NATURAL HAZARDS IN HAWAI‘I: SOME STUDIES OF AWARENESS, RISK PERCEPTIONS AND PREPAREDNESS

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI‘I IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN GEOLOGY AND GEOPHYSICS

December 2005

By
Chris E. Gregg

Dissertation Committee:

Bruce F. Houghton, Chairperson
Michael P. Hamnett
Andrew J. L. Harris
David M. Johnston
Douglas Paton
Donald A. Swanson
DEDICATION

I dedicate this dissertation to the residents of and visitors to the islands of Hawai‘i. May these findings be used to improve the way in which society interacts with great natural processes such as volcanic eruptions and tsunamis.
ACKNOWLEDGEMENTS

I thank Bruce F. Houghton for his guidance and support during this dissertation. I also thank Dave Bercovici and Paul Wessel for supporting this interdisciplinary research within Geology and Geophysics. I am grateful for financial support from the Hawai‘i Sea Grant College Program, U.S.G.S. Volcano Hazards Program, Center for the Study of Active Volcanoes, Jaggar Bequest Fund, and New Zealand Foundation for Research Science and Technology. I thank Roy Lachman and William Bonk for allowing me to use their 1960 data, which forms the foundation of Chapter 5 of this dissertation.

I wish to thank several scientists and emergency managers for their support. These include Brian Yanagi of the International Tsunami Information Center; Don Swanson, Frank Trusdell and Jim Kauahikaua of the Hawaiian Volcano Observatory; Don Thomas and Darcy Bevens of the Center for the Study of Active Volcanoes; and Julie Williams of the Keakealani Outdoor Education Center. I also thank many people in Hawai‘i’s Civil Defense agencies and members of the Tsunami Technical Review Committee and the U.S. Tsunami Hazard Mitigation Program (Jeff LaDouce and others).

My parents, Fred and Virginia Gregg, provided valuable assistance to my family during the course of this study. I am grateful for this and their unwavering support. My greatest acknowledgement goes to my wonderful wife Tami and our four children—Kerri Magen Gregg, Claudia Elizabeth Sue Gregg, Benjamin Blaine Gregg and Samuel Braden Gregg. My children have been an inspiration to me and they are the greatest blessing for which any father could ever hope. Without their undivided love this dissertation would have been a lonely undertaking.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ................................................................................................................ v

TABLE OF CONTENTS .................................................................................................................. vi

ABSTRACT ....................................................................................................................................... x

LIST OF TABLES ............................................................................................................................... xii

LIST OF FIGURES ........................................................................................................................... xiv

LIST OF FIGURES ........................................................................................................................... xiv

CHAPTER 1. INTRODUCTION ........................................................................................................ 1

1.1 Goals, Objectives and Structure ................................................................................................. 6

1.1.1 Goals and objectives .............................................................................................................. 6

1.1.2 Structure ................................................................................................................................ 7

1.2 Mitigation and Preparedness ......................................................................................................... 7

1.2.1 Definitions ............................................................................................................................... 7

1.2.2 Resilience .............................................................................................................................. 8

1.3 Natural Hazards in Hawai‘i ......................................................................................................... 10

1.3.1 Volcanic eruptions ................................................................................................................. 10

1.3.1.1 Mauna Loa ....................................................................................................................... 11

1.3.1.2 Hualalai ........................................................................................................................... 13

1.3.1.3 Kīlauea ............................................................................................................................ 14

1.3.2 Tsunamis .............................................................................................................................. 15

1.4 Social Science Perspectives on Natural Hazards ....................................................................... 17

1.4.1 Awareness, perceptions and preparedness .......................................................................... 18

1.4.2 Hawaiian cultural issues ........................................................................................................ 21

1.4.3 Warnings and messages ......................................................................................................... 22

1.5 Land-Use Planning and Zoning .................................................................................................. 24

1.5.1 Lava flow hazards ................................................................................................................ 25

1.5.2 Tsunami hazards .................................................................................................................. 32

1.6 The Three Research Projects .................................................................................................... 33

1.6.1 Lava flow risk perceptions and preparedness in Kona ...................................................... 35

1.6.2 Attitudes toward engineered mitigation of lava flow hazards ........................................... 37

1.6.2.1 Resurrection of a lost and forgotten survey ................................................................. 38

1.6.2.2 Cultural sensitivity toward lava flow mitigation ............................................................ 39

1.6.3 The siren warning system and natural warning signs of tsunami .................................... 41

1.7 Use of Previously Published Material and Human Subjects ................................................ 42

CHAPTER 2. THE PERCEPTION OF VOLCANIC RISK IN KONA COMMUNITIES FROM MAUNA LOA AND HUALĀLAI VOLCANOES, HAWAI‘I

Abstract ........................................................................................................................................... 43

2.1 Introduction ................................................................................................................................. 44

2.2 Kona ....................................................................................................................................... 47
# CHAPTER 6. CONCLUSIONS

## 6.1 Land-use planning

## 6.2 Lava Flow Hazards, Risk and Preparedness in Kona

## 6.3 Engineering Approaches to Lava Flow Mitigation
6.4 Awareness and Understanding of the Siren-Warning System ........................................ 189
6.5 The Significance of “Don’t Know” Answers ................................................................. 192
6.6 The Telephone Book as an Information Source .......................................................... 192
6.7 Objective Risk and Perceived Risk ............................................................................. 194
6.8 Cutting Through the Fog of Information ..................................................................... 197
6.9 Outreach and Community Preparedness ...................................................................... 200
6.10 Concluding Remarks ................................................................................................. 202

APPENDIX A. SOURCES OF VOLCANO AND TSUNAMI INFORMATION............... 204
APPENDIX B. SURVEY DESIGN, IMPLEMENTATION AND ANALYSES.................... 211
APPENDIX C. DEMOGRAPHICS OF THE KONA SAMPLE .......................................... 217
APPENDIX D. GENERALIZABILITY OF ETHNIC DATA .............................................. 219
APPENDIX E. KONA PROJECT MATERIAL ..................................................................... 220
APPENDIX F. SIREN AND TSUNAMI PROJECT MATERIAL ..................................... 237
APPENDIX G. USE OF PREVIOUSLY PUBLISHED MATERIAL AND HUMAN
SUBJECTS ......................................................................................................................... 252
APPENDIX H. TSUNAMI GUIDELINE PROCEDURES FOR HAWAII ........................ 253
REFERENCES ................................................................................................................. 258
ABSTRACT

Lava flows and tsunamis have destroyed communities in Hawaiʻi and tsunamis have killed hundreds of people. Today, these hazards continue to represent substantial risk to the safety of people and property in Hawaiʻi. Using social science surveys, this dissertation explored issues of hazard awareness, risk perception, and preparedness for lava flows. Separate surveys focused on understanding of a siren warning system, awareness of natural warning signs of tsunami, and public attitudes toward the use of engineered strategies to mitigate lava flow hazards.

Survey findings indicate that a lack of recent eruptions and information tailored to meet the public’s needs on a local level have contributed to low levels of threat knowledge, perceived risk and preparedness for lava flows from Mauna Loa and Hualalai volcanoes in the west side of the island of Hawaiʻi. Analysis of previously unpublished data collected during the 1960 eruption of Kilauea volcano on the same island indicate a high level of support for engineered mitigation to protect the village of Kapoho from lava. Lava diversion strategies are more acceptable among Hawaiian and other ethnic groups if local community members are empowered in the mitigation process.

Understanding of the siren warning system was found to be very low on the four main Hawaiian Islands. A capability to recognize natural warning signs of tsunamis and to evacuate immediately is critical to ensure people’s safety during locally generated tsunamis. However, descriptions of these signs are inconsistent in the literature. Moreover, in Hilo, island of Hawaiʻi, people expect and depend on warnings from official sources.
Better land-use planning strategies are needed for lava flows and tsunamis to reduce vulnerability in areas of high hazard and encourage sustainable development. However, mitigation and preparedness measures are also needed now to facilitate effective response for people already at risk. Effective outreach messages that recognize that awareness of hazards, perceptions of risk and decisions to adopt protective measures are driven by social-cognitive, cultural, and political factors are needed to meet the needs of specific communities. Outreach should also be monitored to ensure success is not overrated.
LIST OF TABLES

TABLE 1.1. COSTS OF SOME NATURAL DISASTERS IN HAWAI'I BETWEEN 1946 TO 199292 ... 5

TABLE 2.1. PERCEPTIONS THAT EACH VOLCANO COULD ERUPT AGAIN BY SURVEY

SUBGROUP ........................................................................................................................... 57

TABLE 2.2. AWARENESS OF YEARS SINCE LAST ERUPTIONS OF HUALĀLAI (ABOUT 200
YEARS AGO) AND OF MAUNA LOA (IN KONA, ABOUT 50 YEARS AGO) BY STUDENTS
AND ADULTS .......................................................................................................................... 59

TABLE 2.3. PERCEPTION OF RESPONSIBILITY FOR PREPARING THE COMMUNITY FOR
FUTURE VOLCANIC ERUPTIONS BY STUDENTS AND ADULTS........................................ 69

TABLE 3.1. TIME OF ONSET OF VOLCANIC TREMOR, TIME OF ERUPTION OF LAVA, AND
WARNING TIMES FOR THE BEST CONSTRAINED ERUPTIONS OF MAUNA LOA

VOLCANO ............................................................................................................................. 91

TABLE 3.2. PERCEIVED MEANING OF THE EMERGENCY WARNING SIREN .................. 94

TABLE 3.3. PERCEIVED RESPONSE IF A LAVA FLOW THREATENED RESPONDENT AT HOME

............................................................................................................................................... 97

TABLE 3.4. PERCEIVED RESPONSE IF A LAVA FLOW THREATENED RESPONDENT AT HOME

............................................................................................................................................... 98

TABLE 4.1. “ERUPTIONS MAY HAPPEN BECAUSE PEOPLE DO BAD THINGS THAT MAKE
MADAME PELE ANGRY” BY SUBGROUP ........................................................................ 125

TABLE 4.2. “SOME PEOPLE HAVE BEEN HELPED BY GIVING GIFTS (OFFERINGS) TO PELE”

BY SUBGROUP ......................................................................................................................... 126

TABLE 4.3. BELIEF THAT RESPONDENT WOULD GIVE GIFTS (OFFERINGS) TO PELE BY

SUBGROUP ............................................................................................................................. 127

TABLE 4.4. WHETHER RESPONDENT EVER GAVE GIFTS TO PELE BY SUBGROUP .......... 127

TABLE 4.5. BELIEF IN PELE BY SUBGROUPS ........................................................................ 128

TABLE 4.6. PERCEPTIONS THAT MANY PEOPLE BELIEVE IN PELE BY SUBGROUP........... 129
TABLE 4.7. "IF YOU HAD TIME, WOULD YOU HELP BUILD DIKES (STONE WALLS) TO HOLD BACK LAVA FROM THE ROAD?" BY BELIEF IN PELE

TABLE 4.8. "SHOULD THE SOLDIERS BOMB THE LAVA TO STOP IT FROM BURNING HOUSES?" BY BELIEF IN PELE

TABLE 4.9. "IF YOU HAD TIME, WOULD YOU HELP TAKE (UNLOAD) THE BOMBS FROM THE TRUCKS TO BOMB THE LAVA?" BY BELIEF IN PELE

TABLE 5.1. TARGETED HAZARDS AND RETURN RATES

TABLE 5.2A. POPULATIONS AND RACE OF COUNTIES IN HAWAI‘I

TABLE 5.2B. ETHNICITY OF THE SURVEY SAMPLE

TABLE 5.3. AWARENESS THAT THE SIREN IS TESTED BY SUBGROUPS

TABLE 5.4. UNDERSTANDING OF THE MEANING OF THE 3-MINUTE SIREN BY SUBGROUPS

TABLE 5.5. UNDERSTANDING OF THE MEANING OF THE SIREN BY NUMBER OF YEARS RESPONDENTS HAVE LIVED IN HAWAI‘I

TABLE 5.6. PERCEPTIONS OF WHAT SIGNS WOULD ALERT RESPONDENT THAT A POSSIBLE TSUNAMI WILL OCCUR BY STUDENTS, ADULTS AND TOTAL
LIST OF FIGURES

FIGURE 2.1A-D. GENERALIZED MAPS OF THE ISLAND OF HAWAI'I ........................................ 49
FIGURE 2.2. PERCEPTION OF RISK FROM HAZARDS AT HOME, SCHOOL AND WORK ....... 65
FIGURE 2.3. AVERAGE PERCEPTION OF TIME UNTIL THE NEXT HAZARD EVENT ............ 66
FIGURE 3.1A-D. MAPS OF THE ISLAND OF HAWAI'I ...................................................... 82
FIGURE 4.1A. OBLIQUE IMAGE LOOKING WEST AND UP THE EAST RIFT ZONE OF KILAUEA, HAWAI'I ................................................................. 112
FIGURE 4.1B. ENLARGEMENT OF KAPOHO SECTION OF FIG. 1A ................................ 112
FIGURE 5.1A-D. GENERAL DISTRIBUTION OF SIRENS ................................................. 149
CHAPTER 1. INTRODUCTION

The Hawaiian Islands are at risk from most meteorological, geological, and hydrological hazards (Fletcher et al., 2002b; Hamnett et al., 1996; Hamnett et al., 1993). These hazards represent highly varying degrees of risk in different areas of the islands, but two hazards represent considerable risk on local and statewide scales, lava flows and tsunamis, respectively. Lava flows and tsunamis are concerns in Hawai‘i because of the destruction they have caused in the past (tsunamis have also killed many people) and the threat they pose to existing development and to the safety of human life (Cox, 1987; Hawaii State Civil Defense, 2002; Macdonald et al., 1983). The physical characteristics of lava flows and tsunamis are relatively well understood compared to our understanding of the reasoning processes that underpin people’s decisions to make wise land-use decisions and take protective measures to ensure their capability to respond to hazards when they occur.

This dissertation focuses on beliefs about and adoption of mitigation, preparedness, and response measures related to lava flow and tsunami hazards and on public awareness of a statewide siren-based warning system for natural hazards in Hawai‘i. A goal of this research is to increase the effectiveness of future public information aimed at facilitating community resilience to lava flows and tsunamis. This can be achieved by considering the influence of social, psychological, cultural, and political factors on people’s awareness of hazards, perceptions of risk, and decisions to adopt protective measures.
Lava flows have caused extensive damage to much of the southern half of the island of Hawai‘i during post-European contact times (Macdonald et al., 1983). Lava flows have destroyed whole communities, but seldom have lava flows threatened human life. However, lava flows have become increasingly recognized as a threat to the safety of human life in many areas of the island (Hawaii State Civil Defense, 2002). This dissertation focused on lava flows because of the increasing threat that lava poses to development and the safety of human lives as a consequence of development of marginal land (i.e., areas of high hazard). It has been 54 years since the last eruption occurred on Mauna Loa volcano on the western side of the island of Hawai‘i (ca. 200 years since the last eruption of Hualālai volcano in that same area; Fig. 2.1a). Such long periods of volcanic quiescence means that few people have experience with preparing for and responding to lava flows in that area. Understanding the factors that influence levels of individual preparedness for and beliefs about official mitigation of lava flows are central aims of this dissertation. There is a need to understand these issues so that public outreach information prepared by, for example, scientific, emergency management, and not-for-profit agencies, can be tailored to meet the needs and expectations of the public. This requires consideration of social, psychological, cultural, and political factors. There is an abundance of information about lava flows, tsunamis and other natural hazards in Hawai‘i (Appendix A), but to what extent has this information improved community resilience to lava flows and tsunamis?

Tsunamis provide a good contrast to lava flows, because they are a statewide hazard rather than a local or regional hazard. Tsunamis in Hawai‘i can originate either locally or from distant places throughout the Pacific Ocean basin. Tsunamis have killed
hundreds of people in Hawai‘i and pose a greater risk to life statewide than any other hazard (Cox, 1987; Dudley and Lee, 1998). This makes it a necessity that residents and visitors are prepared to respond to tsunamis.

The best way to reduce risk from tsunamis is to avoid occupation of tsunami inundation zones. However, much of the development in Hawai‘i is located within these high hazard areas (Raine, 1995) and this requires that the public possess capabilities to respond to meet the unique threats posed by tsunamis. The fact that most people recreate in the coastal zone where tsunamis are dangerous also means that a large number of people must be considered in development and implementation of response plans for diurnal tsunamis. Furthermore, most of the major development in Hawai‘i lies in the coastal plain, and much has occurred since 1960 (Fletcher et al., 2002a). Mitigation measures aimed at reducing risk from tsunamis in these areas have not yet been tested, so there is uncertainty in what to expect during the next big tsunami.

I focused on evaluating people’s understanding of official warning messages and natural warning signs of tsunamis in Hawai‘i. The distance of the source of tsunamis from Hawai‘i will determine the amount of warning time that is available for implementing response measures. Official warnings will presumably be most effective during tsunamis generated from distant sources, because there will typically be several hours of warning time available. Effective response to tsunamis generated locally in Hawai‘i, however, will necessitate a familiarity with and capability to respond to natural warning signs of tsunamis, because warning times will be short (of the order of minutes to tens of minutes). Furthermore, official warning messages may not be received and
acted on prior to the impact of local tsunamis. Natural warning signs include ground shaking from earthquakes and changes in sea level.

The official siren-warning system in Hawai‘i was installed after the devastating tsunami of 1946 in order to provide early warning of tsunamis to the public. However, studies in the 1960s suggested that few people understood the meaning of the siren (Lachman et al., 1961, Havighurst, 1967 #143). Hazards with quick onsets and short warning times, such as local tsunamis and some eruptions, require that people be prepared to respond at all times. Knowing the meaning of the siren and its implications for response and natural warning signs of hazards are central to being prepared.

What are current levels of understanding of the meaning of the siren in Hawai‘i’s communities and to what extent are people aware of natural warning signs of tsunamis? The long time since the last damaging Pacific-wide tsunami (i.e., 44 years) and local tsunami (i.e., 29 years) in Hawai‘i provided an opportunity to measure the influence of these long time periods on levels of understanding of these issues. The lack of recent tsunami hazard experience and lava flow experience in the western side of the island of Hawai‘i makes it important to examine the interpretive processes that influence hazard awareness, risk perception, preparedness, attitudes to mitigation, and perception of and attitudes towards warning mechanisms.

There are several hazards other than lava flows and tsunamis that represent substantial risk in Hawai‘i (e.g., hurricanes, earthquakes, and floods). The risks associated with each of these and other hazards represent significant obstacles to the development and maintenance of sustainable communities in Hawai‘i. Table 1.1 provides examples of the impact of some hazardous events on the islands. I emphasize
that comparing loss values across disasters from different hazards, especially when these events are separated by decades and the comparisons are done by separate entities, must be treated with caution, because each study could have included different items in the calculations and the standard of care with which calculations are based may have varied considerably. Notwithstanding, the table illustrates the impact of multiple hazards on Hawai‘i since the mid-20th century.

Table 1.1. Costs of some natural disasters in Hawai‘i between 1946 to 1992

<table>
<thead>
<tr>
<th>Date</th>
<th>Disaster</th>
<th>Location*</th>
<th>Damage (millions)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/10-11/92</td>
<td>Hurricane Iniki</td>
<td>Kaua‘i</td>
<td>$1,600</td>
</tr>
<tr>
<td>1/3/83-5/3/90</td>
<td>Lava flows</td>
<td>Kalapana, Hawai‘i</td>
<td>$60&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>12/11/87-1/21/88</td>
<td>Flash floods</td>
<td>East O‘ahu</td>
<td>$35</td>
</tr>
<tr>
<td>11/23/82</td>
<td>Hurricane Iwa</td>
<td>Kaua‘i, O‘ahu</td>
<td>$239</td>
</tr>
<tr>
<td>1/7-16/80</td>
<td>High surf, winds, flooding</td>
<td>Statewide</td>
<td>$27.6</td>
</tr>
<tr>
<td>1/8-10/80</td>
<td>Kona storm&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Maui</td>
<td>$12.9</td>
</tr>
<tr>
<td>5/23/60</td>
<td>Tsunami</td>
<td>Hilo, Hawai‘i</td>
<td>$23&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1/13/60-2/19/60</td>
<td>Lava flows, tephra</td>
<td>Kapoho, Hawai‘i</td>
<td>$&gt;5.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>3/9/57</td>
<td>Tsunami</td>
<td>Statewide</td>
<td>$&lt;5&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>8/4-6/59</td>
<td>Hurricane Dot</td>
<td>Kaua‘i, Hawai‘i, O‘ahu</td>
<td>$6</td>
</tr>
<tr>
<td>2/28/55-5/26-55</td>
<td>Lava flows</td>
<td>Puna, Hawai‘i</td>
<td>$2.5&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>4/1/46</td>
<td>Tsunami</td>
<td>Hilo, Hawai‘i</td>
<td>$2.6&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>*Inset in Figure 5.1 of Chapter 5 shows the location of islands. Figure 4.1 shows the location of Kalapana, Hilo and Puna. ** Dollars are reported in the year damage occurred. <sup>a</sup>This value is underrepresented, because the eruption destroyed additional buildings and property since the estimate. <sup>b</sup>Kona storm refers to low pressure winter storms. <sup>c</sup>Dudley and Lee (1998) reported $50 million for damages in this tsunami. <sup>d</sup>Murton and Shimabukuro (1974) reported that damage reports were not available for the 1960 eruption, but the value shown was reported by the Hilo Tribune-Herald (1960a). Damages included homes, land, crops and improvements. More buildings were destroyed in the following weeks, so this estimate is underrepresented. The eruption did not end until February 19. Loss in 1955 was $2.5 million (Murton and Shimabukuro, 1974). <sup>e</sup>Dudley and Lee (1998) reported the damage was estimated at $26 million. After Martin and Chock, Inc. (2003).</sup>
1.1 Goals, Objectives and Structure

1.1.1 Goals and objectives

Reducing risk from natural hazards requires that both officials and the public plan for future hazard events. However, officials and the public perceive risk in different ways. This limits the effectiveness of official risk messages to facilitate widespread adoption of risk-reduction measures by the public. The goal of this dissertation is to help improve communication between the officials who provide risk messages and the public who is supposed to act on the official messages to reduce risk. Improved communication between these two groups is expected to result in a more informed and hazard resistant Hawai‘i.

To work toward this goal, three social science projects were performed in different areas of Hawai‘i to explore risk-related issues surrounding lava flows, tsunamis, and the siren warning system. Two of the projects related to lava flows. The other project related to tsunamis and the warning system. The objectives of the two lava flow projects were (a) to understand factors that contribute to, and hinder, awareness of volcanic hazards, perceptions of risk and preparedness for lava flows from Mauna Loa and Hualalai volcanoes in Kona (i.e., the western side of the island of Hawai‘i), and (b) to explore whether Hawaiian cultural sensitivity was a factor in influencing attitudes toward official efforts to divert the paths of lava flows to protect a town threatened by lava flows from Kīlauea volcano in 1960 (Fig. 2.1a). The objectives of the third project were (a) to determine whether awareness of tests of the siren warning system in Hawai‘i and awareness of the frequency of monthly tests of the siren have positively influenced...
understanding of the meaning of the siren, and (b) to understand people's expectations of
the source of future warnings of tsunamis. For example, do people expect warnings of
 tsunamis to come from official messages, from natural signs, or both?

The goals and objectives of these chapters represent a holistic overview of core
elements of a risk communication program. That is, the determinants of preparedness
can be considered in their own right and in the context of the cultural environment within
which people live. In this way, the effectiveness of a warning system can be considered
in terms of its integration with levels of preparedness. A warning system is not just about
its audibility and its effect on behavior. A good warning system must motivate action in
those prepared to respond. This dissertation integrates these perspectives.

1.1.2 Structure
This dissertation contains six chapters. They include this chapter, four research chapters
and a concluding chapter. Each of the four research chapters stands alone as an
individual manuscript, although chapters cross-reference each other.

1.2 Mitigation and Preparedness
1.2.1 Definitions
The terms mitigation and preparedness are used repeatedly throughout this dissertation,
but they are used inconsistently across various disciplines, so the terms are defined here
to avoid misinterpretation before proceeding further. From a classic perspective,
"mitigate" is defined as, "to make mild, less severe, less rigorous, or less painful;
moderate" (Neufeldt, 1994). For example, mitigation can be used to reduce the impact of
a hazard or the effects of a hazard. In the hazard community, the term is often focused on
longer-term measures and strategies. In this dissertation, the term “mitigation” is used in two contexts. First, the term refers in its broader sense to any effort aimed at reducing the probability of adverse impacts to personal safety and to property. At other times, and in a more specific sense, the term mitigate is used to refer to a specific measure or action that either has been taken or may be taken in the event that a hazard threatens an area. For example, mitigation can include the use of earthen barriers to divert a lava flow.

The term “preparedness” is used in this dissertation to refer to a capacity to take action to reduce the impact of a hazard. It includes having an emergency response plan and the resources to fasten a roof to a house. In this sense, preparedness includes both mitigation steps and the capability to undertake mitigation action. In regard to the latter, preparedness encompasses community support for structural mitigation conducted at a societal level. Analysis of preparedness thus includes issues relating to the perception and interpretation of hazards, risk and mitigation.

In contrast, the Hawai‘i Statewide Hazard Mitigation Forum (2004b) defines preparedness as, “actions taken to save lives before and during a natural disaster. It ensures people are ready for a disaster and respond to it effectively.” The definitions are similar, but the latter definition has a narrower emphasis on saving human lives.

1.2.2 Resilience
Mitigation and preparedness are the key components of community resilience. One important aspect of resilience is the existence of resources capable of being drawn upon to facilitate adaptation and for dealing with the disruption and loss associated with hazard activity (Paton, 2003; Paton et al., 2003b). The other key aspect of resilience is the capacity to use personal and community resources to adapt to adverse hazard impacts.
(Paton, 2003; Paton et al., 2003a). The latter refers not only to individual competencies, but also the degree to which they are sustained by community and institutional mechanisms for consultation and participative decision-making (Paton, 2000; Paton et al., 2003a).

This dissertation is concerned with developing an understanding of factors that influence the adoption of mitigation and preparedness measures. It discusses factors that underpin mitigation and preparedness and factors that affect response to warnings. The latter is a trigger to the use of preparedness resources. This issue is important in two general respects. Firstly, the adoption of mitigation and preparedness measures reduces the risk of loss and injury within a given household. The adoption of these measures also facilitates a capability for coping with the temporary disruption associated with hazard activity and minimizes damage and insurance costs. Secondly, substantial funds are expended annually on risk communication programs intended to facilitate the adoption of mitigation and preparedness measures. From an administrative perspective, an interest in ensuring a return on investment (e.g., reduction in household members' reliance on external agencies, reduced insurance pay-outs for damage) is expected to follow any program that involves expenditure of public funds. Achieving this return on investment requires that risk-reduction initiatives are effective both in promoting the adoption of mitigation and preparedness measures and, given an environment characterized by infrequent hazard activity, in maintaining a state of readiness over time. A lack of effectiveness could result in the loss of life and property. The effectiveness of risk-reduction strategies should be most important in the minds of civil defense and emergency management officials and political leaders in the case of preparedness and mitigation.
1.3 Natural Hazards in Hawai‘i

1.3.1 Volcanic eruptions

The island of Hawai‘i has experienced more volcanic eruptions than any state in the Union, because two of the world’s most active volcanoes are located on the island (e.g., Kīlauea and Mauna Loa). The island also has three other volcanoes (Hualālai, Mauna Kea and Kohala; Fig. 2.1a). The latter two volcanoes have not erupted in thousands of years, but Hualālai’s latest eruption was only about 200 years ago (Kauahikaua et al., 2002; Wolfe and Morris, 1996; Wolfe et al., 1997). Kīlauea is the most active of these volcanoes, followed by Mauna Loa and Hualālai.

A lava-flow hazard-zone map of the island of Hawai‘i was constructed in 1974 by subdividing the island into nine separate lava-flow hazard zones based on the probability of coverage by lava flows (Fig. 2.1b (Mullineaux and Peterson, 1974)). The map was prepared in order to distinguish the degrees of hazard across different areas of the island and to help guide land-use decisions. Lava flow hazards on the island are currently ranked 1 through 9, with 1 being the highest hazard area (i.e., the summit rift zones of Mauna Loa and Kīlauea only) and 9 the lowest hazard area. The entire southern and central portion of the island contains the three active volcanoes. The two inactive volcanoes comprising the northern portion of the island are the least hazardous and therefore receive lower lava flow hazard ratings. The U.S. Geological Survey, Hawaiian Volcano Observatory (USGS, HVO) is in the process of developing new lava-flow hazard-zone maps based on the statistical probabilities of lava covering certain areas (Hawaii State Civil Defense, 2002).
Two significant factors that increase people’s risk from lava flows are their proximity to the most likely eruptive sites and the steepness of ground slope. Many people reside within or near likely eruptive sites at the active volcanoes, and this is a concern. Steep slopes are a potential problem in Kona, particularly on Mauna Loa in South Kona and on Hualālai in North Kona (Gregg et al., 2004b, Chapt. 3). High slope values in these areas will increase the velocity of lava flows (Moore et al., 1987; Trusdell, 1995). When combined with high effusion rates (i.e., volume of erupted material per unit of time) and high volumes of erupted lava, lava flows have the potential to flow rapidly at Mauna Loa and at Hualālai (Kauahikaua et al., 2002; Macdonald, 1954). The presence of relatively low viscosity alkalic lavas at Hualālai will also increase the velocity of its lava flows (Moore et al. 1987). When considered with the proximity of developed areas, which are often located downslope from or within likely eruptive sites, lava flows in these areas represent a substantial concern (Hawaii State Civil Defense, 2002; Moore and Clague, 1991; Trusdell, 1995).

1.3.1.1 Mauna Loa
Mauna Loa is a very large volcano that blankets 5,271 km$^2$ of land, 51% of the surface of the island of Hawai‘i (Lockwood and Lipman, 1987; Trusdell, 1995). The volcano is very active, and over 40% of its surface has been covered by lava flows in the last 1,000 years. Mauna Loa has erupted 39 times since 1832, but it has erupted only twice in the last 50 years (1984 and 1975 (Lockwood et al., 1987)). The latest eruption of Mauna Loa in Kona was in 1950 (Macdonald, 1954; U. S. Geological Survey, 2000).

Mauna Loa erupted much more frequently before 1950 than it has since. For example, between the time when written records began in 1832 and 1950, the volcano
erupted 37 times, on average every 3.2 years (Lockwood and Lipman, 1987). Several of Mauna Loa’s 39 eruptions have been destructive in Kona, and many more eruptions have threatened developed areas (Gregg et al., 2004b, Chapt. 3, Fig. 3.1). For example, the 1859 eruption in North Kona destroyed the village of Wainanali‘i, about 12 miles south of present-day Kawaihae, and another village “Kibele” (or Kiholo (see Barnard, 1995)); the 1868 eruption in Ka‘ū destroyed 37 buildings in Kahuku (Barnard, 1995); the 1926 eruption destroyed the village of Ho‘ōpūloa in South Kona (Finch, 1926); and the 1950 eruption destroyed buildings in the community of Pāhoehoe in South Kona (Macdonald, 1954; U. S. Geological Survey, 2000). All of these events occurred on the south and west flanks of Mauna Loa in the districts of Kona and Ka‘ū (Fig. 2.1c). Mauna Loa has also threatened the largest city on the island, Hilo, on the east side of the island, six times since 1852 (in 1852, 1855, 1880-1881, 1935, 1942, and 1984 (Wolfe and Morris, 1996)). When this latter threat is combined with the threats in Kona and Ka‘ū, eruptions of Mauna Loa threaten a large part of the island. In the districts of Kona, where Chapters 2 and 3 of this dissertation focus, lava flows from Mauna Loa could flow into the island’s major resort areas in North Kona, or lava could flow into other densely and sparsely developed areas in North or South Kona.

In contrast to hazards such as tsunami and earthquakes, volcanic crises can persist for significantly longer periods of time. This raises two related questions. One concerns how long might eruptions of Mauna Loa last? The other concerns the implications of prolonged hazard exposure for community impact, resilience and management. Historically, durations of summit eruptions have ranged from 1 day to about 4.5 years, and flank eruptions (the more likely type to affect Kona) have lasted from about 5 days to
450 days (Lockwood and Lipman, 1987). These durations are significantly shorter than the 21 year duration of the current eruption of Kīlauea (Heliker and Mattox, 2003). Nonetheless, lava from an eruption with a short duration could have significantly longer consequences for local communities. Consequently, community members’ understanding of lava flows and the short and long-term implications of damaging lava flows in a community is important. Contingency plans for sustaining community activities (e.g., volcano tourism, continuity of business) during and following an event that creates significant disruption to community functions is therefore an important issue.

1.3.1.2 Hualālai
Hualālai is a much smaller (751 km²) and less active volcano than Mauna Loa (Moore et al., 1987). Hualālai last erupted twice in ca. 1800. Eruptions of Hualālai are not as well documented as are eruptions at Mauna Loa and Kīlauea, because Hualālai is much less active and there were no first-hand accounts of the ca. 1800 eruptions (Kauahikaua and Camara, 2000). Moore et al. (1987) suggested that eruptions of Hualālai occur on average about every 50 years, but that that the eruptions tend to cluster every couple of hundred years. Lava flows from Hualālai could impact the city of Kailua (the second largest city on the island), the nearby international airport, or a growing visitor area, all of which are within 15 km of the most likely eruptive sites (Gregg et al., 2004b, Chapt. 3, Fig. 3.1c,d). Durations of the most recent eruptions are debatable, but contemporary work suggests durations of several hours to months (Kauahikaua et al., 2002). The uniform hazard rating at Hualālai (i.e., 4) may be reevaluated in light of recent mapping (Kauahikaua et al., 2002). This may have implications for land-use planning on Hualālai, where development is encroaching on the areas where the most recent eruptions occurred.
1.3.1.3 Kīlauea
Kīlauea is the youngest and most active volcano on the island. Holcomb (1987) reported that about 90% of Kīlauea’s surface is younger that about 1,100 years old and about 70% is younger than about 500 years. The volcano occupies a larger area (1,430 km² (Holcomb, 1987)) than Hualālai, but a much smaller area than Mauna Loa. Macdonald et al. (1983) reported that the volcano had erupted 58 times between 1823 and 1982. The current eruption of Kīlauea (the Pu‘u ‘Ō‘ō-Kūpaianaha eruption) began 21 years ago in 1983 and destroyed the community of Kalapana (Fig. 3.1b (Heliker and Mattox, 2003)). This activity provides the most recent example of the impact of lava flows on the island. The eruption is also the source of volcanic gases and aerosols, which are problematic for people and property in many areas of the island.

The long duration of lava flows and volcanic gases from the current eruption are unprecedented hazards in the United States. By September 2002, the eruption had covered 110 km² of land in the District of Puna and destroyed 189 buildings (Fig. 3.1b). The volcanic gas and aerosol hazard is more pervasive than lava flows and it creates chronic and acute health problems (U. S. Geological Survey, 1997a).

Is the current long-duration eruption of Kīlauea abnormal or typical? For the historical record, the duration of the current eruption is abnormal. However, this record dates back only to the late 18th century. In contrast to eruptive behavior in the 19th and early 20th century, volcano researchers (Swanson, 1972) have suggested that the duration of the current eruption is the norm for Kīlauea’s long-term behavior on the east rift zone (Fig. 3.1a). For example, the Mauna Ulu eruption of Kīlauea between May 1969 and July 1974 (Swanson, 1972) was similar in many respects to the current eruption of
Kīlauea, although the Mauna Ulu eruption was of shorter duration. Swanson (1973) suggested that characteristics of eruptions such as those observed during the 1969-1971 part of the Mauna Ulu eruption were more “typical” [emphasis in the original] than any other post-European contact flank eruption in terms of long eruption duration, mild but continuous rate of lava effusion and the large volume of lava erupted (Swanson, 1972; Swanson et al., 1971). The final four years of the Mauna Ulu eruption also had similar slow effusive characteristics. If these two eruptions are typical of the major mountain-building eruptions of Kīlauea’s rift zones, as suggested by Swanson (1973), then evaluations of risk from the lava flow hazard in that area of the island must reflect this style and duration of volcanism. The district where Kīlauea has been erupting has been the fastest growing district in the state for years (County of Hawaii, 2000).

In contrast to low rate of lava effusion, which is characteristic of recent episodes of activity at Kīlauea, other eruptions with expected higher effusion rates, which may have shorter durations, present uniquely different threats to developed property, human safety or both. This is particularly true for subdivisions located on and immediately downslope from the east rift zone. Kīlauea’s recent and relatively mild behavior may cause island residents to underestimate their risk in future eruptions from this and other volcanoes.

1.3.2 Tsunamis

Tsunamis have occurred in the Hawaiian Islands many times in the past, and damage from them has been extensive (Dudley and Lee, 1998). There are two kinds of tsunami threats in Hawai‘i. One is the threat of tsunamis generated from distant sources, which
are typically several thousand kilometers from Hawai‘i and allow between 4 and 15 hours of response time once they are detected (Zetler, 1947). The second type of tsunami threat in Hawai‘i is that of tsunamis generated locally. These tsunamis provide only minutes to an hour of response time once formed (Cox and Morgan, 1977; Zetler, 1947).

Lander and Lockridge (1989) reported that twenty-six damaging tsunamis occurred in the Hawaiian Islands since 1819 (i.e., generated waves with >1 m runup). All but four were from distant sources. The average return rate for large distant-sourced tsunamis is therefore one tsunami every 9 years. By comparison, the average return rate for locally generated tsunamis is much longer (i.e., one tsunami every 46 years). The latest large, destructive Pacific-wide tsunami occurred in 1960 and devastated Hilo. At that time, tsunamis inundated 580 acres of land; killed 61 people; and destroyed about 737 dwellings, businesses and public buildings totaling about $50 million in property damages (Dudley and Lee, 1998). Destructive tsunamis had previously destroyed Hilo just 14 years earlier in 1946 and claimed 159 fatalities in the state (Cox, 1987; Dudley and Lee, 1998). In Hilo alone, almost 500 homes or businesses were destroyed and another thousand severely damaged (Dudley and Lee, 1998). The last locally generated tsunami originated along the south shore of Kīlauea in 1975 (Dudley and Lee, 1998). Two people were killed in this event. Prior to that, a large locally generated tsunami in 1868, again on the southern side of the island of Hawai‘i, destroyed several villages and killed several tens of people (Dudley and Lee, 1998; U. S. Geological Survey, 1999).

Hawai‘i is obviously prone to destructive tsunamis, but 44 years have passed since the last damaging Pacific-wide tsunami and 29 years since the last locally generated tsunami. The lack of recent experience with these two hazards could limit the adoption
of preparedness measures that ensure capabilities to respond effectively to different tsunami threats (Fletcher et al., 2002a). Furthermore, despite the fact that mitigation has occurred in areas of highest risk, such as the near-shore areas of Hilo (Dudley and Lee, 1998), many developed areas remain within tsunami inundation and evacuation zones (see tsunami evacuation zone maps in Hawai‘i telephone books (Verizon Hawaii, 2002)). Such development poses challenges to developing resilient and sustainable communities.

1.4 Social Science Perspectives on Natural Hazards

This dissertation highlights the importance of periodically assessing public issues related to hazards, risk and protective behavior. Changes in population, socio-demographics, commerce, and hazard experience could influence these issues. Accurate estimates of risk, and the development of strategies to effectively manage risk, require an understanding of the interaction between people and natural hazards and risk messages. This interaction is influenced by social, psychological, cultural and political factors.

Physical scientists and the public evaluate risk differently. Physical scientists often focus on understanding the physical nature of hazards and on quantifying risk in terms of economic loss. For example, the U.S. Geological Survey’s Hawaiian Volcano Observatory (HVO) has recently focused on understanding risk from lava flows at Mauna Loa in terms of probability of hazard activity and the value of vulnerability infrastructure (Hawaii State Civil Defense, 2002; Kauahikaua et al., 1998; Trusdell and Graves, 2004). In contrast, people’s understanding of risk, and how they respond to risk, is determined not only by scientific information or direct experience of hazard consequences, but also by the manner in which information and experience interact with psychological, social,
cultural, institutional and political factors. Changing people’s perceptions of risk alone will not necessarily bring about changes in their behavior or increased action to address a particular risk. Similarly, designing a barrier or dropping a bomb that successfully diverts the flow of lava around a village will not necessarily increase people’s acceptance of such mitigation strategies. Indeed, if it is inconsistent with prevailing cultural beliefs, such activities could detrimentally affect relations with decision-makers and increase risk if the latter leads to greater mistrust of official agencies.

The approach adopted in this dissertation is different. Here the focus is on the factors that contribute to household adoption of risk-reduction measures and factors that influence attitudes toward official mitigation strategies that intervene directly to control a hazard (e.g., use of barriers or bombs to change the direction of a lava flow). By examining the relationship between scientific hazard information and the personal, social, psychological and cultural mechanisms that mediate their acceptance and their use in activities that reduce risk, this work will provide more comprehensive models for natural hazard education and other risk-reduction strategies.

1.4.1 Awareness, perceptions and preparedness

The communication of risk about natural hazards and technological hazards is a central focus of contemporary emergency management. There has been tremendous growth in the field of natural hazards (Mileti, 1999; Tierney et al., 1999; White, 1974; White and Haas, 1975) and risk communication (National Research Council, 1989; Sjöberg, 2000; Slovic, 2000) since the 1970s and 1980s, respectively. Public communication of risk about natural hazards, such as information aimed at encouraging the adoption of risk-
reduction measures, has traditionally focused on providing people with accurate hazards and risk information (Smith, 1993). However, recognition is growing that these strategies are incomplete mechanisms to facilitate the adoption of mitigation and preparedness measures (Duval and Mulilus, 1999; Lindell and Whitney, 2000; Mulilis and Duval, 1995; Paton et al., 2000). Findings from the health-protection literature (e.g., the theory of planned behavior and protection motivation theory (Abraham et al., 1998; Bennett and Murphy, 1997; Jones et al., 1997)) suggest that this is due to people’s failure to accommodate cognitive processes used to interpret information and events and make judgments about the feasibility of the mitigation and preparedness actions or otherwise of doing something about a threat or hazard. These cognitive processes influence the relationship between beliefs about risk and the adoption of measures to protect oneself (Adams, 1995; Paton, 2003; Smith, 1993). A number of interpretive processes may serve to limit preparedness, and several of these factors are discussed in regard to the volcano study in Kona (i.e., Chapt’s. 2 and 3). These include unrealistic optimism and normalization biases (Mileti and O’Brien, 1993; Paton et al., 2003a; Weinstein and Klein, 1996), cognitive dissonance (Festinger, 1980), self-efficacy and outcome expectancy (Paton, 2003) and perceived responsibility (Lindell and Whitney, 2000; Mulilis and Duval, 1995).

Eruptions of Kīlauea often allow relatively easy access to observe passive lava flows without explosive activity and ash fall, although this usually coincides with low effusion portions of eruptions such as the current episode of Kīlauea’s eruption. I suspected that many people in Kona would have seen active lava flows at Kīlauea. The typically mild eruptive activity observed recently at Kīlauea could influence people’s risk
perceptions about lava flows unduly, causing them to generalize the situation at Kīlauea to future situations in Kona. Normalization bias suggests that people may infer a capacity to cope with more extreme hazards, such as those that have occurred in Kona and are likely to occur again, from their ability to cope with hazardous events of small magnitudes, such as those that are commonly observed, from a visitor or “tourist” perspective, at Kīlauea (Johnston et al., 1999; Mileti and O’Brien, 1993). Furthermore, Paton et al. (2001a) and Lindell and Perry (1992) found that only direct experience in hazard events was found to influence risk perception, as opposed to vicarious experience (Sjöberg, 2000).

Unrealistic optimism bias describes how people, relative to others within their community, perceive themselves as less vulnerable and/or more prepared than others. This is the same process that results in people perceiving that accidents happen to other people. In a natural hazards context, it can result in a general predisposition to overrate their preparedness for hazards (Johnston et al., 1999; Weinstein and Klein, 1996). These people see the utility of preparedness within a community, but perceive that this need applies to other people, not themselves. The normalization and optimism bias are important concepts, because their presence in a population may reduce the likelihood that people respond to warning messages and react to outreach even while accepting the threat posed by a hazard. For the Kona study, these issues are discussed in Chapter 2.

Self-efficacy refers to people’s perceptions of self-competence to effectively perform risk-reduction strategies. Outcome expectancy refers to people’s beliefs about whether hazard effects are surmountable by human action or not (Paton, 2003). These factors could have significant roles in shaping preparedness for lava flows, because
information specific to preparing for lava flows has not been available and people may perceive that nothing can be done to reduce risk from lava flows. However, the formulation of emergency response plans is one action that should be encouraged (Hawaii State Civil Defense, 2002). Other options to mitigate lava flow hazards include lava diversion and land-use planning and zoning (section 1.5).

People’s perceptions of who is responsible for preparing a community for natural hazards may influence risk-reduction actions (Lindell and Whitney, 2000; Mulilis and Duval, 1995). For example, in a recent New Zealand study (Ballantyne et al., 2000), a longitudinal hazard education program aimed at increasing awareness of volcanic hazards raised awareness of the hazard, but this led to a reduction in preparedness, because people transferred responsibility for their protection to officials whom the people learned were monitoring the hazard. These factors have implications in Hawai’i, where several hazards such as volcanic, tsunami, and meteorological hazards are monitored by Federal agencies, and the monitoring is presumably known among the public.

1.4.2 Hawaiian cultural issues

The research in Chapter 4 of this dissertation discusses attitudes toward controversial mitigation measures that interfere with the paths of lava flows and offers some explanations for how culturally sensitive issues may best be accommodated by official mitigation strategies. The theoretical aspects of this work are based on a small branch of research related to understanding the significance of Hawaiian cultural values and their role in shaping coping mechanisms of Hawaiian people, especially in situations with which the people are thought to have little control (Handy and Pukui, 1958; Heighton Jr,
1971; Howard, 1974; Lee and Newton, 1981). Such situations include lava flows and child birth (Lee and Newton, 1981). In Chapter 4, the significance of a Hawaiian cultural renaissance (Young, 1980) is discussed in the context of land-use decisions, such as those required to protect areas from lava flows with engineered mitigation measures (e.g., earthen barriers, bombs, water, etc). This issue is of considerable importance because short of relocating development that is threatened by lava, intervening in the paths of lava flows is currently all that can be done to protect property. The default is to allow the destruction of development and then implement principles of land-use planning to control development. Understanding Hawaiian cultural beliefs about intervening in lava flows is important in making informed decisions to protect at-risk people and property and to facilitate their participation in risk-reduction strategies.

1.4.3 Warnings and messages

Warning systems are important because they link communities to scientific and civil defense or emergency management agencies and they encourage the adoption of household mitigation and preparedness measures. Moreover, the ability of warning systems to trigger the use of these resources to minimize loss or to trigger key behaviors such as evacuation is fundamental to community resilience. Warning messages must be designed to facilitate prompt action, and to do so they must be designed in ways that are understood by people and that trigger actions. The quality of these actions will be a function of the level of preparedness of communities and community members and the effectiveness of the measures. For example, warnings may signal a need for evacuation; however, the effectiveness of the warning system will be a function of the degree to
which systems are in place to evacuate people and a function of the extent to which households have developed plans that cover their evacuation.

