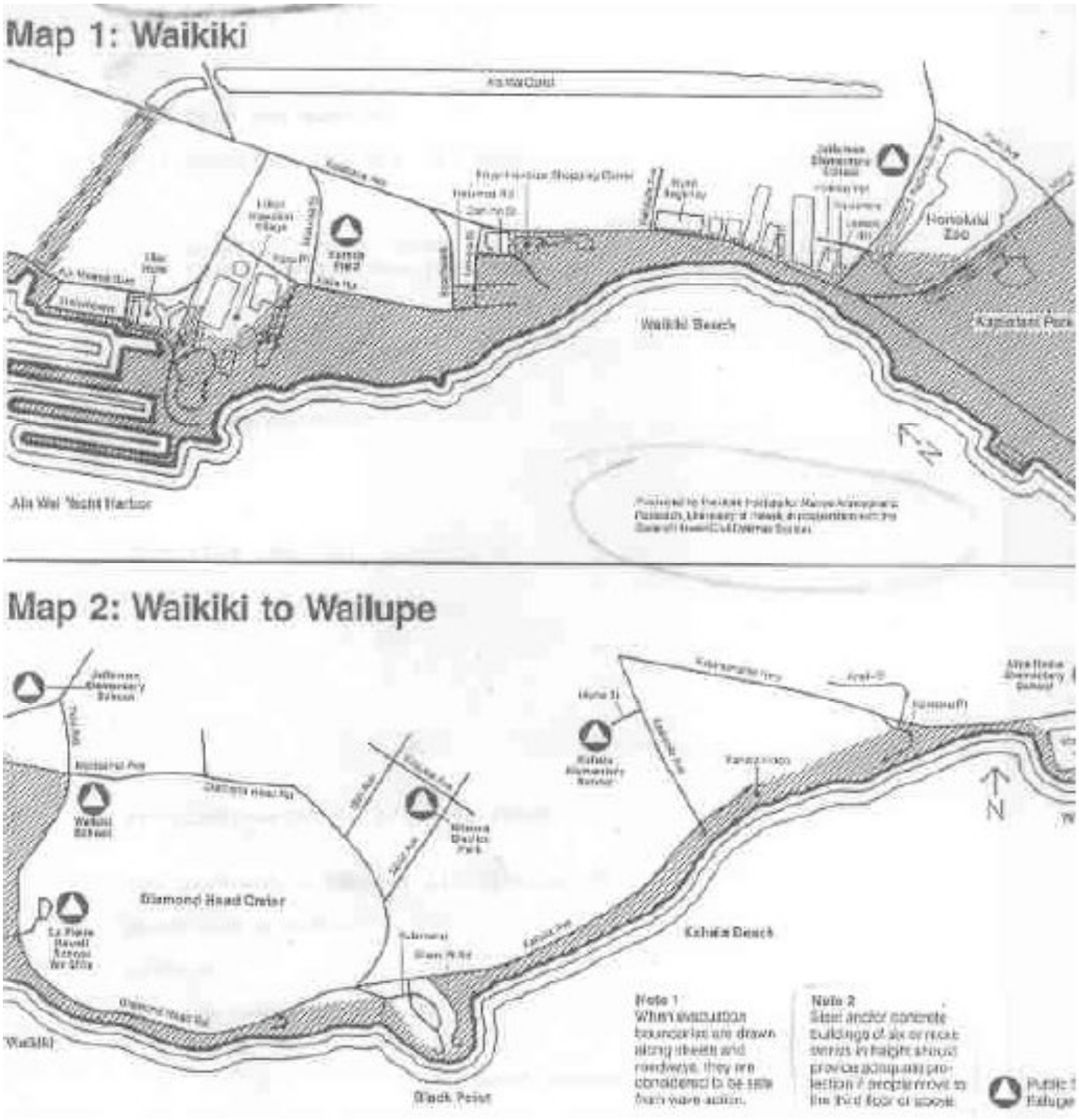

Fig. 4 Evacuation Maps from phone book

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