The response of individuals to formal alert or warning messages is influenced by a number of factors. These actions include risk perception; the nature of the information (e.g., specificity, consistency, accuracy, clarity, media, frequency, certainty, etc); and the personal characteristics of the recipient (e.g., demographics, knowledge, experience of the hazard, social network, etc (Mileti and Sorensen, 1990)). Given the diversity of factors that are predictors of warning effectiveness, it is important to ensure that warnings are tailored to the characteristics of communities. Moreover, these characteristics may change from community to community and from time to time. This underscores the need for monitored outreach. Warning system and community characteristics should be assessed in tandem, and periodically. A failure to do so can reduce the effectiveness of warnings, and thus contribute to unnecessary loss of property and impacts on human safety.

Many examples in the literature describe people failing to evacuate in response to hazard warnings (Mileti and O'Brien, 1993). A detailed study of human behavior in response to siren soundings in the May 23, 1960 tsunami that destroyed Hilo highlighted the severe implications of ambiguity in understanding of the siren (Lachman et al., 1961). No studies of understanding the warning siren in Hawai‘i have been performed since the 1960s, although Raine (1995) explored some aspects of the siren in relation to communication of tsunami warning messages following the 1994 tsunami warning in Hawai‘i. The siren system has been routinely tested for decades, so I was interested in evaluating the effects of these tests on understanding of the meaning of the siren. Some
people believe that public awareness of the meaning of the siren is high simply because tests have been conducted routinely and publicly announced for decades. Furthermore, public awareness of tests of a system should not be taken as indicative of a capacity to act on real warnings. However, there are no data to support this. Another issue I explored is expectations of warnings for tsunamis. Of specific interest is the source from which people expect warnings to be derived. In Chapter 5 of this dissertation, I illustrate the significance of recognizing and responding to natural warning signs of locally generated tsunamis with a discussion of an earthquake and tsunami that occurred in Japan in 1993.

The fundamental theoretical ideas discussed in section 1.4, along with the fact that most outreach efforts frequently consist of a single, blanket release of information without considering the manner in which people receive, interpret and use information, provide the theoretical basis for this dissertation research. In light of the complexity of risk communication, effective outreach strategies require a focus on the needs of people at a local level (Lindell, 1994) and monitoring of outreach to ensure that objectives are achieved and success is not overestimated. Most outreach in Hawai‘i has not been monitored, so how prepared are Hawai‘i’s people?

1.5 Land-Use Planning and Zoning

A number of mitigation measures can be used in Hawai‘i to reduce vulnerability of property and people to lava flow hazards and tsunamis. Land-use planning that controls or prevents development is the most effective mitigation tool (Burby et al., 2000). Building codes are also valuable mitigation tools for hazards such as earthquakes, hurricanes, floods and in some instances tsunamis, but presently they have no application
to the mitigation of lava flows. Thus, the prevention of future development and the resettlement of existing development in high hazard areas are the most effective mitigation strategies. However, where specific future development is essential in areas of high hazard, land use can and should be carefully planned in order to control risk. Furthermore, where development has already occurred, including where new hazard research has increased the ranking of hazards in an area, other activities are required to reduce risk.

Long-term mitigation planning provides communities with an outlet to reduce vulnerability and risk from hazards and to be prepared for post-disaster recovery and reconstruction, which has traditionally been a period of time when hazard mitigation money is made available (Schwab et al., 1998). Compliance with the requirements of the Disaster Mitigation Act of 2000 (U. S. Congress, 2000) has facilitated such planning at county and state levels in Hawai‘i. For example, each county in Hawai‘i and the state have developed hazard mitigation plans (Hawaii Statewide Hazard Mitigation Forum, 2004a).

1.5.1 Lava flow hazards

There are currently no specific restrictions on development in high lava flow hazard areas within either state of Hawai‘i law or Hawai‘i County ordinances (Hawaii State Civil Defense, 2002). Furthermore, most inexpensive and available real estate regions in the state are within the areas of high lava flow hazard. Much of this land is very rural in comparison to the main population centers on the island. A need for affordable land and housing and a desire to live in a rural setting are presumably key factors that influence
people's decisions to live in communities located in these areas. These communities include, among others, Hawaiian Ocean View on the border between the Districts of South Kona and Ka'ū and Leilani Estates in the District of Puna (Fig. 2.1d). Another factor is that people's perception of risk from lava flows is low, due in part to the fact that most people do not believe their community will be inundated by lava within their lifetime (Gregg et al., 2004a, Chapt. 2). These factors contribute to the ideology that people possess a legal right to build in high lava-flow hazard areas.

Official permitting decisions for major development projects in Hawai'i are made on a case-by-case basis. Consideration of lava flow hazards is one factor that contributes to the decision-making process (Hawaii State Civil Defense, 2002). Understanding why residential and commercial development is legal in areas of high lava flow hazard requires a familiarity with the state's Land Use Law (SLUL (State of Hawaii, 2001)). Under the SLUL, the state manages land use by classifying land into one of four districts—Urban, Rural, Agricultural and Conservation. At the state level, the development of state land-use policies involves the Land Use Commission (LUC) and the Office of Planning (OP), although in some cases the Department of Land and Natural Resources, the Department of Agriculture and the Department of Health have also been involved. The state's position is represented by the OP, which often consults requisite authorities from affected Federal, state and county agencies. For example, the Hawaiian Volcano Observatory (Federal) and Civil Defense agencies (state and county) have been historically consulted by the OP about petitions for lands subject to lava flows (Hawaii State Civil Defense, 2002).
The management of land use in specific districts is shared by the LUC and affected counties. The LUC manages land-use boundary changes for all lands in the Conservation District and for lands totaling over 15 acres in the other three districts, whereas the affected counties manage lands of 15 acres or less in the latter (Hawaii State Civil Defense, 2002).

A number of factors influence land-use decisions. One factor is a provision that land use conform to the goals, objectives and policies of the Hawai‘i State Plan (Hawaii State Civil Defense, 2002). Among many policies found in this plan is one to reduce the threat to life and property from volcanic eruptions and other hazards (e.g., earthquakes, tsunamis, flooding, hurricanes, erosion, and other natural or human induced hazards). A special state technical committee was formed a few years ago with the task of reducing the risk to life and property from lava flows (Hawaii State Civil Defense, 2002).

Much of the development at risk to lava flows in HOV (Hawaiian Ocean View) and areas of Puna is located on land that is classified in the Agricultural District. There are also thousands of developable lots in these areas. The Agricultural District is therefore a target of concern among those responsible for managing volcanic risk.

The idea behind classifying land in the Agricultural District is to protect fertile lands and opportunities to farm the lands, but a problem has arisen with this policy because land-use laws allow lands that are poorly suited for agriculture to be designated within the district. This includes lava-covered land. Thus, the zoning policy creates a conflict in land use (Hawaii State Civil Defense, 2002).

Many of the areas in HOV and Puna were already considered for residential use before land-use laws were enacted. Today, there is no significant agricultural use of
these lands, but on such land there are an estimated 60,000 lots in Puna (Hawaii State
Civil Defense, 2002) and 13,000 in a subdivision in HOV (i.e., HOV Estates (Trusdell,
1995)). Construction of single-family dwellings, as opposed to farm dwellings, was
allowed in these subdivisions under Hawai‘i County zoning laws at the time the land was
subdivided. Since the subdivisions were approved prior to June 4, 1976, construction of
single-family dwellings in these subdivisions is still allowed. However, construction of
single-family dwellings elsewhere is not currently allowed on land classified in the
Agricultural District. In other agricultural subdivisions, construction is limited to farm
dwellings, employee housing and structures that have an agricultural use. A solution may
be to find suitable land to swap and then reclassify the land as Conservation (Hawaii
State Civil Defense, 2002).

Despite the conflicting nature of land use in the Agricultural District, Hawai‘i
County land-use policy considers volcanic hazards in its land-use and zoning process.
Major land-use changes call for the location of development in appropriate areas, and the
possibility of exposure to natural hazards such as lava flows is one consideration. The
possibility of inundation of a development by lava flows, and the imposition of strategies
to mitigate the impact of the lava flows, form a part of the county’s decision-making
process. Hawaii State Civil Defense (2002) reported that, generally, these major land-use
changes require the preparation of an Environmental Impact Statement (EIS).

A fairly recent example of land-use planning in Hawai‘i that involved
consideration of lava flow hazards was related to the Hawaiian Riviera Resort
Development Project Proposal of 1988. This case study highlighted how the state and
county of Hawai‘i differed in handling the issues of lava flow hazard in land-use
decisions (Hawaii State Civil Defense, 2002; Kauahikaua et al., 1995). The proposed ocean-front resort petitioned for reclassification of 3,000 acres for mixed use of land near Hawaiian Ocean View and desired to construct a hotel, golf course and small airport (Hawaii State Civil Defense, 2002; Trusdell, 1995). The area was classified agricultural, but it was located in lava-flow hazard zone 2, which is the second highest zone. The LUC (Land Use Commission) became involved in the decision-making process since the area exceeded the 15 acre limit for which the county had jurisdiction.

The proposed location of the resort is an area where the state has recently recognized that lava flows represent a threat to life and property (Hawaii State Civil Defense, 2002). The LUC had no prior experience in dealing with lava flow hazard issues. The Office of Planning opposed the development, but the County of Hawai‘i Planning Department supported the project on the grounds it would stimulate economic growth (Hawaii State Civil Defense, 2002). About one half of the proposal was approved by the LUC in 1991, but an interesting stipulation was the LUC’s imposition of three mitigation strategies (Hawaii State Civil Defense, 2002). These included:

1. That the petitioners provide a notice requirement to inform all prospective occupants of the resort to a land deed covenant of the volcanic, seismic, and tsunami hazards.

2. That the petitioner formulates and implements an emergency preparedness and evacuation plan for the resort. Consultation with county and state Civil Defense agencies was also required.

3. That for evacuation purposes, the petitioner grade and maintain no less than two lateral access roads from the proposed development site to the main highway and
another access road parallel to the coast.

The petitioner was also required to provide evidence that residential structures at the resort could be insured against damage from volcanic eruptions, earthquakes, fire, flood, and tsunamis. Financial problems prevented development of the resort. However, the Hawaiian Riviera Resort project has presumably enhanced the land-use planning decision-making process where lands in high areas of lava flow hazard are concerned.

Reducing vulnerability to hazard-related losses by directing new development away from the area of known hazard through land-use plans and regulations is one natural hazard-mitigation strategy (Godschalk et al., 1999). Traditionally, government entities have condemned land or negotiated purchase of the land as a means of setting hazardous land aside for a public use or purpose. While this is a most effective way to eliminate vulnerability and risk, the concept is often prohibitively expensive. Alternative methods of land-use planning have been approved in Hawai‘i that direct new development away from known hazard areas. Such methods include reclassification of subdivisions to the Conservation District. This would result in less intensive use of the land, but would not necessarily prohibit development of a residence unless the property owner’s development rights were bought out (Hawaii State Civil Defense, 2002). For example, Transfer of Development Rights is a land-use planning technique used to set aside lands from development.

Transfer of Development Rights (TDR) is a process whereby a person owning property that is sought to be preserved may sell to another entity the rights to develop the property. Such lands may include areas of high lava flow hazard. The buyer would then be permitted to develop another property that is more suited for growth above the density
currently permitted for that property. The TDR process can benefit all parties involved (Hawaii State Civil Defense, 2002; Mittra, 1996). A bill was enacted by the Hawaiʻi State Legislature in 1998 that enables counties to exercise the power to transfer development rights (Hawaiʻi Revised Statutes, §§ 46-161 – 46-165).

Reconfiguration of subdivisions and land readjustment are two other land-use planning techniques that may be used to reduce risk. Reconfiguration involves the merging or reconfiguring of lots that have not been sold. This would increase lot sizes and could reduce allowable housing and population density. In comparison, land readjustment involves reassembly of lands held in wide ownership into a format more desirable for redevelopment (Schwab, 1997).

In summary, tens of thousands of developable lots occupy areas of high lava flow hazard, and a number of available land-use planning and zoning strategies exist to mitigate the impact of future lava flows in these areas. However, the future role of these strategies remains uncertain. A number of challenges face the mitigation of lava flow hazards in Hawaiʻi. These challenges include controlling development in areas of highest hazard and resettling those communities at greatest risk. A challenge is to promote preparedness measures that will reduce the risk to safety and property of people who will not relocate to safer areas. This is because most people, at least those in Kona, do not believe eruptions will occur and many people overestimate the time that may be available to respond to lava flows (Gregg et al., 2004a, Chapt. 2).
1.5.2 Tsunami hazards

Tsunami-mitigation planning in Hilo is one of the state's mitigation success stories. However, some mitigation measures have yet to be tested by large tsunamis and most development still occurs in the coastal zone where tsunamis occur. Following the devastating 1946 tsunami that destroyed much of the waterfront district of Hilo, the idea of protective walls, used extensively in Japan, was considered for the city. However, the idea was quickly abandoned when cost estimates indicated the value of the desired protected area was less than the cost of the walls (Dudley and Lee, 1998). A narrow strip of land was established as a buffer zone between Kamehameha Avenue (a road that parallels the Hilo Bay front) and developed areas inland of Hilo Bay. Nearby areas were redeveloped, particularly with flimsy housing (Dudley and Lee, 1998). The buffer zone proved to be effective in limiting damage in the 1957 tsunami, but was less effective in the larger 1960 tsunami (Dudley and Lee, 1998). Currently, Hawai‘i County has identified a range of mitigation measures to address tsunami hazards and risk on the island of Hawai‘i (County of Hawaii Civil Defense Agency, 2003).

Following the 1960 tsunami, some of the vulnerable lands were set aside for recreation and development was prohibited (Dudley and Lee, 1998). However, demand for development of some waterfront areas was too great and hotels were permitted in an area of the waterfront along Banyon Drive. Building codes and ordinances, however, have mitigated the potential impact of future tsunamis on these buildings and their occupants. For example, the lower level of the hotels are designed so that walls will detach and allow tsunamis to wash through the lower portions of the building, reducing stress on load bearing walls (Dudley and Lee, 1998). Another strategy includes vertical
evacuation to the third floor or higher in steel or concrete buildings of six or more stories. This is a critical issue in densely populated urban areas such as the Waikīkī District of Honolulu, where numerous high-rise hotels and office buildings are located.

A number of challenges face emergency management efforts to mitigate tsunami hazards in Hawaiʻi. These include relocating developed areas that are within existing inundation zones and strengthening critical facilities to resist the impact of tsunamis. Other challenges include modeling tsunami inundation and runup for tsunamis derived from multiple sources and establishing safe evacuation zones based on model results. As reflected by participants in a recent state-sponsored tsunami technical meeting in Honolulu, another challenge involves consideration of the impact of earthquake shaking on the structural integrity of buildings to safely serve as sites for vertical evacuation. Another challenge involves developing the capability to establish tsunami evacuations on a local level as opposed to the standard statewide level. However, this capability requires improvements in the ability to effectively model tsunami runup and inundation on a more localized scale and to provide effective evacuation messages for localized areas. Such achievements would reduce the burden of evacuating the entire coastal area, which would ideally allow for greater continuity of business and reduce economic losses.

1.6 The Three Research Projects

I have described the nature of lava flow and tsunami hazards in Hawaiʻi and provided justification for studies of them, as well as the siren system that will alert people to hazard events and the awareness of natural warning signs of tsunamis. I now describe the three research projects that were conducted during this dissertation research. The first
project is linked to perceptions of and preparedness for lava flow hazards from Mauna Loa and Hualalai volcanoes in Kona. This first project is described in Chapters 2 and 3. The second project describes public attitudes toward lava flow mitigation measures. This second project is described in Chapter 4. The third project evaluates statewide public understanding of Hawai‘i’s siren warning system and awareness of natural warning signs of tsunami in Hilo. This third project is discussed in Chapter 5.

Work proceeded in each of the three projects with an investigation of the threat of specific hazards in specific communities, followed by a review of relevant published and unpublished literature and meetings with key agencies and stake-holders. Agencies and stakeholders were contacted in order to identify known concerns and to understand the needs of official agencies that disseminate hazard and risk information to the public. Some of the key agencies and stake-holders I met and corresponded with included the US Geological Survey, Hawaiian Volcano Observatory; the National Oceanic and Atmospheric Administration’s National Weather Service, Pacific Tsunami Warning Center and International Tsunami Information Center; the Hawai‘i State Civil Defense; county Civil Defense Agencies on the islands of Hawai‘i, Maui, O‘ahu and Kaua‘i; the Hawai‘i Coastal Zone Management Program; and the Department of Education. Interaction with the state of Hawai‘i Lava Flow Hazard Mitigation Technical Committee and the Tsunami Technical Review Committee provided opportunities to keep abreast of hazard, risk and mitigation activities and to work among the state’s leading hazard and risk management experts. Collectively, these contacts were important in helping steer the direction of this research and in establishing contacts with people through which the findings may be shared at local and state levels.
The design and implementation of surveys and analyses conducted during each project are discussed in the research chapters. More detailed discussions are provided as Appendix B. The demographics of the Kona project are described in Appendix C. The generalizability of ethnic data collected in projects 1 and 3 are discussed in Appendix D. Copies of survey materials for the Kona and siren/tsunami projects are provided as Appendix E and F, respectively. Below I present a brief outline of each of the research projects.

1.6.1 Lava flow risk perceptions and preparedness in Kona

Population diversity, numbers and density and development in Kona have increased significantly since the latest eruption of Mauna Loa in 1950. Therefore more people and development are now at risk. Mauna Loa and Hualālai volcanoes are certain to erupt again and the fact that eruptions could begin from vents near or within developed areas suggests that communities should be prepared in advance. Furthermore, the volcanic threat is exacerbated by the prospects that there may be little advanced short-term warning of eruptions (Gregg et al., 2004b, Chapt. 3).

Several questionnaire surveys were conducted in Kona to collect data on hazard awareness, risk perceptions, preparedness, etc. A questionnaire was presented to 9th grade students at the two high schools in Kona (Fig. 3.1). Questionnaires were also distributed to one parent or guardian of each of the students and to the adult population at large in Kona (total n=462). The hypothesis tested was that a lack of recent eruptions in Kona has limited residents’ experience with lava flow hazards and that this could
contribute to low levels of hazard awareness, perceptions of risk, and correspondingly low levels of even basic preparedness measures.

The results of the Kona survey are discussed partly in Chapter 2, which is titled, "The perception of volcanic risk in Kona communities from Mauna Loa and Hualalai volcanoes, Hawaiʻi." As discussed in Chapter 2, there are a number of ways in which people in Kona may become aware of volcanic hazards and develop risk perceptions. For example, the persistence of vog from Kīlauea may prompt people to inquire about the source of the vog, and this may prompt inquiries into the volcanoes in Kona—Mauna Loa and Hualalai. The presence of conspicuous lava flows in Kona and the steep profile of Hualalai may also prompt inquiries into the nature of volcanism in Kona. Outreach programs also influence awareness of volcanism. For example, the Center for the Study of Active Volcanoes at the University of Hawaiʻi at Hilo provides classroom lectures about volcanic hazards to Kona students who participate in the Keakealani Outdoor Education Center in Volcano Village on Kīlauea. Furthermore, the Hawaiian Volcano Observatory publishes volcano-related articles in local newspapers and occasionally discusses volcanoes at public seminars.

In Chapter 2, I describe exposure to hazard education in Kona, awareness of hazards, expectations of possible eruptions and the timing of future eruptions, risk perceptions, perceived preparedness and responsibility for preparedness, and the adoption of specific preparedness measures. Chapter 2 discusses the types of outreach information that may be most effective in strengthening and maintaining community resilience.

The issue of short warning times in future eruptions is a focus of Chapter 3. The installation of numerous monitoring instruments on Mauna Loa since the latest eruption
of the volcano in 1984 means that we are better prepared now to detect volcanic unrest than before past eruptions (U. S. Geological Survey, 2003). However, the infrequency of recent eruptions of Mauna Loa and Hualālai, and our corresponding lack of experience with the evaluation of precursory activity, present a high level of uncertainty in terms of knowing what to expect from future eruptions of these volcanoes.

Chapter 3, titled, “Community preparedness for lava flows from Mauna Loa and Hualālai volcanoes, Kona, Hawai‘i,” builds on recent observations of eruptions and precursory activity during the best constrained 20th-century eruptions of Mauna Loa (Gregg et al., 2004b). It focuses on a discussion of public perceptions of the amount of advanced short-term warning (i.e., from volcanic tremor) that may be provided in future eruptions in Kona and how perceptions relate to preparedness. Chapter 3 also evaluates levels of adoption of a number of specific, but non-volcano disaster-preparedness measures that are mentioned in Hawai‘i telephone books. The telephone books are presumably the most widely distributed sources of disaster preparedness information in Hawai‘i (Verizon Hawaii, 2002). Chapter 3 examines the influence of awareness of this material on understanding of the warning system and adoption of preparedness measures.

### 1.6.2 Attitudes toward engineered mitigation of lava flow hazards

The second project of this dissertation was concerned with public attitudes toward mitigation of lava flows in Hawai‘i. Lava flows from the three active volcanoes have covered hundreds of square kilometers of land in Hawai‘i, and several villages and communities have been destroyed in the process. One method of protecting developed areas from lava flows involves the use of engineered mitigation measures that control the
direction of lava flows, but the formulation, adoption and implementation of such measures is an intensely political process (Prater and Lindell, 2000). This is especially true in Hawai‘i, because Hawaiian people are generally thought to oppose such measures (Hawaii State Civil Defense, 2002). Chapter 4 of this dissertation is the first scientific study of public attitudes toward lava flow mitigation in Hawaii. Given the political power of the Hawaiian people, it is important to understand their position on mitigation. Chapter 4 provides a unique perspective of public attitudes toward the use of engineered measures used in an eruption of Kīlauea in 1960. This chapter provides a valuable contribution toward understanding the social, cultural, economic, political and scientific complexities of engineered mitigation in future eruptions of Hawaiian volcanoes and eruptions elsewhere.

1.6.2.1 Resurrection of a lost and forgotten survey
A brief description of how the unpublished data used in Chapter 4 were obtained is important in the context of understanding why the information was collected and how it relates to contemporary issues of hazard mitigation. Such a description is provided below, followed by a discussion of the project itself.

In 2002, I learned of a study of human behavior during the highly destructive eruption at Kapoho (Lachman and Bonk, 1960; Macdonald, 1962). The eruption was unique in Hawai‘i, because the eruption began a few hundred meters from the town center of Kapoho, and lava from the eruption eventually destroyed the entire town. The only published account of the study was in Science in 1960 (Lachman and Bonk, 1960). However, this was only a brief, preliminary announcement of what was a very large and unprecedented social science survey conducted among adults in Kapoho and in three
other communities on the island (n=638). I recognized the potential significance of the 1960 study to understanding public sentiment toward lava flow intervention, and I conducted a literature search for later published manuscripts that reported the findings of the study. Nothing was found. After locating the original researchers and confirming that no later work was published, I received their permission to search for the data and to resurrect, analyze and publish the data if they could be found. The data were subsequently located in the form of raw interview questionnaires in University of Hawai‘i archives, then coded and entered into a statistical software program.

1.6.2.2 Cultural sensitivity toward lava flow mitigation
Cultural sensitivity to lava flow mitigation and other land-use proposals that do not accommodate the interests and values of indigenous people has complicated mitigation activities and development in Hawai‘i and elsewhere. For example, in Hawai‘i conflicts have arisen between Hawaiian activists over land-use development proposals on Kīlauea (Dinell and Goody, 1987; Supreme Court of the State of Hawaii, 1994; Supreme Court of the United States of America, 1992) and Mauna Kea volcanoes (Dalton and Abbott, 2000; Feder, 2004; Reichhardt, 2001). These examples, and an on-going debate over the mitigation of lahar hazards at Mount Ruapheu in New Zealand (Brown, 2004; Galley et al., 2004), provide recent examples of the difficulty in reconciling land-use proposals of economic and public safety perspectives with the needs, desires and expectations of indigenous peoples. Using bombs to mitigate lava flow hazards from Mauna Loa that threatened Hilo have historically received mixed reviews (Jaggar, 1936a, b). Chapter 4 provides a valuable historical perspective on attitudes toward mitigation in Hawai‘i and
then discusses the 1960 data in a modern context of hazard mitigation that may use barriers and bombs.

Chapter 4, titled "Cultural influences on attitudes toward lava flow hazard mitigation measures during the January 1960 eruption of Kīlauea volcano, Kapoho, Hawai‘i," focuses on one aspect of the data collected during the 1960 study. Specifically, data related to ethnic identity and cultural issues about the Hawaiian volcano goddess Pele are used to test the influence of these variables on attitudes toward construction of barriers and use of bombs as mitigation strategies in Kapoho. In addition to illuminating a potentially very significant issue in understanding social risk, this analysis also serves to identify several issues that should be included in future research and intervention agenda.

Mitigation of lava flows with barriers and bombs has been tried in Hawai‘i and overseas (Iceland and Sicily), but the future of such mitigation approaches is uncertain in Hawai‘i. This uncertainty stems from factors such as feasibility, liability, reliability, cost, and, from a mitigation planning perspective, especially cultural issues (Hawaii State Civil Defense, 2002). Decisions to implement mitigation measures may be complicated by cultural sensitivity, particularly because a cultural renaissance has occurred in Hawai‘i (Young, 1980) since the last mitigation was tried in 1960. Cultural sensitivity may discourage actions that physically interfere with the natural flow of lava, because lava flows are thought to be the body of Pele, and the land belongs to her (Hawaii State Civil Defense, 2002; Jaggar, 1936b; Lachman and Bonk, 1960; Lockwood, 2003; Lockwood and Torgerson, 1980).
1.6.3 The siren warning system and natural warning signs of tsunami

The third project of this dissertation was concerned with evaluating people’s understanding of the siren-warning system and natural warning signs of tsunamis. The project is described in Chapter 5, which is titled, “Awareness of a siren-based emergency warning system: Implications for tsunami preparedness in Hawai‘i.” This project was the largest of this dissertation, forming part of five separate studies in five communities on four islands (n=956). Public understanding of the meaning of the siren system in Hawai‘i was studied in each community. The study of natural warnings signs of tsunami was only conducted in Hilo.

The siren system plays a key role in alerting people to specific hazard events. Historically, the system has been used to alert people to tsunamis and hurricanes. However, the sirens may find usefulness in alerting people to other hazards such as volcanic eruptions (T. Kindred, pers. comm, 2003). A limitation of the sirens is that hazards such as lava flows and locally generated tsunamis may impact developed areas before sirens are sounded, although in most hazard events the sirens should provide a timely alert in advance of the impact of hazards on communities. No contemporary study has evaluated how well people understand the sirens.

An objective of the study in Hilo was to describe public expectations of possible warning signs for tsunamis in Hilo. I evaluated these expectations in terms of the relatively short advance warning times that can be expected in future locally generated tsunamis. The extent to which people might expect that warnings of tsunamis would come from official sources such as Civil Defense or from sirens, as opposed to natural warning signs such as changes in sea-level or earthquake shaking, was of specific
Evacuating to higher ground from coastal areas upon notice of natural warning signs of tsunamis will be critical in preventing fatalities in future locally generated tsunamis, because these tsunamis could impact some coastal areas before official warning messages are received and acted upon by the public.

There are several naturally occurring warning signs of tsunamis that could provide notice of hazard events in advance of the siren system (Darienzo et al., in press; Dudley and Lee, 1998). However, no study in Hawai‘i has identified how well people recognize these warning signs. Chapter 5 provides a valuable contribution to the state’s hazard mitigation efforts by highlighting current levels of understanding of the siren, awareness of natural warning signs of tsunamis, and expectations of future warnings.

### 1.7 Use of Previously Published Material and Human Subjects

Chapters 2 and 3 have been published with multiple coauthors on each manuscript. I was the primary author in each manuscript and my adviser, Bruce F. Houghton, was the second author. The other coauthors were doctoral committee members, D. Paton, D.A. Swanson and D. M. Johnston. The review process conformed to the normal practice for revision of thesis text (Appendix G).

Protection of Human Subjects is provided under Title 45 of the U.S. Code of Federal Regulations, Part 46. Research on human subjects was performed in compliance with applications filed with the Committee on Human Subjects (Appendix G).
CHAPTER 2. THE PERCEPTION OF VOLCANIC RISK IN KONA COMMUNITIES FROM MAUNA LOA AND HUALĀLAI VOLCANOES, HAWAI‘I

C.E. Gregg a, B.F. Houghton a, D.M. Johnston b, D. Paton c, DA Swanson d

a Department of Geology and Geophysics, University of Hawai‘i, 1680 East-West Road, Honolulu, HI 96822, U.S.A.
b Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand
c University of Tasmania, School of Psychology, Bag 1-342, Launceston, Tasmania, Australia
d U.S. Geological Survey, Hawaiian Volcano Observatory, PO Box 51, Hawai‘i National Park, HI 96817, U.S.A.


Abstract

Volcanic hazards in Kona (i.e., the western side of the island of Hawai‘i) stem primarily from Mauna Loa and Hualālai volcanoes. The former has erupted 39 times since 1832. Lava flows were emplaced in Kona during seven of these eruptions and last impacted Kona in 1950. Hualālai last erupted in c. 1800. Society’s proximity to potential eruptive sources and the potential for relatively fast-moving lava flows, coupled with relatively long time intervals since the last eruptions in Kona, are the underlying stimuli for this study of risk perception. Target populations were high school students and adults (n = 462). Using these data, we discuss threat knowledge as an influence on risk perception, and perception as a driving mechanism for preparedness. Threat knowledge and perception of risk were found to be low to moderate. On average, fewer than two-thirds of the residents were aware of the most recent eruptions that impacted Kona, and a minority felt that Mauna Loa and Hualālai could ever erupt again. Furthermore, only about one-third were aware that lava flows could reach the coast in Kona in less than
three hours. Lava flows and ash fall were perceived to be among the least likely hazards to affect the respondent’s community within the next 10 years, whereas vog (volcanic smog) was ranked the most likely. Less than 18% identified volcanic hazards as amongst the most likely hazards to affect them at home, school, or work. Not surprisingly, individual preparedness measures were found on average to be limited to simple tasks of value in frequently occurring domestic emergencies, whereas measures specific to infrequent hazard events such as volcanic eruptions were seldom adopted. Furthermore, our data show that respondents exhibit an “unrealistic optimism bias” and infer that responsibility for community preparedness for future eruptions primarily rests with officials. We infer that these respondents may be less likely to attend to hazard information, react to warnings as directed, and undertake preparedness measures than other populations who perceive responsibility to lie with themselves. There are significant differences in hazard awareness and risk perception between students and adults, between sub-populations representing local areas, and between varying ethnicities. We conclude that long time intervals since damaging lava flows have occurred in Kona have contributed to lower levels of awareness and risk perceptions of the threat from lava flows, and that the on-going eruption at Kilauea has facilitated greater awareness and perception of risk of vog but not of other volcanic hazards. Low levels of preparedness may be explained by low perceptions of threat and risk and perhaps by the lack of a clear motivation or incentive to seek new modes of adjustment.

2.1 Introduction
Hawai‘i’s coastal communities are subject to a wide range of frequent and infrequent natural hazards (Fletcher et al., 2002a)—floods, tsunami, storms, extreme weather,
seismicity and volcanic eruptions (Hamnett et al., 1996; Hamnett et al., 1993). As a consequence of rising population densities, increasingly sophisticated facilities, and increasingly complex social and economic infrastructure (Burby, 1998; Johnston et al., 1999), Hawaiian society is growing increasingly vulnerable to experiencing detrimental consequences from natural hazard activity. This vulnerability, coupled with the unpredictability of natural hazards, in regard to nature, scale, timing, duration, and location, increases the importance of increasing community resilience. A key element of the latter concerns ensuring communities and their members are well prepared.

One barrier to hazard readiness is incomplete understanding of the factors that influence individual and societal preparedness, and of how they react to outreach activities prior to these crises. Hazard mitigation strategies typically focus on the physical attributes (e.g., the magnitude, frequency and physical processes of natural hazards, and on engineering and building design), but rarely consider the meaning this has for people or its relationship to risk-reduction behavior. The importance of this relationship is heightened by the fact that technological mitigation measures that increase objective safety may lead to overconfidence and risky behavior (risk homeostasis (Adams, 1995)). Similarly, the dissemination of scientific information by experts within outreach programs that focus only on supplying accurate information to the public, without considering how recipients will react to that information and whether they will use it effectively in the future, ironically can also reduce the perceived need for preparedness (Paton et al., 2000).

Peoples’ acceptance of their vulnerability can increase warning effectiveness and improve preparedness (Lindell and Perry, 1992; Lindell, 1994; Mileti and Fitzpatrick,
1992; Mileti and O'Brien, 1993; Mileti and Sorensen, 1990; Nathe et al., 1999; Perry, 1990), but this link is often uncertain and tenuous (Johnston et al., 1999; Lindell and Whitney, 2000). The dissemination of information related to natural hazards may promote hazard awareness among individuals in a community, but the widely maintained assumption that increasing an individual’s awareness of hazards will result in an increase in their levels of preparedness for natural hazards is not always justified and has fallen well below expectations (Lindell and Whitney, 2000; Paton et al., 2000). No direct relationship between awareness and risk perception has been unequivocally demonstrated. To make matters worse, people confronted with complex issues about which they have a poor understanding, such as volcanic hazards, may transfer all responsibility for their protection to the requisite experts, e.g., the U.S. Geological Survey Hawaiian Volcano Observatory or Civil Defense agencies in the case of Hawai‘i (Paton et al., 2001b) with reduction in preparedness (Lindell and Whitney, 2000; Mulilis and Duval, 1995). These observations highlight the need to articulate people’s understanding of scientific information and technical mitigation measures before embarking on a strategy that involves using this information to facilitate preparedness. Adopting this approach gives scientific and emergency management agencies the opportunity to correct misconceptions first. They can then develop risk communication strategies that build on community knowledge, beliefs, needs and expectations (rather than providing information that reflects only the knowledge and expectations of the scientific community).

Several studies have measured understanding and perception of volcanic hazards and risk during periods of quiescence (D’Ercole et al., 1995; Johnston and Houghton,
1995; Perry, 1990; Perry and Lindell, 1990), after a volcanic crisis (Kartez, 1982; Murton and Shimabukuro, 1974; Saarinen and Sell, 1985; Yoshii, 1992), and before and after a volcanic crisis (Johnston et al., 1999). However, few studies have been conducted in Hawai‘i, whose varied ethnicity, wide cultural framework, and volcanism are unique in the world.

While work on perceptions of risk or preparedness for volcanic hazards in Kona is absent from the literature, some work has been done on Kīlauea volcano (Fig. 2.1a) in the eastern portion of the island (e.g., Lachman and Bonk, 1960; Murton and Shimabukuro, 1974). This study evaluates the perceptions of volcanic hazards from Mauna Loa and Hualālai volcanoes in Kona (Fig. 2.1d).

2.2 Kona

Our study area lies principally in the political districts of North and South Kona, collectively called Kona (Fig. 2.1d), which form the western portion of Mauna Loa and Hualālai shield volcanoes. Both districts in Kona have been adversely impacted by lava flows during historical eruptions of Hualālai and Mauna Loa and by gas emissions from an on-going, 20-year old eruption at Kīlauea. The populations of North and South Kona in 2000 were 28,543 and 8,589, respectively (County of Hawaii, 2000). North Kona includes the second largest city on the island (Kailua-Kona (Kailua), population = 9,870) and is more densely populated than South Kona (County of Hawaii, 2000). Risk to society in Kona as a consequence of future volcanic activity at Mauna Loa and Hualālai has increased sharply since the last eruptions in the area, due to growth in population, infrastructure and its growing economic relationship with tourism. Most of
Kailua is within 15 km of potential eruptive sources. South and North Kona are two of the three greatest areas of concern on the island identified by the state's Lava Flow Hazard Mitigation Plan Technical Committee (Hawaii State Civil Defense, 2002).

2.2.1 Natural hazards and Kona

Volcanic hazards may have a more prolonged impact than other hazards, because of the relatively long durations of precursory and eruptive activity. For example, storms arrive with high wind and rain but generally pass within a few days, and tsunami pass after several hours have elapsed. On the other hand, eruptions at Mauna Loa have had durations of from less than one day to 4.5 years of almost continual activity during the summit eruption of 1872-77, and flank eruptions have had durations from about 5 days to 450 days (Lockwood and Lipman, 1987). The most recent lava flows from Hualālai may have had durations of hours to months (Kauahikaua et al., 2002). Hazards with unpredictable, but potentially such prolonged, duration are thus a special case. The consequences of prolonged interaction with social, economic and physical infrastructure require special attention. Modern hazard mitigation campaigns tend to focus on building resilience in advance rather than compensating retrospectively for loss and deficit (Omar and Alon, 1994; Tobin, 1999; Van den Eyde and Veno, 1999; Violanti et al., 2000). A valid question in Kona and elsewhere on the island is how can society best adapt to future eruptions of varying durations?
Figure 2.1a-d. Generalized maps of the island of Hawai‘i. (a) Topography (contour interval = 1000 feet), volcanoes, major cities, and high schools surveyed (square = Kealakehe; circle = Konawaena). (b) Lava-flow hazard zones (SWRZ = southwest rift zone, ERZ = east rift zone). Bold lines outline volcanoes. (c) Dates of selected recent lava flows; locations of main roads and highways. (d) Political districts. After U. S. Geological Survey (1997b).
2.2.2 Volcanoes
Mauna Loa has erupted 39 times since 1832 (Barnard, 1995), on average every 4.4 years. Subaerial eruptions in 1851, 1859, 1916, 1919, 1926, 1949, and 1950 produced lava flows in Kona (Fig. 2.1c), and a submarine eruption occurred offshore of Kona in 1877 (Moore et al., 1985). The most recent eruption of Mauna Loa in Kona occurred during a 3-week period in 1950 and produced destructive lava flows (Macdonald, 1954; U. S. Geological Survey, 2000). Mauna Loa last erupted in 1984 and threatened Hilo, in the eastern portion of the island (Lockwood et al., 1987; Trusdell, 1995). Hualalai erupted twice in Kona in ca. 1800 (Kauahikaua et al., 2002), but the details of these eruptions are less well documented than those for eruptions of Mauna Loa. Recurrence intervals for Holocene time are on the order of 50 years (Moore et al., 1987). Hualalai has no summit caldera, unlike Mauna Loa, where significant volumes of lava can be impounded within the caldera. The current lava-flow hazard-zone map (Wright et al., 1992) indicates that Hualalai is less hazardous than Mauna Loa and Kilauea, but future refinements to the hazard zone map at Hualalai (Kauahikaua et al., 2002) may increase hazard levels at this volcano.

2.2.3 The nature of volcanic hazards in Kona
Mullineaux and Peterson (1974), Mullineaux (1987); Heliker (1990); and Wright et al. (1992) described volcanic hazards on the island of Hawai‘i and produced hazard-zone maps for lava flows, tephra fall and volcanic gas emissions. Mullineaux et al. (1987) suggested that lava flows are the greatest hazard to property. Lava flows occur more frequently than ash fall in Kona, but they are less frequent than gas emissions, which are derived principally from Kilauea. The lava-flow hazard zones (Fig. 2.1b) are ranked 1
through 9, with 1 the most hazardous and 9 the least hazardous (Wright et al., 1992). South Kona includes zones 1, 2 and 3. North Kona includes mostly zones 3 and 4. All of Hualalai is currently in zone 4. Greater values for slope (Fig. 2.1a) and effusion rates compared to Kilauea contribute to faster-moving lava flows in Kona. The fastest lava flow recorded in Hawai‘i occurred in South Kona during the 1950 eruption of Mauna Loa. One lava flow traveled 24 km in 2.5 hours, an average rate of 9.6 km h\(^{-1}\) (Macdonald, 1954; U. S. Geological Survey, 2000). The existence of faster flows during Hualalai’s last eruptions in ca. 1800 is debatable (Kauahikaua et al., 2002), but certainly steeper slopes enhanced local flow-front advance rates. Then and in the future, steep slopes and high effusion rates combine to produce relatively fast-moving lava flows, which pose heightened concern for society in Kona.

Vog is dominated by aerosol particles in Kona (U. S. Geological Survey, 1997a). Adverse effects of vog in Kona include physical, chemical, and biological damage to plants, water supplies, and respiratory systems. On-going vog problems in Kona are derived primarily from the 20-year-old eruption of Kilauea, but problems also occurred during the Mauna Ulu eruption of Kilauea in 1969 to 1974 (Mullineaux et al., 1987). Tephra fall from Hawaiian volcanoes is generally of greatest consequence near the eruptive sources and thins with distance from source. Tephra from explosive eruptions of Hualalai has not fallen in dense areas of Kailua-Kona and is generally confined to areas of less than about 10 km\(^2\) from the vents (Moore et al., 1987). Eruptions of Mauna Loa have not produced damaging amounts of ash in Kona.

Mullineaux et al. (1987) discussed issues surrounding limitations of mitigating lava flow compared to ash and gas hazards. In Hawai‘i and elsewhere, rock walls have
been hastily constructed to stop or retard the advance of lava flows, earthen dams have been constructed to retain lava, earthen diversion barriers and channels have been constructed and excavated to divert lava, bombs have been dropped to interrupt lava, and water has been sprayed on flows to retard their movement (Barberi et al., 2003; Barberi et al., 1993; Colombrita, 1984; Jaggar, 1945; Lockwood and Torgerson, 1980; Macdonald, 1958, 1962; U. S. Army Corps of Engineers, 1980; Wentworth et al., 1961). More frequently though, people that have been threatened by lava flows in Hawai‘i turn simply to evacuation, although other alternatives have involved appeals to the supernatural. Murton and Shimabukuro (1974) reported that evacuation is the only emergency adjustment with which Puna residents are familiar and that the warning and emergency system is “premised on the belief that if an inhabited area is threatened by lava, evacuation will take place.” Furthermore, they reported that, apart from evacuation, the most widely used of all other adjustments is the “bearing of losses when they occur.” Engineered measures are somewhat controversial and may not be realistic options to mitigate lava flow hazards in Kona (Moore et al., 1987; Mullineaux et al., 1987) where slopes are steep and travel times from source to ocean may be only a few hours or less, unless the measures are implemented well in advance of eruptions. Diversion of lava into otherwise unthreatened areas is a particularly sensitive issue. There are no current plans to implement engineered measures (e.g., diversion barriers) to protect against lava flow hazards in Kona (Hawaii State Civil Defense, 2002).
2.3 The Survey

2.3.1 Survey method
The questionnaire was designed for students, their parents or guardians, and adults at large. The questionnaire used in this study was modified from one developed for studies of volcanic hazard risk perception in New Zealand (Ronan and Johnston, 2001). The questionnaire was reviewed by scientists and emergency managers, pretested, and precoded.

Our data were derived from five separate groups: 9th grade students at (1) Kealakehe High School (n = 132) on Hualālai in North Kona and (2) Konawaena High School (n = 104) on Mauna Loa in South Kona (Fig. 2.1a); (3) and (4), parents or guardians of these students (n = 117 and 44), respectively; and (5) adults at-large (derived from a random survey of Post Office box holders (n = 51) and a survey of residents of Kona awaiting flights to Kona at the international airport in Honolulu (n = 14). We refer to these groups as North and South Kona students, North and South Kona parents, and Adult-at-large. Return rates were: students and airport samples (100%), North Kona parents (89%), South Kona parents (42%), and mail-out adults (10%). The district in which a student attends school is a reasonable proxy for the district in which they reside.

2.3.2 Survey purpose
The survey was designed to evaluate experience with hazard events and educational programs, understanding of the emergency warning system, levels of hazard awareness, perceptions of volcanic risk, and levels of preparedness in Kona, and to identify potential underlying causes and influences. Hazard awareness or knowledge influences risk perception, and perceptions are one driving mechanism for preparedness (Green et al.,
Knowledge of a threat relates to salience of the hazard, levels of past damage incurred, and the extent and timing of contact with hazard information. Perceived risk has been linked to proximity to the hazard source, perceived likelihood of future disasters, and the perceived extent of impact, as well as past experience in disasters. Hazard adjustment reflects perceived risk, the information received regarding protective measures, extent of past damage, self-efficacy (the individuals’ perception of their ability to play a role), and outcome expectancy (i.e., the notion that a community can mitigate hazard consequences (Bishop et al., 2002; Lindell and Whitney, 2000; Paton, 2000)).

The difference in lapsed time since the last eruptions of Mauna Loa and Hualalai to affect Kona provides an opportunity to compare threat knowledge and risk perception as a function of the time since the eruptions. Potentially, perception of which volcano (Mauna Loa or Hualalai) is most likely to erupt should be inversely related to the repose time since the last significant eruption.

2.3.3 Respondents (or sample)
A total of 462 questionnaires were returned (236 students, 226 adults). Demographic data for the student and adult samples, respectively, are: mean age (14.7 years, sd = 0.763 and 44.4 years, sd = 9.389); gender (male = 52.8% and 31.1%). Home and land ownership for adults only is: 57.1% own their home, 31.6% rent, 19% own land in another town and 16% own a second home. Ethnicity, on average, is: White 41.1%; Hawaiian, part-Hawaiian and Pacific Islander 36.5%; Japanese 16.7%; Filipino 12.2%; other 29.6%. Demographic characteristics, while not corresponding exactly to U.S. Census Bureau (2000a, Appendix C) data, do provide a representative profile of major
ethnic groups and allow the tentative generalization of these data to the wider population (Appendix D).

For the North and South Kona parent groups, about 75-76% were female (n = 119), compared to 53% for the Adult-at-large group. Female parents or guardians may be more inclined than their male counterparts to participate in surveys administered through their children’s schools. Moreover, 68% of single parent families in Kona (24%) include female householders (County of Hawaii, 2000).

2.3.4 Knowledge of the volcanic hazard
We explored threat knowledge through questions related to past perceptions of current and future volcanic activity on the island, awareness of the most recent eruptions, understanding of the speed with which lava may flow, experience in hazard events, awareness of the lava-flow hazard zone in which people live, and prior contact with hazard information.

Knowledge of volcanism on the island is high but for Kona specifically is low. For example, 89.6% (n = 387) of respondents recognized Kīlauea as the volcano that has been erupting almost continuously since 1983, although 10.4% (n = 45) were unaware of this fact. This lack of awareness is shared even by people who have resided in Kona for up to 43 years. Knowledge of the threat posed to society in Kona as a consequence of future eruptions of Mauna Loa and Hualālai is low. When asked, “Which volcanoes do you think could erupt again”, about two-thirds (68%) selected Kīlauea, but only a minority believed Mauna Loa and Hualālai could erupt again (Table 2.1). Furthermore, a surprising 8% (n = 35) indicated that “none will erupt again.” Chi-square values indicate significant statistical differences in perceptions of future activity of Mauna Loa ($\chi^2 =$}
39.485; \( p = 0.000 \) and Hualālai \( (\chi^2 = 41.616; \ p = 0.000) \). For the student groups, perception is related to proximity to the hazard source (in this case the volcano on which each student group attends school and presumably resides; contrast Mauna Loa and Hualālai data in Table 2.1). Our data can be contrasted with the findings of Murton and Shimabukuro (1974), who reported that 12% of the respondents in Puna District did not expect eruptions of Kīlauea in the future (79% did)—a surprising finding to us, given the recent and frequent activity of Kīlauea at that time.

The low response for Kīlauea in our sample is unlikely related to misinterpretation of our question, because the five groups in Table 2.1 did not differ in their opinion \( (\chi^2 = 2.285; \ 0.684) \). Moreover, among the 90% who were aware of the long-term activity at Kīlauea, 74.1% (\( n = 286 \)) perceived that Kīlauea could erupt again, and Chi-square analysis indicates that, again, the five groups did not differ in their perceptions \( (\chi^2 = 1.192, \ p = 0.879) \). It is not clear why, among the sub-sample that knew that Kīlauea has been erupting continuously since 1983, that 26% would perceive that Kīlauea could not erupt again. The data may reflect a misperception that, once Kīlauea stops erupting, it could not erupt again.
Table 2.1. Perceptions that each volcano could erupt again by survey subgroup

<table>
<thead>
<tr>
<th></th>
<th>N* Kona Students</th>
<th>S* Kona Students</th>
<th>S Kona Parents</th>
<th>N Kona Parents</th>
<th>Adult*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 131 (%)</td>
<td>n = 100 (%)</td>
<td>n = 42 (%)</td>
<td>n = 116 (%)</td>
<td>n = 65 (%)</td>
<td>n = 454</td>
<td></td>
</tr>
<tr>
<td>Kilaeua</td>
<td>63.4</td>
<td>72.0</td>
<td>66.7</td>
<td>68.1</td>
<td>70.8</td>
<td>67.8</td>
</tr>
<tr>
<td>Mauna Loa</td>
<td>29.8</td>
<td>45.0</td>
<td>57.1</td>
<td>56.0</td>
<td>73.8</td>
<td>48.7</td>
</tr>
<tr>
<td>Hualalai</td>
<td>50.4</td>
<td>20.0</td>
<td>57.1</td>
<td>60.3</td>
<td>55.4</td>
<td>47.6</td>
</tr>
<tr>
<td>Mauna Kea</td>
<td>23.7</td>
<td>24.0</td>
<td>33.3</td>
<td>21.6</td>
<td>36.9</td>
<td>26.0</td>
</tr>
<tr>
<td>Kohala</td>
<td>10.7</td>
<td>15.0</td>
<td>2.4</td>
<td>6.9</td>
<td>7.7</td>
<td>9.5</td>
</tr>
<tr>
<td>None will erupt again</td>
<td>8.4</td>
<td>11.0</td>
<td>7.1</td>
<td>6.9</td>
<td>3.1</td>
<td>7.7</td>
</tr>
</tbody>
</table>

N = North, S = South, Adult = Adult-at-large.

When asked, "Which two of four volcanoes are most likely to erupt next," Mauna Loa and Hualalai were perceived to be more likely to erupt next than Mauna Kea and Kohala; this is a realistic perception. However, only 71% (n = 312) selected Mauna Loa, and two-thirds (n = 289) selected Hualalai. Nearly one-third of the respondents (mostly from South Kohala District) selected Mauna Kea. These perceptions of which two volcanoes are most likely to erupt are linked to proximity to the volcano. Chi-square analyses suggest that perceptions of future activity at Mauna Loa and Hualalai are not proportional to the length of time respondents have lived in Kona.

Perceptions of the timing of recent eruptions also show limited understanding. Lava flows emplaced during the latest eruptions of Hualalai in ca. 1800 remain largely barren in Kona, and portions of the international airport and major highways are built on these flows. When we asked, "When was the last time Hualalai volcano erupted," only one-third answered correctly (i.e., about 200 years ago (Table 2.2)). Less than one-
quarter answered correctly when we asked, “When was the last time lava from Mauna Loa flowed into the ocean in Kona” (i.e., about 50 years ago). The data show a sharp contrast between the responses of the student and adult subpopulations (Table 2.2). The differences in awareness between adults and students are surprising, given the relative exposure of these two subpopulations to hazard education programs, and suggests current programs perhaps do not focus on Kona specifically. Moreover, we found that, among those who indicated that they have been involved in a hazard education program or had studied lava flows in school, overall awareness of the eruptions was no higher than the total shown in Table 2.2. This suggests that hazard education may not have focused on the most recent activity in Kona. This low awareness of the most recent volcanic activity in Kona contrasts with the much greater awareness of activity at Kīlauea.

The potential high velocity of lava flows in Kona is a major issue for hazard mitigation. We asked, “In a future eruption, how quickly could a lava flow reach the ocean in Kona?” The data indicate that about one-third (33.9%, n = 146) selected the correct answer (i.e., 3 hours or less), while slightly more (36.2%) selected 12 hours. The remainder selected longer times of 3 days (5.8%, n = 25) and 1 month (24.1%, n = 104). Amongst those indicating involvement in a hazard education program or that had studied lava flows in school, overall awareness was unchanged (33%). We infer that respondents have a poor understanding of the time scale with which lava flows can travel, and again, that education was not focused on Kona’s situation.
Table 2.2. Awareness of years since last eruptions of Hualālai (about 200 years ago) and of Mauna Loa (in Kona, about 50 years ago) by students and adults

<table>
<thead>
<tr>
<th></th>
<th>Mauna Loa</th>
<th>Hualālai</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Students</td>
<td>Adults</td>
</tr>
<tr>
<td></td>
<td>n = 230</td>
<td>n = 212</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>About 500 years ago</td>
<td>8.7</td>
<td>9.0</td>
</tr>
<tr>
<td>About 200 years ago</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>About 50 years ago</td>
<td>10.9</td>
<td>35.4</td>
</tr>
<tr>
<td>About 20 years ago</td>
<td>4.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Don’t know</td>
<td>76.1</td>
<td>48.1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

* = not applicable.

These data are particularly informative in regard to preparedness. Most respondents live between eruptive sources and the ocean, but it is not clear if people conflate time to reach the ocean with time to reach them or to impact on them. If the warning time exceeds that required to make what they think are the necessary preparations, pre-eruption preparedness will decline. Pre-eruption preparedness is even less likely for those recording one month (24%).

Our data show that, on average, direct experience of natural hazard events that have damaged the respondent’s neighborhood is low (28.3%, n = 122, missing data = 16) and very low for volcanic hazards. Of the 122 with experience, less than 5.8% (n = 7) indicated that either vog, lava flows, or ash fall had damaged their neighborhood. However, in a subsequent question, we asked respondents to “List any damage that vog has caused you or your family’s health or property.” A slight majority of adults (52.3%,
n = 111) and one-third (33.0%, n = 73) of students identified impacts on health. This data could have implications for the nature of preparedness programs. Rather than focusing on hazard characteristics per se, programs may be more effective by focusing on the interaction between these characteristics and community needs. Very few respondents or their relatives have been threatened or affected by a damaging eruption. Only 36 of 422 respondents (8.5%) answered in the affirmative.

Hawaiian eruptions often allow relatively easy access to observe passive lava flows without explosive activity and ash fall. Paton et al., (2001a) and Lindell and Perry (1992) found that only direct experience in hazard events was found to influence risk perception, as opposed to vicarious experience (Sjöberg, 2000). About one-third (37.7%, n = 170) indicated that they had seen active lava flows. This is considerably less than 85% of Puna residents who reported having experienced a number of eruptions on Kīlauea (Murton and Shimabukuro, 1974).

Knowledge of the lava-flow hazard zones is at a very low level. Lava-flow hazard zones are defined for the entire island; i.e. all structures are located within a zone or lie along the boundary of two or more zones. The salience of lava flow hazards may be readily evaluated by the percentage of respondents who are aware of the zone in which they live. Only 15% (n = 44) of respondents indicated they knew the lava-flow hazard zone in which they resided. In reality only 8 of these identified a possible legitimate zone (13 did not respond). The data questions utility of the zones for residential property owners. Knowledge of the hazard zone is higher among those with prior hazard experience and is influenced by ethnicity. For example, Japanese respondents were about four times less likely to know the zone in which they lived than the mean of other
ethnicities (17%). Knowledge also appears to be proportional to the degree of lava flow hazard in which respondents live. For example, 38.5% (n = 10) in hazard zones 2 and 3 were aware, 13.9% (n = 26) in zone 4 and 8.8% (n = 3) in zone 8. Sample sizes were too small to test for statistical significance. These data apply to the adult-at-large and Kealakehe groups.

2.3.5 Hazard education
A slight majority (50.8%, n = 229, missing data = 11) of respondents indicated they have been involved with a hazard education program that informed them about the types of hazards included in this survey. Students claimed greater involvement (59.7%, n = 139) than adults (41.3%, n = 90, $\chi^2 = 15.210, p = 0.000$). 86.1% of students (n = 118) selected school as the source of the information compared to 64.0% (n = 57) of adults. On average 30.1% (n = 68) selected Hawai‘i Volcanoes National Park (HVNP), and 13.7% (n = 31) could not remember. However, only 5.1% (n = 7) of students selected other sources compared to 49.4% of adults (n = 44). The latter data suggest that adults receive information from sources not recognized by students.

The extent to which lava flow, vog, and ash fall hazards have been taught or discussed at school is disproportional, with an emphasis on lava flows. A majority of students (53.7%, n = 124) indicated they had studied or discussed lava flows, compared to only about one-third of adults (34.9%, n = 66). Similarly, more than twice as many students had studied or discussed vog than adults (31.2%, n = 72 compared to 14.8%, n = 28). For ash fall, student and adult responses were similar (average = 18.1%, n = 76).

The U.S. Geological Survey (USGS) Hawaiian Volcano Observatory (HVO) disseminates information through a weekly newspaper column titled, Volcano Watch,
which is published in local newspapers and posted on the internet (since late 1994). To evaluate exposure to *Volcano Watch*, which is devoted to topics such as volcanic hazards and processes on the island of Hawai‘i and to informational topics related to other volcanoes in the U.S. and overseas, we asked, “Did you know that *Volcano Watch* is a Big Island newspaper column on volcanoes,” to which on average 40% (n = 171) answered in the affirmative. The difference in student and adult responses is statistically significant (32.1% versus 48.1%, $\chi^2 = 11.391; p = 0.001$). Of those respondents who answered in the affirmative, those who indicated they read *Volcano Watch* last week included 41.7% (n = 101) of adults, but only 19.4% (n = 13) of students (average = 32.5%, n = 53). Similarly, 38.8% (n = 26) of students indicated they never read it compared to 0% for adults. On average, 27% (n = 44) read *Volcano Watch* last month and a further 24.5% read it last year. The data illustrate the contrast in use of different sources of hazard information among students and adults. This is not the same as utilizing it or even rendering it meaningful in the manner anticipated. More work is needed to examine the factors that influence interpretation and how it is rendered salient.

People believe HVNP is a significant source of hazard education. A majority (52.3%) of student respondents indicated they have participated in a 3-day field trip to HVNP (mostly as 5th or 6th grade students), and about 80% (n = 168) of the adults indicated they have visited HVNP and learned about volcanic hazards. We did not evaluate what type of educational material the adults were exposed to at HVNP, but a question remains, what did they learn from displays and brochures versus what was taught by HVNP personnel or other officials? A concern is that respondents may wrongly associate their mere presence inside HVNP with hazard education, or confuse
their knowing where information could be obtained with their actual knowledge (Paton et al., 2000).

We asked respondents to rate the consistency of all volcanic information that they had received in Hawai‘i. Adults (51%, n = 105) perceive information to be more consistent than students (30%, n = 64), whereas students (43.2%, n = 92) are more uncertain about the consistency than are adults (25.2%, n = 52). This is surprising, since a significantly greater percentage of students indicated that they had studied lava flows and vog in school. The data suggest a need for clarification of some information, and whether this could reflect other factors (e.g., independent search through the web), which furnishes information that is less accurate or unrelated to the Hawaiian situation. On average, 13.1% had not heard anything and 12.2% indicated the information was fairly to very inconsistent.

To evaluate preferred sources of information, we asked participants where they would look for information about future volcanic activity on the island: Only one source (television and radio) is favored by a majority of respondents (58.4%, n = 261); 34.5% (n = 154) selected USGS HVO website, a similar number selected Civil Defense, and 30.9% (n = 138) selected “internet”. Between about 11% and 14% selected school, Police and Fire Department, telephone book and local library. An interesting issue is the possibility that respondents are recalling sources related to hazards with which they are familiar rather than describing actual preferences (Ballantyne et al., 2000). The latter authors conducted a pre- and post-volcanic education survey. Information during the pre-survey revealed that pamphlets in the mail box were identified by respondents as their preferred medium to receive hazard information. However, the subsequent evaluation of a
pamphlet based education strategy revealed that this medium proved highly unsuccessful. The authors inferred that people identified media as what they were familiar with rather than from thinking about the relationship between medium and effectiveness. This is supported by the large number of responses (937) to a question where respondents were not asked to make multiple selections.

2.3.6 Perceptions of risk
The public’s perception of risk have been linked to proximity to the source of a hazard (i.e., Mauna Loa and Hualālai), perceptions of the likelihood of future disasters, and the extent of impact, as well as past experience in disasters. The island of Hawai‘i is built of volcanoes, so society exists everywhere on some portion of the five volcanoes. In our survey, respondents live predominantly on Hualālai and Mauna Loa, but also on the lower flanks of Mauna Kea and Kohala. Respondents were found to have a good understanding of the two volcanoes nearest to their home and identified Hualālai (74.7%, n = 339) and Mauna Loa (64.1%, n = 291). Proximity of some respondents to Mauna Kea moderated responses for Hualālai.

To evaluate the popular perception of risk across a variety of hazards that occur in Kona, we asked participants, “Thinking about the chances of property damage and loss of life or injuries, which are the two most likely hazards that could affect you at home, school (students only) and work (adults only; Fig. 2.2). Risk is generally perceived to be greatest at home, and lava flows are perceived to represent a greater threat than vog and ash fall. The responses may reflect the volume of information received about each hazard as opposed to an objective analysis of risk exposure among all the hazards, although this cannot be determined from the data.
Figure 2.2. Perception of risk from hazards at home, school and work. Gas leak includes chemical spill; violence includes violent incident at school (students only) or at work (adults only); storm includes with high winds and lightning.

To evaluate the perception of repose period, we asked, “When do you think the next hazard events are likely to affect your community?” Results (Fig. 2.3) are shown for those perceiving that an event will occur “within the next year” and “within the next 1 to 10 years.” Responses for greater than 10 years are not shown but make up the residue. The results indicate that the times in which volcanic hazards are perceived to likely affect the respondents’ community vary widely. Vog is considered to be the most likely hazard to affect the respondents’ community within the next year, but ash fall and lava flows are among the least likely. For vog, the number of females (78%, n = 21) selecting “within the next year” was different from the 44% (n = 10) of males. Data for vog are derived only from the Adult at-large group. For lava flows, the percentage of students who selected within the next 1 to 10 years (31%, n = 71) was statistically different from the
responses of adults (18.1%, n = 39; \( \chi^2 = 10.585, p = 0.005 \)) and suggests a greater perception of risk among students.

![Figure 2.3](image)

Figure 2.3. Average perception of time until the next hazard event is likely to effect respondents' community. Gas leak includes chemical spill.

### 2.3.7 Preparedness

Data indicate that the majority of preparedness measures that have been adopted in Kona focus on frequent but low-impact household emergencies rather than infrequent but more damaging natural hazards. From a list of 21 preparedness measures, we asked respondents to select those measures that their family had taken. We then divided the measures into two groups, those that may also be used for frequent domestic emergencies (e.g., having a flashlight, first aid kit, fire extinguisher) and those applying only to infrequent hazard events (e.g., having the household water heater secured to the wall, buying extra insurance, having an emergency contact in another town, or having property inspected for vulnerability to natural hazards). The data do not represent preparedness
measures taken to protect against a specific hazard, but they do show the tendency for people to adopt measures that are less time consuming and less expensive to undertake (mean = 65.7%, sd = 16.0) rather than more involved and time consuming measures (26.5%, sd = 9.6 (Mileti and Fitzpatrick, 1992)). For frequently occurring hazards, adults consistently indicated levels of preparedness higher than did students, but for infrequently occurring hazards, students’ perceptions of preparedness were higher in all but two of the preparedness measures.

The perception of preparedness of and within a community can have important implications for actual preparedness at the individual level. For example, Weinstein and Klein (1996) described an “unrealistic optimistic bias” in which a majority of respondents rated themselves as being more prepared (less vulnerable) and more skilful than the average. While individuals may be aware of a need for greater preparedness within the community, the need is not recognized as applying to them. As a result, individuals may be less likely to participate in activities designed to increase preparedness and act on warning messages (Johnston et al., 1999). To evaluate the perception of preparedness, we asked, “How prepared do you believe the following people and groups of people are for a damaging earthquake,” using a scale ranging from 1 (very prepared) to 4 (not at all prepared). On average, our data indicate that respondents perceive themselves as less prepared (mean 2.61, sd = 1.047) than their family (2.54, sd = 1.039) and emergency management agencies (2.07, sd = 1.369), but more prepared than the community (2.85, sd = 1.217) in general and imply the presence of an unrealistic optimism.

Mulilis and Duval (1995) and Lindell and Whitney (2000) found that a reduction in preparedness results when persons assign responsibility for their personal safety to
others. To evaluate the perception of responsibility for preparedness for volcanic eruptions, we asked, "Who should be responsible for preparing the community for future volcanic eruptions" (Table 2.3). These data are significant, in that respondents believe that individuals in the community are less responsible than the emergency management officials or agencies. This comes as no surprise; considering that, in the prior question, respondents perceived officials to be the most prepared for a damaging earthquake. The transfer of responsibility for oneself to others could reflect differences in expertise (Ballantyne et al., 2000) and the inference that those agencies that are funded by tax dollars to manage hazards should take responsibility for the safety of people in their community.

We found that, on average, only one-third of respondents indicated that their families had a plan of action for how to act in an emergency such as a lava flow, hurricane, or earthquake. This suggests that plans involving lava hazards may be even less common. Furthermore, only one-third had practiced what to do during an emergency at home; slightly more knew the location of an emergency evacuation shelter near their school or home.
Table 2.3. Perception of responsibility for preparing the community for future volcanic eruptions by students and adults

<table>
<thead>
<tr>
<th></th>
<th>Students n=230 (%)</th>
<th>Adult n=212 (%)</th>
<th>Total n=442 (%)</th>
<th>$\chi^2$; $p^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Defense</td>
<td>78.7</td>
<td>89.2</td>
<td>83.7</td>
<td>8.843; 0.003</td>
</tr>
<tr>
<td>USGS, HVO</td>
<td>56.5</td>
<td>74.1</td>
<td>64.9</td>
<td>14.896; 0.000</td>
</tr>
<tr>
<td>Police, fire departments</td>
<td>57.8</td>
<td>62.7</td>
<td>60.2</td>
<td>1.110; 0.292</td>
</tr>
<tr>
<td>Every individual in the community</td>
<td>49.1</td>
<td>58.5</td>
<td>53.6</td>
<td>3.886; 0.049</td>
</tr>
</tbody>
</table>

$^a\chi^2 = \text{Chi-square value; } p = \text{probability. Missing data = 20. USGS = U.S. Geological Survey. HVO = Hawaiian Volcano Observatory.}$

In the Puna District on Kīlauea, Murton and Shimabukuro (1974) found that a few Hawaiians believed that a kahuna (priest) or Madam Pele (the volcano goddess) will tell them when an eruption will occur. In contrast, they reported that many haole (Caucasian) newcomers believed that scientific monitoring by the HVO can predict the occurrence of eruptions. The researchers also reported that many more people, especially old Hawaiians, offer gifts to Pele. Lachman and Bonk (1960) reported on belief in Pele during the 1960 eruption in Puna, but suggested that belief was not limited to any one religious creed, ethnicity, age level, or degree of education. To evaluate the association of Pele with volcanic eruptions, we asked, “Who or what controls whether or not a Hawaiian volcano erupts?” For those selecting only one answer (n = 376), on average a majority (58.5%, n = 220) selected pressure beneath each volcano, whereas only 15% selected chance, 12.8% Pele, 9% God, and 4% other. Students (20.8%), especially in South Kona, were more likely to select Pele than adults (4.3%), whereas three-quarters of adults selected pressure beneath each volcano, compared to only 42% of students. Fifty
four respondents chose to select multiple answers. Among these, 32 selected Pele, 31 God and 42 pressure. Together, the data suggest a mixed perception of the causes of volcanic eruptions in Hawai‘i, with beliefs rooted in physical volcanic processes held by a good majority (61%), followed by spiritual beliefs in Pele and God by about one-third. Our findings show that belief in Pele is strongest among Spanish respondents. For example 44% (n = 7) of Spanish people selected Pele alone, Hawaiian (30%, n = 8), Filipino (22%, n = 10), and part-Hawaiian (20%, n = 18). Less than 13% of other ethnicities such as White, Japanese, and Portuguese selected Pele alone. The data suggest that belief in Pele as a controlling factor in volcanic eruptions is shared by a minority and agree with the finding of Lachman and Bonk (1960) that belief in Pele is not limited to any one ethnic group. These data have significant implications for risk perception, preparedness, and attentiveness to public education.

2.4 Discussion

2.4.1 Awareness and preparedness
Overall, our data suggest that knowledge of the threat to Kona from eruptions of Mauna Loa and Hualalai is low. Why is this so? Lack of exposure to hazard programs may not be the cause—a majority of respondents indicated they had participated in hazard education programs. The data suggest a need for analysis of how their preexisting beliefs and expectations impinge on information received (e.g., transfer of responsibility). Surprisingly, respondents who participated in a hazard education program or studied lava flow hazards in school did not show improved awareness of the most recent eruptions or the velocity with which lava flows can travel compared to those who had not participated in education programs and did not study lava flows in school. Perhaps the information
provided may not have focused on Kona's situation, or it was not retained by the respondents, because exposure has not greatly improved their knowledge or understanding of their volcanic hazards. This suggests a need to explore the content of education programs received prior to the 9th grade and their effects on improving awareness and understanding.

Within the Kona hazardscape, volcanic hazards are given a low priority by residents. Knowledge of the lava hazard zones is at a very low level. Lava flows and ash fall were perceived to be the least two hazards that are likely to affect the respondents' community within the next 10 years. This is potentially problematic given the volcanoes' potential for sudden onset and long duration.

On average direct experience in a damaging natural hazard of any type is low and is much lower for volcanic hazards, although experience with vog appears to be much higher. Moreover, very few respondents have relatives who have been affected by a damaging eruption. It is possible that widespread direct exposure to non-damaging lava flows (37%) has fostered the perception that future volcanic eruptions will be similar to those they have witnessed on television or in person (e.g., at Kīlauea) and thus caused a normalization bias (Johnston et al., 1999; Mileti and O'Brien, 1993), rendering respondents less attentive to hazard information and less likely to respond to warnings than they might be otherwise.

With these levels of awareness and knowledge, preparedness is predictably at relatively low levels. The broader issue of hazard preparedness (or a lack thereof) is not specific to the volcanic threat. Moreover, individuals suffer from an unrealistic optimism bias. Because respondents also believe that individuals in the community are less
responsible than the emergency management officials or agencies, they may be less inclined to attend to hazard information or react to warnings. In other words, the very fact that specific agencies (e.g., scientific, emergency management) disseminate information and advice on preparedness may actually reduce the perceived need for personal preparedness as a consequence of a transfer of responsibility (Ballantyne et al., 2000; Mulilis and Duval, 1995).

There is a need for education programs that target specific groups and identify methods that promote information exchange between students and adults. Media like Volcano Watch are read by the adult population (especially Whites) but not by students. In both cases, questions regarding the meaning and utilization of this source for preparedness should be considered. Identifying primary preferences for accessing volcanic information is an important consideration. Of eight potential sources, only one (television or radio) was stated as being preferred by a majority of respondents. However, this may reflect familiarity rather than an objective assessment of the medium.

2.4.2 Engineered measures
Engineered measures to mitigate lava flow hazards are not planned for Kona and are unlikely to be implemented (Hawaii State Civil Defense, 2002). Nonetheless, if engineered solutions are implemented, but cannot be guaranteed 100% effective, additional outreach is required to counter phenomena (i.e., risk homeostasis) that may increase risk-taking behavior. If engineered solutions are not implemented, then additional community outreach is needed to increase awareness of the uniqueness of the volcanic threat in Kona and to promote adoption of realistic preparedness and response measures that will foster resilience in future eruptions.
2.4.3 Adult versus student
We chose to focus on the contrast between student and adult populations, because there is a growing tendency for hazard education programs to target children. This appears to be based on the ease with which children can be approached in large numbers (e.g., in school settings) but also on an assumption that children will later share the information with family members, and those with neighbors, and so on. This assumption needs validating. Our data show that student and adult perceptions differ markedly in many instances.

Our data show that students have received more hazard education in general, as well as specific to volcanic hazards, yet students show lower awareness of the most recent activity of their neighboring volcanoes and the fact that those volcanoes could erupt again. Moreover, fewer students reported that volcanic information was consistent, and a greater number were uncertain about the consistency of the volcanic information. However, despite this, students were more likely than adults (by a factor of 1.7) to perceive that a lava flow could affect their community within the next 10 years.

As anticipated, experience in hazardous events is directly related to age. Surprisingly though, adults consistently indicated that their family had taken more household preparedness measures for frequent emergencies, whereas students reported higher levels of more involved measures such as those needed for more infrequently occurring hazards. This is an interesting inconsistency that requires further analysis to better understand.
2.4.4 North Kona versus South Kona
Perceptions of past and future volcanic activity are linked to proximity to the hazard source, especially among students. For example, students from each school district are more knowledgeable of, and perceive a greater threat from, the volcano on which they attend school and presumably live. Similarly, parents from each school are more knowledgeable of the recent volcanic activity at this volcano. Parents from both schools perceive Mauna Loa and Hualalai as the two volcanoes most likely to erupt next, although Hualalai is perceived to be less likely to erupt by South Kona parents compared to North Kona parents. A greater percentage of parents from South Kona (one-third) perceive damaging lava flows within the next 10 years as opposed to North Kona parents (11.5%). This time frame may reduce the perceived urgency to prepare. A similar, but less pronounced difference was observed between the students from these districts and together suggests a greater perception of threat from future lava flows in the area of higher hazard (i.e., Mauna Loa in South Kona). Overall awareness of the most recent lava flows at both volcanoes remains low. Nonetheless though, awareness of the most recent activity is greater for Hualalai than for Mauna Loa in both North and South Kona, and may be a reflection of the greater salience of Hualalai as a volcano or recent outreach efforts such as USGS's Volcano Watch to increase public awareness of Hualalai as a volcano in repose that will likely erupt again.

2.4.5 Influence of ethnicity
Ethnicity was found to influence the beliefs about whom or what controls volcanic eruptions, perceptions of future volcanism in Kona, the extent to which respondents have
received hazard education, and perceptions of who is responsible for preparing communities for future eruptions and preparedness.

Our data suggest that belief in Pele as the sole controlling factor of Hawaiian eruptions is low in Kona overall, ranging between 20% and 44% for people of part-Hawaiian, Filipino, Hawaiian, and Spanish ethnicities, respectively; whereas such beliefs were below 13% for other ethnicities. In contrast, belief in pressure alone as the controlling factor was shared by a majority to 71% of people of Hispanic (not Spanish or Portuguese), Japanese, and White ethnicities. A modern study of Hawaiian culture and spiritual beliefs regarding volcanism and its influence on decision making, preparedness, and mitigation is long overdue.

We found that Whites are more aware of the volcanic threat from Hualālai and Mauna Loa than are respondents of other ethnicities. However, a minority of Whites (41.8%) indicated they had participated in a hazard education program, compared to 57% of other ethnicities, and suggests that factors other than involvement in hazard education programs influence awareness and perceptions of volcanic activity. Pacific Islanders (excluding Hawaiian) were much more likely than other ethnicities to perceive USGS as the party responsible for preparing the community for future eruptions (94% compared to 64% for other ethnicities) and less than half as likely to perceive responsibility to lie with individuals (24% compared to 55% for other ethnicities). Similarly, Japanese respondents (95%) were more likely than other ethnicities (82%) to attribute responsibility for community preparedness for volcanic eruptions to Civil Defense.

These observations highlight the importance of examining how cultural and ethnic factors influence interaction with hazard issues and agencies. We infer that these individuals
have transferred responsibility for preparedness to the authorities and that these groups may be less inclined to attend to information and respond to warnings. Filipino, Spanish, and Japanese Americans were much less likely to perceive Mauna Loa as a volcano that could erupt than were other ethnicities and so may be less likely to make preparations for future eruptions. Portuguese and Spanish respondents (80% and 73%) were found to have participated in hazard education programs much more than other ethnicities (about 50%), yet Spanish respondents showed lower awareness of the volcanic threat from Mauna Loa. Finally, only 21% of Japanese respondents were aware of *Volcano Watch* compared to 43% of other ethnicities, suggesting that information contained in *Volcano Watch* is less likely to be disseminated within the Japanese community. Together these data suggest that awareness of the volcanic threat in Kona varies significantly among ethnic groups, but that participation in hazard education programs is not a prerequisite for awareness. The data also suggest some deficiencies in the content of hazard educational material, the ability for respondents to recall information, or widespread dissemination and acceptance of educational material. Education initiatives that are tailored to meet the needs of specific parts of communities are needed. In other words, the blanket provision of the same information is unlikely to be effective and its failure to accommodate specific needs may engender a sense of mistrust in the agencies providing information.

2.5 Conclusions
At Kona (and throughout the Big Island) awareness of volcanism is extremely high, but this general awareness has not translated into knowledge of the specific future threat to Kona communities. The low levels of individual preparedness for volcanic eruptions in Kona is consistent with both the low to moderate knowledge of the threat posed by
Mauna Loa and Hualālai and the findings of others that, historically, few adjustments for lava flow hazards have been made in Hawai‘i. Kates (1971) discussed the low levels of preparedness that can be expected in communities where the frequency of a hazard is low.

The greater frequency of eruptions from Mauna Loa in South Kona suggests a need to improve community preparedness for volcanic eruptions there; but a greater number and density of people and infrastructure occur downslope of potential eruptive sources in North Kona. The majority of respondents are not likely to make plans for an eruption, as they do not believe an eruption will occur. Furthermore, even for those who believe an eruption could or is likely to occur, there is no indication that this perception has translated into increased preparedness such as having a response plan. This reflects the anticipated timing of hazard activity and speed of onset—these combine to reduce the perceived urgency about preparedness. An expectation is that a long warning period will provide sufficient time for preparation (i.e., between onset of activity and it reaching them). Such perceptions may be difficult obstacles in encouraging new ways of adjusting to the volcanic threat in Kona. One thing is clear though: current community understanding and preparedness on Hualālai, and particularly Mauna Loa falls short of that required for a volcanic crisis, particularly for those eruptions with short onset and high effusion rates on steep slopes that would impact Kona in just a few hours (and some sparsely inhabited areas in less time than that). Misconceptions about potential future eruptions from these volcanoes, and realistic times for lava flows to reach developed areas, contribute to perceptions of low risk and need to be corrected. Scientific and technical knowledge in itself is likely to be ineffective as a means of facilitating
preparedness. This is not to say that it should not be provided. Indeed it should. However, it is vitally important, firstly, to identify and correct gaps or misconceptions in peoples' knowledge. Secondly, information should be presented in a manner that is consistent with the needs and expectations of the community and in a way that is (1) consistent with the reasoning processes involved in rendering information meaningful and (2) readily used in preparedness actions. Our advanced knowledge of the physics of volcanic eruptions must be integrated with understanding how community members differ in regard to how they obtain, process, and utilize information. This is vital in the process of promoting and sustaining community resilience and the ability of individuals to adapt to the consequences of future eruptions in Kona.

These findings can be used to focus future hazard education initiatives or surveys. Education initiatives that promote general hazard awareness and focus on the situation and needs at county or state level are only the first steps in building community resilience to natural hazards. Initiatives are needed now that focus specifically on Kona, its environment and the characteristics of its constituent groups. The high reports of damage from vog may be effective starting points for future education programs, because Paton et al. (2001b) found that people are more likely to listen to hazard-related information and make adjustments to behavior when the information has an immediate effect on their livelihood or well being. Future hazard education initiatives must also evaluate the changes in threat knowledge, risk perception, and preparedness as a result of exposure to the educational material. Achieving resilience also requires that attention is directed towards the nature of the relationship between scientific and emergency management agencies and communities, with the emphasis on community development and
empowerment (Paton, 2000). A valid question in Kona and elsewhere on the island is how can we persuade society to make the adaptations needed for both long- and short-duration eruptions from sites other than the currently active Kilauea east rift zone? This calls for strategies that involve more than just the provision of factual information (Paton, 2000). Creating a realistic understanding of the likelihood of future eruptions is an important starting point to facilitate this shift of thinking.
CHAPTER 3. COMMUNITY PREPAREDNESS FOR LAVA FLOWS FROM MAUNA LOA AND HUALĀLAI VOLCANOES, KONA, HAWA'I

C.E. Gregg a, B.F. Houghton a, D. Paton b, D.M. DA Swanson c, Johnston d

a Department of Geology and Geophysics, University of Hawai'i, 1680 East-West Road, Honolulu, HI 96822, U.S.A.
b University of Tasmania, School of Psychology, Bag 1-342, Launceston, Tasmania, Australia
c U.S. Geological Survey, Hawaiian Volcano Observatory, PO Box 51, Hawai'i National Park, HI 96817, U.S.A.
d Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand


Abstract
Lava flows from Mauna Loa and Hualālai volcanoes are a major volcanic hazard that could impact the western portion of the island of Hawai'i (e.g., Kona). The most recent eruptions of these two volcanoes to affect Kona occurred in A.D. 1950 and ca. 1800, respectively. In contrast, in eastern Hawai'i, eruptions of neighboring Kīlauea volcano have occurred frequently since 1955, and therefore have been the focus for hazard mitigation. Official preparedness and response measures are therefore modeled on typical eruptions of Kīlauea.

The combinations of short-lived precursory activity (e.g., volcanic tremor) at Mauna Loa, the potential for fast-moving lava flows, and the proximity of Kona communities to potential vents represents significant emergency management concerns in Kona. Less is known about past eruptions of Hualālai, but similar concerns exist. Future lava flows present an increased threat to personal safety because of the short times that may be available for responding.
Mitigation must address not only the specific characteristics of volcanic hazards in Kona, but also the manner in which the hazards interact with the communities likely to be affected. This paper describes the first steps in developing effective mitigation plans: measuring the current state of people’s knowledge of eruption parameters and the implications for their safety. We present results of a questionnaire survey administered to 462 high school students and adults in Kona. The rationale for this study was the long lapsed time since the last Kona eruption, and the high population growth and expansion of infrastructure over this time interval. Anticipated future growth in social and economic infrastructure in this area provides additional justification for this work.

The residents of Kona have received little or no specific information about how to react to future volcanic eruptions or warnings, and short-term preparedness levels are low. Respondents appear uncertain about how to respond to threatening lava flows and overestimate the minimum time available to react, suggesting that personal risk levels are unnecessarily high. A successful volcanic warning plan in Kona must be tailored to meet the unique situation there.

3.1 Introduction
Of five volcanoes on the island of Hawai‘i (Kīlauea, Mauna Loa, Hualālai, Mauna Kea, and Kohala; Fig. 3.1a), the first three have erupted since about A.D. 1800, although with very different frequencies. Lava flows are a well-known hazard from Kīlauea volcano on the eastern side of the island, but are less frequent at Mauna Loa and even less so at Hualālai (Macdonald et al., 1983). This paper focuses on future lava flows from Mauna Loa and Hualālai volcanoes affecting the western portion of the island (i.e., Kona, Fig. 3.1b). We also describe the results of a popular survey of individual preparedness for
responding to future lava flows from Mauna Loa and Hualalai. Findings of this survey are discussed in the context of the lava-flow hazards in Kona and volcano monitoring systems and warning plans.

Figure 3.1a-d. (a) Island of Hawai‘i, topography (contour interval = 100m), volcanoes and selected rift zones (dashed lines; SWRZ = southwest rift zone of Mauna Loa, ERZ = east rift zone of Kīlauea, NWRZ = northwestern rift zone of Hualalai, SERZ = southeastern rift zone of Hualalai). (b) District boundaries and place names. Bold lines outline our study area. (c) General study area. Lava-flow hazard zones are shaded and numbered 1 (highest hazard) to 9 (lowest hazard; excludes zones 5 and 7 of Kīlauea and Mauna Loa).
Kea. After Wright et al. (1992). The area of Hualalai is defined by lava-flow hazard zone 4; Mauna Loa by zones 1, 2, 3 and 6. Zones 8 and 9 represent areas of Mauna Kea and Kohala, respectively. Dates of selected recent lava flows (A.D.) and advance times (h = hours (after Hawaii State Civil Defense, 2002)). Primary and secondary through roads (bold lines) are shown with all other roads, including 4-wheel drive roads (light lines (after U. S. Census Bureau, 2000b)). A boat marks the location of a small-boat harbor. (d) Population densities of 2000 Census Tract boundaries illustrating the distribution of people within the study area (County of Hawaii, 2000). Major resort areas and schools surveyed are shown.

3.2 Kona

Our study area lies in the political districts of North Kona and South Kona, collectively called Kona, which are located on Hualalai and the western portion of Mauna Loa shield volcanoes. These districts have populations of 28,543 and 8,589, respectively (County of Hawaii, 2000). North Kona includes the second largest city on the island (Kailua-Kona, also known simply as Kailua; population 9,870; Fig. 3.1b) and has a higher population density (58 persons per mile\(^2\)) than does South Kona (26 persons per mile\(^2\), Fig. 3.1c, d; (County of Hawaii, 2000)). Risk to society in Kona (e.g., residents, tourists and the built environment) as a consequence of future volcanic activity at Mauna Loa and Hualalai has increased with rapid growth in population and tourism (Kona’s principal economic resource) and expansion of infrastructure. In 1998, nearly 1.1 million people visited Kona (County of Hawaii, 2000). Many developed areas are within 15 km of vents at Hualalai’s summit and northwest and southeast rift zones and along Mauna Loa’s southwest rift zone (Fig. 3.1a). Radial vents could occur within developed areas on Mauna Loa’s west flank in Kona or on Mauna Loa’s north flank (Trusdell, 1995). Few roads connect Kona to other parts of the island (Fig. 3.1c). Three of five 20th-century eruptions of Mauna Loa in South Kona produced lava flows that severed the main arterial highway (Highway 11). If repeated today the most recent lava flows of Hualalai would sever the two arterial highways in North Kona and thus separate Kailua and its
international airport from the island's primary and growing resort industry further north (Fig. 3.1d).

Social and demographic characteristics of Kailua differ from the largest settlement on the east rift zone of Kīlauea (Pāhoa, Fig. 3.1a,b). For example, comparisons of US Census Bureau (U. S. Census Bureau, 2000a) data show that Kailua, in contrast to Pāhoa, differs with regard to language spoken at home, race and ethnicity, per capita income and level of education attained. However, the Census data also show, not unexpectedly, that housing occupancy in Kailua is more seasonal and recreational in use than in Pāhoa and that people in Kailua are more transient than those in Pāhoa. These differences between east and west Hawai‘i may strongly influence preparedness for, and response to, volcanic eruptions. The last eruption of Mauna Loa in Kona was in 1950 (Macdonald, 1954). The last eruption of Hualālai was A.D. 1801 (Kauahikaua et al., 2002).

3.3 Social Science
Few systematic studies of human behavior in response to volcanic eruptions have been conducted in Hawai‘i (Lachman and Bonk, 1960; Murton and Shimabukuro, 1974), and none at all in Kona (Gregg et al., 2004a, Chapt. 2). Hazard education programs in Hawai‘i have lacked the involvement of social science to measure potential changes in hazard awareness, risk perception and adjustment adoption (i.e., how people cope with, prepare for, respond to, or otherwise live with specific hazards) resulting from the programs. Consequently, the effectiveness of education programs is unknown. Particularly problematic has been the lack of systematic and theoretically rigorous research into how natural hazards in Kona interact with the social and economic
characteristics of the community. In the absence of these data, it is difficult to formulate detailed risk-reduction and preparedness plans. Consequently, risk-reduction planning in Kona requires an evaluation of two elements: 1) community members’ knowledge of the different volcanic hazards that might affect them, and 2) the extent to which these people’s understanding of mitigation actions is appropriate given the nature of the prevailing hazards.

3.4 Lava Flow Hazards at Mauna Loa and Hualālai in Kona
Lava-flow hazard zones for the island of Hawai‘i are ranked 1 (most hazardous) through 9 (least hazardous (Wright et al., 1992)). South Kona includes zones 1, 2 and 3 of Mauna Loa; North Kona mostly zones 3 and 4 of Mauna Loa and Hualālai, respectively. All of Hualālai is currently in zone 4 (Fig. 3.1a-c). Relatively steep slopes and high effusion rates at these volcanoes contribute to the higher flow velocities, thus posing a considerable threat to Kona because most commercial and residential development lies at the foot of these steep slopes (near the coast) and in the paths of future lava flows (Moore et al. 1987; Fig. 3.1c,d). Lava flow-front velocities in Hawai‘i are generally less than walking speed (3-5 km hr⁻¹ (Mullineaux et al., 1987)). In Kona flow-front velocities have sometimes been much faster (e.g., average over 24 km = 9.6 km hr⁻¹ at Mauna Loa in 1950; Macdonald 1954). Similar velocities have been proposed for lava flows during the most recent eruptions of Hualālai (Kauahikaua et al., 2002). Flows often reach the ocean in Kona (Trusdell, 1995). Figure 3.1c illustrates that times taken for selected recent lava flows from Mauna Loa to reach the ocean in Kona have ranged from less than 3.5 hours to 120 days (Hawaii State Civil Defense, 2002). Moore et al. (1987) concluded that recurrence intervals for Hualālai during the Holocene are one eruption about every 50
years, although eruptions tend to cluster. At Mauna Loa the recurrence interval since 1832 is one eruption every 4.4 years (39 eruptions since 1832 (Barnard, 1995)). Return periods of this nature suggest some urgency in regard to both understanding community risk attitudes and implementing risk-reduction and readiness strategies.

3.5 Experience with Lava Flows
In Hawai‘i, recent (i.e., since about A.D. 1955) human experience in adjusting and responding to lava flows in inhabited areas is greatest for Kīlauea (in the Puna District) and to a lesser extent in the area around Hilo (Fig. 3.1b), which was last threatened in 1984 by Mauna Loa lava flows (Lockwood et al., 1987). Several means of adjusting to lava flows are possible; but evacuation was found to be the standard response to lava flows in the Puna District (Murton and Shimabukuro, 1974). Other means of adjustment in Hawai‘i have included land-use zoning restrictions that prevent or limit development of vulnerable areas, fire insurance, tax incentives, resettlement, government loans, religious appeals to supernatural beings and simply the bearing of losses.

Murton and Shimabukuro (1974) found that residents of the Puna District on Kīlauea believed the quality of life in that area was so great that it outweighed the volcanic risk, and so the people were content to live in a zone of relatively high volcanic hazard, despite awareness of available land and jobs in safer areas of the island. This raises another potential problem for creating risk acceptance among community members. People who have made costly decisions about things that they value (e.g., purchasing a house or electing to live in a specific area) may seek to ignore information that casts their decision in a negative light, such as being told that they have chosen to live in an area capable of being destroyed by lava flows (a process called cognitive
dissonance (Festinger, 1950). Similar behavior can arise when the attitudes that underpin peoples’ lifestyle choices (e.g., deciding to live in a particular place) are more salient than those for protection against infrequently occurring hazards (Ajzen, 1985; Paton, 2003). Thus, while people may acknowledge the relevance of protective actions, they are overridden by their lifestyle choices. Moreover, people may adopt a fatalistic attitude toward lava flow hazards. In Hawai‘i, this has involved religious appeals such as prayer and offerings to the volcano goddess, Pele (Lachman and Bonk, 1960; Murton and Shimabukuro, 1974). Promoting preparedness in this context will involve understanding these attitudes and developing ways of reconciling them with the emergency management objective of reducing risk, including maintaining trust in scientific and administrative agencies.

3.6 Evacuation and Traffic Control
Future large eruptions of Mauna Loa’s southwest rift zone and Hualālai in Kona may progress quickly and produce lava flows that travel up to tens of kilometers in a few hours or less, generally faster than velocities expected for typical flows at Kīlauea. Radial vent eruptions on Mauna Loa’s north and west flank occur outside the rift zones (e.g., 1859 eruption and 1877 submarine eruption, Fig. 3.1c (Trusdell, 1995)) and could represent a greater problem than rift zone eruptions because of their potential to begin closer to or within developed areas. Each instance will require rapid emergency response. Such response decisions are made by the administrator of the Hawai‘i County Civil Defense Agency (HCDA).

The logistics involved with evacuating areas in Kona are a concern. The few roads that provide access may simplify planning for evacuation but create a problem
should lava flows sever these roads. Highways 11 and 190 are the primary roads in Kona and they are sub-parallel to the coast (Fig 3.1c). One secondary road provides access to the ocean in South Kona where the lava flow hazard is highest. This and other more minor roads may be essential in the evacuation of people to the ocean if people are trapped by bifurcated lava flows. However, many of these minor roads are narrow, winding and in places are located on steep terrain, especially in South Kona. There are three small-boat harbors in Kona (Fig. 3.1c), so the limited number of roads and harbors may combine to complicate the evacuation of people to the ocean. During the 1950 eruption of Mauna Loa, low cloud cover and smoke and gases from burning forests ignited by lava flows caused poor visibility. A National Guard aircraft was used to contact a group at risk of isolation by advancing lava flows (Finch and Macdonald, 1950). The group included police and scientists and underscored the danger that lava flows in forested areas in Kona can pose to anyone.

Tight controls on use of roadways would be needed to preclude looting and vandalism, which are often concerns among people who resist evacuation from their homes. Looting and vandalism were reported by more than half of the homeowners evacuated during eruptions of Kilauea in the 1960s, but were reported only twice in eruptions in 1977 (Sorensen and Gersmehl, 1980), 1985 and 1990 (H. Kim, pers comm, 2003). The near absence of looting and vandalism in these later eruptions was attributed to Civil Defense authorities having warned the public of the serious consequences of such criminal actions, and having gained the community’s trust in the officials’ ability to safeguard personal property. Moreover, Civil Defense maintained strict enforcement of security in and around the hazard zone (H. Kim, pers. comm, 2003).
3.7 Warning Systems (General and Volcanic)

3.7.1 General warning system
Civil Defense instructions in Hawai‘i may simply be broadcast over radio in less extreme events, or over radio, television and cable television systems using the Emergency Alert System (EAS) and through police, fire department, civil defense, and civil air patrol aircraft in emergencies. Sirens are located on all the Hawaiian Islands to alert the public to potential emergencies. These sirens could be employed in volcanic eruptions (T. Kindred, pers. comm., 2003). In a survey in Hilo, Lachman et al. (1961) found that understanding of the meaning of the sirens was ambiguous during the tsunami of May 23, 1960 that destroyed much of Hilo. These authors reported that at that time the siren meant simply “alert,” with no indication of what behavioral response was expected of the public upon hearing it. Only 4.6% of respondents in the survey were aware of this. Currently, the siren is defined as an “Attention Alert Signal.” A siren sounding of 3-minute duration is intended to prompt the public to tune to a radio or television for more information. The sirens are tested monthly in Hawai‘i; however, we are unaware of any published studies that describe the effects of these tests on individual and collective preparedness to respond to warnings (Mileti and O’Brien, 1992; Mileti and Sorensen, 1990) or evaluate current understanding of the sirens throughout the island(s).

3.7.2 Response to volcanic hazards
Volcanic crisis response in Hawai‘i is currently based largely on strong but informal relationships among scientific groups, emergency managers and community associations. Response begins with interpretation of monitoring data collected by the U.S. Geological Survey’s Hawaiian Volcano Observatory (HVO). Once signs of renewed volcanic unrest
are detected and confirmed (e.g., significant ground inflation or prolonged volcanic
tremor), HVO reports the activity directly to HCDA, which then makes decisions on
informing, alerting, warning, or evacuating the public. HCDA has a standard operating
procedure for volcanic eruptions and may choose to form an emergency operations center
to manage public response to volcanic unrest.

Historically, the earliest reports of some eruptions were made by people other
than HVO staff or equipment, caused in part by problems with monitoring equipment
(Lockwood et al., 1987; Sorensen and Gersmehl, 1980). This suggests a need for
redundancy in the monitoring and warning network, especially in areas where eruptions
may impact society quickly, as a consequence of either fast moving lava flows or
eruptions that begin in developed areas (e.g., areas of Kona and the districts of Puna and
Kaʻū, Fig. 3.1b).

The need for advanced intensive instrumentation monitoring, and a rapid response
capability, is exemplified in Table 3.1, which indicates that warning times (e.g., as
provided by detection of volcanic tremor) are short for the best constrained 20th-century
eruptions of Mauna Loa. The ability to detect volcanic unrest or an imminent eruption
has improved since the last Mauna Loa eruption in 1984, but the short-term warning
period will likely be of the order of tens of minutes to a few hours rather than days. The
number and sensitivity of seismic stations on Mauna Loa have increased, and other
monitoring techniques (e.g., real-time tilt and strain meters, near real-time GPS data)
have been deployed (U. S. Geological Survey, 2003). However, the infrequency of
recent Mauna Loa and Hualālai eruptions, compared with those from Kīlauea, has limited
our understanding of what precursors to expect, suggesting an obvious need for advanced preparedness for eruptions in Kona and, also, in neighboring Ka‘ū.

Table 3.1. Time of onset of volcanic tremor, time of eruption of lava, and warning times for the best constrained eruptions of Mauna Loa volcano

<table>
<thead>
<tr>
<th>Eruption date (A.D.)</th>
<th>Time of Tremor Onset*</th>
<th>Time of Eruption*,**</th>
<th>Warning Time*** (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1926</td>
<td>01:36</td>
<td>&gt;03:00</td>
<td>-84 a</td>
</tr>
<tr>
<td>1933</td>
<td>05:43</td>
<td>&lt;07:00</td>
<td>&lt;77 b</td>
</tr>
<tr>
<td>1940</td>
<td>22:59</td>
<td>&lt;23:30</td>
<td>&lt;31 c</td>
</tr>
<tr>
<td>1950</td>
<td>21:04</td>
<td>&lt;21:25</td>
<td>&lt;21 d</td>
</tr>
<tr>
<td>1975</td>
<td>22:51</td>
<td>23:42</td>
<td>51 e</td>
</tr>
<tr>
<td>1984</td>
<td>23:30</td>
<td>01:25</td>
<td>115 e</td>
</tr>
</tbody>
</table>

* Times given in Hawai‘i Standard Time (first two digits equal hours; second two digits equal minutes). ** Time of eruption corresponds to the first account of visual observation of lava at the ground surface or detection by satellite in the case of the 1984 eruption. *** Warning time = Time of Eruption minus Time of Tremor Onset. a Finch (1926); b Jaggar (1933); c Macdonald (1954); d Finch and Macdonald (1950); e Lockwood et al. (1987).

Unless based on systematic research into the interaction between volcanic hazards and people in Kona, as opposed to simply extending plans developed for, say, the Puna District, the quality and efficacy of plans may be limited (Sorensen and Gersmehl, 1980). Response planning and mitigation should link social networks with formal administrative and scientific agencies. Thus planning should include developing mechanisms required to empower the community rather than imposing strategies (Paton, 2000).

**3.8 Disaster Preparedness Information**

Disaster Preparedness Information (DPI) in Hawai‘i is disseminated by Civil Defense agencies via telephone books (Verizon Hawaii, 2002). Neither a discussion of volcanic
hazards nor lava-flow hazard-zone maps are provided in the DPI, although lava flow
warning information was provided from 1960 to 1982. Our survey evaluated public
awareness of some features of the DPI, as well as the extent to which its
recommendations for general preparedness have been adopted. The value of this means
of disseminating preparedness information may be limited—e.g., Ballantyne et al. (2000),
in a New Zealand study, showed that respondents confused their knowledge of the
existence of a source of hazard information with thorough understanding of that material.
If people overestimate existing knowledge in this way, they may be less responsive to
new information, less likely to perceive a need for preparation, and may reduce the risk
they attribute to a hazard (Paton et al., 2000). 'Self-reporting' of measured and perceived
preparedness should be treated cautiously and must be verified to ensure accuracy of
reporting and to accommodate measurement problems associated with self-report data
(Paton et al., 2000).

3.9 The Survey

3.9.1 Purpose, methods and people
We set out to evaluate awareness of primary disaster information and the meaning of the
alert siren, the extent of preparedness for evacuation, and perceptions of emergency
response. Findings are discussed in the context of lava flow hazards, monitoring systems
and response plans. See Chapter 2, Section 2.3.3 for a discussion of methods employed
and characteristics of the sample.
3.9.2 Awareness of disaster preparedness information and warning siren

It is unlikely that significant portions of society will relate the DPI (Disaster Preparedness Information) describing other hazards to volcanic hazards, partially because perceptions and understanding of risk from volcanic hazards are so low (Gregg et al., 2004a, Chapt. 2). On average, respondents showed a good awareness that DPI material was in the telephone book (70%, n = 122; these data apply only to the adult-at-large and South Kona groups). However a slight majority (51.6%) of the 122 had neither read the material nor read it between one and five years ago. The ability to recall specific information is of a greater significance than simple awareness. We tested the recall ability of those respondents who indicated they had read the disaster preparedness information in the telephone book (n = 99) through cross-tabulations with a question regarding the meaning of the warning siren, which is explained in the DPI. On average 51% of these respondents were aware of the meaning of the siren, but adults were much more aware (73.4%) than students (8.6%). However, whether or not the respondent was aware of the DPI being in the telephone book, or whether respondents ever read the material, does not significantly change awareness of the meaning of the siren. This suggests that sources of information other than the DPI (e.g., familiarization during routine monthly tests of the siren, or discussions with other people) are influencing levels of awareness of the meaning of the siren, although these were not tested. Overall, 45.9% of the respondents are aware of the meaning of the siren (Table 3.2), although again awareness was much higher among adults. The district within which respondents live was not a significant factor in influencing awareness of the siren.
Table 3.2. Perceived meaning of the emergency warning siren

<table>
<thead>
<tr>
<th></th>
<th>Students</th>
<th>Adults</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n) (%</td>
<td>(n) (%)</td>
<td>(n) (%)</td>
</tr>
<tr>
<td>Attention Alert Signal, listen to radio or television for instructions from local authorities</td>
<td>57 27.1</td>
<td>134 65.0</td>
<td>191 45.9</td>
</tr>
<tr>
<td>Don't know</td>
<td>80 38.1</td>
<td>45 21.8</td>
<td>125 30.0</td>
</tr>
<tr>
<td>Hurricane warning issued</td>
<td>45 21.4</td>
<td>22 10.7</td>
<td>67 16.1</td>
</tr>
<tr>
<td>Hurricane watch issued</td>
<td>28 13.3</td>
<td>5 2.4</td>
<td>33 7.9</td>
</tr>
<tr>
<td>Total</td>
<td>210 100</td>
<td>206 100</td>
<td>416 100</td>
</tr>
</tbody>
</table>

*a Respondents were asked to select a meaning from those shown above.

3.9.3 Preparedness

In the DPI, Civil Defense recommends that individuals develop a response plan for an emergency. Having and practicing this plan can strengthen an individual’s ability to cope with adversity during hazard events. On average, only one-third (n = 149) of the respondents indicated that their families had an emergency plan for a lava flow, hurricane, or earthquake. Furthermore, only one-third claimed to have practiced what to do during an emergency at home (n = 145); and only slightly more claimed to know the location of an emergency evacuation shelter near their school or home. These data can be contrasted with those of Menzer (2000) for the eastern portion of the island, where 59% of those surveyed claimed to have a household evacuation plan.

We asked, “Have you ever practiced what to do during an emergency at home, at school (students only), and at work (adults only).” We also asked, “Has your family practiced together what to do if there is an emergency?” Some caution in the interpretation of these data is required. For example, if responses relate to more commonly occurring activities such as fire drills, these data may reflect people inferring a
capability to respond to each of the hazards that could affect them (i.e., volcanic versus earthquake, versus tsunami) from their practicing fire drills, with the possible consequence of people overestimating their preparedness. Emergency response plans are practiced less at home (33%, n = 145) than at work (40.9%, n = 83) and much less than at school (79.6%, n = 189). An individual whose family has an emergency plan of action is 2.2 times as likely to have practiced what to do during an emergency at home and is 3.2 times as likely to practice with their family. Thus, a household plan of action facilitates both individual and group practice of how to respond to an emergency. A limitation in interpretation of these data is that the adequacy of the response plans was not evaluated. It does, however, provide a good basis from which to develop more hazard specific preparedness.

Having a designated rendezvous place for the family or a place to leave a message during an emergency is suggested in the DPI. Given the uncertainty of vent locations and the large areas affected in eruptions, establishing a single rendezvous place that will be effective in all eruptions may require a location at least several tens of kilometers from one's home. On average, less than one-third (29.6%) claimed to have a rendezvous place. We cross-tabulated the responses of those who indicated earlier that their family had a plan of action (n = 149) with this question. The percentage that designated a rendezvous point only increased to 47.3% and suggests some deficiencies in the quality and content of the response plans. In contrast, Menzer (2000) found that 57% (n = 251) of those in the eastern side of the island had designated a meeting place, suggesting a higher level of preparedness there. This greater level of preparedness may reflect the higher incidence of lava flows or other hazards in that part of the island.
The DPI also recommends that people pick an emergency contact in another town. On average, only 29% (n = 129) in our study claimed to have done so. Together these data suggest a low level of adoption of basic disaster preparedness measures recommended in the DPI.

3.9.4 Responding to lava flows
Fewer than 5% of Kona respondents have experience with damaging lava flows and only 37% have seen active lava flows (probably relatively slow moving flows at Kīlauea (Gregg et al., 2004a)). These data contrast starkly with the 85% of respondents who experienced eruptions in the Puna District (Murton and Shimabukuro, 1974). Mauna Loa and Hualālai volcanoes will almost certainly erupt again, so consideration of people’s reactions is important in order to anticipate human behavior during future eruptions and to ensure that strategies developed to encourage preparedness can counter misconceptions. We asked respondents, “What would you do if a lava flow threatened you in your home?” (Table 3.3). The “other” data from Table 3.3 includes write-in responses presented in Table 3.4. Overall, the data suggest that there is no single and primary means of responding, and no clear picture of how to react to lava flows. A frequent response (61.6%) was to remove valuables from the home. While we did not evaluate the types of valuables that are expected to be removable during an eruption, we infer that these respondents believe that lava flows will move sufficiently slowly to permit removal of valuables. Removal of valuable property from houses, and whole structures themselves, has been common practice during recent eruptions at Kīlauea, because there is generally sufficient time between an alert and the arrival of lava flows in inhabited areas (U. S. Geological Survey, 1997b). Combining the response “move to
higher ground in order to avoid the flow" (Table 3.3) with the write-in responses "go to a safe place" and "go out to sea" (Table 3.4) into a general response of "evacuate," makes it the second most frequent response (n = 287; 63% of 456).

| Table 3.3. Perceived response if a lava flow threatened respondent at home a |
|--------------------------------------------------|--------|       |
| Listen to the radio/television for instructions from local authorities | 321    | 70.4  |
| Remove my most valuable possessions from my home                  | 281    | 61.6  |
| Move to higher ground in order to avoid the flow                  | 221    | 48.5  |
| Contact authorities for information                               | 216    | 47.4  |
| Immediately go out and take a close-up look at the lava            | 76     | 16.7  |
| Other                                                             | 108    | 23.7  |

a Respondents were asked to select a response(s) from those shown above. * Column percent does not equal 100 because respondents could record multiple responses.

These data are interesting in light of the time available for response to lava flows in Kona. Several of these choices require a time frame that could be unrealistic. For example, the time needed for officials to confirm an eruption and disseminate evacuation information could exceed the time available before lava flows impact developed areas. Similarly, the time required for individuals to contact authorities, particularly if high traffic volumes clog telephone lines, could delay self-evacuation and removal of property. For responses that include checking on family, the lack of selection of an appropriate meeting place for family members could complicate response to an eruption unnecessarily. Also, more specific information on what constitutes "a safe place" and the types of valuables expected to be removed needs to be determined (given the potential for short warning periods).
Table 3.4. Perceived response if a lava flow threatened respondent at home

<table>
<thead>
<tr>
<th></th>
<th>(n)</th>
<th>(%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go to a safe place</td>
<td>43</td>
<td>39.8</td>
</tr>
<tr>
<td>Go out to sea</td>
<td>23</td>
<td>21.3</td>
</tr>
<tr>
<td>Check on family</td>
<td>16</td>
<td>14.8</td>
</tr>
<tr>
<td>Check on neighbors</td>
<td>9</td>
<td>8.3</td>
</tr>
<tr>
<td>Spray water, construct barricade</td>
<td>6</td>
<td>5.6</td>
</tr>
<tr>
<td>Pray</td>
<td>4</td>
<td>3.7</td>
</tr>
<tr>
<td>Get pet</td>
<td>4</td>
<td>3.7</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
<td>13.0</td>
</tr>
</tbody>
</table>

*These are write-in data for the 108 respondents who wrote a response in the “other” category of Table 3.3. *Column percent does not equal 100 because respondents could record multiple responses.

The DPI advises that the telephone should be used only in serious emergencies in order to keep the lines clear for emergency communications. We assume, however, that the 47% who indicated they would contact authorities (Table 3.3) would do so using a traditional telephone or cellular phone. The data presented above suggests that the number of respondents who would call the authorities, if extrapolated to the community as a whole, is likely to exceed the capacity of the telecommunications systems and complicate the task of emergency management and scientific agencies to obtain, collate and disseminate information by telephone. The telephone system is unlikely to crash per se, but could yield busy signals for specific telephone numbers. While not examined specifically here, this point highlights the need for dedicated inter-agency information and decision-management systems to be developed, tested and implemented (Paton and Flin, 1999).

Currently, HVO and HCDA are connected by telephone, cell phone, radio, email and fax. Radio links are tested monthly.
In contrast to our data, Murton and Shimabukuro (1974) found that, in response to a question asking what action could be taken when an eruption occurred, 98 of 101 Puna respondents indicated “evacuate” and only two indicated “remove valuables.” This latter percentage is in stark contrast to the nearly 62% of our Kona respondents. The low response for removing valuables at Kīlauea is surprising considering the frequency with which property had been removed from the paths of lava flows during recent eruptions. However, it is also encouraging. Some residents at least may have realized how quickly an eruption can evolve. Awareness of other adjustment options among respondents at Kīlauea was evident from further questioning by the interviewers. Caution should be used in contrasting the Kona and Puna data, because the Kona data are based on a written questionnaire whereas Murton and Shimabukuro’s (1974) data were based on interviews, with additional questioning to extract more information. Our questionnaire provided only space for write-in answers. Nonetheless, the contrasts do suggest differing opinions regarding response to lava flows. Specifically, people in the Puna District had a common perception of how to respond (evacuate without removing valuables), whereas respondents in Kona were largely undecided (a majority listed three responses and no single response was selected by more than 70%).

3.10 Discussion
The absence of information about lava flow hazards in the DPI is a concern and could contribute to uncertainty about how to respond to them. It is unclear why the information is absent, given the recent and frequent impacts of lava flows on developed areas of the island, but it may reflect a degree of uncertainty about how to describe appropriate preparedness and response actions.
Responding to lava flows. Scientists, emergency response agencies and the community at large lack experience in dealing with Kona lava flows because of the long time since lava flows last occurred there. This lack of experience may hamper evacuation of people and valuable property. Some people will likely need to be evacuated to the ocean or by helicopter, owing to the limited number of roads in Kona that can be used for evacuation. For these reasons, there is a need for evacuation planning, followed by outreach programs to improve public response capabilities. Furthermore, curiosity will draw sightseers (residents and tourists) to the eruption; evacuation and response plans must include how to manage the logistics of these people.

Our respondents underestimated the velocity with which lava flows can travel in Kona and so may overestimate the available time to react and thus their current levels of preparedness. More outreach is needed to alleviate this perception. Also, the short time frames within which scientific, emergency management, and community responses must be made, say between the onset of tremor and the arrival of lava in inhabited areas, is another potential concern. There is a clear need for advanced planning for eruptions in the areas of highest hazard and risk. This largely includes the entire Kona population from the terminus of the 1859 flows in North Kona southward to the 1868 lava flows on Mauna Loa’s southwest rift zone (Fig. 3.1c (Hawaii State Civil Defense, 2002)).

Weisel and Stapleton (1992) reported that many evacuees of Kalapana (Fig. 3.1b) on Kīlauea chose to evacuate to a temporary camp in Kalapana as opposed to official shelters some 12 miles away. This reiterates the importance of official plans that accommodate local values and opinions. If planning is not done, evacuation may
contribute to, rather than ameliorate, stress among affected people. There is a need to evaluate the public’s options and intentions regarding temporary shelter.

Awareness of the meaning of the siren by only a minority of residents (46%) is a significant concern, particularly for students. The provision of siren information in the telephone book, and routine siren tests, have not promoted high levels of understanding of the siren, indicating a need to reevaluate how this important information is disseminated.

3.11 What now?
The following are suggested starting points for improving the official and public capacity to meet effectively the demands of future lava flows in Kona.

- Development of evacuation plans based on an assumption that certain key roads will be blocked, as recommended as implementation strategies in the Lava Flow Hazard Mitigation Plan (Hawaii State Civil Defense, 2002);
- Evaluation of the carrying capacity of public telephone and cell phone systems in light of the agencies that respondents intend to contact during eruptions;
- Co-ordination of monthly siren tests with radio and television advertising, and testing of the communities’ interpretation of the siren, to raise understanding of the meaning of the siren and to ensure that repeated testing does not lead to people overestimating their capacity to respond;
- Creation of brochures that show evacuation routes (including the contingent routes—see above) and safe areas distributed to residents. A team of local officials from Kona communities should assist in the development of the
evacuation and response plans (including advising people of areas they may wish to identify as family meeting places);

- Similar information provided for tourists and distributed via hotels and motels in a manner similar to successful exercises for hurricanes on Kaua‘i and tsunami in the State of Washington;

- Specific outreach for Kona to promote the development of effective home-based preparedness measures for lava flows. A range of educational materials specific to Kona are needed to raise the level of preparedness for lava flows. Techniques could include public seminars, media coverage, a web site, video and school lesson plans which have a homework component that promotes student and parent or guardian interaction. Preparedness should include, but is not limited to:

1. Knowing the range of volcanic threats and corresponding risk posed to individuals and their property;

2. Being familiar with natural warning signs of an eruption (e.g., tremor, earthquakes, lava glow, fume jets, etc) and knowing that the siren means to listen to a radio or television for information from officials;

3. Knowing how and where to obtain emergency information and assistance and to organize and maintain an emergency supply kit as described in the DPI;

4. Knowing the range of likely warning periods and the types of personal property items that can be removed within these periods;
Knowing evacuation routes and having an evacuation plan, and alternate plan in case roads are blocked, as well as knowing where and how to contact and meet family if they are separated.

- Modification of the DPI in the Hawai‘i telephone book to include volcanic hazards, particularly as they relate to how to prepare for and respond to lava flows in Kona. The expected range of warning times before the eruption begins, as well as the expected range of travel times for lava flows to reach developed areas should be clearly stated. The telephone book should not be the only means for disseminating this type of information.

### 3.12 Conclusions

Social and demographic characteristics and lava-flow hazards in Kona are generally different from those in areas of the Puna District where eruption frequency and experience in responding to lava flows is greater. These differences require that official and public preparedness and response measures for eruptions be tailored for Kona and even cultural differences between subsets of the Kona population. Future outreach efforts aimed at, for example, increasing understanding of the warning siren or adoption of preparedness and response measures, must acknowledge that people with contrasting backgrounds differ in the manner in which they receive, interpret, and utilize information prior to and during volcanic crises. It is critical to know the impact and value of future outreach efforts which will necessitate longitudinal surveys of hazard perception and preparedness.

This exploratory survey has highlighted a number of problems and indicates a need for better links between volcanologists, emergency managers and Kona
communities. It is crucial to focus efforts by these groups on promoting and enhancing preparedness intentions and actions, rather than further improvements in the supply of hazard information. A rapid, effective response, building on realistic understanding of the threat and risk to lava flows in Kona is critical for community resilience in responding to future eruptions. The recent change from deflation to inflation at Mauna Loa, which has been interpreted as potentially an early precursor of future eruption, adds some urgency to this work (U. S. Geological Survey, 2003).

Whereas this paper has generally focused on the threat of faster-moving lava flows, all flows in Kona may not necessarily be emplaced rapidly. Slower lava flows can be expected during eruptions with lower effusion rates and in areas where the slope is low (e.g., portions of coastal North Kona).
CHAPTER 4. CULTURAL INFLUENCES ON ATTITUDES TOWARD LAVA FLOW HAZARD MITIGATION MEASURES DURING THE JANUARY 1960 ERUPTION OF KĪLAUEA VOLCANO, KAPOHO, HAWAIʻI

Abstract
Volcanic landscapes and phenomena have long been the focus of great cultural identity for indigenous peoples. Uncertainty over how to integrate these complex cultural factors into planning for hazard mitigation is proving one of the greatest obstacles in mitigation measures, rather than a lack of understanding of the hazards or of engineering design of mitigation strategies. Hawaiian people have traditionally used prayer and offerings to pay respect to the volcano goddess Pele, whereas engineered attempts to control the lava flows that have long threatened their society were unknown prior to arrival of Europeans in the 18th century. This results in a potential conflict between Hawaiians and the officials who make decisions to intervene in the paths of lava flows.

In 1960, Kīlauea volcano erupted along its lower east rift zone for the second time in five years. The 1960 eruption destroyed the entire village of Kapoho, which consisted of 70 buildings and 300 residents. A large and unprecedented social science survey was undertaken during the eruption to develop an understanding of human behavior and beliefs among the adult evacuees (n = 160). Identical studies were also performed in three control towns located at varying distances from the eruption site (n = 478). During these studies, data were collected that characterize ethnic grouping, attitudes toward Hawaiian cultural issues such as belief in Pele, and attitudes toward lava flow mitigation measures. Using these unpublished data, this chapter is concerned with testing the
relationship between Hawaiian cultural issues and attitudes toward the use of lava flow mitigation measures. This is important in a modern context of future lava flow hazard mitigation, as the state of Hawai‘i has recognized that a cultural renaissance has occurred in Hawai‘i since the last intervention in 1960 and that modern Hawaiian cultural sensitivity to mitigation, regardless of other issues relating to reliability, liability and funding of mitigation measures, could alone prevent intervention in future lava flows (Hawaii State Civil Defense, 2002). The growing population, population density and increasing value of infrastructure in areas vulnerable to lava flows, and renewed precursor activity at Mauna Loa provide both justification and urgency for this work.

Data indicate that on average 72% of respondents favored the construction of barriers to hold back or divert lava to protect Kapoho from lava flows, but far fewer agreed with the military’s use of bombs (14%). However, about one-third conditionally agreed with the use of bombs when local participation was involved. I conclude that barriers are perceived to be much less obstructive to the natural flow of lava than bombs and that this factor and community participation (i.e., community empowerment) contribute to higher levels of acceptance of mitigation strategies. Whether support still exists today for engineered mitigation of lava flow hazards is unknown, but a modern comparative study is needed before the next damaging eruption.

4.1 Introduction

The island of Hawai‘i comprises five volcanoes (Kīlauea, Mauna Loa, Hualālai, Mauna Kea, and Kohala; Chapt. 3, Fig. 3.1), but only the first three are considered active and have erupted since ca. 1800 A.D; the other two volcanoes have not erupted in 4,000 years or longer (Wolfe and Morris, 1996; Wolfe et al., 1997). Lava flows from the active
volcanoes represent a substantial hazard to much of the southern half of the island and have been the primary volcanic hazard with which people have shown concern since the arrival of Europeans in the early 18th century (Mullineaux and Peterson, 1974). However, volcanic gas emissions from Kīlauea are increasingly recognized as a major long-term concern in many areas of the island because of the prolonged duration of eruptions of Kīlauea (Gregg et al., 2004a, Chapt. 2; U. S. Geological Survey, 1997a). The first and second largest cities on the island (Hilo and Kailua-Kona; Fig. 3.1), along with two international airports, numerous hotels, lifelines and other infrastructure, are located on the flanks of Mauna Loa and Hualālai, so the risk to society as a consequence of future lava flows in these areas represents a legitimate concern (Gregg et al., 2004a, Chapt. 2; Gregg et al., 2004b, Chapt. 3; Hawaii State Civil Defense, 2002; Trusdell, 1995). Indeed, increasing population and development means that risk is increasing substantially over time.

In recognition of the threat posed by lava flows, the Governor of Hawai‘i convened a Lava Flow Hazard Mitigation Technical Committee (LFHMTC, the Committee) in 2000 to “reduce the risk of loss of life and property from the hazard of lava flows” on the island of Hawai‘i (Hawaii State Civil Defense, 2002). A report prepared by the Committee, titled, Lava Flow Hazard Mitigation Plan: Reducing the Risk of Lava Flows to Life and Property, discussed, among many topics, the possibility of using engineered measures to mitigate future lava flows in high risk areas. However, the report also highlighted the fact that several issues could preclude the use of such measures in future eruptions of Hawaiian volcanoes. These include liability, reliability, funding and cultural issues. Using unpublished social science data collected during the
eruption of Kīlauea volcano in 1960, this dissertation chapter is primarily concerned with
describing the implications of cultural issues in relation to the mitigation measures used
in 1960. These data provide a framework on which to build a similar contemporary
study, which was a recommendation in the Committee's report.

A variety of engineered mitigation measures have been tried in Hawai‘i to divert
or contain lava since the A.D. 1881 eruption of Mauna Loa threatened Hilo. These
include the use of bombs and earthen barriers or walls, and to a lesser extent water
The idea that Hawaiian cultural beliefs and engineered mitigation of lava flows may be at
odds with each other arises out of belief in Pele, the goddess of volcanoes and the best
known of Hawaiian deities (Emerson, 1993).

In 1955, Kīlauea erupted along its lower east rift zone (Fig. 4.1) after a long
period of volcanic quiescence in that area, dating back to 1840. The 115 years of
volcanic quiet had “lulled the people residing in the District of Puna (Chapt. 3, Fig. 3.1)
into a false sense of security” and caught residents off guard (Macdonald et al., 1983).
The 1955 eruption destroyed a few houses in the village of Kapoho (15 by lava, a few
others by shaking during earthquakes), but five years later, in 1960, a second eruption
inundated the entire village of Kapoho with lava and tephra during 38 days of eruptive
Initially, earthquakes and tephra fall were the primary hazards of concern. However, lava
flows quickly became the most threatening hazard and proved to be the most destructive
in terms of damage to buildings and destruction of land. Volcanic gases also became a
major health concern. Sulfur dioxide in the air threatened the evacuation of the largest
city on the island—Hilo, some 30 km north of Kapoho (Pierce, 1960). By the end of the eruption Kapoho was destroyed and its 300 residents were permanently displaced. Many evacuated to a new subdivision located about 8 km west of Kapoho (i.e., Kaniahiku Village).

When the 1960 eruption began in Kapoho, a social science survey conducted by R. Lachman and W.J. Bonk was immediately begun to investigate security-seeking behavior (coping strategies) in the unique context of a Hawaiian volcanic eruption. The survey consisted of interviews of evacuees from Kapoho and three control communities located at varying distances from the volcano (Hilo, \( n = 126 \), Pā‘auhau, \( n = 147 \), and Waimea, \( n = 205 \); Fig. 4.1). A very brief and preliminary description of the study was published in 1960 in Science (Lachman and Bonk, 1960). At that time the study was still in progress. However, circumstances, principally the advent of the May 23, 1960 tsunami that destroyed nearby Hilo (Lachman et al., 1961), diverted the work of the researchers from Kapoho, leaving the Kapoho data archived but unpublished. None of the data described in this chapter have thus been published or fully examined.

Presented here are original unpublished data from this unprecedented but forgotten social science survey exploring the relationship of cultural belief in Pele and Hawaiian ethnicity with attitudes toward the use of bombs and earthen barriers to protect Kapoho from lava flows. Data presented here cannot be used to infer modern attitudes toward mitigation, but they illustrate a widespread acceptance of barriers in 1960 and underscore the need for a contemporary survey to understand current opinions toward mitigation.
Future eruptions may provide little advanced warning (i.e., measured as the time between the onset of an eruption and arrival of destructive lava flows in inhabited areas (Gregg et al., 2004b, Chapt. 3). Thus, the time needed to implement engineered mitigation measures (i.e., conception, design, construction, etc.) may exceed the warning time available. This was a lesson learned in Kapoho in 1960 and in Hilo in 1984 (Associated Press, 1960a; Stapleton, 1984). Consequently, decisions concerning mitigation should be resolved well in advance of an eruption where possible. A recommendation in the Lava Flow Hazard Mitigation Technical Committee’s report was that mitigation strategies to protect Hilo be reviewed (Hawaii State Civil Defense, 2002). This is a step toward long-term mitigation planning, but given the complexities of intervention, it is unlikely that the mitigation strategies will be implemented in the near future.

4.1.1 The 1955 and 1960 eruptions of Kīlauea
The 1955 eruption occurred along a 16-km-long series of en echelon fissures sub-parallel to Kīlauea’s east rift zone (Macdonald and Eaton, 1955, 1964). The eruption lasted for 88 days (Macdonald et al., 1983). In Kapoho, the eruption was confined to the western perimeter of the village because lava was prevented from flowing into the town by the presence of a topographically high prehistoric spatter rampart that served to retard the advance of lava (Macdonald, 1959). The eruption was of a smaller volume than the following 1960 eruption, which began in Kapoho, but the 1955 eruption covered a greater area. The 1955 eruption produced nearly $9 \times 10^7$ m$^3$ of lava covering 15.9 km$^2$ of land (Macdonald et al., 1983). Affected lands included 450 hectares of agricultural cropland that was covered by lava or ash and an additional 520 hectares of crops that were
destroyed by either fire ignited by lava or from volcanic gas. Over 60 homes were destroyed or made uninhabitable and 10 km of roads were inundated with lava. The monetary cost of the immediate destruction was estimated at $2.5 million (Murton and Shimabukuro, 1974). This figure would have been much greater if it had included costs of emergency response, loss of wages and the costs associated with relocating displaced people.

In contrast, the 1960 eruption began on January 13 from a 900-m-long series of en echelon fissures just a few hundred meters north of the town center of Kapoho. Flows from this fissure system eventually consumed the entire village of 70 structures. The impending disaster was immediately apparent, where just eight days after the eruption began on January 21, 1960, President Eisenhower declared Kapoho a major disaster area and opened the door for Federal emergency aid, although the aid would not be available immediately (Associated Press, 1960). The eruption produced 1.1x10^8 m^3 of lava covering 10.7 km^2, the fourth largest eruption of Kīlauea in written history. The lower area coverage in 1960 compared to 1955 is attributable to ponding of lava in the Kapoho graben (Richter et al., 1970). Amazingly, Murton and Shimabukuro (1974) reported that no detailed information was made available for loss and damages in this eruption. However, several newspaper articles in the local Hilo Tribune-Herald newspaper indicated monetary losses exceeded $4 million by January 20, 1960 alone, only one week after the onset of the eruption (Associated Press, 1960a). Loss estimates rose to $5.5 million by February 3 (Pierce, 1960).
Figure 4.1a. Oblique image looking west and up the east rift zone of Kilauea, Hawai'i. Recent lava flows of Kilauea and Mauna Loa (post 1800 A.D.) are shown in red. The five volcanoes are labeled in black, place names in white. White box outlines Kapoho area and lava flows of the 1960 eruption (Fig. 4.1b below). Dates of nearby recent lava flows are shown around the Kapoho area.

Figure 4.1b. Enlargement of Kapoho section of Figure 4.1a showing lava flows of the 1960 eruption in relation to the location of eruptive vents, buildings and barriers that were constructed to hold back lava from developed areas.
4.1.2 Hawaiian culture and Pele

A cultural renaissance has occurred in Hawai‘i since the last engineered mitigation in 1960 (Young, 1980), and Hawaiian culture is high on current political and social agendas. Throughout the world volcanoes have long been the source of great spiritual significance (Cyranoski, 2004; de Boer and Sanders, 2002; Orbell, 1999), and in Hawai‘i this fact is well illustrated (Emerson, 1993; Reichhardt, 2001). Perhaps the best known of the Hawaiian deities is the volcano goddess Pele, who is believed to reside in the summit of Kīlauea (Emerson, 1993).

Cultural issues, such as belief in Pele and other Hawaiian deities, are very powerful forces that are becoming decisive factors in land-use planning and development in Hawai‘i. For example, opposition to development of a geothermal energy venture on Kīlauea in the Puna District by Pele advocates led to lengthy litigation at both state and Federal levels (Dinell and Goody, 1987; Supreme Court of the State of Hawaii, 1994; Supreme Court of the United States of America, 1992). Similarly, an ongoing conflict between Hawaiian activist groups and the scientific community over cultural issues involving Hawaiian deities and proposed development of astronomical observatories on nearby Mauna Kea volcano has delayed major construction projects that exceed US$50 million and which are thought to contribute $150 million annually to the economy (Feder, 2004; Reichhardt, 2001). However, the cultural issues surrounding the proposed development are complex— even the Hawaiian community is divided in opinion over whether or not to support the development (Dalton and Abbott, 2000). Together these examples highlight the significance of cultural issues and the difficulty in achieving positive outcomes where land-use proposals conflict with cultural issues. Reconciling
economic growth and cultural issues with land-use considerations can be difficult, even when great economic benefit is at hand.

An example of cultural sensitivity in a volcanic setting elsewhere in the world can be found in New Zealand. In 1953, a lahar was triggered by unexpected drainage of the summit lake of Mount Ruapehu volcano. The lahar destroyed the Tangiwai railway bridge, which led to the derailment of a train carrying 285 people—one-hundred and fifty one of these people died (Galley et al., 2004). Lahars are a frequent hazard at Ruapehu. Māori (indigenous people of New Zealand) are playing decisive roles in decisions to mitigate the extreme hazard (Brown, 2004; Galley et al., 2004; Taig, 2002). The New Zealand government is debating the idea of mitigating the hazard, but cultural sensitivity among the Māori and environmentalists is making mitigation activities unlikely at the summit of Ruapehu. Cultural sensitivity there relates to the spiritual significance of the undisturbed summit of Mount Ruapehu. Currently, the Government has maintained that their stance of no engineered mitigation is based on the grounds that mitigation is too dangerous, but others have suggested that “political correctness, not danger, has led to the decision to not intervene with mitigative action because the Government does not want to upset the Māori or environmentalists” (Brown, 2004).

In Hawai‘i, interesting questions are, how has Pele gained such significance; how strong are beliefs in Pele; who shares these beliefs; and where do people learn about Pele? While no studies have investigated these issues, a review of the literature shows that Pele began receiving a great deal of written attention with the arrival of Europeans, prior to which written records were not available in Hawai‘i. Early discussions of Pele were recorded by the Rev. William Ellis (Ellis, 1963) and Samuel M. Kamakau
(Kamakau, 1992). Also, Charlot (1998) summarized five of six lengthy newspaper serials on Pele and another deity, Hi‘iaka, that were published between 1861 to 1911. On December 29, 1959, about two weeks prior to the outbreak of lava in Kapoho in 1960, earthquakes began being felt in the Kapoho area and a front-page article of the local newspaper read, “Madame Pele appears to be stalking about out of sight with a satchelful of eruption potentialities” (Hilo Tribune-Herald, 1959). In this regard, Hawaiian newspaper articles about Pele seem to be quite common, especially when eruptions begin (Barnard, 1996).

Before the arrival of Europeans, volcanic eruptions impacted upon the indigenous people of Hawai‘i and helped shape their spiritual beliefs about volcanoes and volcanic processes and their consequences (i.e., volcanic hazards). An understanding of these issues is important. For example, the focus of contemporary emergency management agencies is with reducing the impact of volcanic hazards. However, in a cultural context, mitigation and preparedness measures must be developed in ways that are consistent with cultural beliefs and coping strategies. If this is not possible, it is pertinent to include cultural factors as risk elements to the extent that cultural reluctance to adopt specific mitigation measures can add to the impact of a hazard on society. Finally, the latter is relevant to considering the response and rebuilding activities that may be required in the event that specific mitigation measures are not adopted.

Nimmo (1986) suggested that belief in Pele was much more significant in the day-to-day life of people who lived in areas of frequent volcanic activity (e.g., Districts of Puna, Ka‘ū, South Kona and North Kona; Chapt. 3, Fig. 3.1) rather than in other parts
of the Hawaiian islands, where Pele was more of a mythical figure known in legends and chants.

Traditional Hawaiian beliefs hold that land in the southern half of the island (i.e., south of the Wailuku River, which forms a portion of the boundary between Mauna Loa and Mauna Kea) belongs to Pele and that to interfere with natural lava flow paths would upset Pele’s tempestuous nature (Murton and Shimabukuro, 1974). The lava flow itself can be identified with the body of the goddess, i.e., Pele can supposedly manifest herself as a lava flow and take what she wants when she wants; so one should not interfere. However, it is apparently acceptable to offer prayer and sacrifices to Pele in hopes she would spare specific land from lava flows, because many people, including Hawaiian royalty, have done these things (Baldwin, 1953; Kamakau, 1992). To pay respect to Pele, people continue to give gifts or offerings such as flowers, meat, liquor, candy, fruit and tobacco (Lachman and Bonk, 1960; Murton and Shimabukuro, 1974). Today, one can easily observe offerings of leis and liquor at the overlook platform at the upper ledge of Halema’uma’u crater on the summit of Kīlauea.

4.1.3 Mitigation of lava flow hazards in Hawai‘i
Two options have been exercised to mitigate lava flow hazards in Hawai‘i—spiritual appeals to Pele and engineered intervention. Spiritual attempts include giving offerings and gifts to Pele in hopes that she would spare land from lava flows (Lachman and Bonk, 1960; Murton and Shimabukuro, 1974). This type of mitigation would significantly outnumber engineered attempts designed to physically control movement of the lava.

The results of engineered mitigation of lava flows in Hawai‘i (e.g., barriers, bombs, water) have received mixed reviews, but the efforts have proven valuable to our
understanding of how lava behaves in response to mitigation measures. Furthermore, the efforts in Hawai‘i and elsewhere have demonstrated that mitigation measures are technically feasible given certain volcanic and topographic conditions (Barberi et al., 2003; Colombrita, 1984; Lockwood and Romano, 1985; Lockwood and Torgerson, 1980; Macdonald, 1958, 1962).

4.1.3.1 Barriers
The earliest attempt to control lava with engineered measures in Hawai‘i occurred during the eruption of Mauna Loa in 1881. Here, a small stone wall and moat were hastily constructed and excavated to protect areas of Hilo against lava flows (Jaggar, 1937; Macdonald, 1958), but a plan was also made to construct a larger wall with the hands of 1000 men, although it was not implemented because the eruption stopped (Baldwin, 1953). Other proposals detailing the construction of barriers to divert lava flows and protect Hilo date back to at least 1937 (Jaggar, 1937; Macdonald, 1958), but apart from the 1880-1881 eruption, barriers have been implemented in Hawai‘i only during the 1955 and 1960 eruptions of Kīlauea (Macdonald, 1958, 1962).

The legal implications of lava intervention are concerns. For example, during the 1960 eruption in Kapoho, legal concerns directly interfered with the selection of locations for barriers (Wilhelm, 1960c). During the 1984 eruption of Mauna Loa, plans to construct barriers to protect Hilo were discussed but not implemented (Lockwood et al., 1987). At that time the Puna Sugar Company, a major land holder in Hawai‘i, threatened to sue the State when the company received word that plans for barrier intervention under consideration could impact upon their property (Hawaii State Civil Defense, 2002). In this instance, liability issues could have precluded mitigation had the eruption not
stopped before lava destroyed developed land. Bombs and water were also considered as mitigation alternatives in the 1984 eruption, but they too were not used (Hilo Tribune-Herald, 1984).

Diversion barriers were constructed most recently in Hawai‘i in 1986 on Mauna Loa to protect a weather observatory, but they have not yet been tested by an eruption (Moore, 1982). Elsewhere in the world, the earliest recorded and the most recent engineered mitigation of lava flow hazards was at Mount Etna on the island of Sicily (Barberi et al., 2003; Lyell, 1875). Barriers have been successful and feasible at Mount Etna when considered in the context of a cost-benefit ratio (i.e., the ratio of cost of barrier construction to value of property saved). For example, Barberi et al. (2003) reported a cost-benefit ration of 1:20 for barriers that were constructed in the 2003 eruption.

4.1.3.2 Bombs

The use of explosives to alter the course of lava flows was first suggested by an anonymous kama‘aina (i.e., native-born) in 1881 and later by Lorrin A. Thurston in the early 1920’s, but explosives were not used until 1935 (Lockwood and Torgerson, 1980). To divert lava flows of Mauna Loa, bombs were dropped on flows during eruptions that threatened Hilo in 1935 and again in 1942 (Finch and Macdonald, 1949; Jaggar, 1936b; Macdonald, 1958). The use of bombs to disrupt the cone that grew in Kapoho in 1960 and which fed the destructive lava flows and tephra was considered but never implemented because of technical and legal considerations. For example, much of the land was privately owned, and the landowner emphatically refused to permit the Army to bomb the lava, stating that the only way it would happen while he owned the land was if the state condemned the land and took control (Hilo Tribune-Herald, 1960b; Wilhelm,
Macdonald (1962) reported that volcanological conditions were not conducive to bombing the cone, the ramparts or the flows. However, the channel of the main lava flow between the eruption site and the ocean had become clogged, so bombing the obstruction was considered as a means to clear a pathway for the lava to reach the ocean. However, there was no way then of determining where the blockage was located (Wilhelm, 1960b). Today this problem may be overcome with modern thermal imaging instruments.

4.1.3.3 Water
Other mitigation efforts in Hawai‘i include the use of water to cool lava flows. This was done to protect a lighthouse and buildings during the 1960 eruption (Macdonald, 1962; Pierce, 1960; Wilhelm, 1960a). Water was also used to cool flows and dampen houses in more recent eruptions of Kīlauea in Kalapana. The use of water to cool lava flows is best known from the 1973 eruption of Eldfell volcano on Heimaey, Iceland (Jónsson and Matthíasson, 1974).

4.2 Cultural Issues and Mitigation
In Hawai‘i, no published systematic study of cultural issues (e.g. belief in Pele and Hawaiian ethnic grouping) is available to help arrive at decisions regarding whether or not to intervene in the paths of lava flows. Likewise, no publication describes public attitudes toward the use of mitigation measures. The interventions during the eruptions of Mauna Loa in 1881, 1935 and 1942, as well as Kīlauea in 1955 and 1960 provide historic precedence for engineered intervention, but they say nothing of public opinion toward mitigation. Contemporary discussion of this issue is complicated by it happening during periods of volcano quiescence when cultural and cost issues take precedence. Peoples’ attitudes may change if developed areas are threatened again. Consequently,
substantial knowledge of the basis of cultural, and other constraints, is required and should be accommodated in risk communication efforts.

In a meeting held in 1935 to discuss intervention with a Mauna Loa lava flow threatening Hilo, high ranking military officers, local public officials, and Thomas Jaggar (the volcanologist in-charge and founder of the Hawaiian Volcano Observatory) jointly reported that, “...public opinion demanded that something be done to divert or stop this lava flow” (Jaggar, 1936a). There is no reference to how the committee determined the extent of public opinion in favor of intervention in the path of the lava flow, a procedure which was implemented about one week later when bombs were dropped from low flying military aircraft to disrupt the flow (Jaggar, 1936b). In contrast, and in response to proposals for bombing the lava flows to protect Hilo, Hawaiians predicted that “any attempt to bomb the flows would anger the goddess [Pele] who would immediately vent her wrath upon the city and cause widespread destruction” (Jaggar, 1936b). This comment highlights a need for greater understanding of cultural beliefs and their origins. If these are known, it may be possible to develop strategies that reconcile cultural and mitigation needs.

4.3 The Study

4.3.1 Objectives and methods
The foremost objective of this paper is to present social science data collected in 1960. I use these data to establish the relationship between Hawaiian cultural issues and attitudes toward engineered mitigation measures used in Kapoho in 1960. The basic hypothesis tested here is that acceptance of the use of engineered mitigation measures in 1960 was inversely related to belief in Pele and Hawaiian ethnicity. Attitudes toward the use of
bombs and barriers are the dependent variables. Belief in Pele and ethnicity are the independent variables. In the original study it was not possible to communicate the notion of degree of belief in Pele, so all that was ascertained was the presence or absence of belief, although respondents were able to answer “don’t know” in response to questions about belief in Pele.

Many issues surrounding the volcanic disaster in Kapoho were investigated in the original 1960 study. These issues included attitudes toward lava-flow hazard mitigation; communication of the state of the emergency; self-reliance; the manner of relocation; and levels of “security seeking behavior.” The latter refers to the idea that during times of extreme stress and uncertainty, such as that endured by evacuees of the 1960 eruption in Kapoho, people exercise a coping strategy that involves offerings or prayers to deities or gods such as Pele (Lee and Newton, 1981).

From the initial day of the emergency in Kapoho, January 13, 1960, observations of the behavior of evacuees from Kapoho in the evacuation center were made by the original researchers—R. Lachman and W. J. Bonk. An interview questionnaire was prepared and administered to all but one of the adult evacuees in Kapoho and to the three control groups. The daughter of the former postmaster of Kapoho was a student of Lachman and her participation made it possible to interview virtually all of the adults in the village of Kapoho (R. Lachman, pers. comm, 2003). Time did not permit a pre-test of the survey questionnaire.

The interviews were conducted by Lachman, Bonk and students at the University of Hawai‘i in Hilo and the data were collected over the four month period immediately following the start of the eruption. Questionnaires were translated into six languages,
owing to the diverse ethnic backgrounds of island residents. These languages included local pidgin English, Japanese, Korean, and three Filipino dialects. In total, 638 questionnaires were completed. The data for the Kapoho subgroup consists of parameter rather than sample values (i.e., virtually the whole population was sampled in Kapoho as opposed to a sample of the population). The three control groups, however, are sample values drawn from a small and finite population. The number of interviews requested in the control groups is not known, so response rates cannot be determined. The Hilo subgroup was an Army Reserve installation, while the other three subgroups can generally be regarded as being drawn from communities with an agriculturally based economy.

The population of Hawai‘i County in 1960 was 61,332. The total sample therefore represents about 1% of the total population of the island at that time. The population of Kapoho prior to the 1960 eruption was about 300, including adults and children. The sub-sample of 160 therefore represents a majority of the entire population of Kapoho.

4.3.2 Demographics

4.3.2.1 Age and gender
The mean, median and mode age data for the entire sample was 40, 37 and 18 years, respectively (sd = 17 years). The Hilo Army Reserve (Hilo) subgroup was considerably younger than the other three subgroups. The mean age of the Hilo subgroup was 23 years (sd = 5.2 years), whereas the mean ages of the other subgroups were 42 years (Waimea, sd = 13.8 years), 43 years (Pā‘auhau, sd = 14.3), and 48 years (Kapoho, sd = 18.7 years). Gender was 64.3% male (n = 410), 35.6% female (n = 227; missing data = 0.2%, n = 1).
All of the Hilo subgroup was male, compared with between 47% and 62% for the other two groups, respectively. Thus, the Hilo subgroup was uniquely biased in terms of age and gender.

4.3.2.2 Race and ethnicity
Five hundred and twenty five of 638 respondents claimed one race. Among these 525 respondents, people of Asian descent comprised the bulk of each subgroup (66.7% to 83.1%, mean = 76.0%). Japanese was overwhelmingly the most common Asiatic race claimed (mean = 52.2%; range = 43.9% in Pāʻauhau to 62.3% in Waimea), followed by Filipino (mean = 18.3%; range = 2.5% in Waimea to 29.8% in Kapoho). A few other people were Korean, Chinese and Mongolian. Other races claimed included Hawaiian or part-Hawaiian (10.7%), White (9.9%) and other (3.4%). One hundred and thirteen respondents selected two or more races. Of these 113, about 81% selected Asian races, 80% selected Hawaiian or part-Hawaiian, and 65% selected Caucasian races. Ten percent selected other races.

4.4 Results (Cultural and Mitigation Beliefs)
4.4.1 Cultural beliefs
Various beliefs and behavior regarding Pele should be characterized before presenting data regarding attitudes toward mitigation. Several questions were asked to evaluate these issues.

First, volcanic eruptions are sometimes said to occur as a consequence of someone or some people having offended Pele (Jaggar, 1936b; Macdonald, 1962). Recent anonymous personal communications from residents of the nearby village of
Kalapana (Fig. 4.1a), which was destroyed by lava flows in the 1980s and 1990 (Hazard Mitigation Team, 1990), indicate that at least some local people believe that the Kalapana disaster was caused by an influx of “bad people” into the Puna area who were living untraditional lifestyles. Some locals suggested that the lava flows that destroyed Kalapana were a manifestation of Pele’s anger toward the newcomers.

Table 4.1 shows the responses of the four subgroups in the study (i.e., Kapoho, Hilo, Pāʻauhau, and Waimea) to the statement, “Eruptions may happen because people do bad things that make Madam Pele angry.” Overall, most people disagreed with the statement, suggesting that people largely believed that other factors influence whether eruptions occur. This is generally consistent with Gregg et al. (2004a, Chapt. 2), who, in a study of volcanic hazard risk perception on the western side of the island, found that three-quarters of the adults responded that they believed pressure beneath volcanoes caused volcanic eruptions, rather than Pele and other factors.
Table 4.1. “Eruptions may happen because people do bad things that make Madame Pele angry” by subgroup

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Kapoho</th>
<th>Pā'auhau</th>
<th>Waimea</th>
<th>Hilo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>n</td>
<td>37</td>
<td>16</td>
<td>39</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>23.1</td>
<td>11.0</td>
<td>19.4</td>
<td>10.3</td>
</tr>
<tr>
<td>Don’t know</td>
<td>n</td>
<td>54</td>
<td>51</td>
<td>48</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>33.8</td>
<td>34.9</td>
<td>23.9</td>
<td>38.9</td>
</tr>
<tr>
<td>No</td>
<td>n</td>
<td>69</td>
<td>79</td>
<td>114</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>43.1</td>
<td>54.1</td>
<td>56.7</td>
<td>50.8</td>
</tr>
<tr>
<td>Total</td>
<td>n</td>
<td>160</td>
<td>146</td>
<td>201</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

χ² = 20.875, df = 6, p = 0.002. Missing data = 5.

Some people believe they can be “helped” by giving offerings (or gifts) to Pele (Jaggar, 1936b). “Help” may include having advanced warning of an eruption or having one’s property spared from inundation and destruction by lava. In response to the statement, “Some people have been helped by giving gifts (offerings) to Pele,” data indicate that few people agreed (average = 16.8%, Table 4.2). Most people were either undecided or disagreed with the statement.
Table 4.2. “Some people have been helped by giving gifts (offerings) to Pele” by subgroup

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Kapoho</th>
<th>Pā‘auhau</th>
<th>Waimea</th>
<th>Hilo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>38</td>
<td>23.8</td>
<td>37</td>
<td>8</td>
<td>107</td>
</tr>
<tr>
<td>Don't know</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>73</td>
<td>45.6</td>
<td>63</td>
<td>85</td>
<td>279</td>
</tr>
<tr>
<td>No</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>30.6</td>
<td>105</td>
<td>32</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>100</td>
<td>205</td>
<td>125</td>
<td>636</td>
</tr>
</tbody>
</table>

$\chi^2 = 55.378, \text{ df } = 6, p = 0.000$. Missing data = 2.

I expected that the frequency of people who would give gifts would be similar to the percentage who believed that people have been helped by giving gifts. However, in response to the question, “Would you give gifts (offerings) to Pele,” on average a majority said no, and only 21.1% said yes (Table 4.3). A subsequent question asked if the respondent had ever given gifts (offerings) to Pele (Table 4.4). The frequency with which respondents have ever given offerings to Pele was much lower than those who said they “would” give offerings in the previous question.
Table 4.3. Belief that respondent would give gifts (offerings) to Pele by subgroup

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Kapoho</th>
<th>Pā'auhau</th>
<th>Waimea</th>
<th>Hilo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>28.8</td>
<td>50</td>
<td>8</td>
<td>134</td>
</tr>
<tr>
<td>Don't know</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>18.1</td>
<td>38</td>
<td>63</td>
<td>153</td>
</tr>
<tr>
<td>No</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>53.1</td>
<td>116</td>
<td>54</td>
<td>348</td>
</tr>
<tr>
<td>Total</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>100</td>
<td>204</td>
<td>125</td>
<td>635</td>
</tr>
</tbody>
</table>

$\chi^2 = 68.813$, df = 6, $p = 0.000)$. Missing data = 3.

Table 4.4. Whether respondent ever gave gifts to Pele by subgroup

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Kapoho</th>
<th>Pā'auhau</th>
<th>Waimea</th>
<th>Hilo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6.3</td>
<td>11</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>Don't know</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.3</td>
<td>1</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>No</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>147</td>
<td>92.5</td>
<td>191</td>
<td>119</td>
<td>597</td>
</tr>
<tr>
<td>Total</td>
<td>(n)</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>159</td>
<td>100</td>
<td>203</td>
<td>125</td>
<td>633</td>
</tr>
</tbody>
</table>

Missing data = 5. Data are too small to test for statistical significance.

Expressed belief in Pele was found to be low (Table 4.5). On average only 28.1% of respondents indicated they believed in Pele; most people said they did not. The higher levels of belief in Pele reported by the Kapoho subgroup (38.1%), is an expected finding considering the greater frequency of volcanic activity in Puna compared to the northern
part of the island where no eruption has occurred in thousands of years. However, belief was nearly equally as strong in the Waimea subgroup. The reason or reasons for the low levels of belief recorded by the Hilo subgroup is unclear. The greater frequency of “don’t know” responses consistently reported by the Hilo subgroup suggests a degree of apathy. For example, from a list of 15 questions asked in the survey, the Hilo subgroup, in comparison to the other subgroups, more frequently indicated “don’t know” in all but one question. However, the indecisiveness may also be explained by the soldiers’ uncertainty about community perceptions of their role in mitigation strategies in Kapoho.

Table 4.5. Belief in Pele by subgroups

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Kapoho</th>
<th>Pa‘auhau</th>
<th>Waimea</th>
<th>Hilo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n)</td>
<td>61</td>
<td>38</td>
<td>64</td>
<td>16</td>
<td>179</td>
</tr>
<tr>
<td>(%)</td>
<td>38.1</td>
<td>26.0</td>
<td>31.4</td>
<td>12.7</td>
<td>28.1</td>
</tr>
<tr>
<td>Don’t know</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n)</td>
<td>42</td>
<td>30</td>
<td>47</td>
<td>61</td>
<td>180</td>
</tr>
<tr>
<td>(%)</td>
<td>26.3</td>
<td>20.5</td>
<td>23.0</td>
<td>48.4</td>
<td>28.3</td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n)</td>
<td>57</td>
<td>78</td>
<td>93</td>
<td>49</td>
<td>277</td>
</tr>
<tr>
<td>(%)</td>
<td>35.6</td>
<td>53.4</td>
<td>45.6</td>
<td>38.9</td>
<td>43.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n)</td>
<td>160</td>
<td>146</td>
<td>204</td>
<td>123</td>
<td>636</td>
</tr>
<tr>
<td>(%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

χ² = 47.072, df = 6, p = 0.000. Missing data = 2.

So far, these data indicate that a minority of respondents had strong personal beliefs related to Pele, but not surprisingly the Kapoho subgroup consistently expressed higher levels of beliefs than did the control groups. Table 4.6 presents some interesting data regarding belief in Pele in comparison to Table 4.5, where Table 4.6 explores attitudes toward the statement, “Many people believe in Pele.”
Table 4.6. Perceptions that many people believe in Pele by subgroup

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Kapoho</th>
<th>Pā'auhau</th>
<th>Waimea</th>
<th>Hilo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (n)</td>
<td>94</td>
<td>85</td>
<td>149</td>
<td>64</td>
<td>392</td>
</tr>
<tr>
<td>(%)</td>
<td>59.1</td>
<td>58.2</td>
<td>72.7</td>
<td>50.8</td>
<td>61.6</td>
</tr>
<tr>
<td>Don't know (n)</td>
<td>49</td>
<td>45</td>
<td>36</td>
<td>52</td>
<td>182</td>
</tr>
<tr>
<td>(%)</td>
<td>30.8</td>
<td>30.8</td>
<td>17.6</td>
<td>41.3</td>
<td>28.6</td>
</tr>
<tr>
<td>No (n)</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>10</td>
<td>62</td>
</tr>
<tr>
<td>(%)</td>
<td>10.1</td>
<td>11.0</td>
<td>9.8</td>
<td>7.9</td>
<td>9.7</td>
</tr>
<tr>
<td>Total (n) (%)</td>
<td>159</td>
<td>146</td>
<td>205</td>
<td>126</td>
<td>636</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

$\chi^2 = 23.885$, df = 4, p = 0.001. Missing data = 2.

On average, about 62% of respondents perceive that “many people believe in Pele,” which is significantly more than the 28% who expressed personal belief in Pele in the previous question. The reasoning for this difference is unclear, but it may reflect a reluctance to express personal belief in Pele. Some people may have been hesitant to admit a belief in Pele, because even the Hawaiian language was considered inferior for many decades in the 20th century. Alternatively, the difference may represent an unrealistic cultural bias whereby people overrate belief in a cultural figure.

4.4.2 Mitigation beliefs

In the investigation of coping strategies during the eruption, the survey asked three questions to measure attitudes toward the construction of barriers and the use of bombs. These were, 1) “If you had time, would you help build dikes (stone walls) to hold back the lava from the road;” 2) “Should the soldiers bomb the lava to stop it from burning houses;” and 3) “If you had time, would you help take (unload) the bombs from the
trucks to bomb the lava.” An analysis of the responses (Table 4.7, 4.8 and 4.9) shows that barriers were widely accepted, but bombs were not nearly as desirable. One means of measuring cultural sensitivity to engineered mitigation in 1960 is to contrast attitudes toward the mitigation with belief in Pele and race or ethnicity. Data from responses to these questions were therefore described in terms of belief in Pele and ethnic grouping.

Table 4.7 is a cross-tabulation of attitudes toward the construction of earthen barriers to hold back lava according to belief in Pele. On average, nearly three-quarters of respondents agreed with the use of barriers to hold back lava. This included a majority of each subgroup. Whether or not respondents believed in Pele had little or no influence on attitudes toward construction of barriers.

In contrast to the widely accepted use of barriers, on average only 14% believed soldiers should use bombs to control lava flows (Table 4.8). Not surprisingly, those who expressed belief in Pele were among the least likely to agree with this option.

Table 4.7. “If you had time, would you help build dikes (stone walls) to hold back lava from the road?” by belief in Pele

<table>
<thead>
<tr>
<th>Believe in Pele</th>
<th>Yes (n)</th>
<th>Don't know (n)</th>
<th>No (n)</th>
<th>Total (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>136</td>
<td>114</td>
<td>207</td>
<td>457</td>
</tr>
<tr>
<td>(%</td>
<td>76.0</td>
<td>63.7</td>
<td>74.7</td>
<td>72.0</td>
</tr>
<tr>
<td>Don't know</td>
<td>9</td>
<td>34</td>
<td>22</td>
<td>65</td>
</tr>
<tr>
<td>(%</td>
<td>5.0</td>
<td>19.0</td>
<td>7.9</td>
<td>10.2</td>
</tr>
<tr>
<td>No</td>
<td>34</td>
<td>31</td>
<td>48</td>
<td>113</td>
</tr>
<tr>
<td>(%</td>
<td>19.0</td>
<td>17.3</td>
<td>17.3</td>
<td>17.8</td>
</tr>
<tr>
<td>Total</td>
<td>179</td>
<td>179</td>
<td>277</td>
<td>635</td>
</tr>
</tbody>
</table>

$\chi^2 = 22.181, \text{ df } = 4, p=0.000$. Missing data = 3.
Table 4.8. “Should the soldiers bomb the lava to stop it from burning houses?” by belief in Pele

<table>
<thead>
<tr>
<th>Believe in Pele</th>
<th>Yes</th>
<th>Don’t know</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>(n)</td>
<td>10</td>
<td>15</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>5.6</td>
<td>8.3</td>
<td>23.6</td>
</tr>
<tr>
<td>Don’t know</td>
<td>(n)</td>
<td>54</td>
<td>67</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>30.5</td>
<td>37.2</td>
<td>31.2</td>
</tr>
<tr>
<td>No</td>
<td>(n)</td>
<td>113</td>
<td>98</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>63.8</td>
<td>54.4</td>
<td>45.3</td>
</tr>
<tr>
<td>Total</td>
<td>(n)</td>
<td>177</td>
<td>180</td>
<td>276</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 39.098, \text{ df} = 4, \ p=0.000. \text{ Missing data} = 5. \]

Table 4.8 indicates that few people agreed that the soldiers “should” have bombed the lava. However, Table 4.9 indicates that considerably more people agreed with the use of bombs when there was direct community participation in the mitigation activity. Again, those who expressed belief in Pele were the least likely to agree with the use of bombs.
Table 4.9. "If you had time, would you help take (unload) the bombs from the trucks to bomb the lava?" by belief in Pele

<table>
<thead>
<tr>
<th>Believe in Pele</th>
<th>Yes</th>
<th>Don't know</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes (n)</td>
<td>50</td>
<td>43</td>
<td>116</td>
<td>209</td>
</tr>
<tr>
<td>(% )</td>
<td>28.4</td>
<td>24.0</td>
<td>41.9</td>
<td>33.1</td>
</tr>
<tr>
<td>Don't know (n)</td>
<td>21</td>
<td>48</td>
<td>35</td>
<td>104</td>
</tr>
<tr>
<td>(%)</td>
<td>11.9</td>
<td>26.8</td>
<td>12.6</td>
<td>16.5</td>
</tr>
<tr>
<td>No (n)</td>
<td>105</td>
<td>88</td>
<td>126</td>
<td>319</td>
</tr>
<tr>
<td>(%)</td>
<td>59.7</td>
<td>49.2</td>
<td>45.5</td>
<td>50.5</td>
</tr>
<tr>
<td>Total (n)</td>
<td>176</td>
<td>179</td>
<td>277</td>
<td>632</td>
</tr>
<tr>
<td>(%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

$\chi^2 = 32.772, \text{ df } = 4, p = 0.000$. Missing data = 6.

Next I combined the race data to two categories consisting of respondents who claimed 1) Hawaiian or part-Hawaiian (Hawaiian) ethnicity versus 2) Asian, Caucasian or other ethnicities. Cross-tabulating these data with attitudes toward mitigation indicated that ethnic grouping was significant in all three questions relating to mitigation, but the influence of ethnic grouping was generally small. For example, among those claiming Hawaiian ethnicity, 63.4% (n = 92) agreed with barrier construction (24.8% disagreed; 11.7% were undecided). In comparison, among those who claimed other ethnicities, 74.6% (n = 367) agreed with barrier construction (15.7% disagreed; 9.8% were undecided; $\chi^2 = 7.673, \text{ df } = 2, p = 0.022$).

For the question of whether soldiers should bomb the lava, only 12.7% (n = 18) agreed among those who claimed Hawaiian ethnicity; most people disagreed (70.4%), and a few were undecided (16.9%). In comparison, 14.6% (n = 72) of those who claimed
other ethnicities agreed with the soldiers' use of bombs. Again, most people disagreed (48.1%), and 37.3% were uncertain ($\chi^2 = 24.701$, df = 2, p = 0.000).

Finally, among those who claimed Hawaiian ethnicity, 26.9% (n = 39) agreed that they would help carry the bombs. Most people disagreed (66.2%) and a few were undecided (6.9%). In comparison, a few more of those who claimed other ethnicities agreed that they would help carry the bombs (35.0%; n = 171). Most respondents that claimed other ethnicities disagreed (45.8%), while 19.2% were uncertain ($\chi^2 = 27.780$, df = 2, p = 0.000).

4.5 Discussion

4.5.1 The 1960 data
These data illustrate that belief in Pele and ethnic grouping were significant in influencing attitudes toward the use of bombs and barriers as mitigation strategies. However, the influence of these variables was small. Community support for barrier construction was high (average = 72%), even among those who believed in Pele and those who claimed Hawaiian ethnicity. In contrast, the use of bombs to mitigate lava flows was much less desirable. Only 14% of respondents agreed with the soldiers' use of bombs. However, over twice as many respondents (33%) agreed with the use of bombs when there was direct community participation in the bombing measure. This finding is consistent with those of other hazard studies (Paton and Bishop, 1996), which found that community involvement in decisions about setting risks standards and the kinds of required emergency preparedness or mitigation measures influences a community's behavior, particularly if the community is likely to be directly affected by a hazard. Allocation of blame is greatly affected by the extent of prior community consultation,
making this issue an important one in the context of post-eruption litigation in the event of losses. It appears that through involving the community in decision making about dealing with risks people become less likely to want to ‘scapegoat’ those responsible for managing high risk entities. This appears to be due to the community being made aware of the trade-offs involved in creating safer environments. Thus, communities are more satisfied because there has been procedural justice. These factors are likely to impact on the resilience of a community after a disaster and should reduce psychological impacts.

The far greater acceptability of barriers compared with bombs is likely due to the fact that the use of barriers was perceived as much less disruptive to the natural flow of lava than bombs, but I infer that community participation was also a key factor in the responses. The difference in responses recorded for the two questions regarding the use of bombs limits the number of possible explanations concerning attitudes toward bombing. Had respondents wholly disagreed with the use of bombs, then I would have expected to see no difference in responses to the two questions, but this was not the case; the difference in percent agreeing with use of bombs was, on average, 18.9%. I infer that the higher percent agreeing that they would help unload the bombs to bomb the lava, combined with the high percentage agreeing with construction of the barriers, may reflect greater enthusiasm for community participation in mitigation as opposed to simply that of soldiers’ participation (Paton and Bishop, 1996). Furthermore, in response to another question of the survey—“what should be done by the authorities to help people during the eruption,” a respondent from Kapoho commented that “local people [should be used] to direct traffic ... and ... make reports, not only outsiders,” suggesting that community participation was desirable in other aspects of the eruption as well.
Attitudes in Hawai‘i regarding engineered measures are generally assumed to reflect cultural issues, as is now occurring on nearby Mauna Kea volcano and recently with the Puna Geothermal Venture near Kapoho. However, I have demonstrated that these variables (i.e., belief in Pele and ethnic grouping) did not greatly divide public opinion over all mitigation proposals in Kapoho in 1960. Nearly equal percentages of the subgroups expressing belief or disbelief in Pele agreed with barrier mitigation. However, the responses differed on the issue of mitigation by bombing; the percentage agreeing with the use of bombs varied by up to 18% depending on belief in Pele. Ethnic grouping produced similar, but not identical, results in terms of attitudes toward mitigation. Specifically, a strong majority of respondents who claimed Hawaiian and those who chose other ethnicities agreed with barrier construction; and the percent of each ethnic group that agreed with the soldiers’ use of bombs was nearly equal (Hawaiian = 12.7%; other = 14.6%). However, the real difference was in terms of the percent who disagreed with the soldiers’ use of bombs. For example, 22.3% more respondents of Hawaiian ethnicity disagreed with the soldiers’ use of bombs compared to those claiming other ethnicities. For the question concerning whether respondents would help unload the bombs, a few more people who claimed other ethnicities agreed that they would help (8.1% more than those who claimed Hawaiian). Hawaiians were more opposed to the idea—20.4% more Hawaiians disagreed that they would help unload the bombs than those claiming other ethnicities.

Community participation (i.e., community empowerment) may have been an understated but significant factor in acceptance of barriers and, to a lesser extent, bombs. These data could reflect an idea that strict adherence to cultural tradition was less
significant when a person’s home, employment and community were threatened directly by lava, provided that the mitigation activities respected and adhered to cultural values and tradition and provided that the participation of local people was ensured.

4.5.2 Mitigation in a modern context

The 1960 data are derived from a period when significant changes were occurring in the frequency of eruptions at Kilauea and Mauna Loa. Volcanic activity was declining at Mauna Loa and increasing at Kilauea (Macdonald et al., 1983). For example, between 1832 and 1950, Mauna Loa erupted on average once every 4 years (Lockwood et al., 1987), but in 1960 no eruption had occurred in the previous 10 years. In contrast, activity was increasing at nearby Kilauea. Two eruptions had occurred in the lower District of Puna near Kapoho since 1955, but prior to 1955 there had not been an eruption in lower Puna since 1840, and prior to 1840 the most recent eruptions were ca. A.D. 1790 and 1750 (Fig. 4.1 (Holcomb, 1987)). What effect these changes in eruptive frequency and location had on individual perceptions of risk and ultimately attitudes toward lava flow mitigation is unknown. However, presumably, in 1960 the residents of Hilo had been relaxed for several decades, given the fact that the frequency of threatening Mauna Loa eruptions was declining. The most recent eruption had occurred in Kona (on the other side of the mountain; (Macdonald, 1954)), and Hilo had not been threatened by lava flows since 1942. In contrast, people in Puna were probably worried when the 1960 Kapoho eruption began, because it was the second eruption in that area in the past five years.

During the 1930s and 1940s, many residents of Hilo would have been aware of the volcanic threat from Mauna Loa and of the mitigation activities tried there in 1935
and 1942. However, since 1942, only one eruption, 20 years ago in 1984, has occurred to remind people dramatically of the volcanic threat posed to Hilo by lava flows from Mauna Loa (Lockwood et al., 1987). Even longer is the period of time elapsed since the last mitigation measure to protect Hilo from Mauna Loa lava flows was tried in 1942.

Some valid questions arise from the change in perception of volcanic threat and levels of experience with eruptions and mitigation. First, how has the lack of experience with threatening Mauna Loa eruptions in Hilo affected people's perceptions of their volcanic risk? Second, does the lack of recent experience with Mauna Loa lava flows and with mitigation measures affect both awareness of, and agreement (or disagreement) with, mitigation measures? In other words, what are the underlying factors that influence attitudes toward mitigation? The 1960 data suggest that it is possible that attitudes of many people are more a reflection of their awareness of prior mitigation activities and of mitigation outcomes rather than deeply held cultural or spiritual beliefs.

The situation in Puna may be quite different with regard to the first question (i.e., risk perception), because the volcanic threat along the now populated lower east rift zone has been very frequent since 1955 (i.e., eruptions occurred in 1960, 1961, 1962, 1963, 1965, 1968, 1969, 1972, 1973, 1974, 1977, 1979 and virtually continuously since 1983), although there are many more factors involved in risk perception than just experience (Gregg et al., 2004a, Chapt. 2). Experience with lava flow mitigation measures among residents of Puna is also probably higher than in Hilo, because intervention was more recently attempted in Puna (1960 and 1955) than in the Hilo area (1942 and 1935). However, Puna has been the fastest growing district in Hawai‘i for years, so many new
residents there now may not be familiar with the volcanic threat and particularly with mitigation. The same may be true for Hilo.

Several outcomes from mitigation measures used on Mauna Loa and Kīlauea could complicate community understanding of the efficacy of different mitigation options and their outcomes. I have not performed an exhaustive study to identify these outcomes, but a few that have surfaced during this study include:

1. A respondent in the 1960 survey indicated that U.S. Army personnel involved with one or more of the bombing measures on Mauna Loa in 1935 and 1942 were subsequently killed in an oil fire. At least some locals believed the deaths were a result of Pele’s revenge for the bombing.

2. Personal communications from an anonymous Kalapana resident indicate that, during the volcanic disasters in Kalapana during the 1980s and early 1990’s, the use of water by firemen to cool advancing lava flows was seen unfavorably by some local people. In at least one instance, firemen utilized scarce, private drinking water supplies collected from a rain-catchment reservoir to cool a lava flow that was threatening to ignite a single house located in the path of a lava flow. This flow stopped advancing for at least several days (maybe a month), but nearby flows began flowing with seemingly increased vigor and eventually destroyed about a dozen houses. In light of this sequence of events, some locals concluded that the water sprayed onto the initial lava flow caused that flow to temporarily stop but also caused the other lava flows to flow more vigorously and ultimately destroy many homes instead of only one. One perception of these events was an idea that is sometimes heard among island residents – i.e., that
“Pele will take what she wants, when she wants, so one should not interfere with lava flows.” The fact that the first house was also later destroyed by other lava flows appears to have increased community dissent for mitigation. This may include the use of water and possibly all other mitigation too.

3. Barriers constructed during the 1955 and 1960 eruptions of Kilauea were overcome and breached by lava. Years later, Murton and Shimabukuro (1974) found that most respondents in a study in Puna perceived volcanic eruptions as “uncontrollable” (86%). The highly maintained opinion that eruptions are uncontrollable may be a reflection, at least in part if not entirely, of respondents’ awareness of the inability of the barriers to completely hold back lava in the 1955 and 1960 eruptions. However, this cannot be confirmed from existing data. Furthermore, an article that appeared in a local Hilo newspaper titled, “How to cope with pre-disaster stress,” written by the branch director of the Mental Health Association in Hawai‘i County during the 1984 eruption of Mauna Loa, seems to reaffirm the idea of eruptions as uncontrollable. The article stated that “The greatest cause of stress is the feeling that you have little or no control over the situation ... and let’s face it; we have little or no control over Pele” (Critchlow, 1984).

4. Surprising debate over barrier construction arose during construction of earthen barriers to protect Kapoho in 1960. The debate did not involve Hawaiians, believers in Pele or other culturally sensitive issues, but rather the scientific community, who argued over the fundamental reasons for barrier construction. During construction of one barrier, Wilhelm (1960c) reported, that “There is no
dissenting vote among the workers on the job of constructing the dam [the barrier], and there is no word of discouragement heard among them. The only disagreement comes from some of the men associated with the Hawaiian Volcano Observatory [HVO]. A few hold that the dam won’t work.” Among the HVO “men” were J.P. Eaton, then seismologist with the HVO, and the man who was directing the construction of the barriers—G.A. Macdonald, then Professor of Geology at the University of Hawai‘i and volcanologist-consultant to the Hawai‘i State Civil Defense Agency and to the Governor (Quinn) during the Kapoho eruption (Wilhelm, 1960c). Professor Macdonald favored barrier construction. Two examples of such disagreement between the scientists related to a) the fundamental reasons for construction of the barriers (i.e., personal and theoretical reasons versus needs of the community); and b) the reasons for placement of a specific barrier (i.e., this involved technical, feasibility and liability issues).

These findings highlight the need for planning mitigation activities well in advance of eruptions. This idea was underscored by Governor Quinn, who, while speaking to a group of military and Civil Defense officials during the 1960 eruption, said that “we cannot continue to throw up a dike just 24 hours before the lava gets to an area.” (Associated Press, 1960a).

Mitigation is still a developing field and will probably be a source of considerable debate during future mitigation efforts, even among the scientific community. Although lessons can be learnt from the more recent Italian experiences on Mt. Etna (Barberi et al., 2003; Barberi et al., 1993; Colombrita, 1984).
These examples illustrate the complexities of evaluating the costs and benefits of mitigation measures. This makes it difficult to develop an underlying rationale for mitigation that can be used by residents to make judgments using available data, including issues regarding the feasibility of implementing mitigation measures within the time frames necessitated by unpredictable hazard activity. Superimposed on these reasoning processes are attributions of causality that reflect cultural beliefs. The above examples illustrate how community member's explanations of the cause of eruptions may be based on the actions of a deity. These anecdotes can become part of the community folklore, rendering risk communication regarding unpredictable hazard activity even more complex.

No published studies have characterized public awareness of the mitigation strategies tried at Mauna Loa, Kapoho and Kalapana. People's understanding of the outcomes of these mitigation measures could strongly influence public perceptions of the utility of mitigation and attitudes toward use of mitigation measures in future eruptions. Such a study is long overdue and could prove valuable in correcting community misperceptions about the purposes of mitigation. It could also help streamline decision-making processes in future eruptions.

The extent to which people will choose to uphold perceptions of what Hawaiian tradition, as they understand it, would dictate when lava threatens may prove to be a more decisive factor in individual opinions of mitigation than belief in Pele. People may reject mitigation measures if their perception of Hawaiian tradition is that nothing should be done that would interfere with the natural path of a lava flow. In other words, people may not openly express belief in Pele, but they may disagree with mitigation as a
consequence of their perceptions of Hawaiian tradition. In this sense, it is critical to involve local people in mitigation decisions, and to understand how Hawaiians traditionally approached matters over which they had little or no control (Lee and Newton, 1981). Some work in the field of social psychology may provide some basic insight into this latter issue.

In a paper titled, *Cultural Aspects of Coping*, Lee and Newton (1981) discussed a type of coping strategy used by Hawaiians during childbirth. This work built on the concept of “Psychic Phase of Relationship” described by Handy and Pukui (1958). In this concept, the interactions of Hawaiians with external and internal environments are automatically internalized into a sequence described as “sensation-emotion-observation-interpretation-rationalization.” Lee and Newton (1981) reported that stresses during childbearing by Hawaiians were attributed to external spiritual influences rather than physiological processes. Traditional beliefs about volcanism also involve external spiritual influences. According to Howard (1974), “Anything that reduces an individual’s sense of competence, or control of his own destiny, is likely to increase reliance on supernatural behavior forms ...” Lee and Newton (1981) went on to state that:

Augmentation of physiological processes was a common practice [among Hawaiians]. However, it is significant that written accounts make little mention of specific attempts to minimize pain or discomfort directly. This may be related to the underlying attitude that stresses result from spiritual rather than physiologic processes. Methods used were aimed at hastening the birth process so that if pain did occur, its duration could be shortened. A pregnant woman was advised to “...move her abdomen to-and-fro gently *(ho'oni'oni)* to loosen the baby so that it would not stick at birth” (Pukui, 1942)...
foods were eaten, which were thought to act as lubricants. Herbs...were used to hasten the birth process (Pukui, 1942)...and special massage techniques...were used.”

This work reinforces the value of community participation within the mitigation process (Paton & Bishop, 1996). In addition to its direct effects on risk acceptance and support of mitigation, this approach, if it extends to direct involvement in defining the problems posed by hazards and developing and implementing strategies to deal with them, increases the potential to develop self-efficacy and action coping (Paton, 2000). Self-efficacy refers to personal beliefs about acting effectively and action coping is choosing action directed at changing a situation. The latter serve to enhance well-being and the level of preparedness likely to prevail within a community (Paton, 2003). Lee and Newton (1981) concluded that there is still evidence that reliance upon sociopsychic relationships remains a characteristics of both value systems and coping strategies among Hawaiian communities today [in 1981], despite the westernization of Hawai‘i since ca. 1800.

These findings from social psychology may mean, in terms of lava flows and mitigation of their hazards, that precedence exists for Hawaiian people to interfere physically in what is perceived to be a spiritual matter (childbirth). There are already precedents for Hawaiians interfering in lava flow paths with spiritual measures, but the focus here was on hastening the process of childbirth, and numerous efforts were undertaken in this effort. In one respect, lava flows could be analogous to the birth of a child. Lava is born from the mountain and delivered to the land or sea. As with childbirth, efforts taken to hasten the flow of lava to the ocean while invoking minimal change in the natural flow of lava may be looked upon with greater respect than efforts
that grossly modify the flow of lava. In this regard, Lockwood and Torgerson (1980) recognized the need to maintain mitigation strategies in parallel with natural processes where feasible. For example, these authors described the process of bombing an active cone as, "...accelerate[ing] natural collapse processes." By doing so, the idea of bombing is perceived as less obstructive because it is simply accelerating a natural process. However, such analogies and mitigation in general would need to have significant community endorsement in order to help alleviate the potential conflict that may arise between the public and officials.

4.6 Conclusions
Cultural issues surrounding land-use decisions are becoming increasingly powerful forces in Hawai‘i and elsewhere. These forces will continue to strengthen as people seek to identify and perpetuate the cultures of indigenous people. As acknowledged in the Hawai‘i Lava Flow Hazard Mitigation Plan, Hawaiian cultural issues will be among the most important factors to be considered in decisions to mitigate lava flow hazards with engineered measures in future eruptions. The Puna Geothermal Venture and observatories on Mauna Kea provide recent testament to the far-reaching impacts of cultural issues in land-use proposals in Hawai‘i. Data from the 1960 survey clearly establish widespread community support for barriers and suggest that even bombs are acceptable as a mitigation strategy when the community participates. Such beliefs were not limited to non-Hawaiians and non-believers in Pele. Many people, including those of Hawaiian ethnicity and those who expressed belief in Pele, agreed with these forms of mitigation. From the perspective of the future of lava flow hazard mitigation in Hawai‘i, it is important to understand contemporary beliefs related to mitigation, because much of
the populated areas and critical infrastructure of the island are at risk from future eruptions and Hawaiian interests are high on the political agenda.

Cultural aspects of mitigation of lava flows are more complex than have been assumed by current assessments and plans. Thus, the Kapoho study should be used as a basis for a comparative modern study in Hawai‘i and elsewhere where mitigation of volcanic and other hazards is a concern among minority groups. Mitigation discussions with at-risk communities should consider the economic and social implications of intervention versus non-intervention and how intervention can best accommodate Hawaiian values and customs. Integration of such data is desirable now to plan properly for and respond to future eruptions. The increasing value of development on Mauna Loa’s flanks and renewed activity at Mauna Loa provide some urgency for this work (Trusdell, 1995; U. S. Geological Survey, 2003).

These findings would provide a baseline to measure and evaluate future community attitudes toward hazard mitigation in Hawai‘i, but they also may have implications for other volcanic areas where cultural beliefs and practices of indigenous people may conflict with those of a more westernized society.
CHAPTER 5. AWARENESS OF A SIREN-BASED EMERGENCY WARNING SYSTEM: IMPLICATIONS FOR TSUNAMI PREPAREDNESS IN HAWAII

Abstract
Since the 1940's a network of pole-mounted sirens has been in place in populated areas of Hawai‘i to provide an early public alert of future emergencies such as enemy attack and tsunamis. These sirens have sounded for tsunamis and hurricanes and have been routinely tested for 26 years. However, studies in the 1960s showed that understanding of the meaning of the siren sounding was low at that time. In 2003, I performed surveys of middle-school student and adult residents in Hawai‘i (n = 956) to measure the effect of awareness of the siren tests and monthly test frequencies on current understanding of the siren. The siren now means to tune to a radio or television station for information. I show that, while awareness of siren tests and monthly test frequencies is very high, these factors do not correlate with increased understanding of the purpose of the siren, which is very low (mean = 12%).

During locally generated tsunamis, warning times between wave generation and their arrival onshore could be of the order of minutes to tens of minutes and preclude the use of official warning systems such as sirens and the Federal Emergency Alert System. Awareness of natural warning signs of tsunamis such as earthquake shaking and unusual sea-level changes could prove valuable in promoting adaptive behavioral response during such events. Analysis of a subgroup from Hilo, where tsunamis have been most damaging in Hawai‘i, indicates that awareness of natural warning signs is low to
moderate. Furthermore, on average, a majority expects that the warning signs of
tsunamis will be alerts provided by official sources.

Repeated testing of the sirens is probably responsible for the high levels of
awareness of the sirens and of test frequencies. However, a lack of effective outreach
relating to the meaning of the siren has contributed to the low levels of understanding of
the role of the siren. The task of developing an informed public has been made difficult,
in part, by repeated changes in the number, tone, duration and meaning of siren
soundings since inception of the system. The level of understanding of the siren as a
warning to tune to a radio or television station for hazard-specific information needs
improvement. So does the level of understanding of natural warning signs of tsunamis.
The capability of the siren system to serve as an alert or warning for tsunamis and other
hazards is limited by several factors. However, effective response to the siren is a key to
maintaining the continuity of business and reducing impacts on property and human
lives. Similarly, people’s capability to recognize and immediately respond to natural
warning signs of local tsunamis will help save lives.

5.1 Introduction
The Hawaiian Islands are situated in the remote north-central Pacific Ocean and are at
risk to a wide range of natural hazards (Fletcher et al., 2002a). Tsunamis represent a
major threat among these hazards in terms of historical fatalities and the potential for
wide-spread destruction, because tsunamis can wrap around the coastline and impact
coastal regions where populations and infrastructure are densest (Dudley and Lee, 1998;
Fletcher et al., 2002a). The possibility of locally generated tsunamis substantially
reduces the available response time of the communities at risk and highlights the
importance of effective warning systems and prompt and appropriate behavioral response upon receipt of warning messages. Warning messages include official messages, but natural signs of tsunamis may also provide a warning to people.

In 1940 (J. Johnston, pers. comm, 2005), a network of pole-mounted sirens was emplaced in populated areas in Hawai‘i to alert people to enemy attack. Following the destructive A.D.1946 tsunami, which claimed 159 fatalities in Hawai‘i, the sirens have been used to alert people to tsunamis. This warning system still exists but has had frequent changes relating to technical issues, e.g., number of tones and duration of soundings, and to the philosophy of its use. I investigated the history of the sirens and conducted five social science surveys to explore adult and student understanding of the sirens on the four principal Hawaiian Islands—Hawai‘i, Maui, O‘ahu and Kaua‘i (Fig. 5.1). In particular, I focus aspects of the study on a subgroup in Hilo on the island of Hawai‘i (Fig. 5.1; population 40,759 (U. S. Census Bureau, 2000a)), and issues of home-based preparedness for tsunamis.

Hawai‘i has 1.2 million residents and 6.4 million annual visitors (State of Hawaii, 2002a). Most development that supports this population lies along narrow stretches of coastal flat land, both near and within tsunami inundation zones (Fletcher et al., 2002a). For example, Raine (1995) reported that over 60,000 people on the island of O‘ahu lived within tsunami evacuation zones in 1995. Most of the development in Hawai‘i has occurred since the last large, damaging tsunami in 1960, so people have little direct experience with the hazard and how to respond. The lack of experience with what to expect in future tsunamis and how to respond to protect one’s safety and property complicates the task of predicting how the public will respond to future tsunami
warnings. A lack of monitored outreach in relation to the siren system in Hawai‘i complicates the task of accurately evaluating levels of public understanding of the siren and people’s expectations of their behavioral response to siren soundings. Short-term official warnings may be rare events during local tsunamis, and the public’s behavior in response to tsunami warnings or watches can have significant impacts on business continuity (Dudley and Lee, 1998). Consequently, we need knowledge of community beliefs regarding what it will do, how it plans, and what types of instructions will have to be provided for response under urgent and stressful circumstances such as siren soundings and tsunami warnings.

Figure 5.1a-d. General distribution of electronic and mechanical sirens in relation to coastlines, where most development in Hawai‘i occurs. Gaps along the coast typically reflect rural areas. The large solid black dot and adjacent number are the total number of sirens on that island. The ratio shown reflects kilometers of tidal shoreline to the total number of sirens. Large unfilled circles mark centers of each survey; respondents reside both within and outside of the circle. Inset shows relative locations of islands. Siren data after Hawaii State Civil Defense (2004a).
Two examples of the most recent tsunamis in Hawai‘i illustrate the need for informed and prepared communities that are at risk to tsunamis. These include the 1960 tsunami from the Aleutian Islands that destroyed most of downtown Hilo and killed 61 people in Hawai‘i (Cox and Mink, 1963; Eaton et al., 1961; Lachman et al., 1961). It also includes the 1975 tsunami, which was generated off the south shore of Kīlauea volcano on the island of Hawai‘i; two people were killed (Dudley and Lee, 1998).

A recent tsunami generated in Japan better underscores the need for a populous that is prepared for local tsunamis. On the evening of July 12, 1993 an earthquake near Hokkaido, Japan generated tsunamis that destroyed, among other areas, the town of Aonae on the isolated tip of Okushiri Island, Japan (population 1600). The first waves arrived in Aonae within 4-5 minutes of the earthquake, but, remarkably, only 107 people died, even though no house was left standing (Dudley and Lee, 1998). Many of the observed fatalities were consequences of people trying to evacuate by automobile or because they searched for family members. The number of fatalities was low because many people recognized earthquakes as a precursor to tsunamis and immediately evacuated by foot to higher ground upon feeling the earthquake. Assuming that all 1600 people were in Aonae during the earthquake (10:17 PM local time), a staggering 97% survival rate can be inferred. This disaster could have been of a much greater magnitude had the residents not recognized that earthquake shaking is a natural warning sign of imminent tsunamis and that they needed to evacuate immediately. The events at Okushiri Island provide clear evidence of the significance of tsunami education in mitigating tsunami fatalities.
The significance of improving the quality of tsunami education was underscored by Gonzales (1999), who reported that fatalities in tsunamis were significantly higher in countries with no tsunami education program than in Japan, where tsunami education is strong. Gonzales (1999) reported that, in Japan, about 15% of 150 tsunamis during the previous 100 years were damaging or fatal, whereas in Indonesia over 50% of 34 tsunamis were damaging or fatal. Other factors could explain this disparity, but tsunami education is indisputably a critical factor in reducing fatalities.

A relatively recent tsunami warning in Hawai‘i highlights the potential economic toll of tsunamis on business activity, even when no dangerous waves occur. For example, the 1986 tsunami generated in the Aleutian Islands prompted issuance of a statewide “tsunami warning” in Hawai‘i that resulted in US$30 million in losses (includes lost business activity), even though the tsunami was a “non-event” (no damaging waves; Dudley, 1998). This point highlights the need for communities at risk to tsunamis to respond in ways that maximize business continuity and minimize losses. A more recent statewide tsunami warning in 1994 may have cost $50 million in lost business activity (L. Kong, pers. comm, 2004). A tsunami watch was issued in September 2003 after a magnitude 8.1 earthquake in Japan, but the watch was cancelled before evolving to a tsunami warning (Honolulu Advertiser, 2003).

5.2 Social Science
Research on public response to warning messages shows that response is complicated by numerous factors (Lindell and Perry, 1992; Sorensen, 2000; Tierney et al., 1999). For example, in a study surrounding the 1989 Loma Prieta earthquake in the San Francisco area, Mileti and Obrien (1992) showed that the social psychological process that explains
public response to post-impact warnings is different from the one which explains public response to pre-impact warnings. They modeled response to warnings as a sequence referred to as the "hear-confirm-understand-believe-personalize-respond" model of risk communication, where people shape their perceptions of risk and behavior through stages following receipt of a warning of risk. This process is not the same for all people and can be influenced by a number of factors including age, gender, level of education, etc. The rarity of warning events also means that people often look to others to clarify what may be perceived as an ambiguous situation (Latane and Darley, 1976).

In the 1960's, a number of research studies specific to Hawai'i focused, at least in part, on awareness of the meaning of the sirens in Hawai'i. These early studies showed that public understanding of the meaning of the siren was very low (Havighurst, 1967; Lachman et al., 1961). In a more recent study that compared understanding of the meaning of the siren among students and adults in the western side of the island of Hawai'i (i.e., Kona), Gregg et al. (2004b, Chapt. 2) reported a much higher level of understanding of the siren, especially among adults (adults = 65%, students = 27.1%) and suggested that familiarity with routine siren testing may help explain the observed levels of understanding in Kona. In addition, Havighurst (1967) and Raine (1995) suggested that a majority of respondents would tune to a radio or television station for information if they heard the siren. Raine (1995) also found that a majority of people would turn on the radio in response to a tsunami warning, but he identified inconsistencies between respondent's perception of their response to a tsunami warning and actual response undertaken in a real tsunami warning in 1994.
5.3 Hazards and Siren Warning System
I limit my discussion of hazards in this paper to tsunami and hurricanes, because these are the hazards for which the siren system has historically been used. Civil Defense officials also plan to use the siren to warn of “enemy attack,” but no such event has occurred to activate the sirens. In terms of natural hazards and fatalities, tsunamis have claimed more lives than other natural hazards in Hawai‘i (Cox, 1987; Raine, 1995), but hurricanes have also caused fatalities and extensive destruction—most recently in 1992 (Hurricane Iniki (Chiu, 1995)).

The siren system is most commonly used for tsunamis and hurricanes and was recently used during warnings of a hurricane in 1992 and a tsunami in 1994. In contrast to tsunamis, hurricanes typically allow a greater alert time than tsunamis, during which people can prepare for a hazard event. For example, a hurricane watch means a hurricane is expected to impact Hawai‘i in less than 36 hours, and a hurricane warning means the impact is expected in less than 24 hours. In comparison, a tsunami watch or warning will provide minutes to about 15 hours of advanced alert or warning before waves impact Hawai‘i, depending on the distance of the source of the wave’s from Hawai‘i.

5.3.1 Tsunamis
Most tsunamis that affect Hawai‘i have sources several thousand miles away at the perimeter of the Pacific Ocean (Fletcher et al., 2002a). Even at high wave velocities, of the order of 400 to 500 miles per hour (Cox and Mink, 1963), these distant-sourced tsunamis or tele-tsunamis allow several hours (~4-15 hours) of warning time between the generation of the tsunamis and their first arrival on Hawaiian shores (Dudley and Lee, 1998; Zetler, 1947). However, tsunamis have also been generated from the Hawaiian
Islands themselves (Cox, 1984; Cox and Morgan, 1977; Lander and Lockridge, 1989). These tsunamis are referred to as “locally generated” or “urgent tsunamis” and have dramatically shorter warning times than distant-sourced tsunamis. Warning time is the difference in time between the generation of tsunami waves and the arrival of the first wave onshore, which is typically several minutes to ~1 h for local tsunamis in Hawai‘i (Dudley and Lee, 1998; Macdonald et al., 1983; Zetler, 1947). This means that at-risk communities must be prepared to respond to two types of tsunami warnings.

In Hawai‘i, Lander and Lockridge (1989) reported that 26 damaging tsunamis have occurred in the Hawaiian Islands since A.D. 1819 (i.e., waves with >1 m runup). About 85% of these (all but 4) were from distant sources. Local tsunamis occurred in 1868, 1919, 1952 and 1975 (Lander and Lockridge, 1989). Thus, distant-sourced tsunamis occur more often in Hawai‘i than do local tsunamis (Macdonald et al., 1983), which suggests a special need to prepare for them. However, the urgency of local tsunamis demands that we also be well prepared for them.

5.3.1.1 Natural warning signs of tsunamis
Several warning signs of tsunamis occur naturally and could serve to alert people of impending tsunamis before official sirens are sounded and emergency messages are broadcast. These signs include earthquake shaking, sea-level fluctuations (Darienzo et al., in press; Dudley and Lee, 1998; Gonzalez, 1999) and various sounds that have been described as thunder, thunder-bolt, locomotives and helicopters (Gonzalez, 1999; Shuto, 1997). However, the behavior of tsunamis in coastal waters is complex and not always the same (Gonzalez, 1999; Lander and Lockridge, 1989). For example, tsunamis may evolve on shore as a breaking wave, as a wall of water or as a tide-like flood (Gonzalez,
Furthermore, the leading waves of tsunamis can arrive as a trough or a crest, and this will determine whether sea level first rises or lowers at the shore (Lander and Lockridge, 1989). However, the speed with which sea level may change in response to tsunamis is not well defined in the literature and, along with the idea of sea level changing, are points of confusion. Words or phrases sometimes used in peer- and non-peer-reviewed literature to describe how the sea level will behave at the shore include the following. Some of these are described as warning signs and are suggested to be signals to evacuate.

- Rapid or gentle rising or falling of sea level (Lander and Lockridge, 1989).
- Lowering or receding of sea level, a change in sea level, a noticeable rise or fall in sea level (National Oceanic and Atmospheric Administration, 2004b).
- A breaking wave, a wall of water, or a tide-like flood (Gonzalez, 1999).
- Relatively gentle rise of water level, flooding of the shore, or a wave with steep front and much turbulence that strikes the shore with great violence. The withdrawal of water or the rise of water level (Macdonald et al., 1983).
- Rapid draw down or sudden rise (Darienzo et al., in press).

Regarding earthquakes as natural warning signs of tsunamis, the interpretations of earthquake shaking at Okushiri Island in 1993 was the key factor in the 97% survival rate of the residents of Aonae. This illustrates the significance of earthquake shaking to serve as a natural warning sign of tsunamis. However, as for descriptions of sea-level
fluctuations, descriptions of earthquakes and earthquake shaking as warning signs of tsunami are also inconsistent. For example, the literature reports:

- “A strong earthquake may cause tsunamis. Go to high ground immediately” (Verizon Hawaii, 2002). This is the official information in Hawai‘i telephone books.
- Evacuate if an earthquake is felt (National Oceanic and Atmospheric Administration, 2004b).
- Evacuate if there is “strong, prolonged ground shaking” (Gonzalez, 1999)
- “If you feel a large earthquake, you should wait for a warning or evacuate” (National Oceanic and Atmospheric Administration, 2004a).
- “If hard shaking takes place for 15-20 seconds, you should evacuate” (National Oceanic and Atmospheric Administration, 2004a).
- “If you are in a coastal area and if you are frightened due to the intense shaking, you should evacuate” (National Oceanic and Atmospheric Administration, 2004a).

5.3.2 Siren-based warning system
The siren warning system is a network of pole-mounted rotating and stationary sirens emplaced on telephone-type poles throughout populated coastal and inland areas of the Hawaiian Islands. Early on in the history of the system, multiple siren tones referred to specific hazard threats, notably enemy attack and tsunamis. However, currently there is one siren tone for all hazards. This single siren tone is defined in the disaster preparedness information of Hawai‘i telephone books as the, “Attention Alert Signal,”
which means “tune your radio or television to any station and listen for emergency information and instructions” (Verizon Hawaii, 2002).

Currently Hawai‘i has 168 fully functional electronic sirens, 166 additional sirens that need further upgrading, and 167 areas with gaps in coverage (N. Ogasawara, pers. comm, 2004). Many of the gaps occur in inland areas away from the coast where tsunamis are a greater hazard, although the inland areas may still be impacted by a hurricane. There are also gaps in coverage of coastal areas, but these areas are typically rural and have fewer residents and visitors than other areas where siren coverage is greater. Figure 5.1 illustrates the general distribution of these sirens on the islands where I conducted surveys. The density of sirens is greatest on O‘ahu, where nearly three-quarters of Hawai‘i’s population resides, and much less on Kaua‘i, Maui and especially the island of Hawai‘i because of differences in population numbers and land area or kilometers of shoreline.

The network of sirens supplements the Federal Emergency Alert System (EAS; formerly the Emergency Broadcast System (EBS) and CONELRAD—Control of Electromagnetic Radiation (Federal Communications Commission, 2003). The CONELRAD warning system began in 1951 and controlled the frequencies with which radio stations could operate. The EBS evolved from CONELRAD to provide the President of the United States with a means to address the public in the event of a national emergency. The more advanced EAS allows emergency information to be disseminated over radio, television and cable television before or after sirens are sounded. While not all emergency broadcasts require implementation of the EAS or sounding of sirens, the EAS is an official avenue for communicating emergency information to people
in Hawai‘i, including residents, visitors and tourists. Civil Defense messages, such as those to evacuate, may also be disseminated through police, fire department, civil defense, and civil air patrol aircraft. If sirens are sounded, standard operating procedures of Civil Defense require EAS messages to follow the siren soundings in order to inform the public about the reason for activation of the siren alert signal (Hawaii State Civil Defense, 2004b, Appendix H).

Information relating to the siren has been available in Hawaiian telephone books since May 1960, and routine tests of the sirens have been conducted by Hawai‘i State Civil Defense since 1978. It is unclear how siren information was disseminated to the public prior to May 1960. During the tests, sirens are sounded for 30 seconds at 11:45 AM on the first workday of each month.

No published studies show a correlation between awareness of these tests and understanding of the meaning of the siren. In a study on O‘ahu, Raine (1995) found that 12% of surveyed respondents reported they either did not hear or could not remember if they heard the sirens sound during the 1994 tsunami warning issued in Hawai‘i. If extrapolated across the population, many people in Hawai‘i may not hear the sirens when they sound. Moreover, some sirens are stationary and provide a uniform tone, but others rotate, causing the sound to resemble the wailing (rising and falling) tone used until recently to indicate enemy attack. This may lead to confusion in the interpretation of siren soundings, whose sound varies depending on these and other factors (e.g., wind, urban noise, etc). As ambiguity regarding interpretation of the warning increases, the greater is the likely delay in response.
5.3.2.1 Current criteria for sounding sirens

Hawai‘i State Civil Defense (HSCD) coordinates initial siren sounding with all counties for a distant tsunami and County Civil Defense Administrators sound their respective sirens for evacuation (Hawaii State Civil Defense, 2004b). The timing of siren soundings in relation to a hazard event depends on a number of factors. For tsunamis, the primary factor is the distance of the tsunami source from Hawai‘i. If the threat of tsunamis is from a distance source, then sirens are not planned to sound until a tsunami “warning” has been issued. A tsunami warning means tsunamis have been formed (Verizon Hawaii, 2002). In this event, standard operating procedures of Civil Defense call for sirens to sound 3 h prior to impact of the first wave on Hawai‘i’s shores, then again at 2 h, 1 h and 0.5 h prior to impact of the first wave, although this schedule is not widely publicized (Hawaii State Civil Defense, 2004b, Appendix H). If the threat of tsunami is from a local source in Hawai‘i, sirens may be sounded immediately. For example, an earthquake generated anywhere in Hawai‘i of magnitude ≥6.9 meets HSCD’s criteria to establish a “Local Urgent Tsunami Warning,” which means sirens are sounded immediately (Hawaii State Civil Defense, 2004b).

Sirens are sounded at county levels. The lack of control over isolated use of many sirens within individual counties is problematic and may unnecessarily inconvenience people outside the danger or evacuation zones. For example, sirens sounded throughout a county for hazards such as localized lava flows would prove unnecessarily disruptive to areas outside the hazard zone.
5.4 The Survey

5.4.1 Methodology
Write-in questionnaires were selected as the survey instruments and designed after (Paton, 2003). Five similar questionnaires were prepared, each one specific to an individual hazard prevalent in the study area. For example, two surveys were conducted in separate areas on the island of Hawai‘i. A tsunami-focused survey was conducted in Hilo, because the tsunami hazard is most pronounced there, and a volcanic hazard survey was conducted in Pāhoa because of the high volcanic hazard in that area. Similarly, on Maui, a flood survey was conducted in north-central Maui; and a storm survey was conducted in southeastern O‘ahu. Finally, a hurricane survey was conducted in southeast Kaua‘i.

Survey questionnaires were distributed to middle-school students and to one of their parents or guardians. Students completed surveys in the school classroom under the supervision of the coauthors, school teachers or graduate student assistants. Adults completed their questionnaire at their leisure, i.e., away from school. The questionnaires collected baseline facts and information related to general emergency preparedness and preparedness for specific prevailing hazards. Finally, the questionnaires evaluated awareness of the siren soundings and siren test frequencies and understanding of the siren soundings. Demographic information was also collected. Most of the approximately 45 questions on each survey questionnaire were associated with the preparedness phase of the study and will be published elsewhere. Three questions were asked specifically about the respondent’s understanding and interpretation of the sirens. For the Hilo subgroup,
an additional question explored people’s perceptions of the source of future tsunami
warnings.

5.4.2 Sample size
The total sample size is 956, including 440 students and 516 adults. The rate of return for
questionnaires was 44% for students and 39% for adults. Table 5.1 shows the target
hazard in each survey, sample sizes of individual subgroups of students and adults and
rates of return.

Table 5.1. Targeted hazards and return rates for surveyed groups

<table>
<thead>
<tr>
<th>Survey groups</th>
<th>Target hazard</th>
<th>Distributed (n)</th>
<th>Returned (n)</th>
<th>Return Rate (%)</th>
<th>%* of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pāhoa adult</td>
<td>Volcanic</td>
<td>329</td>
<td>64</td>
<td>20</td>
<td>6.7</td>
</tr>
<tr>
<td>Hilo student</td>
<td>Tsunami</td>
<td>186</td>
<td>78</td>
<td>42</td>
<td>8.2</td>
</tr>
<tr>
<td>Hilo adult</td>
<td>Tsunami</td>
<td>186</td>
<td>88</td>
<td>47</td>
<td>9.2</td>
</tr>
<tr>
<td>Maui student</td>
<td>Flood</td>
<td>288</td>
<td>146</td>
<td>51</td>
<td>15.3</td>
</tr>
<tr>
<td>Maui adult</td>
<td>Flood</td>
<td>288</td>
<td>142</td>
<td>49</td>
<td>14.9</td>
</tr>
<tr>
<td>O'ahu student</td>
<td>Storm</td>
<td>227</td>
<td>127</td>
<td>56</td>
<td>13.3</td>
</tr>
<tr>
<td>O'ahu adult</td>
<td>Storm</td>
<td>227</td>
<td>125</td>
<td>55</td>
<td>13.1</td>
</tr>
<tr>
<td>Kaua'i student</td>
<td>Hurricane</td>
<td>301</td>
<td>89</td>
<td>30</td>
<td>9.3</td>
</tr>
<tr>
<td>Kaua'i adult</td>
<td>Hurricane</td>
<td>301</td>
<td>97</td>
<td>32</td>
<td>10.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2333</td>
<td>956</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

*Expressed as percent of total return

5.4.3 Demographics
Demographics of the sample are as follows. The mean age of the sample was 13.4 years
(sd = 0.568) for students and 42.9 years (sd = 7.668) for adults. Gender, for students, was
38.6% male and 58.6% female (2.8% did not respond). For adults, gender was 23.4% male and 74.4% female (2.2% did not respond). In all subgroups, except the student
subgroups from Maui and O'ahu, the percentage of male respondents was disproportionately smaller than females (i.e., >20%). This suggests that not only are adult females more likely to participate in questionnaire surveys (Gregg et al., 2004a, Chapt. 2), but perhaps their female children are, too, because students were required to provide parental consent.

Hawaiian residents have a very diverse ethnic background. For example, the State of Hawai‘i had the highest percentage of people who reported more than one race in the latest US Census (U. S. Census Bureau, 2000a). Table 5.2a shows populations and race for the counties in Hawai‘i in contrast to the ethnic background described by our sample (Table 5.2b). On average, the data suggest that Caucasians and Asians are underrepresented by about 7%, Hawaiians by 6% and those selecting multiple ethnicities by about 10%. However, the extent to which I can evaluate the influence of ethnicity is limited, because comparisons of the survey sample data with U.S. Census 2000 data were made difficult by unforeseen changes in the format of the U.S. Census 2000 questions regarding race and ethnicity (Appendix D). Notwithstanding, these data provide a good cross-section of all major ethnic groups in Hawai‘i.
### Table 5.2a. Populations and race of counties in Hawai‘i

<table>
<thead>
<tr>
<th>County</th>
<th>Population 2000</th>
<th>Caucasian (%)</th>
<th>Asian (%)</th>
<th>Pac. Is.* (%)</th>
<th>Other (%)</th>
<th>Two or more (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawai‘i</td>
<td>148,677</td>
<td>31.5</td>
<td>26.7</td>
<td>11.2</td>
<td>2.0</td>
<td>28.4</td>
</tr>
<tr>
<td>Maui</td>
<td>128,094</td>
<td>33.9</td>
<td>31.0</td>
<td>10.7</td>
<td>2.2</td>
<td>22.2</td>
</tr>
<tr>
<td>O‘ahu</td>
<td>876,156</td>
<td>21.3</td>
<td>46.0</td>
<td>8.9</td>
<td>3.9</td>
<td>19.9</td>
</tr>
<tr>
<td>Kaua‘i</td>
<td>58,463</td>
<td>29.5</td>
<td>36.0</td>
<td>9.1</td>
<td>1.6</td>
<td>23.8</td>
</tr>
<tr>
<td>State</td>
<td>1,211,537</td>
<td>24.3</td>
<td>41.6</td>
<td>9.4</td>
<td>3.4</td>
<td>21.4</td>
</tr>
</tbody>
</table>


### Table 5.2b. Ethnicity of the survey sample

<table>
<thead>
<tr>
<th>Survey location</th>
<th>Caucasian (%)</th>
<th>Asian (%)</th>
<th>Pac. Is.* (%)</th>
<th>Other (%)</th>
<th>Two or more (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawai‘i**</td>
<td>23.5</td>
<td>35.7</td>
<td>23.0</td>
<td>3.9</td>
<td>10.9</td>
</tr>
<tr>
<td>Maui</td>
<td>8.3</td>
<td>58.7</td>
<td>19.1</td>
<td>2.8</td>
<td>7.6</td>
</tr>
<tr>
<td>O‘ahu</td>
<td>19.0</td>
<td>50.0</td>
<td>7.9</td>
<td>6.7</td>
<td>12.7</td>
</tr>
<tr>
<td>Kaua‘i</td>
<td>20.4</td>
<td>47.3</td>
<td>11.8</td>
<td>0.5</td>
<td>17.7</td>
</tr>
<tr>
<td>Total</td>
<td>17.2</td>
<td>48.6</td>
<td>15.7</td>
<td>3.7</td>
<td>11.7</td>
</tr>
</tbody>
</table>

*Pacific Islander (includes Hawaiian and part-Hawaiian). **Includes Pāhoa and Hilo. Missing data = 3.1%

### 5.5 Results

#### 5.5.1 Awareness and understanding of siren tests and sirens

The sirens have been operable and routinely tested for decades, so I predicted that levels of awareness that the sirens are tested and awareness of the frequency with which the tests occur would be high. Indeed, on average, about 77% of students and nearly all adults (92%) answered “yes” to a question asking if the sirens were tested (Table 5.3).

An interesting finding was that the percentage of students who said the sirens were tested was highest in Hilo 92% and decreased with increasing distance from Hilo toward Maui.
(77%), O'ahu (73%) and Kaua'i (68%). More extensive educational outreach regarding tsunami hazards and preparedness in the high-risk Hilo area may have fostered higher levels of awareness of the siren tests among students than in areas of the other islands where tsunami have been less destructive than in Hilo and where such outreach is presumably less common. This is not to say that tsunami education has not and does not exist in areas of other islands; indeed it does, but to a limited extent relative to such education in Hilo. The trend was not observed among adults, but awareness of the tests among parents was uniformly high (i.e., it ranged from 85.7% in Pāhoa to 95.4% in Hilo).

Awareness of the frequency with which the sirens are tested was high, with some 77% of respondents aware that the tests were conducted monthly (67% of students and 86% of adults) rather than annually. Awareness of the test frequency for students was again highest in Hilo (89.3%) and lowest in Kaua'i (47.7%). Awareness in Maui was 64.1% and in O'ahu it was 69.4%. In contrast, 97.7% of the adult respondents from Hilo were aware of the test frequency, as well as 85.9% from Pāhoa, 80.9% from Maui, 84.4% from O'ahu, and 84.2% from Kaua'i.
Table 5.3. Awareness that the siren is tested by subgroups

<table>
<thead>
<tr>
<th>Awareness of siren tests</th>
<th>Students</th>
<th></th>
<th>Adults</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
</tr>
<tr>
<td>Yes</td>
<td>332</td>
<td>76.9</td>
<td>462</td>
<td>91.7</td>
<td>794</td>
<td>84.8</td>
</tr>
<tr>
<td>Don’t know</td>
<td>91</td>
<td>21.1</td>
<td>34</td>
<td>6.7</td>
<td>125</td>
<td>13.4</td>
</tr>
<tr>
<td>No</td>
<td>9</td>
<td>2.1</td>
<td>8</td>
<td>1.6</td>
<td>17</td>
<td>1.8</td>
</tr>
<tr>
<td>Total</td>
<td>432</td>
<td>100</td>
<td>504</td>
<td>100</td>
<td>936</td>
<td>100</td>
</tr>
</tbody>
</table>

$\chi^2 = 42.046, \text{df} = 2, p = 0.000$

On the basis of our prediction that awareness of the siren testing would be high, I predicted that understanding of the siren would be commensurately high. To elicit people’s understanding of the meaning of the siren sounding and its implications for behavioral response in the current study, I asked an open-ended question—“What does the Hawai‘i Emergency Alert System’s (EAS) steady three minute siren tone indicate?” Understanding of the specific meaning of the siren (i.e., tune to a radio or television station for information) was found to be very low. On average, correct student and adult responses were 1% and 13%, respectively (Table 5.4). The disparity in correct responses between students and adults is consistent with the results of Gregg et al. (2004b, Chapt. 2). A majority of both the student and adult subgroups either indicated that they “don’t know” the meaning of the siren or they did not respond to the question, clearly indicating a lack of understanding or perhaps apathy (i.e., both in wanting to know answers to such questions and in attitudes toward the questionnaire).
Table 5.4. Understanding of the meaning of the 3-minute siren by subgroups

<table>
<thead>
<tr>
<th>Interpretation of the meaning of the siren*</th>
<th>Students</th>
<th>Adults</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t know</td>
<td>301</td>
<td>254</td>
<td>555</td>
</tr>
<tr>
<td>Other (emergency, disaster, alert, tsunami, flood, etc)</td>
<td>207</td>
<td>243</td>
<td>450</td>
</tr>
<tr>
<td>Tune to radio/television</td>
<td>3</td>
<td>66</td>
<td>69</td>
</tr>
<tr>
<td>Total**</td>
<td>511</td>
<td>563</td>
<td>1074</td>
</tr>
</tbody>
</table>

*These are abbreviated write-in responses. *Percent given as percent of respondents.

Sixty-six of the 69 respondents who recorded an accurate meaning of the siren were adults. Of these 66, there were significant differences in understanding across the five subgroups of adults representing different islands ($\chi^2 = 16.187$, df = 4, p = 0.003).

Twenty-eight of the 66 individuals live on O‘ahu (i.e., 22.4% of the total sub-sample of 125 O‘ahu adults) and 12 were from Kaua‘i (12.4% of the sub-sample). Of the island of Hawai‘i subgroups, 8 were from Pāhoa (12.5% of the sub-sample) and 9 were from Hilo (10.2% of the sub-sample). Finally, 9 were from Maui (6.3% of the sub-sample). While the sample from each island was only drawn from one community or city on that island (except Hawai‘i island), these data suggest that the islands having the highest and lowest accurate understanding of the siren are O‘ahu and Maui, respectively. The reason or reasons for this are unclear, but differences in demographic characteristics between the subgroups are likely factors.

Some of the responses in the “other” category of Table 5.4 could be considered partially correct (Attention Alert Signal, alert). However, they are less accurate than
“tune to radio/television.” The following provides a closer look at responses in the “other” category.

Some respondents associated the siren with the terms “emergency” (6% of adults and 3% of students), “warning” (5% of adults and 3% of students), and “attention alert” or “alert” (5% of adults and 2% of students). Other people interpreted the siren to mean a tsunami was possible or imminent, or as a tsunami warning (8% of adults and 9% of students). Fewer respondents (3% of adults and 8% of students) related the siren to hurricanes and even fewer to other hazards, although many students related the siren to the specific hazard under investigation in their respective survey. Several people related the siren to “enemy attack” or “war” (2% of adults and 1% of students), suggesting that old official siren definitions are still a part of modern cognition. Finally, a few respondents associated the siren with a test of the system (3% of adults and 2% of students), which has obvious implications for timely response to siren soundings.

5.5.1.1 Statistical significance
I evaluated the effect of awareness of the siren tests and test frequency on interpretations of the meaning of the siren using results from the subgroup of 504 adults. Results are not reported for students because only 3 students were aware of the meaning of the siren. Responses to the question asking if the sirens were tested were condensed to two values (1 = yes and 2 = no or don’t know). Similarly, responses to a subsequent question asking about the frequency of the test were condensed to two values (1 = monthly and 2 = annually or don’t know). Responses to the question asking about the meaning of the siren were also condensed to two values (1 = tune to television/radio and 2 = don’t know or other).
On average, only 14% of the adults who knew the sirens were tested also knew the meaning of the sirens. However, in those respondents that did not know the sirens were tested, none knew the meaning of the siren ($\chi^2 = 6.904$, df = 1, p = 0.009).

Similarly, using the subgroup of 462 adults that were aware that the siren was tested, only 15% of those who knew the frequency of the tests also knew the meaning of the siren.

The number of years that adult respondents indicated they had lived in Hawai‘i were condensed to 10-year increments. These data were analyzed against understanding of the meaning of the siren. Length of residency did not appear to systematically influence people’s understanding of the siren (Table 5.5). Understanding of the meaning of the siren peaked to 20% in those who had lived in Hawai‘i for 40-49 years. One possible reason for this is that those in the 40-49 years group would have been living in Hawai‘i during the devastating 1960 tsunami, and this may have made tsunami issues more salient.
Table 5.5. Understanding of the meaning of the siren by number of years respondents have lived in Hawai‘i.

<table>
<thead>
<tr>
<th>Understanding of siren*</th>
<th>0-9</th>
<th>10-20</th>
<th>30-40</th>
<th>40-50</th>
<th>50-72</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19</td>
<td>29</td>
<td>39</td>
<td>49</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Don’t know or other**</td>
<td>57</td>
<td>75</td>
<td>60</td>
<td>109</td>
<td>102</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>96</td>
<td>90</td>
<td>84</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Tune to radio/television</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>21</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>16</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>78</td>
<td>67</td>
<td>130</td>
<td>127</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

*TThese are abbreviated responses. **This category of response includes respondents that indicated they did not know the meaning of the siren or entered an inaccurate response.

5.5.2 Expectations of tsunami warning signs (Hilo sub-sample)

Damage to property and fatalities from tsunamis has been higher in Hilo than in any other place in Hawai‘i. Not surprisingly, tsunami-outreach education has focused on preparing residents of Hilo for future tsunami. When combined with the history of tsunami damage in Hilo, I hoped to identify high levels of awareness of natural warning signs for tsunami, despite the low levels of experience in tsunamis recorded by the adults surveyed in Hilo. For example, only 16% indicated they had experienced a tsunami. Table 5.6 shows write-in responses to the question, “What signs would alert you that a possible tsunami will occur?” While many students and adults perceived that either earthquakes or unusual sea-level changes or fluctuations would alert them to tsunamis, most people had the perception that an official notice would alert them (e.g., siren sounding, Civil
Defense, police, etc). The data suggest an expectance and dependence on government officials and agencies.

Table 5.6. Perceptions of what signs would alert respondent that a possible tsunami will occur by students, adults and total.

<table>
<thead>
<tr>
<th></th>
<th>Student</th>
<th>Adult</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
</tr>
<tr>
<td><strong>Official warning (siren, police)</strong></td>
<td>59</td>
<td>76.6</td>
<td>55</td>
</tr>
<tr>
<td><strong>Unusual sea-level changes</strong></td>
<td>35</td>
<td>45.5</td>
<td>33</td>
</tr>
<tr>
<td><strong>Earthquakes</strong></td>
<td>18</td>
<td>23.4</td>
<td>45</td>
</tr>
<tr>
<td><strong>Radio, television, news, media</strong></td>
<td>26</td>
<td>33.8</td>
<td>28</td>
</tr>
<tr>
<td><strong>Other geophysical event</strong></td>
<td>4</td>
<td>5.2</td>
<td>8</td>
</tr>
<tr>
<td><strong>Friends, family, neighbors, etc</strong></td>
<td>1</td>
<td>1.3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>3</td>
<td>3.9</td>
<td>1</td>
</tr>
<tr>
<td><strong>Did not respond</strong></td>
<td>1</td>
<td>1.3</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total responses</strong>*</td>
<td>147</td>
<td>191</td>
<td>181</td>
</tr>
</tbody>
</table>

*These are abbreviated write-in responses. **Percent given as percent of respondents. ***Percent does not total 100 because some respondents recorded multiple responses.

The data in Table 5.6 also indicate that, not surprisingly, the responses for earthquakes and changes in sea-level are inconsistent. For example, responses identified as earthquakes included a range of earthquake terms and phrases such as *earthquake, strong earthquake* and *big earthquake*. Similarly, responses identified as unusual sea-level changes included a broad range of terms and phrases, such as *quickly receding tide, receding tide, high waves and can see bottom of ocean*. However, the finding that many people recognize that there are natural warning signs of tsunamis, regardless of how they describe them, is encouraging.
The data provide an understanding of the very basic cognitive characteristics of respondents in relation to alerts of future tsunami and can be used to focus future outreach efforts aimed at increasing awareness of these characteristics. Moreover, considering the significant role that recognition of natural warning signs and corresponding evacuation of coastal areas has played in reducing fatalities in tsunamis, such as at Okushiri Island, the moderate awareness of these signs in the Hilo subgroups suggests a need to focus on these issues there. Given the greater extent of tsunami education and outreach in Hilo, I anticipate that results for the Hilo subgroup represent a best case scenario for awareness of natural warning signs of tsunami in communities in Hawai‘i. A limitation of these data is that the accuracy with which people can discern these phenomena in an actual tsunami event cannot be determined. Furthermore, the manner in which people would respond once they perceive the indicated sign or signs (earthquake, receding tide, etc) cannot be determined from these data.

5.6 Discussion
The level of basic preparedness for tsunamis is low, as measured by the understanding of the meaning of the siren used to warn people. Gregg et al. (2004b, Chapt. 2) found no correlation between respondents’ understanding of the meaning of the siren and review of disaster preparedness information in the telephone book (the primary source of information that explains the meaning of the siren) and suggested that familiarity of the routine siren tests may help explain the observed levels of understanding of the siren in Kona. However, I have shown that this is not so. Awareness of the siren tests and test frequencies is very high among both adults and students, but only 15% of adults who were aware of the frequency of the siren tests also knew the meaning of the siren.
Informal communications about the siren between members of the public may be a primary factor in promoting understanding of the meaning of the siren.

Raine (1995) reported that nearly everyone’s first and second responses to hearing the warning siren in 1994 were to turn on the radio (65%) or television (26%). Despite this, most people did not even hear of the 1994 evacuation through the radio or television announcements, but rather by telephone calls with family, friends and neighbors (Raine, 1995). In our study, only 13% of adult respondents indicated that the siren meant tune to a radio or television station, but, by comparison with Raine’s study, I suspect that many more than this will actually turn on the radio or television upon hearing the siren. However, this says nothing about how people will interpret and respond to messages received from the radio or television during and after future emergency messages. For example, Dudley and Lee (1998) reported that many people went to the ocean to watch the waves arrive when the tsunami warning was issued in 1994, which complicated official efforts to evacuate people to safer places inland from the coast. Also, several hundred incautious surfers went out to ride the tsunamis (Dudley and Lee, 1998). Presumably these people were aware of the tsunami warning, but their interpretations of the threat was apparently not sufficient to overcome their desire to drive to the beach to watch the waves arrive or to go surfing. These points highlight the complexity in having the public respond to messages in ways that complement emergency response rather than hinder it.

These observations reiterate the findings of Johnston et al. (in press). Specifically, awareness of such actions on the part of others may influence citizen’s perceptions of the efficacy of evacuation or other actions in response to a warning. There
is a clear need to better understand the relationships between formal emergency messages and behavioral response, such as response to siren soundings and Emergency Alert System messages, and informal communications, such as those between family, friends and neighbors through person-to-person contact and the use of cellular phones, telephones, and so on.

The fact that people will walk or drive to the ocean to watch the tsunami is a testament to the fact that people want to see tsunamis. People have gone to the ocean to watch tsunamis even after receiving messages that such areas were being evacuated because of elevated risk there. The identification and designation of safe tsunami viewing areas may satisfy public curiosity and help alleviate problems with managing incautious sightseers during future tsunami warnings. It may also help facilitate public trust in official agencies. These tsunami viewing areas would be located in safe places where viewing is optimal. Road or foot access to these areas would also have to avoid tsunami danger zones. While the logistics of organizing and maintaining large crowds in such areas could be complicated or prohibitive, the idea is worth exploring, especially in less densely populated areas. In urban sectors where high topography provides no optimal viewing area, portions of buildings with planned “vertical evacuation” (i.e., evacuation of people to third or higher floors in ≥6-story buildings) may provide a partial solution. This strategy should be considered as complimentary to direct evacuation strategies of official tsunami response plans. This is especially true given that public curiosity can increase the risk of people engaging in risky behavior such as going to dangerous areas to try and view tsunamis, which can increase the risk to others by blocking or congesting evacuation routes.
Tsunami behavior is dynamic, so there is no single aspect of tsunami waves that characterizes all tsunamis in coastal areas. Still, recognizing the changes in sea level as a consequence of tsunamis can play an important role in limiting fatalities in future tsunamis. Likewise, the degree of ground-shaking from earthquakes will be a result of numerous factors and shaking will vary from place to place. Earthquakes that produce both strong and mild ground-shaking in specific coastal areas have produced destructive tsunamis (Dudley and Lee, 1998; Lander and Lockridge, 1989; Maramai and Tinti, 1997). Therefore, the degree of ground shaking should not be used as a determinant of behavioral response. The best rule of thumb is for people in coastal areas to evacuate and move to higher ground if any shaking is felt. This will inevitably result in the evacuation of some areas that are not subsequently impacted by tsunami waves, so educational outreach must address this concern.

The issues involved in warning of local tsunamis are complex and the current official warning system cannot ensure that the at-risk public will receive a timely warning of local tsunami. Therefore, a new warning signal is needed that prompts people in hazardous areas to evacuate immediately, since the short-warning times effectively prohibit or severely limit opportunities for any search for information prior to action. Furthermore, given the critical role that natural warning signs of tsunamis can have in alerting people to tsunamis, people must be familiar enough with these natural warning signs to evacuate immediately upon notice. This natural warning mechanism should be viewed as complementary to the official warning system, but it should also be viewed as potentially the only warning that will be received prior to the arrival of tsunamis on shores.
Under the current siren system, the public needs to immediately seek out emergency information from radios or televisions once sirens are sounded. However, as outlined above, warnings can create a sense of ambiguity that results in delays as people look to others to clarify the situation. Response to warnings is also affected by how people perceive the consequences and likely effectiveness of their actions. For example, Johnston et al. (in press) found that community members may not respond to warnings if they do not believe that appropriate evacuation options are available. This includes a perceived inability to get to high ground quickly enough, concerns that roads will be blocked by traffic, and a need to collect their children if the event occurs during school hours. Johnston et al. (in press) also noted that people may not respond to warnings for fear of looking foolish in the event that the tsunami event is a false alarm or less intense (i.e., of lower magnitude) than expected. Thus, mitigation needs to ensure that effective warning signals are provided, but it is equally important to ensure that those people and agencies developing mitigation plans understand the beliefs and attitudes of the populations at risk, correct any pertinent misconceptions, and ensure that people have plans that cater for themselves and the needs of the community.

Some people in our surveys associated the siren with the hazard under investigation in each study. For example, most children in Maui associated the siren with floods, and in O‘ahu, with storms. These associations are consistent with Mileti and O’Brien (1992, see their discussion of environmental information receiver characteristics). These researchers suggested that the characteristics of people who receive warnings that impact how they process risk information can be classified into three so-called “information receivers,” (environment, social and psychological
attributes). The *environment receiver* includes physical and social cues, such as whether the survey was completed during a hazard event, or in the case of our surveys, which hazard was the focus of questioning. Our data suggest that students may be more affected by the *environment receiver* characteristic than are adults. This possibility should be considered in future outreach and surveys that involve multiple hazards in order to reduce biased results.

The high frequency and wide range of responses recorded in the “other” category of Table 5.4 provide insight into the broad and flawed current interpretations of the siren. Many people either defined the siren as an alert or associated it with a specific natural hazard, a test of the system, war, etc. These responses may be associated with 1) prior hazard experience where sirens were used (tsunami, hurricane), 2) having obtained older information from a time when sirens had different hazard specific meanings, 3) having received inconsistent information from any source, or perhaps 4) the *environment receiver* of Mileti and O’Brien (1992).

5.7 Conclusions
Awareness of the siren system and the routine testing of the system is very high in Hawai‘i. However, this awareness has not fostered acceptable levels of understanding of the system. A clear need exists to raise awareness of the meaning of the siren and its implications for behavioral response. There is also a need to raise awareness of natural warning signs of local tsunamis and their implications for behavioral response. The high survival rates recorded at Okushiri Island that resulted from at-risk people’s immediate recognition of and response to natural warning signs of tsunamis should set the pace for emergency management everywhere. As highlighted by Dudley and Lee (1998), the
survival rate could have been even higher had people not tried to evacuate by car, returned to retrieve valuables, or waited for family and friends to evacuate. As highlighted by Dudley and Lee (1998), in tsunamis that provide little advanced warning, the old saying handed down in the high tsunami hazard Sanriku district of Japan to reduce casualties seems especially meaningful. It says, “Tsunami ten-den-ko,” and means, “In a tsunami, every man for himself.”

The current single siren tone for all hazards makes educational outreach easier than if there were multiple tones, because the public is not required to learn and remember the differences in tones. However, the two types of tsunami threats posed by local and distant tsunamis require separate warning mechanisms. Hazard events with short warning times, such as local tsunamis, could impact people and property before the sirens are activated and before people can tune to a radio or television to hear emergency information. Moreover, people at the beach may not have a radio or television and other warning sources (e.g., civil defense, police, civil air patrol, etc) may not alert people before waves impact areas. This suggests a flaw in the existing system. Hence, there needs to be a single danger alert for beachgoers to evacuate to an area where they can learn more about the emergency situation at hand.

Public information about the siren warning system has traditionally focused on supplying accurate information, without considering the ways in which society interprets and uses the information. Changes in the content of information have not been accompanied by an evaluation of the impact of the information on the public, and the effectiveness of these efforts is unknown but likely overestimated.
Disaster preparedness and response information needs to reach a diverse Hawaiian society, including visitors and tourists. Outreach should be tailored to meet the demands of these groups and subgroups within each. Some logical next steps to improve Hawai‘i’s readiness and response for future tsunamis and other hazard events that utilize the siren are to:

1. Coordinate monthly State Civil Defense siren tests with prime-time television, cable television, radio and newspapers to reach a wider audience and raise understanding of the siren as an alert that means tune to a radio or television station for information.

2. Teach siren information and other related disaster preparedness in Hawai‘i’s public and private schools (Menzer, 2000), and utilize research studies in formulating lessons aimed at increasing home-based preparedness and response capabilities.

3. Make siren and response information available for tourists and tourism sector staff through various sources, including staff training.

4. An educational video about tsunamis and natural warning signs of tsunamis that is rooted in Hawaiian tradition may facilitate high levels of public interest about tsunamis and response to them. The video could be modeled after successful educational programs such as the ahupua‘a concept of land subdivision in Hawai‘i. Given Hawai‘i’s ethnic diversity, information from other countries with significant tsunami hazards would also be very useful.

5. Use social science to measure the effectiveness of 1 through 4 above and to ensure that objectives of outreach efforts are achieved and not overestimated.
CHAPTER 6. CONCLUSIONS

I begin this chapter with a discussion of the relationship between land-use planning and the adoption of protective measures. This is followed by a discussion of observations drawn from the specific studies covered by Chapters 2-5. I then discuss objective and perceived risk and problems with getting information to people. I conclude with a discussion of some aspects of outreach and preparedness in the state of Hawai‘i.

6.1 Land-use planning
Mileti (1999) reported that natural hazards are estimated to cost the U. S. public about $500,000,000 per week ($26 billion per year). Such staggering figures, and realizations that the high costs of response and recovery from hazard events should be reduced by long-term mitigation planning strategies, have fueled interest in the concept of sustainable hazard mitigation (Godschalk et al., 1999). Burby et al. (2000) reported that the “Second National Assessment on Natural Hazards and Related Technological Hazards calls land-use planning the single most promising approach for bringing about sustainable hazard mitigation.” However, other mitigation and preparedness strategies must also be considered in areas where development has already taken place in high hazard areas and where such development is unlikely to be resettled.

Land-use strategies could be used to influence existing and future development. However, this is assuming that those responsible have the information available, that hazard assessment is funded at levels that render it comprehensive, and that those responsible for planning such strategies understand the implications of each type of hazard for different aspects of human land-use and that they can weigh up the costs and
benefits of different planning options. The latter illustrates the importance of social justice within this process (Paton and Bishop, 1996). The applicability of land-use planning is limited somewhat to hazards that have known and predictable geographic distributions. This includes, for example, tsunamis, floods, storm surge, and lava flows from summit and rift zone eruptions. Issues regarding return periods, and the costs/benefits of development also influence mitigation planning. Mitigation planning also needs to be undertaken within a framework of public participation and empowerment. Thus, there is a need for comprehensive planning rather than a focus on any one approach.

Given the politics of hazard mitigation (Prater and Lindell, 2000), Burby et al. (2000) and Paton and Bishop (1996) highlighted the need for designing stakeholder participation in the development of hazard mitigation plans. In this approach, mitigation plans must be rooted in public support, because local officials are unlikely to vote for mitigation measures that are highly controversial. Tsunamis pose an interesting issue in this context because of their link to development in coastal areas that are in high demand by both residential and commercial populations. Such areas include high-end houses and hotels that support the visitor industry.

Chapter 4 underscored the need for community participation in mitigation decisions through a study of the cultural implications of intervening in the paths of lava flows. Building a foundation of public support for mitigation begins with research that explores awareness and perceptions and sets the stage for the formulation and dissemination of information aimed at gaining public attention and support to facilitate risk-reduction actions at the level of individual households, businesses and communities.
Engineered measures to control the paths of recent lava flows in Hawai‘i have been short-term mitigation strategies organized and implemented in response to volcanic eruptions that posed imminent threats to population centers. Barriers that protect an observatory on Mauna Loa are an exception; they were constructed during a period of volcanic quiescence in 1986. If the political implications of engineered mitigation strategies are alleviated (Lockwood, 2003; Prater and Lindell, 2000), and if it can be established that specific measures will be cost-effective solutions to reduce losses from lava flows, then the measures offer the prospect of becoming a longer-term solution to protect areas such as portions of Hilo. A recent state report has called for review of a 1977 “State Emergency Plan to Protect Hilo from Lava Flows” (Hawaii State Civil Defense, 2002).

Other strategies are also available that could contribute to, and facilitate, sustainable hazard mitigation (Burby, 1998; Godschalk et al., 1999). Concepts of Transferable Development Rights, reconfiguration of subdivisions and land readjustment each offer unique ways to reduce long-term vulnerability and risk from lava flows and tsunamis (Goldschalk et al., 1999; Schwab, 1997). There is a need to focus on adoption of these long-term, land-use-planning strategies while balancing them with the former shorter-term solutions (e.g., engineered measures, household preparedness, etc). In other words, Hawai‘i should move toward the adoption of mitigation strategies that decrease human occupation of marginal lands. While this gets underway, however, we must ensure that people already occupying marginal lands, and who will continue to do so into the foreseeable future, are prepared to reduce their risk to property and personal safety. Residential subdivisions occupying the rift zones of the active volcanoes of Kīlauea and
Mauna Loa are within the boundaries of marginal land and provide an excellent example where land-use planning could limit vulnerability by preventing further development and relocating existing development.

The situation with tsunamis in Hawai‘i is similar to that with lava flows. For example, Raine (1995) reported that 60,000 people on O‘ahu reside within the tsunami inundation zone and that many more travel and work within this danger zone.

Developing a capability to respond to tsunamis (e.g., having an emergency response plan, knowing the meaning of the siren and natural warning signs of tsunami, establishing safe tsunami observation areas for the public) should be balanced with other mitigation efforts aimed at reducing the long-term vulnerability of at-risk development. Developing a capability to respond to tsunamis must also be balanced against the choices made by people and the county in regard to lifestyle and economic issues. Thus, mitigation is a complex, multi-faceted phenomenon that calls for a mix of strategies.

6.2 Lava Flow Hazards, Risk and Preparedness in Kona

The continuation of uncontrolled development in areas of highest hazard (the rift zones and areas immediately downslope in Kona, Ka‘ū, and Puna) is increasing the risk from lava flows for the occupants of these areas. Risk to the county, state and Federal government and tax payers is also rising in parallel with that of owners and occupants. Apart from the burden of response and recovery costs arising from future eruptions that threaten these areas, concern is increasing over county and state liability regarding the existing and continued development of these marginal lands. There are neither plans for a resettlement of populations at risk nor plans to buy them out. Laws and ordinances
prohibiting future development are lacking and this poses great obstacles to building resilient and sustainable communities.

The long time intervals since the latest lava flows in Kona, and perhaps a lack of widespread and frequent volcanic information specific to the unique situation in Kona, have limited awareness of the fact that Mauna Loa and Hualalai are volcanoes in repose that will erupt again. Perceptions of eruptions and lava flows (especially speed of onset of eruptions and the time it takes lava to reach developed areas) may also be limited by these factors. Given current low levels of both knowledge of volcanic hazard processes and preparedness to deal with their consequences, the issues of quick onset and short response times elevate the importance of household planning and preparedness. Integrating geological, emergency management, planning, and social science expertise will facilitate these outcomes.

Preparedness for lava flows and other infrequently occurring hazards in Kona is limited by a lack of experience in damaging events and cognitive factors that negatively influence decisions to adopt risk-reduction measures. Several psychological processes hinder the adoption of risk-reduction actions. For example, widespread direct or indirect experience with typical low-effusion, slow-moving lava flows erupted recently at Kīlauea may contribute to a normalization bias (Mileti and O'Brien, 1993), causing observers to perceive that future eruptions of Mauna Loa and Hualalai in Kona will erupt lava in a manner similar to that at Kīlauea. It would be beneficial to develop an effective means of translating the experience at Kīlauea to more accurate perceptions of eruptions in Kona. A belief that lava flows in Kona will be slow moving could discourage preparedness if
people assume that they will have plenty of time to prepare and plan for an eruption after one has started.

There is a perceived lack of urgency to prepare for eruptions in Kona. This is a concern, because the perceived urgency of response has been shown to positively influence response to warning messages (Sorensen, 2000). Considering the lack of perceived urgency to respond, and the fact that lava flows in Hawai‘i impact more localized areas than earthquakes and large storms, it is not surprising that lava flows are perceived to represent relatively little risk to people and their property throughout Kona.

The low levels of basic preparedness measures recorded in Kona may also be influenced by other factors, such as the lack of risk-reduction information specific to lava flows. This may contribute to low perceptions of self-efficacy to prepare for lava flows and to low outcome expectancies of lava flows (Paton, 2003). This is not surprising, because a commonly heard expression is that “nothing can be done about lava flows.” Perhaps this expression applies not only to controlling eruptions or lava flows but also to preparing for eruptions. Indeed, 30 years ago Murton and Shimabukuro (1974) concluded that evacuation was the primary adjustment to the threat of volcanic hazards in Puna, and that this may have been the consequence of the widespread perception that eruptions are “uncontrollable.” The only other adjustment identified in that study was the bearing of losses. Bearing losses is not a mitigation strategy unless the losses are deemed acceptable. One challenge facing land-use planners and communities is to determine the levels of acceptable risk in specific areas. Once this is known, attention can be directed toward developing sustainable mitigation strategies in areas where risk is unacceptable.
There is a need to identify risk-reduction measures specific to lava flows, and to disseminate this information to the people at risk. Even if the measures are limited to having an emergency response plan and supporting actions, people need to know that options exist to reduce risk to property and personal safety. Information about other long-term mitigation strategies such as Transferable Development Rights, reconfiguration of subdivisions and land readjustment should also be made available to the public and emphasized among the parties that may be interested.

Promoting the adoption of emergency response plans and other risk-reduction actions could be limited by factors such as perceived responsibility, unrealistic optimism bias, and cognitive dissonance. In the latter, people seek to ignore information that casts their decisions in a negative light (Festinger, 1980). This is particularly problematic in the areas of highest hazard. Reducing cognitive dissonance in people at risk will require that physical volcanic hazard outreach information be disseminated to the local people in ways that relate the hazard information to their daily activities, to the things that are important to them, and in ways that increase self-efficacy and positive outcome expectancy (Paton, 2000).

The transfer of responsibility from oneself to officials creates a barrier to outreach that may serve to reduce actual preparedness, perceptions of the need for preparedness, or both (Ballantyne et al., 2000; Lindell and Whitney, 2000; Mulilis and Duval, 1995). This outcome is becoming increasingly apparent within the literature, yet there is no clear rationale for its occurrence. Several reasons have been proposed, including the long-term decline in community empowerment, the imposition of government decisions on communities, and the transfer of responsibility to experts when presented with
information that is interpreted as threatening or difficult to understand. A positive point is that community empowerment has been recognized as a key factor in gaining local support for the development and maintenance of mitigation plans, and it is becoming an increasingly common component of official hazard mitigation plans (Burby et al., 2000; U. S. Congress, 2000). However, hazard policies that increase individual liability for personal losses in hazard events and that reduce government subsidies equitably across society are also needed to help reduce the transfer of responsibility.

The unrealistic optimism bias for earthquakes observed in Kona poses problems for the development of resilient communities. People exhibiting this bias may acknowledge a need for preparedness within their community, but they do not recognize the need as applying to themselves. These people are less likely to act on warnings and participate in community activities (Johnston et al., 1999). The earthquake data are particularly interesting, considering that earthquakes are perceived to represent the highest level of risk in Kona. Earthquakes probably provide the highest level of risk in terms of frequency of the hazard event, even though earthquakes have not recently proven catastrophic in Hawai‘i. This represents a particular problem for risk communication. One approach to dealing with this issue could involve personalizing information by focusing people’s attention on the implications of hazard information for themselves, their family, their livelihood and so on. A second approach could focus on how individuals differ from other community members. This approach, however, would need to be examined in future research. Managing these issues requires that physical scientists and emergency managers 1) work with community planners to build understanding of natural hazards, 2) facilitate risk acceptance among community groups
and members, and 3) relate official mitigation strategies, which are designed to safeguard everyday activities of people and communities, to community members by integrating hazard education and community development (Paton, 2000).

6.3 Engineering Approaches to Lava Flow Mitigation

Volcanoes have long been a source of great cultural and spiritual identity for people throughout the world. Considering this and the political powers of Hawaiian people, it is no surprise that a political concern over cultural sensitivity to the use of engineered lava flow mitigation measures accompanies a social move to preserve Hawaiian culture and heritage. Data from the 1960 Kapoho study provide important insights into the cultural sensitivity concern that has been recognized by others for many decades. Chapter 4 showed that cultural sensitivity was a significant factor in attitudes toward lava flow mitigation strategies. However, the influence of the cultural sensitivity was small. Chapter 4 also suggests that the concept of community empowerment, which underpins contemporary hazard mitigation planning, was already on the move in Hawai‘i in 1960. The findings provide a good foundation for a contemporary study of public attitudes and cultural sensitivity to the use of mitigation measures. Short of a contemporary study, these findings may help mitigate a potential conflict between Hawaiian cultural interest groups and officials who make decisions on implementing mitigation strategies.

If modern attitudes toward mitigation parallel those measured in 1960, then there is widespread acceptance of the use of engineered mitigation strategies to protect areas from lava flows. Furthermore, the use of barriers would be more desirable than the use of bombs. This is not a surprising finding and probably reflects perceptions that barriers
interfere less with the natural flow of lava than do bombs (Lockwood, 2003). Greater acceptance of bombing as a mitigation strategy may be facilitated by drawing analogies of bombing with natural collapse processes as suggested by Lockwood and Torgerson (1980).

Barrier construction has been shown to be feasible and cost-effective at Mt. Etna (Barberi et al., 2003). However, bombing strategies may be more cost-effective than barrier construction (Lockwood and Torgerson, 1980). As such, a contemporary study should be done to evaluate relative attitudes toward bombing lava flows in specific areas of volcanoes relative to population centers. Furthermore, strategies that intervene in lava flow paths should probably reflect a plan for lava to be directed toward the ocean and along a route as natural as practicably achievable (D.A. Swanson, pers. comm, 2002).

Acceptance of engineered mitigation transcended ethnic boundaries in 1960. An interesting inference from the data is that acceptance of barriers and bombs appears to be greater when local people are included as participants in mitigation strategies; the people were interested in remedying, or at least helping to remedy, their own disaster. Equity and fairness in environmental consultation influence community risk acceptance, which is an important precursor of commitment to reducing risk (Paton and Bishop, 1996). Community consultation based on social justice principles increases a community’s awareness of the trade-offs involved in environmental management decisions and in creating safer environments. Community consultation also reduces the likelihood of the community blaming authorities should damaging hazard activity occur outside what is expected (Paton and Bishop, 1996). This may have legal implications that mitigate liability over specific intervention outcomes.
Attitudes toward engineered mitigation must be understood in terms of the factors that contribute to the attitudes, such as awareness of prior mitigation strategies and their outcomes. Perceptions of past mitigation objectives and outcomes may strongly influence contemporary attitudes toward mitigation. If community approval of mitigation strategies is desired, these issues should be anticipated and accounted for in advance of the design and implementation of mitigation plans through community empowerment of Hawaiians and other local people. From political and planning perspectives, comparison of public attitudes toward specific mitigation measures with cost-benefit analyses would be helpful in the decision-making process. Whether Hawaiian cultural values and customs can be respected and preserved in conjunction with the use of engineered mitigation remains to be seen.

6.4 Awareness and Understanding of the Siren-Warning System

The longevity of the siren system in Hawai‘i, and the public’s familiarity with the routine siren tests and the monthly test frequency, have not promoted levels of understanding of the meaning of the siren above that measured in surveys in the 1960s. This is surprising and should be a major concern for the state.

A clear understanding of the meaning of the siren is essential to convey urgent messages to the public in a timely manner. Misunderstanding the siren may result in delays in obtaining information, which could be disastrous. It may also contribute to high levels of people seeking to confirm the siren’s meaning using telecommunications systems, which could clog telecommunications lines. However, despite the siren system’s important role in emergency management, the system has limitations that
require the development and use of alternative warning strategies for hazards with short
warning periods such as local tsunami.

Effective public response to local tsunamis in Hawai‘i will require public
awareness of natural warning signs of tsunamis, particularly given the possibility that the
official siren system will not provide a warning of tsunamis before waves arrive on
shores. Residents in Hilo are aware of natural warning signs of tsunamis, but they expect
and depend on warnings of tsunamis to come from official sources. The ability of natural
warning signs of tsunamis to complement the official siren system will require that
people are aware of the natural signs, that they possess a capability to recognize them,
that they recognize dangerous coastal areas, and that they have a plan to evacuate these
areas immediately upon recognizing the signs. However, acting on this option would
require not only new public education initiatives, it would also require community
development work to change attitudes regarding the transfer of responsibility for
preparedness to formal authorities.

One last major concern, which deserves immediate attention, is that people need
to be informed about what they should do when the siren sounds if they are in low-lying
coastal areas (e.g., at the beach) compared to areas of higher elevation. Should the
people seek information from radios or televisions or should they immediately run to
higher ground? Furthermore, should they go to higher ground only if they feel ground
shaking? Or, should they go to higher ground immediately upon hearing the siren,
regardless of the presence or absence of ground shaking? These are simple questions, but
ones that are not adequately addressed in official information.
The existing Disaster Preparedness Information (DPI) in telephone books expects two things about people and earthquakes in relation to tsunamis. First, the DPI expects that people will know when they are in a safe place versus an unsafe place. Second, the DPI expects that earthquake shaking will provide a mental signal that a siren sounding is a warning of imminent tsunamis, and hence people should evacuate immediately if they are in an unsafe place. Whether people recognize a safe area versus an unsafe area, and whether they possess a capability to conflate being in an unsafe area with ground-shaking and its implications for tsunami and immediate evacuation, is unknown. If time is of the essence in local tsunami and the only people who need to evacuate are those in low-lying coastal areas, there should be a warning mechanism that signals to these people that they should evacuate immediately to higher ground, without seeking information from radios, televisions or anybody or anything. Additional education would also be required to facilitate people’s recognition of both the danger zone and the safe zone to which they would evacuate.

One important finding in warning system research is “that a single warning concept will not equally serve the requirements of all hazards” (Mileti and Sorensen, 1990; Sorensen, 2000). This dissertation has highlighted some limitations of the existing siren system to meet the demands of multiple hazards. The potential liability over these issues should prompt the attention of the state.

Sorensen (2000) suggested that short-term hazard warning systems (i.e., less than years) may hinder the movement toward sustainable hazard mitigation by allowing the occupation of marginal lands. This is a valid point, but one that must also be considered in the light of the costs and benefits of development, cultural issues concerning land
occupation, and the return periods of hazards. The existence of a warning system may indeed facilitate development in the vulnerable coastal plain and thus increase riskier behavior. However, a warning system will always be essential for reducing risk from tsunamis in Hawai‘i, because people everywhere recreate in the coastal zone.

6.5 The Significance of “Don’t Know” Answers

Student respondents, in comparison to adults, responded to many questions in the dissertation surveys by selecting the “don’t know” option. This could reflect student apathy toward the questions and hazard and preparedness issues in general. Students may believe that their parents are responsible for ensuring their family’s protection. However, the Kona study suggests that only slightly fewer students than adults believed each individual in the community was responsible for preparing the community for volcanic eruptions (49% versus 58%). A limitation of interpreting these data is whether or not each subgroup of students and adults conflates “individual” with its own subgroup.

In contrast to student responses, adults showed higher levels of awareness of hazard issues. Apart from student apathy, the disparity in responses may lie in the source, content or quality of the information received. Additional research would be required to accurately understand the influences of different hazard information sources on awareness, perceptions and the adoption of risk-reduction measures.

6.6 The Telephone Book as an Information Source

The Disaster Preparedness Information (DPI) in Hawai‘i telephone books is the most widely available source of preparedness information in Hawai‘i, but its influences on
understanding of the siren-warning system and the adoption of measures that reduce risk to property and personal safety are probably below official expectations.

The Kona project questioned the effectiveness of the DPI to facilitate widespread understanding of the siren system. Furthermore, the siren project showed that understanding of the meaning of the siren is low across the state, despite the long time period during which the siren has been explained in the DPI.

The Kona project showed that there was a low level of adoption of basic preparedness measures recommended in the DPI. Indeed, levels of preparedness may be even lower. For example, in a New Zealand volcano hazard preparedness survey, Ballantyne et al. (2000) inferred that respondents were confusing their awareness of hazard response measures in the telephone book with an understanding of the material. That is, they may know the source of relevant information but not know the information per se. This is less of a problem for hazards with a long warning time, and more significant for hazards with a short warning time. In regard to the former, two issues arise. One concerns the effect of stress on information search and action during a warning period. The other is more general and relates to the fact that over-estimating knowledge may reduce a perceived need to attend to new information and/or to prepare. Such misrepresentations and overestimations of preparedness pose challenges to surveys that attempt to measure home-based preparedness through self-report surveys, such as those described in this dissertation.
6.7 **Objective Risk and Perceived Risk**

There is often a disparity between expert and public estimations of risk. One possible explanation lies in the contrast in perspective on risk. We can term the two “objective” and “perceived risk.” Experts use objective analyses of the probability of hazard activity and its consequences to form estimates of risk for use in decisions. However, a disparity commonly exists between this procedure and the manner in which the public interprets and acts on hazard and risk information (Adams, 1995; Paton, 2003). This may severely limit the extent to which the public implements plans to reduce their risk.

Studies show that people’s understanding of risk and response to risk is determined by the interaction of psychological, social, cultural, institutional and political factors (Burns et al., 1993; Paton, 2003; Paton et al., 2003a). This is in addition to commonly maintained factors such as exposure to scientific information, direct physical contact with hazards and the extent of damage incurred. Consequently, it is crucial during risk analysis to understand how the public uses these factors to shape their risk decisions. Social-psychological processes such as risk compensation, unrealistic optimism and normalization biases and perceived responsibility for preparedness can undermine the effectiveness of risk communication messages. The failure of official risk messages to accommodate culturally sensitive issues in ways that are sympathetic to community needs may also undermine their effectiveness.

According to the risk compensation construct, people maintain a cognitive balance between risk and safety. Any activity that increases perceived safety can increase levels of risk behavior (Adams, 1995). This is because people assume that an activity designed to reduce risk from one hazard will eliminate related hazards, resulting
in a reduction in their preparedness for other hazards. Another example includes the relationship between risk acceptance and awareness and perceptions of the monitoring and warning capabilities of official agencies, such as the Hawaiian Volcano Observatory (HVO) and the Hawai‘i County Civil Defense Agency (HCDA). Awareness of these capabilities may contribute to people’s acceptance of higher levels of risk, causing them to build in unsafe areas and without adopting risk-reduction measures. People may perceive that monitoring and warning systems will be sufficient to reduce risk to acceptable levels. In other words, the very fact that HVO and HCDA monitor volcanic activity and develop mechanisms to warn the public may contribute to riskier behavior as a consequence of the operation of a risk compensation mechanism. Furthermore, like risk compensation, normalization bias and unrealistic optimism bias are also important concepts. Their presence in a population may reduce the likelihood that people respond to warning messages and react to outreach.

Considering how people perceive threats and their ability to cope with the threats requires consideration of social-cognitive and affective processes. Such processes are generally not considered in the objective calculation of risk. Objective calculations of risk are seldom all-inclusive. The calculations often exclude some factors that contribute to loss, such as loss of business or employment, some aspect of infrastructure, etc. Objective calculations of risk also seldom include consideration of the manner in which people perceive risk or how they respond to risk messages. For example, do people respond with increased stress, worry, fear, denial, cognitive dissonance, low self-efficacy, low outcome expectancy?
A final issue to consider is that changing people's perceptions of risk alone will not necessarily bring about a positive change in risk-reduction behavior. Paton (2003) modeled how people make decisions about the adoption of risk-reduction strategies as a social-cognitive process incorporating variables from numerous other risk communication studies. The model holds that people may not prepare if they do not perceive or accept their personal risk. However, irrespective of the level of perceived risk, actions may not be taken to reduce risk if people, for example:

1. Perceive that hazard effects are insurmountable (low outcome expectancy).
2. Do not perceive that they have the competence to act (low self efficacy).
3. Do not exhibit problem- or action-coping mechanisms.
4. Lack appropriate resources for implementing strategies (low response efficacy).
5. Transfer responsibility for their safety to others (low perceived responsibility).
6. Lack trust in information sources.
7. Underestimate the likely timing, magnitude and urgency of hazard events.

In summary, risk is a function of social, psychological, cultural and political processes as well as the value placed on vulnerable material objects. Risk is not absolute. This mode of thinking allows for a clear distinction to be drawn between objective measures of risk and perceptions of risk. Perceived risk can be amplified or attenuated through the operation of personal, social psychological and community factors (Kasperson et al., 1988; Pidgeon et al., 2003). This may result in interpretations that differ substantially from the objective, scientifically derived calculations of risk. Effective management of risk must include consideration of both concepts. This dissertation has highlighted a need
to move toward an integration of these modes of thinking. This includes development of models that account for both types of risk.

6.8 Cutting Through the Fog of Information

How do we get hazard-related information to all segments of the public and in a format that is acceptable, understandable, can be rendered meaningful, and facilitates risk-reduction action? These are challenges facing the outreach strategies of organizations today.

Cutting through the thick fog of daily advertisements and information that bombard our society is difficult. Advertisements solicit attention to every product imaginable, and people everywhere—on television, radio, telephone, internet—are trying to get their message and product across to the public. Hazard-related information is a small fraction of the volume of advertisements, but what information do people pay attention to and why? In what form do people prefer to receive this information? Moreover, how do data on self-reported preferences correlate with positive use of outreach material?

Research has shown that people pay attention to the information when it has a direct meaning for their livelihood (Paton, 2000). Self-reported preferences of sources of information do not always positively correlate with action taken to reduce risk, but research has shown that, while television and radio are somewhat effective, people prefer to receive information in a written form so they can refer to it as needed (Nathe et al., 1999). People also prefer information from many credible sources within community and professional networks, and in a simple, clear, consistent and attractive form (Nathe et al.,
Information is more effective in promoting risk-reduction action when it is tailored to the needs and expectations of individual communities and subgroups of these communities (Lindell, 1994). For example, information for middle-class homeowners should not be the same as that for renters (Nathe et al., 1999).

Information aimed at encouraging the adoption of risk-reduction measures has traditionally focused on providing people with accurate information about hazards and risk (Smith, 1993). However, such strategies have scarcely been successful in facilitating the adoption of mitigation and preparedness measures (Duval and Mulilus, 1999; Lindell and Whitney, 2000; Mulilis and Duval, 1995; Paton et al., 2000). This is not to say that other information is not available (Appendix A). Indeed, there is an abundance of specific recommendations for protecting personal safety and property for specific hazards. Such information is disseminated by a variety of local, state and Federal agencies and not-for-profit organizations. However, the information is scarcely if ever accompanied by research that measures the effectiveness of the information in achieving the desired result.

Notable concerns with some information found in the literature exist. For example, information about natural signs of tsunamis is inconsistent and ambiguous. There is also absence of mitigation and preparedness information specific to lava flows and information in general is seldom tailored to meet the needs of specific areas or groups of people.

The limited success of many outreach initiatives to promote high levels of risk-reduction behavior is due to a lack of consideration of cognitive processes people use to interpret information and make decisions about taking action to reduce risk. These
processes influence the relationship between beliefs about risk and the actions taken to reduce risk (Adams, 1995; Paton, 2003; Smith, 1993). Interpretive processes such as unrealistic optimism and normalization biases, cognitive dissonance, risk compensation, self-efficacy, outcome expectancy, and perceived responsibility may hinder the acceptance of information, therefore never allowing outreach a chance, even if the information initially gets through the fog. Cutting through the fog will require outreach that avoids the traditional approach of initially trying to increase hazard awareness and risk perceptions. Rather, such efforts must counteract the negative impact of interpretive processes by focusing on, for example, how the information directly benefits people’s immediate livelihood.

The continued involvement of social science in monitoring outreach requires financial support above that which would be required for the common one-time provision of information (e.g., a mail-out of information with no follow-up). There is considerable empirical research showing disconnects between hazard awareness and risk perception and risk-reduction behavior. The liability of not monitoring outreach deemed critical to prevent the loss of life and property demands that government officials should be creative about finding additional funding resources.

Funding for mitigation activities is often available after disasters occur. Therefore it is important to plan outreach strategies in advance of the financial window of opportunity following disasters. Outreach programs may then be implemented during the window of opportunity when media, public, and political attention is highest, and maintained and monitored through time to ensure objectives are being met.
6.9 Outreach and Community Preparedness

Raising community levels of mitigation, preparedness and response capabilities will require carefully planned outreach initiatives that consider the social-cognitive variables discussed here and in Paton (2003). It will also require the closer integration of outreach within a community development framework (Burby et al., 2000; Paton, 2000). Outreach must acknowledge that people differ in regard to the manner in which they may receive hazard information, how people may interpret the information and especially how they utilize it in the contexts of framing risk perceptions and whether they form intentions to seek additional information or to prepare. For lava flows and local tsunamis, this includes identifying and establishing preparedness and response strategies and strengthening perceptions related to self-efficacy and outcome expectancy. For the siren, this includes accommodating findings that people will seek to confirm and personalize risk messages such as siren soundings or evacuation messages (Mileti and O'Brien, 1992). For example, people who spend time to confirm a local tsunami warning could put themselves at increased risk. A challenge is to develop ways to allow people to confirm and personalize a warning message for hazards with short warning times. Outreach for local tsunamis should focus on developing unique messages that promote positive adaptive behavioral responses in official and natural warnings (Raine, 1995). Outreach should also provide people with an outlet to confirm distant tsunami warnings (Sorensen, 2000).

Paton’s (2003) social-cognitive model that predicts preparedness as a process suggests that, for several hazards, including lava flows, earthquakes, and tsunamis, only the formation of intentions to “undertake preparedness” measures is correlated with
preparedness. In contrast, intentions to “seek information” are not correlated. Indeed, the latter suggests that decisions to prepare and decisions not to prepare may not represent opposite ends of a continuum. Rather, they may reflect different reasoning processes (Paton et al., 2003a). Outreach efforts should, therefore, focus on strengthening variables that are linked to intentions to prepare. Sometimes this will mean foregoing initiatives aimed at increasing levels of hazard awareness and perceptions of risk, because these may already be at high levels. In contrast, outreach may need to focus on variables such as self-efficacy, outcome expectancy, sense of community, or critical awareness. Critical awareness is how much people talk or think about hazards (Paton, 2003). This reinforces the importance of members of the geological community interacting with the social community in ways that involve discussion of how hazards affect issues important to community members. Outreach initiatives and mitigation plans should focus on empowering the public to strengthen their community through gaining participation of local businesses, civic organizations, community leaders, and schools (Paton, 2000).

While not examined specifically in this dissertation, it seems worthwhile here to briefly discuss a liability issue involving the state’s provision of hazard and risk information in an area prone to rockfall hazards. Recent court rulings over liability for death and injury arising from rockslides on O‘ahu are rooted in the “quality” of information provided to warn of danger, not simply the provision of information describing hazard and risk. This may seem surprising, but it is real (Leone, 2003; State of Hawaii, 2002b). There is a need to examine the recent case-law pertaining to rockfall and the relationship of these findings to other major hazards where hazard and risk
information is provided by the state to reduce risk to property and human life (e.g., tsunami, lava flows). This seems particularly relevant to development in areas of high hazard and where there is no legal record that owners are made aware of a natural hazard or risk from the hazard.

There is a dearth of empirical support showing disconnects between hazard awareness, risk perception and preparedness. Models such as Paton (2003) illustrate the influence of numerous interpretive processes that act on decisions to undertake specific action such as to take risky actions or not to take risky actions. If governments continue to provide information aimed only at increasing awareness of hazards and risk perceptions in places where it is recognized that a threat to life and property exists, the governments will place themselves at increasingly higher levels of liability for death and injury. This is because the information provided by the government did not account for other social-cognitive influences on decision-making, which is well established in the literature.

6.10 Concluding Remarks

The findings of this dissertation provide important insights into the relationship between people and lava flow and tsunami hazards and the siren warning system. These findings improve our understanding of issues such as normalization bias, unrealistic optimism bias, perceived responsibility, cognitive dissonance, risk compensation, and the ethnic, cultural and experiential factors that contribute to risk perceptions and preparedness in the diverse and dynamic ethnic and hazard settings in Hawai‘i. These results will help to improve existing behavioral models across various hazards and for various ethnic groups.
Mitigation information needs to be finely tuned at a local scale and in ways that accommodate social-psychological and cultural diversity in Hawai‘i. Levels of preparedness need to be raised by strengthening community involvement in mitigation planning. Finally, communities need to be critically surveyed to evaluate current levels of awareness, perceptions, and preparedness prior to hazard events, and to audit change and successes of future mitigation efforts. Without redesign of the content of outreach information and how that information is disseminated, and without monitoring the outreach, the success of outreach may be overestimated and Hawai‘i may remain in some respects unprepared for major natural hazards.
APPENDIX A. SOURCES OF VOLCANO AND TSUNAMI INFORMATION

There is an abundance of hazard, mitigation, preparedness, response and recovery information available to people on the island of Hawai‘i. These sources include television and radio stations, newspapers, the internet, books, pamphlets, single page fliers (e.g., Fact Sheets), telephone books, community-based seminars, Hawai‘i Volcano National Park, museums, schools, videos and person to person contact. However, these sources are not uniformly available to everyone. This section provides a list of information sources, and the focus is on providing electronic links to information sources. I note, however, that while there is an abundance of information about lava flows, there is an absence of information related to mitigation, preparedness and response for this hazard. A concern for some sources is the inconsistency of information. Given the broad field of individuals and agencies preparing and publishing information related to hazards and disasters, it is inherent that information conflicts from time to time. However, the consistency of information is a key element in determining behavioral response to official warnings and in forming risk perceptions and maintaining public trust in officials (Mileti and O'Brien, 1992; Mileti and Sorensen, 1990; Raine, 1995). It follows, then, that there is a need to identify a methodology for the development and maintenance of hazard- and disaster-related information across various fields and agencies so that public information may be provided in an accurate and consistent manner.

Electronic information available through the internet is the most voluminous of the information sources, but most of the information is not peer-reviewed, and the quality
and accuracy of the material varies considerably. Not everyone has a computer or even access to a computer, so not everyone possesses a means to use a computer. Other limitations to people obtaining web-based information relates to people’s sense of self-efficacy with operating computers and navigating the web, their knowledge of where to search for information, and the limitations of their computer hardware, software and connection speeds. Many people are simply intimidated by computers and therefore unable to take advantage of what the internet offers in terms of information.

Notwithstanding, the internet is a medium through which people will continue to search for and receive hazard related information. For example, about 10 years ago a study of tsunami risk perception on O‘ahu (Raine, 1995) found that the internet was not identified as a source of tsunami information by survey respondents. In contrast, by 2001 the internet had exploded in growth. A survey in Kona found that 31% of respondents identified the internet as a preferred source of information about volcanic hazards on the island of Hawai‘i (Gregg et al., 2004a, Chapt. 2). Direct comparison of these two different findings should be treated cautiously, because the early respondents had only an opportunity to write in responses for the internet, whereas the latter respondents were allowed to select internet from a list of other sources of information. Also, the more recent survey respondents may have selected sources with which they were familiar, rather than where they actually preferred to receive information. Interestingly, in both studies, radio and television were the sources still favored by a majority. So while the internet provides a wealth of opportunity and promises of more information, the radio and particularly television appear to still be the most popular resources. There are problems with this, because studies have shown that the media bias reporting information about
natural hazards and disasters (Raine, 1995). For example, Raine (1995) concluded that, from a review of 633 newspaper articles published in the Honolulu Advertiser between 1929 and 1994, the media focused on tsunamis immediately after tsunami events with an emphasis on providing morbidity and mortality statistics, whereas few articles devoted attention to exploring positive adaptive behavioral responses that residents could take to protect their health and safety. A need exists for this and similar information to be provided to the public in an effective manner.

Another concern involves the provision of hazard-related information to the public relative to increasing amounts of other advertisements from numerous sources. According to Martin Schiller of the Schiller Advertising Group in Honolulu, “It is very hard to get through the fog. People are bombarded daily with hundreds of messages from people and companies trying to get their message across.” This underscores the need for social science monitoring of outreach efforts aimed at increasing community resilience.

Below I provide links that emphasize volcanic and tsunami hazards in Hawai‘i, including issues relating to mitigation, preparedness, response and recovery.

**Sources of Volcanic Information**

**US Geological Survey**

The US Geological Survey, Hawaiian Volcano Observatory (USGS, HVO) is the key source of online information about volcanic hazards in Hawai‘i. The information is methodical and frequently updated. Volcanic information produced by USGS is kept together in the following lists of information sources so that it may be easily reviewed.

• Volcanic and Seismic Hazards on the Island of Hawai‘i. This reference also covers tsunamis. See http://pubs.usgs.gov/gip/hazards/contents.html and http://hvo.wr.usgs.gov/hazards/
• Methane gas explosions, http://volcanoes.usgs.gov/Products/Pglossary/methane.html
• Real time volcanic gas (vog) data at Hawai‘i Volcanoes National Park, http://www2.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.htm
• Fact Sheets
• Ocean entries (i.e., where lava enters into the ocean), http://hvo.wr.usgs.gov/hazards/oceanentry/main.html
• Collapse of land into the ocean at active lava ocean entries, http://hvo.wr.usgs.gov/hazards/oceanentry/deltacollapse/
• Explosions of lava and steam at active lava ocean entries, http://hvo.wr.usgs.gov/hazards/oceanentry/deltaexplosions/
• Waves of superheated water (30 - 69°C) at active lava ocean entries, http://hvo.wr.usgs.gov/howwork/entrytemp/rnain.html
• “Volcano Watch” is a weekly USGS article published in the Hilo-Tribune Herald’s Sunday newspaper and West Hawai‘i Today’s Monday newspaper. Articles usually relate to volcanic and seismic concerns on the Island of Hawai‘i, http://hvo.wr.usgs.gov/volcanowatch/
• Kilauea- general information, http://hvo.wr.usgs.gov/kilauea/

  - overview and summaries of hazards, http://hvo.wr.usgs.gov/maunaloa/hazards/main.html,
  - Mauna Loa- table of historical eruptions (start date, duration, location, area, volume), http://hvo.wr.usgs.gov/maunaloa/history/historytable.html
  - Mauna Loa- account of the last eruption in Kona (i.e., 1950), http://hvo.wr.usgs.gov/maunaloa/history/50_06_01/
  - Mauna Loa- account of the most recent eruption (i.e., in 1984), http://hvo.wr.usgs.gov/maunaloa/history/1984.html


Other

• The American Red Cross, http://www.redcross.org/services/disaster/0,1082,0,593,00.html
• Hawaiʻi Coastal Zone Management Program, http://www.hawaii.gov/dbedt/czm/
• Visitor safety information for Hawaiʻi Volcanoes National Park, http://www.nps.gov/havo/visitor/lava.htm#fumes
• FEMA Fact Sheet on volcanoes, http://www.fema.gov/hazards/volcanoes/volcanof.shtml
• Mothemature-hawaii.com (contains mitigation planning and preparedness and links to state and county mitigation plans), http://www.mothemature-hawaii.com/county_hawaii/volcano_hawaii.htm
• Hawaiʻi County Hazard Mitigation Plan (Interim plan), http://www.mothemature-hawaii.com/county_hawaii/planning.htm
• University of Hawaiʻi at Hilo, Center for the Study of Active Volcanoes, http://www.uhh.hawaii.edu/~csav/nathaz/
• The American Red Cross, http://www.redcross.org/services/disaster/0,1082,0,593,00.html
Sources of Tsunami Information

- NOAA, Pacific Tsunami Warning Center, http://www.prh.noaa.gov/ptwc/
  - FAQs, http://wcatwc.arh.noaa.gov/frequently.htm
  - TsunamiReady information http://wcatwc.gov/tsunamiready/tready.htm
- USGS tsunami and earthquake information, http://walrus.wr.usgs.gov/tsunami/
- The American Red Cross, http://www.redcross.org/services/disaster/0,1082,0_592_,00.html
- The National Tsunami Hazard Mitigation Program, http://www.pmel.noaa.gov/tsunami-hazard/

Sources of Emergency Management Information

- Hawai‘i State Civil Defense (HSCD), http://www.scd.state.hi.us/
  - Preparedness, response and recovery information from HSCD, http://www.scd.state.hi.us/links.html#preparedness
- Pacific Disaster Center (contains background hazard information and links to FEMA and other preparedness sites), http://www.pdc.org/hazard_info.php
  - Three key steps that individuals and families should take to be properly prepared for unexpected emergencies, http://www.dhs.gov/dhspublic/display?theme=14&content=462
Non-electronic Sources of Volcano and Tsunami Information

- UH Hilo, Center for the Study of Active Volcanoes provides a variety of community-based services. These include:
  - Visiting schools to teach about earthquakes and tsunamis (4th grade), volcanic hazards (6th grade), and hurricanes and floods (8th grade).
  - Public seminars held biannually at the UH Hilo campus
  - Seminars located in specific communities (i.e., at Community Associations)
  - Teacher -training workshops
  - Hazard mitigation videos have been produced and are available to the public
- The National Park Service offers an After Dark in the Park seminar that sometimes covers hazard-related topics, http://www.nps.gov/havo/afterdark/adip.htm
- The Keakealani Outdoor Education Center in Volcano Village is a state funded program aimed at teaching students environmental stewardship and about natural hazards, http://www.k12.hi.us/~kau/Spirit/2007/koec.html
- The Hawai‘i Thoracic Society and the American Lung Association produce information brochures on volcanic gases and how to mitigate their adverse effects
- The Jaggar Museum at the HVO has displays about volcanic and seismic hazards
- Hawai‘i Volcanoes National Park Visitor Center has displays about volcanic and seismic hazards
APPENDIX B. SURVEY DESIGN, IMPLEMENTATION AND ANALYSES

Design of Surveys
In each of the surveys, except for that at Kapoho, data were desirable from students and their parents or guardians in order to contrast awareness, perceptions and the exchange of information between the two age groups. Hazard educational outreach often focuses on providing school-aged children with information, apparently due to several reasons. For example, large numbers of students can be reached in classroom settings easier than large numbers of adults can be organized. Public seminars that target adults may be biased and therefore would not well represent the adult public at large.

There is a presumption that students will take information learned at school and disseminate this to their parents or guardians and from there to other families, neighbors, or friends and so on (Ronan and Johnston, 2001). This idea suggests that information taught at school trickles into the community, but little to no empirical data support this presumption (Ronan and Johnston, 2001). Also, it is expected that teaching young people about natural hazards, mitigation and preparedness issues instills in them a sense of knowledge and responsibility from which wise risk-reduction decisions may be better made in their adulthood.

In order to evaluate the relative awareness and perceptions of hazard-related issues between students and their parents or guardians, data were collected, using survey questionnaires, from middle or high school students (8th and 9th grade) and one of their parents or guardians. The Kona project also involved the collection of survey data from
the adult public at large (through the distribution of questionnaires to post office box holders) in order to obtain a better cross section of the overall adult population in Kona. This scheme would allow me to better generalize the findings across the general population in Kona. The survey questionnaire was developed from Ronan and Johnston (2001).

For purposes of determining preparedness in homes, the information collected from adults was most desirable, because adults rather than students will presumably be the initiator of mitigation and preparedness measures in a home. An additional incentive for collecting information from students was that students may be readily relocated for a resurvey if there are major changes in outreach content or exposure to hazard events.

Implementation

The Kona and siren and tsunami projects

A package of survey material was organized, distributed to students and then provided to a parent or guardian of each student. The package contained three items, 1) a cover letter that explained the nature and purpose of the study, 2) a consent form that a parent or guardian was asked to sign if they would allow their child to participate in the study, and 3) a questionnaire to be completed by a parent or guardian. Parents or guardians who completed their questionnaire at home were asked to return the questionnaire to the school for collection. If the parent or guardian of a student approved of their child’s participation in the survey, they were required to sign and return to the school an executed consent form. The student was then allowed to be included in the study.
Surveys of the students were conducted in classroom settings. In the Kona project, I conducted the survey at Konawaena High School, but faculty at Kealakehe High School conducted the survey there. In each case, a procedure was followed to ensure that surveys were conducted in a similar manner. For example, students were initially informed that the survey was being done to collect information about their environment in an effort to help their community. Students were then told that their participation was voluntary and that they did not have to participate. All students were required to sign an assent form before beginning the survey. Each survey required 20 to 40 minutes to complete. Surveys were followed by a discussion and answer session when time permitted.

The samples of students and parents or guardians of the students were biased, because the sampling design excluded people from the Kona population who did not have a ninth grade student attending a public school in Kona. Furthermore, I had no control over which parent or guardian (i.e., male or female) completed the survey at home. Thus, other biases could have been introduced (i.e., the prevalence of female householders to complete questionnaires as opposed to males). In order to be able to better generalize survey findings across the entire adult population in Kona, I attempted to obtain a random sample from adults through random mailing of survey questionnaires to post office box holders. Nearly everyone has a post office box in Kona, because the delivery of mail by postal routes is very limited. This provided an opportunity to randomly select participants, but low return rates limit how well the data can be generalized. Appendix C and D discusses the limitations of the use of the data.
Survey questionnaires were disseminated only to students (8th grade) and one of either their parents or guardians in the siren and tsunami project. This was in part due to a desire to focus on the relationship of student and parent/guardian awareness and perceptions and in part on a lack of funding to support a random sample of the adult population at large. The data from this project are also biased, because of the reasons provided for the Kona project and because no random sample of the adult population was obtained. However, the higher number of respondents in this study helps to alleviate this concern.

Selection of survey locations for the siren/tsunami project
The design of this study centered on a need to collect data across a broad range of natural hazards and from areas across the state. The selection of target hazards and communities was based on factors such as geographic dispersal, the frequency and magnitude of the prevailing hazard in the area, historical damage in the community in terms of damage to buildings and loss of life, the time that has elapsed since the last damaging event, and on the population size. In general, the surveys were conducted in communities that had been impacted by a specific hazard since 1960 and where the hazard still poses a threat to people or development, or both. In this sense, it was assumed that, where there was a relatively recent hazard event with a large magnitude in a community, people should be familiar with the hazard. The surveyed communities, school names and targeted hazards are shown below, along with a brief description of why the hazard was targeted for that community. A map showing the survey locations is provided in Chapter 5 (Fig. 5.1).

1 Island of Hawai‘i, Hilo, Hilo Intermediate School, tsunamis. Tsunamis have been more damaging in Hilo than in any other area in Hawai‘i, although the last big
event was in 1960 (Dudley and Lee, 1998; Fletcher et al., 2002a). Some people
surveyed reside in tsunami inundation zones in Hilo. Hilo is the largest city on
the island.

2 Island of Hawai‘i, Pāhoa, Pāhoa Intermediate School, lava flows. Pāhoa is the
largest city on the east rift zone of Kīlauea. The school is zoned for much of the
developed areas at risk to eruptions of the lower east rift zone of Kīlauea,
including the current eruption.

3 Maui, Kahului, Konawaena Middle School, stream flooding. Floods are a
frequent problem from Iao Stream in the Wailuku-Kahului area of Maui, which is
the major population center on the island (Fletcher et al., 2002b);

4 O‘ahu, southeast portion of the island, Niu Valley Middle School, severe storms.
Severe storms were targeted in southeast O‘ahu because they impact the heavily
populated area relatively frequently (Fletcher et al., 2002b; Martin and Chock
Inc., 2003). The area is a relatively densely populated suburb of Honolulu.

5 O‘ahu, northeast portion of the island, Kahuku Middle School, high surf and
tsunamis. High surf is a frequent hazard in the north shore area of O‘ahu, and
tsunamis have also impacted the area (Fletcher et al., 2002a; Martin and Chock
Inc., 2003). The study area is relatively rural compared to southeast O‘ahu.

6 Kaua‘i, southeast portion of Kaua‘i, Kamakahelei Middle School, hurricanes.
Hurricane Iniki caused extensive damage across all areas of Kaua‘i in 1992 (see
Chapt. 1, Table 1.1). Particularly hard hit was the area zoned by Kamakahelei
Middle School, which includes portions of Līhu‘e, the largest city on the island.
The Kapoho project

Observations of the behavior of the evacuees from Kapoho were made by Roy Lachman and William J. Bonk, the original researchers in the study, throughout the duration of the eruption. A questionnaire interview was promptly prepared by Lachman and Bonk when the eruption began. The questionnaire was translated into six languages (i.e., local pidgin English, Japanese, Korean, and three Filipino dialects). The questionnaire interviews began being administered to adult evacuees of Kapoho the day after the eruption began. Time did not permit a pre-test of the questionnaire. All but one of the adult evacuees from Kapoho was interviewed (R. Lachman, pers. comm, 2003). Lachman, Bonk and their students from the University of Hawai‘i at Hilo conducted the interviews. Interviews were also administered to people in three communities located at increasing distance from the site of the eruption. The communities included an Army Reserve Camp in nearby Hilo, and the communities of Pā‘auhau (near modern-day Honoka‘a) and in Waimea (Chapt. 4, Fig. 4.1). The data were collected over a four month period.

Analyses

All data collected in this dissertation were numerically coded and entered into the
Statistical Package for the Social Sciences (SPSS®). After the data files were cleaned,
frequency counts and descriptive statistical analyses were performed. Cross-tabulations
were performed on dependent and independent variables and by layers. Chi-square
analysis was used to test for statistical significance.
### APPENDIX C. DEMOGRAPHICS OF THE KONA SAMPLE

Comparison of the Kona sample to the Kona public and County of Hawai‘i

<table>
<thead>
<tr>
<th></th>
<th>Kona Sample</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South Kona</td>
<td>North Kona</td>
<td>Adult-at-Large</td>
<td>Sample Total</td>
<td>South Kona</td>
<td>North Kona</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td><strong>Race and Ethnicity</strong> a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>20.4</td>
<td>36.0</td>
<td>48.4</td>
<td>32.8</td>
<td>34.1</td>
<td>47.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>12.9</td>
<td>15.4</td>
<td>12.5</td>
<td>14.2</td>
<td>24.1</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific Islander *</td>
<td>48.3</td>
<td>28.4</td>
<td>25.0</td>
<td>34.2</td>
<td>20.5</td>
<td>16.6</td>
</tr>
<tr>
<td>Other</td>
<td>7.5</td>
<td>10.0</td>
<td>12.5</td>
<td>9.6</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Two or more **</td>
<td>10.9</td>
<td>10.2</td>
<td>1.6</td>
<td>9.2</td>
<td>18.9</td>
<td>17.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Tenure (adults)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own home</td>
<td>70.7</td>
<td>55.4</td>
<td>50.8</td>
<td>59.0</td>
<td>62.2</td>
<td>58.5</td>
</tr>
<tr>
<td>Rent</td>
<td>29.3</td>
<td>44.6</td>
<td>49.2</td>
<td>41.0</td>
<td>37.8</td>
<td>41.5</td>
</tr>
<tr>
<td><strong>Median Age</strong> ***</td>
<td>44</td>
<td>43</td>
<td>48</td>
<td>45</td>
<td>41.2</td>
<td>39.4</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23.8</td>
<td>25.0</td>
<td>46.9</td>
<td>31.1</td>
<td>50.4</td>
<td>50.3</td>
</tr>
<tr>
<td>Female</td>
<td>76.2</td>
<td>75.0</td>
<td>53.1</td>
<td>68.9</td>
<td>49.6</td>
<td>49.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

= Race alone, except for Hawaiians, part-Hawaiians and Pacific Islanders. County data refers to County of Hawai‘i (source = U. S. Census Bureau, 2000a). * Includes Hawaiian, part-Hawaiian, or other Pacific Islander. ** Includes Hawaiians, part-Hawaiians and Pacific Islanders and any other race. *** Includes adults only. Median age of county is biased and low because it includes all ages. Mean age of sample is biased because it includes only adults only. Median age of students was 15 years.

The table above shows some basic demographic data of the Kona survey sample in comparison to the Districts of North and South Kona and the County of Hawai‘i. The Kona sample included ninth grade students and their parents or guardians and an adult-at-large sub-sample. The latter was randomly drawn from post office box holders in Kona, but it is biased because of return rate was low (10%). Our overall Kona sample was
therefore not drawn from a random sample of the Kona population. Nonetheless, the table above indicates that the ethnic data of our Kona Sample match the Kona-Public data reasonably well. The percent of Caucasians and Asians is underrepresented by 8% and 6% while the percent of Pacific Islanders is over represented by about 16%. Those claiming other ethnicities were a mixture of several ethnicities, but Portuguese and Spanish comprised several percent of the total (Appendix D).

Larger surveys with greater case numbers drawn randomly from the general population of students and adults would be needed to generalize across the general population in Kona.
APPENDIX D. GENERALIZABILITY OF ETHNIC DATA

Comparisons of the Kona and tsunami/siren project ethnic data with Census 2000 data may be misrepresentative because questions regarding race and ethnicity in the 2000 Census study differed from previous censuses. People were allowed to select more than one race in the Census 2000, and ethnicity was determined by the race of the father and the mother (this means four possible answers—up to two each). However, in the 1980 and 1990 census tabulations, a person's ethnicity was determined by self-identification (the way I measured ethnicity) or by the race of the mother, thus mixed race was not a separate category because people could only select one race (County of Hawaii, 2000; U. S. Census Bureau, 2000a). Therefore ethnicity as shown in these projects is based on self-identification whereas ethnicity in the census would be tabulated by race of a person's mother and father.
Dear Parent or Guardian:

The University of Hawai‘i at Manoa and the US Geological Survey are jointly conducting a study of community attitudes and beliefs toward lava flows in Kona. The findings of this study will be used to help communities in Kona to become more effectively involved in the well being of Kona. You and your child have been selected from other households in Kona to participate in this study.

We seek you and your child’s attention to questions in two attached questionnaires, marked Parent/Guardian Questionnaire and Student Questionnaire. The questionnaires are similar, but not identical. In your household, the adult who should complete the Parent/Guardian Questionnaire is the parent or guardian who most recently had a birthday. This should take about 20 minutes. We have enclosed the Student Questionnaire for your review; however, your child should complete this questionnaire during her/his school class. All replies will be confidential. We will only report on general trends and will not disclose you or your child’s name.

Also attached are two consent forms for you to sign. Please read and sign both forms. After you have completed the Parent/Guardian Questionnaire, place it, the blank Student Questionnaire, and one copy of the signed consent forms in the enclosed envelope and have your child return it promptly to the appropriate teacher. Keep one copy of each consent forms for your records. Your child cannot participate in the survey unless they return a signed Parent/Guardian Consent Form to their teacher. We cannot use your completed questionnaire unless you return a signed Adult Consent Form.
We hope you participate in the survey. If you have additional information that you would like to share with us, please feel free to contact us.

Sincerely,

Chris E. Gregg
Geologist

Attachments: Parent/Guardian Consent Form (2 copies),
Adult Consent Form (2 copies)
Two Questionnaires (Parent/Guardian and Student)
Dear Kona Resident:

The University of Hawai‘i at Manoa and the US Geological Survey are jointly conducting a study of community attitudes and beliefs toward lava flows in Kona. The findings of this study will be used to help communities in Kona to become more effectively involved in the well being of Kona. Your household has been selected from other households in Kona to participate in this study.

We seek your attention to questions presented in an enclosed questionnaire. The strength of our study and the accuracy of our findings depend largely on the attention that you give to the questions. To better understand the range of community opinions, we seek to obtain responses from men and women of different ages. In your household, the person who should complete the questionnaire is the adult (age 18 or older) who most recently had a birthday. The questionnaire takes about 20 minutes to complete. All replies will be confidential. We will only report on general trends and will not disclose your name.

Please read and sign the attached Consent Form and keep one copy for your records. After you have finished, please place the completed questionnaire and the consent form in the enclosed postage-paid envelope and drop it in a mailbox.
We look forward to hearing from you. If you have additional information that you would like to share with us, please feel free to contact us.

Kind Regards,

Chris E. Gregg,

Attachments: Questionnaire, Consent form (2 copies)
APPENDIX E3. Kona parent, guardian and adult-at-large consent form

AGREEMENT TO PARTICPATE IN

Lava Flow Hazards in Kona

(Title of Project)

Chris E. Gregg, Geology and Geophysics, POST 710A, University of Hawai‘i at Manoa, 1680 East-West Road, Honolulu, 96822, Phone 808-956-7897, Fax 956-5512

(Principal Investigator’s name, address, and phone and fax number)

Certifications

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to inquiries that I may have made concerning project procedures and other matters and that I have been advised that I am free to withdraw my assent and to discontinue participation in the project or activity at any time without prejudice.

I herewith give my consent to participate in this project with the understanding that such assent does not waive any of my legal rights, nor does it release the Principal Investigator or the institution or any employee or agent thereof from liability for negligence.

Signature

(Name of participant, print)

(Signature of participant)

Date ______________________________________

(If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, write to: Committee on Human Studies, University of Hawaii, 2450 Maile Way, Honolulu, HI 96822. Phone: (808) 956-5007. Please reference the above listed project title and the Principal Investigator’s name.)
APPENDIX E4. Kona parent or guardian consent form for students

AGREEMENT TO PARTICPATE IN

Lava Flow Hazards in Kona

(Title of Project)

Chris E. Gregg, Geology and Geophysics, POST 710A, University of Hawai‘i at Manoa, 1680 East-West Road, Honolulu, 96822, Phone 808-956-7897, Fax 956-5512

(Principal Investigator's name, address, and phone and fax number)

Certifications

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to inquiries that I may have made concerning project procedures and other matters and that I have been advised that I am free to withdraw my child’s assent and to discontinue their participation in the project or activity at any time without prejudice.

I herewith give my consent for my child to participate in this project with the understanding that such assent does not waive any of my or my child’s legal rights, nor does it release the Principal Investigator or the institution or any employee or agent thereof from liability for negligence.

Signature

__________________________________________
(Name of student, print)

__________________________________________
(Name of parent/guardian, print)

__________________________________________
(Signature of parent/guardian)

Date ________________________________

(If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, write to: Committee on Human Studies, University of Hawaii, 2450 Maile Way, Honolulu, HI 96822. Phone: (808) 956-5007. Please reference the above listed project title and the Principal Investigator’s name.)
APPENDIX E5. Kona student assent form

AGREEMENT TO PARTICPATE IN

Lava Flow Hazards in Kona

(Title of Project)

Chris E. Gregg, Geology and Geophysics, POST 710A, University of Hawai‘i at Manoa, 1680

East-West Road, Honolulu, 96822, Phone 808-956-7897, Fax 956-5512

(Principal Investigator’s name, address, and phone and fax number)

Certifications

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to inquiries that I may have made concerning project procedures and other matters and that I have been advised that I am free to withdraw my assent and to discontinue participation in the project or activity at any time without prejudice.

I herewith give my assent to participate in this project with the understanding that such assent does not waive any of my legal rights, nor does it release the Principal Investigator or the institution or any employee or agent thereof from liability for negligence.

Signatures

(Name of student, print)

(Signature of student)

Date _______________________

(If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, write to: Committee on Human Studies, University of Hawaii, 2450 Maile Way, Honolulu, HI 96822. Phone: (808) 956-5007. Please reference the above listed project title and the Principal Investigator’s name.)

cc: Signed copy to participant
APPENDIX E6. Kona lava flow questionnaire

Directions: Please fill in the background information below and then answer the following 50 questions. Some of the questions contain more than one question. Answers to the questions have numbers beside them and in some places there are boxes to check. To indicate your answer, please circle the number or check the appropriate box beside your answer. SELECT ONLY ONE ANSWER FOR EACH QUESTION UNLESS REQUESTED TO CIRCLE OR CHECK MORE.

Name: ______________________________
Gender: ____ Male ____ Female.
Age: __________ City: ______________________________

Which best describes your ethnic or cultural identity?
- Part-Hawaiian
- Filipino
- Hawaiian
- Pacific Islander
- Spanish

White
Japanese
Hispanic (of any Hispanic origin)
Portuguese
Other (please specify) ______________

1. Thinking about the chances of property damage and loss of life or injuries, which are the two most likely hazards that could affect you at home?
   1. Flood
   7. Severe storm (high winds and lightning)
   2. Lava flow
   8. Earthquake
   3. Large sea wave (tsunami)
   9. Chemical spill or gas leak
   4. Volcanic ash fall
   10. Landslide
   5. Wild Fire
   11. Hurricane
   6. Vog

2. Thinking about the chances of property damage and loss of life or injuries, which are the two most likely hazards that could affect you at work?
   1. Flood
   7. Severe storm (high winds and lightning)
   2. Lava flow
   8. Earthquake
   3. Large sea wave (tsunami)
   9. Chemical spill or gas leak
   4. Volcanic ash fall
   10. Landslide
   5. Wild Fire
   11. Hurricane
   6. Vog
   12. Violent incident at work

3. When do you think the next hazard events (in bold) are likely to affect your community?

<table>
<thead>
<tr>
<th>Flood</th>
<th>Severe Storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 within the next year</td>
<td>1 within the next year</td>
</tr>
<tr>
<td>2 within the next 10 years</td>
<td>2 within the next 10 years</td>
</tr>
<tr>
<td>3 within my lifetime</td>
<td>3 within my lifetime</td>
</tr>
<tr>
<td>4 not within my lifetime</td>
<td>4 not within my lifetime</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lava Flow</th>
<th>Earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 within the next year</td>
<td>1 within the next year</td>
</tr>
<tr>
<td>2 within the next 10 years</td>
<td>2 within the next 10 years</td>
</tr>
<tr>
<td>3 within my lifetime</td>
<td>3 within my lifetime</td>
</tr>
<tr>
<td>4 not within my lifetime</td>
<td>4 not within my lifetime</td>
</tr>
</tbody>
</table>
4. Should one of these hazard events occur in the future, how likely is it that it could injure you?

<table>
<thead>
<tr>
<th>Event</th>
<th>Likelihood</th>
<th>Event</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical spill or gas leak</td>
<td>Likely</td>
<td>Volcanic ash fall</td>
<td>Likely</td>
</tr>
<tr>
<td>1 within the next year</td>
<td></td>
<td>1 within the next 10 years</td>
<td></td>
</tr>
<tr>
<td>2 within the next 10 years</td>
<td></td>
<td>3 within my lifetime</td>
<td></td>
</tr>
<tr>
<td>3 not within my lifetime</td>
<td></td>
<td>4 not within my lifetime</td>
<td></td>
</tr>
<tr>
<td>Landslide</td>
<td>Likely</td>
<td>Violent incident at work</td>
<td>Likely</td>
</tr>
<tr>
<td>1 within the next year</td>
<td></td>
<td>1 within the next 10 years</td>
<td></td>
</tr>
<tr>
<td>2 within the next 10 years</td>
<td></td>
<td>3 within my lifetime</td>
<td></td>
</tr>
<tr>
<td>3 not within my lifetime</td>
<td></td>
<td>4 not within my lifetime</td>
<td></td>
</tr>
<tr>
<td>Wild Fire</td>
<td>Likely</td>
<td>Hurricane</td>
<td>Likely</td>
</tr>
<tr>
<td>1 within the next year</td>
<td></td>
<td>1 within the next 10 years</td>
<td></td>
</tr>
<tr>
<td>2 within the next 10 years</td>
<td></td>
<td>3 within my lifetime</td>
<td></td>
</tr>
<tr>
<td>3 not within my lifetime</td>
<td></td>
<td>4 not within my lifetime</td>
<td></td>
</tr>
<tr>
<td>Large sea wave (tsunami)</td>
<td>Likely</td>
<td>Vog</td>
<td>Likely</td>
</tr>
<tr>
<td>1 within the next year</td>
<td></td>
<td>1 within the next 10 years</td>
<td></td>
</tr>
<tr>
<td>2 within the next 10 years</td>
<td></td>
<td>3 within my lifetime</td>
<td></td>
</tr>
<tr>
<td>3 not within my lifetime</td>
<td></td>
<td>4 not within my lifetime</td>
<td></td>
</tr>
</tbody>
</table>
5. A. Have you ever been involved in an education program that informed you about the types of hazards discussed so far? 1. Yes 2. No

B. If Yes, where? **Circle all that apply.**
1. At school
2. Hawai‘i Volcanoes National Park
3. Can't Remember
4. College
5. Other (Please specify) ___________

C. If yes, who taught the program: **Circle all that apply.**
1. School Teacher
2. FEMA (Federal Emergency Management Agency)
3. Civil Defense
4. UH-Hilo, Center for the Study of Active Volcanism
5. US Geological Survey, Hawaiian Volcano Observatory
6. Other (Please specify) ___________________

6. Which hazards did you study or discuss when you were in school? **Circle all that apply.**
1. Flood
2. Lava flow
3. Large sea wave (tsunami)
4. Volcanic ash fall
5. Wild Fire
6. Vog
7. Severe storm (high winds and lightning)
8. Earthquake
9. Chemical spill or gas leak
10. Landslide
11. Hurricane
12. Violent incident in school

7. A. Have you ever had your neighborhood damaged by any of the hazards mentioned so far? 1 Yes 2 No

B. If yes, which hazard(s) and when: ________________________________

8. Which hazard(s) scare or upset you? **Circle all that apply.**
1. Flood
2. Lava flow
3. Large sea wave (tsunami)
4. Volcanic ash fall
5. Wild Fire
6. Vog
7. Severe storm (high winds and lightning)
8. Earthquake
9. Chemical spill or gas leak
10. Landslide
11. Hurricane
12. Violent incident at work

9. If an emergency happened, some kids and adults get upset. That is normal. If you got upset, who do you feel would be able to help you feel less upset? **Circle all that apply.**
1. Yourself
2. Your family
3. Your other relatives
4. Your work
5. Your Friend’s

10. Which two volcanoes are closest to your home? **Circle two.**
1. Kilauea
2. Mauna Kea
3. Mauna Loa
4. Hualalai
5. Kohala
11. Which volcanoes do you think could erupt again? **Circle all that apply.**
   1. Mauna Loa
   2. Kohala
   3. Mauna Kea
   4. Hualalai
   5. Kilauea
   6. None will erupt again

12. **A.** Have you ever seen a volcano erupt?  
   1. Yes  
   2. No  

   **B.** If yes:  
   1. On TV  
   2. Live  

   **C.** If yes, what was erupted?  
   1. Ash  
   2. Lava Flows

13. What would you do if a lava flow threatened you in your home? **Circle all that apply.**
   1. Immediately go out and take a close-up look at the lava
   2. Listen to the radio or television for instructions from local authorities
   3. Remove my most valuable possessions from my home
   4. Move to higher ground in order to avoid the flow
   5. Contact authorities for information
   6. Other (please specify) ____________________

14. Which volcano on the Big Island has been erupting almost continuously since about 1983?  
   1. Kilauea  
   2. Mauna Kea  
   3. Mauna Loa  
   4. Kohala  
   5. Hualalai

15. In a future eruption, how quickly could a lava flow reach the ocean in Kona?  
   1. Three days  
   2. Twelve hours  
   3. One month  
   4. Three hours or less

16. Which of the following things would you do during an earthquake if you were inside your home? **Circle all that apply.**
   1. Run outside
   2. Stay inside
   3. Take cover under a table, desk, bench or by a wall
   4. Listen to the radio or television for instructions from local authorities
   5. Contact authorities for information

17. What would you do in the event of a tsunami (large sea wave) warning if you were at home? **Circle all that apply.**
   1. Stay inside
   2. Go outside and take cover
   3. Listen and react to information from local authorities
   4. Go about 1/2 mile inland or to a place at least 100 feet above sea level
   5. Go to the ocean and watch for the sea wave to come in
   6. Contact authorities for information
18. Have you ever discussed any of the following hazards with your child?
   1. Flood  1 Yes  0 No
   2. Lava Flow  1 Yes  0 No
   3. Large sea wave (tsunami)  1 Yes  0 No
   4. Volcanic ash fall  1 Yes  0 No
   5. Wild Fire  1 Yes  0 No
   6. Vog  1 Yes  0 No
   7. Severe Storm  1 Yes  0 No
   8. Earthquake  1 Yes  0 No
   9. Chemical spill or gas leak  1 Yes  0 No
  10. Landslide  1 Yes  0 No
  11. Hurricane  1 Yes  0 No
  12. Violent incident in school  1 Yes  0 No

19. Does talking about these hazards upset your child?  
   1. Yes  2. Not sure  3. No

20. If you talked about any of these hazards, did you bring it up or did your child?  
   1. I did  2. My child

21. Do you encourage your child to talk to you about emergencies or hazards?  
   1. Yes  2. No

22. Do you explain new information on disaster preparedness to your child?  
   1. Yes  2. No

23. If yes, did your child want to discuss how to be prepared for hazard events?  
   1. Yes  2. No

24. Does your family have an emergency plan of action that tells you how to act during an 
    emergency, such as the coming of a lava flow, hurricane or earthquake?  
   1. Yes  2. No

25. A. Have you ever practiced what to do during an emergency:  
    At home?  1. Yes  2. No
    At work?  1. Yes  2. No

   B. Has your family practiced together what to do if there is an emergency?  
    1. Yes  2. No

26. A. In an emergency and if everyone can't be at home, do you know where you would 
    meet your family or leave a message?  1. Yes  2. Not sure  3. No

   B. If yes, where? ____________________________

27. How much did your family prepare for the Y2K problem before the New Year (2000)?  
28. Has your family done any of the following to prepare for a hazard or emergency? Circle all that apply.

1. Have a flashlight
2. Protect breakable household items
3. Put strong latches on cabinet doors
4. Store hazardous materials safely
5. Add "lips" to shelves to keep things from sliding off
6. Strap water heater
7. Install flexible tubing to gas appliances
8. Bolt house to foundation
9. Stockpile water and food for three days
10. Have a portable radio and spare batteries
11. Have a fire extinguisher
12. Have a smoke detector
13. Have a first aid kit
14. Store wrench near gas turn-off valve
15. Pick an emergency contact person in another town
16. Someone in family has learned how to put out fires
17. Buy additional insurance (e.g., home)
18. Someone in family has learned to provide first aid
19. Find out if you are in an area particularly vulnerable to a natural or other kind of hazard (e.g., earthquake, lava flow, flood, chemical spill)
20. Have home inspected for preparedness
21. Have a plan (map) showing exits at your house, and where to turn off water, electricity, and gas.

29. Which two volcanoes do you think are most likely to erupt next?
1. Mauna Loa
2. Hualalai
3. Mauna Kea
4. Kohala

30. Earthquakes in Kona cause volcanic eruptions 1 True 2 False

31. Where would you prefer to look for information about future volcanic activity on the island of Hawai‘i?
1. TV and radio
2. Internet
3. Police and Fire Departments
4. Hawaiian Volcano Observatory (website)
5. Your local library
6. School
7. Civil Defense
8. Telephone Book
32. How prepared do you believe the following people and groups of people are for a damaging earthquake?

<table>
<thead>
<tr>
<th></th>
<th>Very prepared</th>
<th>Somewhat prepared</th>
<th>Not very prepared</th>
<th>Not at all prepared</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>You</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Your family</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Your community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Civil Defense</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Fire &amp; Police Departments</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

33. Hualalai is a little known active volcano. When was the last time it erupted?
1. About 500 years ago
2. About 20 years ago
3. About 200 years ago
4. Don’t know

34. When was the last time lava from Mauna Loa flowed into the ocean in Kona?
1. About 500 years ago
2. About 20 years ago
3. About 50 years ago
4. Don’t know

35. Who should be responsible for preparing the community for future volcanic eruptions? 
   Circle all that apply.
1. Civil Defense
2. Police and Fire Departments
3. Hawaiian Volcano Observatory, US Geological Survey
4. Every individual in the community.

36. Which of the following is true with regard to your family? Circle all that apply.
1. Rent a home in Kona
2. Own a home in Kona
3. Own a second home in a town other than my primary home
4. Own land in another town
5. Own a business
6. Other (please specify) ____________________________

37. Who or what controls whether or not a Hawaiian volcano erupts?
1. Pele
2. Pressure beneath each volcano
3. Just “chance.” Meaning, we do not know when, why, or where volcanoes will erupt
4. God
5. Other (please specify) ____________________________
38. Which of the following reflects the most important reason why your family lives where they do on Mauna Loa or Hualalai? **Circle all that apply**
   1. We enjoy looking over the blue Pacific Ocean
   2. The dry climate
   3. The community is a great place to live and raise a family
   4. We like the rural setting compared to metropolitan areas like Honolulu
   5. We inherited the land or the land has always been ours
   6. My job requires us to live here
   7. Land is cheap

39. A. Have you visited Hawai‘i Volcanoes National Park and learned about volcano hazards? 1 Yes 2 No

   B. If yes, when did you last visit?
      1. Less than 5 years ago  2. 5 to 10 years  3. Over 10 years

40. A. Do you know the location of an emergency evacuation shelter near your home or work? 1 Yes 2 No

   B. If yes, where is it?

41. How long have you lived in Kona? _____ Years

42. A. Think about everything you have heard about future volcanic eruptions from Mauna Loa and Hualalai, and even the other Big Island volcanoes. Was this information consistent or inconsistent?
   1. I have not heard anything  4. Fairly inconsistent
   2. Fairly consistent  5. Very Inconsistent
   3. Consistent  6. Unsure

   B. If yes, when was the last time you read it?
      1. Last week  2. Last month  3. Last year

43. Have you or any of your relatives (siblings, parents, grandparents, aunts, uncles, cousins, etc) been threatened by an eruption or sustained damage to property during the 1900s?
   1 Yes  2 No
   If yes, please describe:
   Where: ___________________________
   When: ___________________________
   Damage: ___________________________

44. List any damage that vog (volcanic haze or smog) has caused you or your family’s health or property. ___________________________
45. Following is a list of statements on how you feel about living in your community. Please use the scale below to show how much each statement applies to you, or doesn't apply to you. Check one box in each row.

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A bit</th>
<th>To some extent</th>
<th>Quite a bit</th>
<th>Very much</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel ‘at home’ in this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am satisfied living in this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am a useful member of this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I have the same values and beliefs as my neighbors</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I feel I don’t belong in this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I am interested in knowing what goes on in this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I would be happy to leave this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I know my neighbors and/or other community members</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I have no active involvement in this community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

46. Please think about your life in your community at present. Choose a number from the scale below that shows how much you agree or disagree with each of the following statements. Check one box in each row.

<table>
<thead>
<tr>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Disagree strongly (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Life in your community</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel I have control over most things that happen in my life and in the community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>There is no way I can solve some of the problems I have by myself</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I can’t do much to change what happens in my life or in the community</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Somehow problems in my life usually solve themselves</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
47. Below is a list of statements that describe ways different people deal with problems. Would you please think of how you have dealt with problems you have had over time, and note which statements describe what you have done, what you have done in part, and what you have not done. Please use the following scale, and check the appropriate answer for each statement.

<table>
<thead>
<tr>
<th>Ways to deal with problems</th>
<th>I have done</th>
<th>I have done in part</th>
<th>I have not done</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tried to forget the whole thing</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Talked to someone to find out more about the situation</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Went on as if nothing had happened</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Talked to someone you knew had useful suggestions</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Wished that the situation could be over with</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Discussed the problem with your family</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

48. What does the Hawai‘i Emergency Alert System’s “steady three minute siren tone” indicate?
1. A hurricane watch has been issued
2. A hurricane warning has been issued
3. Attention Alert Signal, listen to the radio or television for instructions from local authorities.
4. Don’t know

49. A. Do you know in which lava flow hazard zone your home is located? 1 Yes 2 No
   B. If yes, please write the zone in the space provided? ________________

50. A. Did you know that the GTE telephone book contains information on how to prepare for natural disasters? 1 Yes 2 No
   B. If yes, when was the last time you read it?
      1 Within the last month 3 Within the last 5 years
      2 Within the last year 4 Have not read it

THANK YOU FOR YOUR PARTICIPATION!
Dear Parent or Guardian:

The University of Hawai‘i, the Hawai‘i Sea Grant College Program, and the New Zealand Institute of Geological and Nuclear Sciences are jointly conducting a study of community attitudes and beliefs toward tsunamis in Hawai‘i. The findings of this study will be used to help local communities better prepare for future events. You and your eighth grade child have been selected to participate in this very important study.

You can help in this study by completing the enclosed questionnaire and having your child return it to school in the attached envelope. This should take about 15 minutes. All replies will be confidential. We will only report on general trends and will not disclose your name or any other personal information that you provide.

Please consent for your child to participate in the study by signing the form titled "Agreement to Participate in-,” which is printed on the back of this paper. Your consent to participate is assumed by returning the completed questionnaire. When you finish the questionnaire, place your completed questionnaire and the signed form in the
envelope provided and have your child return it to their appropriate teacher at school. If you do not wish to participate, please have your child return the questionnaire blank and the signed form to their teacher.

Thank you very much for your time and participation. Your opinions are very important to the success of this study. In a recent study in Kona, 9 out of every 10 parents returned completed questionnaires. The survey was a big success and will help us focus on the specific needs of Kona communities. I hope you help us help your community by participating. If you have any questions, please feel free to contact me at 808-956-6213.

Very Kind Regards,

Mr. Chris E. Gregg

Enclosures: Consent Form (2 copies)
Parent or Guardian Survey
Postage paid envelope
APPENDIX F2. Parental consent form for students

AGREEMENT TO PARTICIPATE IN-

Resilience of Hawaiian Coastal Communities to Natural Hazards

(Title of Project)

Chris E. Gregg, Geology and Geophysics, POST 710A, University of Hawai‘i at Manoa, 1680 East-West Road, Honolulu, 96822, Phone 808-956-6213, Fax 956-5512

(Principal Investigator’s name, address, and phone and fax number)

Certifications

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to inquiries that I may have made concerning project procedures and other matters and that I have been advised that I am free to withdraw my child’s consent and to discontinue their participation in the project or activity at any time without prejudice.

I herewith give my consent for my child to participate in this project with the understanding that such assent does not waive any of my legal rights, nor does it release the Principal Investigator or the institution or any employee or agent thereof from liability for negligence.

Signature

____________________________
(Name of student, print)

____________________________
(Name of parent/guardian (participant), print)

____________________________
(Signature of parent/guardian (participant)

Date ________________________

(If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, write to: Committee on Human Studies, University of Hawaii, 2450 Maile Way, Honolulu, HI 96822. Phone: (808) 956-5007. Please reference the above listed project title and the Principal Investigator’s name.)
APPENDIX F3. Student assent form

AGREEMENT TO PARTICIPATE IN
Resilience of Hawaiian Coastal Communities to Natural Hazards

(Title of Project)

Chris E. Gregg, Geology and Geophysics, POST 710A, University of Hawai’i at Manoa, 1680 East-West Road, Honolulu, 96822, Phone 808-956-6213, Fax 956-5512

(Principal Investigator’s name, address, and phone and fax number)

Certifications

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to inquiries that I may have made concerning project procedures and other matters and that I have been advised that I am free to withdraw my assent and to discontinue participation in the project or activity at any time without prejudice.

I herewith give my assent to participate in this project with the understanding that such assent does not waive any of my legal rights, nor does it release the Principal Investigator or the institution or any employee or agent thereof from liability for negligence.

Signature

______________________________
Name of student, print

______________________________
Signature of student

______________________________
Date

(If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, write to: Committee on Human Studies, University of Hawaii, 2450 Maile Way, Honolulu, HI 96822. Phone: (808) 956-5007. Please reference the above listed project title and the Principal Investigator’s name.)
APPENDIX F4. Hilo Parent or Guardian Tsunami Survey

Directions: Please circle or check (✓) one response to each question unless asked to check more. Please answer questions in order starting with number 1 (this is important).

1. How long have you lived in: a. The Hawaiian Islands _______ years
   b. The city you live in now _______ years
   c. Your current house _______ years

2. Which cartoon best illustrates tsunami? (check one only)

   1.  □
   2.  □
   3.  □
   Don’t know

3. What signs would alert you that a possible tsunami will occur?

4. Tsunamis occur as: 1 One big wave
   2 Some big waves and some small waves
   3 Don’t know

5. Please describe how often you:
   a. Think about tsunami
      Once a week 5
      Once a Month 4
      A few times a year 3
      Rarely 2
      Never 1
   b. Talk about tsunami
      Once a week 5
      Once a Month 4
      A few times a year 3
      Rarely 2
      Never 1
   c. What kinds of things do you talk or think about?

6. Please describe the extent to which you agree or disagree with each of the following statements:

   Strongly Agree  Neither Agree nor disagree  Disagree  Strongly disagree
   Tsunamis could pose a threat to your personal safety.
   5  4  3  2  1
   Tsunamis could pose a threat to your daily life (e.g., work, leisure).
   5  4  3  2  1
   Tsunamis could pose a threat to your property.
   5  4  3  2  1
7. The following questions relate to other members of your community. Please describe the extent to which you agree or disagree with each of the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunamis could pose a threat to the personal safety of most of the people who live in your community.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Tsunamis could pose a threat to the daily activities (e.g., work, leisure) of most of the people who live in your community.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Tsunamis could pose a threat to the houses or properties of most of the people who live in your community.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

8. Please describe the extent to which you agree or disagree with each of the following statements. Damaging tsunami will occur within the next:

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 months</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>12 months to 5 years</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5 to 10 years</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Greater than 10 years</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

9. Have you experienced a tsunami:
   (a) If yes, what year(s)                        1 Yes 0 No
   (b) Did you experience damage to your home (i.e., requiring any repairs or insurance claims) 1 Yes 0 No
   (c) ...were you injured                        1 Yes 0 No

10. Please describe the extent to which you agree or disagree with each of the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunamis are too destructive to bother preparing for.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Preparing for tsunamis will not significantly reduce damage to my home should a tsunami occur.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Preparing for tsunamis will not improve my everyday living conditions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Preparing for tsunamis will not improve the value of my house/property.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
### 10-continued

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparing for tsunamis will not significantly improve my ability to deal with disruption to family/community life following a tsunami.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Preparing for tsunamis is inconvenient for me.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

### 11. In regard to the issues and problems that you deal with in your everyday life,
please describe the extent to which you agree or disagree with each of the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have considerable control over what happens in my life.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I can solve most of the problems I have by myself.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>What happens to me in the future mostly depends on me.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I can do a lot to change many of the important things in my life.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I can do just about anything if I really set my mind on it.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I rarely feel helpless in dealing with the problems of life.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

### 12. In regard to primary responsibility for household preparedness for tsunami,
please describe the extent to which you agree or disagree with each of the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel responsible for preparing myself for major tsunamis</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Government officials are responsible for making sure that I am prepared for the occurrence of major tsunamis.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
13. In regard to dealing with problems in your *everyday life*, please describe on a scale from 1 (I usually don’t do this at all) to 4 (I usually do this a lot) how much of each of the following you do:

<table>
<thead>
<tr>
<th>Action</th>
<th>I usually do this a lot</th>
<th>I usually don’t do this at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>I try to come up with a strategy about what to do</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>I make a plan of action</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>I think hard about what steps to take</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>I think about how I might best handle the problem</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

14. In the next month or so, do you intend to:

<table>
<thead>
<tr>
<th>Action</th>
<th>Definitely</th>
<th>Possibly</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Check your level of preparedness for tsunamis</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>- Increase your level of preparedness for tsunamis</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>- Become involved with a local group to discuss how to reduce damage or losses from tsunamis</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>- Seek information on tsunami risk</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>- Seek information on things to do to prepare</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

If you intend to seek information on tsunami risk and/or preparedness, please list two sources/organizations you would contact:

a.  

b.  

15. In regard to living in this *community* generally, please describe the extent to which you agree or disagree with each statement following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree or disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel like I belong in this community</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I believe my neighbors would help me in an emergency</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Even if I had the opportunity I would not move out of this community.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I feel loyal to the people in my community</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I often have friends over to house to see me.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I plan to remain a resident of this community for a number of years.</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
16. The following tasks can be done to minimize damage and disruption at your house if tsunamis occur. In regard to your household, please record whether each statement currently applies to you.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>I found out if my home is in a tsunami inundation zone</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I know the height of my house above sea level</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I know the distance of my house from the coast.</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I have purchased flood insurance</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I have accumulated enough tools to make minor repairs to my home following a major tsunami</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I have a household tsunami emergency plan</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>The plan includes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where the family should meet if tsunamis occurred while family members are separated (e.g., during the day while at school, work)</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Directions to nearest evacuation shelter</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>If yes, where is the shelter (specify name)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I have picked a place to evacuate to that is at a higher elevation than my home</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>I have taught family members where to turn off: gas</td>
<td>1</td>
<td>2</td>
<td>3 have no gas</td>
</tr>
<tr>
<td>electricity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A wrench(s) is stored beside the turn off valve for gas and water</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

16b. If you own your own house please complete the following (check all that apply)?

If not, skip to 16c.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
<th>Done before I moved into house</th>
</tr>
</thead>
<tbody>
<tr>
<td>I had a structural engineer or licensed building inspector to evaluate the house for preparedness for tsunamis.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I added a waterproof veneer to exterior walls</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I anchored water tanks.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I elevated home above expected flood levels</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I have ensured that the supporting walls in the house are oriented perpendicular to the ocean to resist forces of tsunami waves</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
16c. I have an emergency supply kit specifically set aside.  
If yes, it contains (check all that apply):
- Flashlight  
- Batteries for flashlight  
- Battery powered radio  
- Spare batteries for radio  
- First aid kit  
- 6 quarts of water (in plastic containers) per family member  
- Water purification tablets  
- 3 days supply of dehydrated or canned food per person in the family  
- A portable stove or barbecue and fuel for cooking  
- An extra supply of essential medicines  
I check the contents/operation of my emergency kit every month.  
I have a fire extinguisher.  
I know how to operate a fire extinguisher.  
All contents of my emergency kit are contained in one place.

17. The following activities help minimize disruption to a community if tsunamis occur. Please record whether they currently apply to your community.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Yes</th>
<th>No</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the neighborhood have a tsunami response plan?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Have you been involved in meetings on tsunami preparedness:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- at school?</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>- in the local community?</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Have you discussed the need for tsunami preparedness with:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- your neighbors?</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>- official agencies?</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

18. Please rate (from 1 = not at all prepared to 5 = very prepared) the extent to which you perceive each of the following is prepared to deal with a major tsunami.

<table>
<thead>
<tr>
<th>Role</th>
<th>Very Prepared</th>
<th>Not at all prepared</th>
</tr>
</thead>
<tbody>
<tr>
<td>You</td>
<td>5 4 3 2 1</td>
<td></td>
</tr>
<tr>
<td>Other members of your community</td>
<td>5 4 3 2 1</td>
<td></td>
</tr>
<tr>
<td>Government officials</td>
<td>5 4 3 2 1</td>
<td></td>
</tr>
</tbody>
</table>
19. In regard to your general feelings about living in this community, please describe the extent to which you agree or disagree with each statement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I trust my government officials to respond to meet the day to day needs of its residents.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I trust my community leaders.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I trust my government officials to do what is necessary should tsunamis occur.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

20. To what extent might each of the following prevent you preparing for tsunamis? Please rate the impact of each statement from 1 (not at all) to 5 (a great deal).

<table>
<thead>
<tr>
<th>Statement</th>
<th>A great deal</th>
<th>Not at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>The cost.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>The skill or knowledge required.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Time to do them.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>There are other things to think about.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Need for co-operation with others.</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

21. Please read each of the following statements and describe (on a scale from 1 = not at all to 5 = A great deal) the extent to which they apply to you.

<table>
<thead>
<tr>
<th>Statement</th>
<th>A great deal</th>
<th>Not at all</th>
</tr>
</thead>
<tbody>
<tr>
<td>When I am near the beach and I feel an earthquake, my first thought is, “will it cause a tsunami?”</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>I would never move to a place where there was a higher risk of tsunamis.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>I avoid things that remind me of tsunamis.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>If I think there might be a tsunami, I make sure I am close to a safe place.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>I avoid thinking about tsunamis.</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
22. Please read each of the following statements and describe the extent to which you agree or disagree with each.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither Agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

- There may be tsunamis, but they won’t be that bad.
- The location of tsunamis will be far away from here and have little impact on us.
- The likelihood that major tsunamis will occur here has been greatly exaggerated.
- I have been fine during the tsunamis we have had and I will be fine in the next one too.

23. When was the last damaging tsunami to affect the island of Hawaii?

- 1 1996
- 2 1975
- 3 1964
- 4 1960
- 5 1946
- 6 Don’t know

24. How many buildings were destroyed in Hilo during the tsunami of May 1960?

- 1 Don’t know
- 2 About 500
- 3 About 250
- 4 About 125
- 5 About 60
- 6 None

25. How many lives were lost in Hilo during the tsunami of May 1960?

- 1 Don’t know
- 2 About 500
- 3 About 250
- 4 About 125
- 5 About 60
- 6 None

26. What does a tsunami “watch” indicate?

- 1 Don’t know
- 2 Tsunamis are possible, get ready
- 3 Tsunamis have been formed, evacuate coastal areas immediately

27. What does a tsunami “warning” indicate?

- 1 Don’t know
- 2 Tsunamis are possible, get ready
- 3 Tsunamis have been formed, evacuate coastal areas immediately

28. Do you live in a tsunami inundation zone?

- 1 Yes
- 2 No
- 3 Don’t know
29. How much time can there be between one tsunami wave and the next wave?

1. Don’t know 3. 1 minute to 30 minutes
2. 1 to 5 minutes 4. Over 30 minutes

30. Which of the following are options for places that you and your family could evacuate to if needed during an emergency today? (check all that apply)

- Don’t know
- Friend’s house
- Relative’s house
- Official shelter
- Somewhere very close to your neighborhood

31. If you had to evacuate your home today, where would you expect to evacuate to? (check only one)

1. Don’t know
2. Friend’s house
3. Relative’s house
4. Official shelter
5. Somewhere very close to your neighborhood

32. During recent tsunami warnings in Hawaii, many people went out to surf the waves?

1. True 2. False 3. Don’t know

33. Would you try and surf tsunamis?

1. No 2. Possibly 3. Definitely

34. What does the Hawai‘i Emergency Alert System’s (EAS) “steady three minute siren tone” indicate?

1. Don’t know 2. (specify) ________

35. Is there a test of the siren?

1. Yes 2. No 3. Don’t know

If yes, how often is the siren tested?
1. Don’t know
2. Once a month
3. Once a year
4. Never

36. If a tsunami warning is issued, what factors might influence whether you would:

Secure your home

Evacuate
37. When do you think the following hazards are likely to damage your home?

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Within next 12 months</th>
<th>Within 1 to 5 years</th>
<th>Greater than 5 years</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Storms</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Hurricane</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Flood</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>High surf</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Tsunami</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Lava flow</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Vog</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

38. When do you think the following hazards are likely to damage your work?

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Within next 12 months</th>
<th>Within 1 to 5 years</th>
<th>Greater than 5 years</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Storms</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Hurricane</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Flood</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>High surf</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Tsunami</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Lava flow</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Vog</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

39. Which best describes the situation where you live?

1. We own the home
2. We rent a house
3. We rent a condominium or townhouse
4. Don’t know

40. Age: _____

41. Gender: 1 Male       2 Female

42. Which of the following ethnic groups do you most identify (check only one)

1. Hawaiian
2. Caucasian (white)
3. Japanese
4. Pacific Islander
5. Portuguese
6. Korean
7. Filipino
8. Chinese
9. Hispanic
10. Samoan
11. Other ____________________
43. In which of the following categories is your yearly household income (before tax):
   1. $24,999 or less
   2. $25,000 – 34,999
   3. $35,000 – 49,999
   4. $50,000 and over

44. Exact Street Address (not P.O. Box). ____________________________
    City ____________________________
    Zip code ______________
    If you have a Post Office Box number, what is it? _______ Zip_______

    If you do not have a street address with a number, what is the name of the street you live on? ____________________________
    What is the name of the nearest street that intersects the street you live on? ______

    THANK YOU.
APPENDIX G. USE OF PREVIOUSLY PUBLISHED MATERIAL AND HUMAN SUBJECTS

Chapters 2 and 3 have been published with multiple coauthors on each manuscript. Each chapter was written as a manuscript completely by the first author and then circulated among coauthors for review and comment. The manuscripts were then revised based on the feedback of coauthors. In no instance were whole sections of chapters written by the coauthors. In this sense the process conformed to the normal practice for revision of thesis text. This dissertation either meets or exceeds requirements concerning "Use of Previously Published Work" as described by the University of Hawai‘i at Mānoa, Graduate Division.

Applications to conduct research on human subjects were filed as required with the Committee on Human Studies (CHS) at the University of Hawai‘i. The Kona project was approved by CHS on January 19, 2001 (CHS #10927). The Kapoho project was approved by CHS on February 4, 2003 (CHS #12073). The siren/tsunami project was approved by CHS on February 13, 2003 (CHS #11861).
APPENDIX H. TSUNAMI GUIDELINE PROCEDURES FOR HAWAII

March 2004

1. **PTWC Bulletins.** The Pacific Tsunami Warning Center (PTWC) alerts the international arena of the Pacific basin and the State of Hawaii of potential or confirmed tsunamis with two main categories of messages. PTWC's "International Bulletins" are sent to most of the countries around the rim and in the interior of the Pacific Basin, as well as to all US interests in the Pacific outside the WC/ATWC area of responsibility (AOR that includes Alaska, British Columbia, Washington, Oregon, and California.) PTWC's "Hawaii Bulletins" are addressed to Civil Defense in the State of Hawaii. Both categories of messages may be issued for potential or confirmed tsunamis generated by earthquakes in the seismic belts around the Pacific Rim, or by earthquakes within the State of Hawaii. For both international and Hawaii users of the system, there are four levels of alert: 1) information, 2) advisory, 3) watch, and 4) warning. Within these levels may be some distinctions (e.g., for Hawaii a warning for a distant event is distinct from a warning for a local event).

a. **International Bulletins.** PTWC's "International Bulletins" fall into four basic categories for handling events around the Pacific with increasing degrees of threat. Magnitude thresholds for these bulletins as well as their corresponding Hawaii bulletins are now based on the moment magnitude, Mw, as opposed to the formerly used Richter magnitude, Ms.

i. **Tsunami Information Bulletin.** Issued for Pacific Basin earthquakes with magnitudes of 6.5 to 7.5, inclusive, or for even larger Pacific earthquakes if they are inland or deep inside the earth or outside the Pacific Basin (e.g., in the Sea of Japan or in one of Indonesia's seas). No destructive Pacific-wide tsunami threat exists based on historical earthquake and tsunami data. There may be some threat of a local tsunami in the region near the earthquake epicenter. A supplement will be issued if any tsunami signal is recorded. 

*** However, if the event is in the WC/ATWC AOR with a magnitude between 7.1 and 7.8, inclusive, PTWC will issue a special fixed, non-expanding Tsunami Advisory Bulletin. The WC/ATWC will issue a regional warning and watch for their AOR. ***

---

ii. **Fixed Regional Tsunami Warning and Advisory Bulletin.** Issued for Pacific Basin earthquakes with magnitudes of 7.6 to 7.8, inclusive. In the historical record, some earthquakes in this size range have generated local or regional destructive tsunamis, but none a Pacific-wide destructive tsunami. Areas within 1000 km of the epicenter are put into a warning. For all other areas the message is an advisory only. The warning and advisory will be continued, with supplemental bulletins issued at least hourly, until sufficient sea level data are received to make an evaluation. The warning area will not expand. The series of bulletins will end with a cancellation. *Hawaii will be issued corresponding initial, supplemental, and final Advisory Bulletins as appropriate.*

iii. **Expanding Regional Tsunami Warning, Watch, and Advisory Bulletin.** Issued for Pacific Basin earthquakes with magnitudes of 7.9 or greater. In the historical record, many earthquakes of this size have generated local or regional destructive tsunamis, and a few have generated Pacific-wide destructive tsunamis. Areas having less than three hours until estimated first wave arrival (at the time the bulletin is issued) are put into a warning. Areas having three to six hours until estimated first wave arrival are put into a watch. For all other areas the bulletin is an advisory. The warning, watch, and advisory will be continued, with supplemental bulletins issued at least hourly, and with warning and watch areas expanding according to the rules described above, until sufficient sea level data are received to make an evaluation. This series of bulletins will end with either a cancellation or an upgrade to a Pacific-Wide Warning. *Hawaii will be issued a warning, watch, or advisory as appropriate according to the rules described above, with two notable exceptions. If the earthquake epicenter is north of 35 degrees north latitude, then Hawaii will initially be put into a watch even if it is still more than six hours until estimated initial wave arrival. This is by a prior agreement with Hawaii State Civil Defense. In addition, Hawaii may be put into a warning, watch, or advisory status at any time due to circumstances as the event unfolds, if agreed to by SCD and PTWC.*

iv. **Pacific-Wide Tsunami Warning Bulletin.** Issued following confirmation of a tsunami of sufficient size to have the potential for widespread destruction in the Pacific Basin. A Pacific-wide Warning would normally be generated by an earthquake with a magnitude of 7.9 or greater and would therefore be preceded by a series of Expanding Tsunami Warning, Watch, and Advisory Bulletins until the decision to upgrade was made based on sea level
readings. A Pacific-wide Warning will be continued, with supplemental bulletins issued at least hourly, until the tsunami has impacted all areas at risk and tsunami waves are diminishing or below dangerous levels on most gauges. This series of bulletins will end with a cancellation. Hawaii will be issued corresponding warnings and a cancellation unless, due to circumstances of the event, it is agreed by SCD and PTWC to keep Hawaii out of a warning. In that case Hawaii would be issued a series of advisories including a final advisory.

b. Hawaii Bulletins for Distant Events. PTWC's "Hawaii Bulletins" for distant events fall into four categories corresponding to the four levels of alert: 1) information, 2) advisory, 3) watch, and 4) warning. These bulletins are intended to reflect information provided in the International Bulletins, but the language is tailored to Hawaii's regional interest. For example, all times in these bulletins are given in Hawaii Standard Time. Both Moment Magnitude, Mw, and Richter Magnitude, Ms, will be promulgated in these bulletins, although the Richter magnitude may not be available in initial bulletins when insufficient time has elapsed to collect the necessary seismic waveform data.

i. Tsunami Information Bulletin. Issued by criteria specified above in section 1.a.i, a Tsunami Information Bulletin for Hawaii provides information about a large Pacific earthquake that poses no threat of having generated a Pacific-wide destructive tsunami that could strike the State. In rare instances, Hawaii might experience small sea level changes for such an event.

ii. Tsunami Advisory. Issued by criteria specified above in all four sections of 1.a, a Tsunami Advisory for Hawaii generally indicates that a tsunami warning has been issued by PTWC or WC/ATWC for some other part of the Pacific. Depending upon the situation, there is a possibility that Hawaii could be elevated to watch or warning status in the near future and some additional awareness and readiness is prudent. Advisories are issued at least once an hour, usually simultaneous with PTWC's International Bulletins, until they are ended with a final advisory.

iii. Tsunami Watch. Issued by criteria specified above in section 1.a.iii, a Tsunami Watch indicates a large earthquake has occurred and there is the threat of a destructive tsunami striking Hawaii in less than six hours but more than three hours (relative to the time the bulletin was issued). The estimated arrival time of the first tsunami wave is given in the bulletin. A Watch is issued when sea level readings and other data are inconclusive for upgrading to a warning or canceling. Watches are issued at least once an hour, usually
simultaneous with PTWC's International Bulletins, until they are either upgraded to a warning or ended with a cancellation.

iv. **Tsunami Warning.** Issued by criteria specified above in sections I.a.iii and I.a.iv, a Tsunami Warning indicates a large earthquake has occurred and there is the threat of a destructive tsunami striking Hawaii. In some cases a warning for Hawaii may be issued as part of a Pacific-Wide Warning when sea level readings and other available data confirm that a widespread destructive tsunami is underway. In other cases a warning may be issued to Hawaii when sea level and other data are inconclusive but there is less than three hours until the estimated arrival time of the first tsunami wave. The estimated arrival time is given in the bulletin. Warnings are issued at least once an hour, usually simultaneous with PTWC's International Bulletins, until they are cancelled.

c. **Hawaii Bulletins for Local Events.** PTWC's "Hawaii Bulletins" for local events fall into only two categories - a Local Tsunami Information Bulletin, and an Urgent Local Tsunami Warning. Seconds are critical for local tsunamis, since tsunami waves can come onshore immediately in the vicinity of the earthquake epicenter, and within minutes the waves can race along the coast and strike nearby population centers. Consequently, bulletins for local events are issued initially by voice on HAWAS for immediate action, with a more detailed text message issued in the following minutes over the Interisland Data Net (IDN). Initial bulletins for local events are preceded by a brief "Heads-Up Message" to alert warning points and EOC's that a bulletin is coming and to get ready to respond quickly and appropriately.

i. **"Heads Up" Message.** A HAWAS only voice announcement from PTWC that a Hawaii earthquake has just occurred and it is investigating. (NOTE: State Warning Point conducts an immediate roll call.) PTWC will issue one of the following bulletins within the next few seconds to minutes at most based on their analysis of the event.

ii. **Local Tsunami Information Bulletin.** Initial HAWAS voice announcement indicating that a Hawaii earthquake has just occurred with a magnitude less than or equal to 6.8. No tsunami is expected. (NOTE: State Warning Point immediately disseminates HAWAS voice information.) A "hard copy" text bulletin with more detailed information will be issued by PTWC over the IDN following the voice announcement. PTWC will continue to monitor nearby sea level and runup instruments and upgrade to an urgent local tsunami warning if warranted based on all available data.

iii. **Urgent Local Tsunami Warning.** Initial HAWAS voice announcement indicating an urgent local tsunami warning is in effect
for designated counties or for the entire State of Hawaii. The warning is based on the occurrence of a Hawaii earthquake with a magnitude of 6.9 or greater, or on other earthquake, sea level, and runup data indicative of a destructive local tsunami. (NOTE: State Warning Point immediately initiates action to evacuate designated county coastlines.) A “hard copy” text message with more detailed information will be issued by PTWC over the IDN following the voice announcement. Supplemental warning messages may be issued as time permits over HAWAS and IDN with updated information, particularly sea level readings and runup gauge triggers. The warning will end with a cancellation over HAWAS and the IDN when tsunami wave activity has subsided to safe levels on most gauges. (NOTE: State Warning Point immediately disseminates voice information. The “All Clear” is issued by the Civil Defense of the affected Counties.)

2. **Siren Sounding.** Tsunami Warnings are accompanied by sounding of sirens, and disseminated over the Statewide Emergency Alert System (EAS) as soon as practicable.

   a. SCD coordinates initial statewide siren sounding with all counties for a distant tsunami.

   b. Evacuation siren soundings are made as determined by County Civil Defense Administrators.

      i. Each sounding is accompanied by a “live” EAS broadcast clearly specifying the area for which the broadcast is applicable.

      ii. Sounding of siren by each county will be closely coordinated, when possible, with other counties and SCD over the State HAWAS.

      iii. Siren evacuation soundings are generally made at the following intervals:

         1. Three hours from first estimated tsunami wave arrival.
         2. Two hours from first estimated tsunami wave arrival.
         3. One hour from first estimated tsunami wave arrival.
         4. Thirty minutes from first estimated tsunami wave arrival.

3. **Warning Cancellation.** PTWC issues a Warning Cancellation when the threat of a tsunami wave no longer exists for the State of Hawaii.

4. **All Clear.** The counties independently announce an “All Clear” message when they determine it is safe to re-enter tsunami evacuation zones and necessary precautions are in place. Counties use EAS to distinguish between Tsunami Warning Cancellation and an “All Clear” announcement.
REFERENCES


